# We-cycle <br> A Systems Approach to Improving Recycling Practices at Wellesley College 



Environmental Studies Capstone Course (ES 300)

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## Executive Summary

The Spring 2018 Environmental Studies 300 class was charged with assessing Wellesley College's recycling system and drafting recommendations for change. Analysis of our recycling system is especially pertinent in light of China's recent policy restricting imports of waste. The impact of this restriction has been felt broadly, and has even forced Wellesley College to temporarily change the facility that our recycling is sent to.

In conducting analysis and compiling recommendations, we aimed to improve recycling rates, reduce our campus environmental burden, and maximize the revenue of the college. To analyze the impact that different types of changes would have on recycling rates and rates of incorrect recycling, we conducted several experiments. These experiments included: collecting pledges, implementing a three-stream system with specialized lids, making recycling more convenient by providing recycling bags, introducing signs with messages designed to increase recycling participation, and implementing a single-stream system. We also surveyed students, faculty, and staff on reasons they do not recycle. We analyzed the ideal number of streams to collect and sort into, which facility to send our recycling to, and ways in which we could reduce waste brought to campus.

We found that infrastructure changes are more effective than changes aimed at increasing recycling behavior. Our primary recommendation is to introduce a four-stream recycling system - mixed paper, mixed plastics, metal, and glass - sent to the Town of Wellesley Recycling and Disposal Facility. This system allows the college to avoid any issues with regard to facilities not accepting commingled recycling, and to take advantage of lower costs and higher revenues. The recycling system must be uniform and consistent across campus to eliminate the difficulty of finding recycling bins, which was identified as an issue in our survey. We recommend the use of specialized lids on these bins, which our experiment found to be effective. We do not recommend using messaging or pledges, as these changes were not shown to be effective in increasing recycling rates.

Informational signage should be implemented to help recyclers identify what can and cannot be recycled. In addition, education on recycling should be incorporated into students' introduction to campus through a handout given during Orientation on what is and is not recyclable in each stream. Proposed signs and handouts are included in Appendix A.

We also identified priority areas for reduction of waste brought to campus. The sale of glass-packaged goods must be eliminated from on-campus retail due to the high cost of glass recycling. Paper use should be limited by the implementation of a campus-wide paper printing cap, and academic departments should no longer purchase paper cups. The purchase of plastic bottles should also be decreased through eliminating plastic from on-campus retail centers, installing filtered water dispensers, and eliminating plastic bottles from large-scale events.

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## Introduction to ES 300

ES300 is a project-based capstone course for students of the Environmental Studies (ES) Program. Each spring, senior and junior ES majors and minors design a comprehensive study to address an environmental issue on campus and devise potential solutions. We approached this project from multiple angles - quantitative and qualitative - drawing on all resources available to us, and using the skills and tools we have developed through previous ES courses and experiences. While we are all ES majors or minors, we each carry with us interdisciplinary perspectives and diverse backgrounds in approaching the issue of interest. This year, we chose to assess ways to improve recycling at Wellesley College. Under the guidance of Professor Beth DeSombre, we examined the academic literature, designed and executed various experiments, and analyzed our results to make recommendations to the College for ways to increase proper recycling on campus. To accomplish such a feat, we organized ourselves into leadership roles and project teams to tackle different pieces of the project.

## Motivations For This Study

Our client for this project was the Wellesley College Office of Sustainability. The Director of Sustainability tasked our class with identifying ways to improve recycling on campus. Reconsidering our current recycling practices has become increasingly important in light of China's recent ban on a number of waste imports, announced in July 2017. We have already begun to experience the consequences of this decision in the form of increased recycling costs and limitations on the recycling streams accepted by local recycling and disposal facilities. To adapt and improve our recycling system, we conducted a number of experiments, based on research on effective recycling strategies, to assess what behavioral and infrastructural changes would encourage increased and correct recycling on campus.

In assessing behavioral and infrastructural changes, our aim was to reduce the environmental burden of our waste creation, promote environmental sustainability, and reduce the costs - or maximize the revenue - associated with recycling on campus. Recycling at Wellesley College benefits both the environment, by repurposing resources; and the College, by creating a revenue-generating waste stream. Creating a more effective recycling system will increase the environmental and financial benefits of Wellesley's recycling practices.

## Metrics

After completing our experiments and other analyses, we evaluated our results based on various metrics to decide which recycling solutions were best. We considered the cost to the College, both upfront and long term, and institutional ease (including both the initial setup and maintenance of recycling systems). Individual ease (the time and lifestyle changes required for an individual person to recycle) and fairness to campus employees were considered qualitatively. Our quantitative environmental metrics were resource conservation, greenhouse gas emissions, and toxicity to humans and the environment.

## 1. Background

### 1.1 Background: Why Recycle?

## Ethical, Educational, and Legal Obligations:

Recycling is one of the most accessible and convenient methods for everyday people to engage in environmentally friendly behavior. It is an impressively pure form of altruism, ${ }^{1}$ and is one of the most widely known and participated-in waste reduction tools. ${ }^{2}$ Furthermore, many colleges, like Wellesley, have a legal obligation to recycle (see: Background: Massachusetts Recycling Laws). ${ }^{3}$

Recycling is also a learned behavior. Education on the benefits of recycling and of various recycling methods are important factors motivating recycling. The more knowledgeable about recycling people are, the more likely they are to be more invested in it. Wellesley College's student population arrives on campus every year with exposure to varied waste management methods, and varied knowledge of recycling. Therefore, education about recycling is especially important in order to bring everyone on campus up to the same recycling standard. After learning about appropriate recycling practices here on campus, students may then take that knowledge beyond campus and improve recycling practices in their households or workplaces.

## Reducing Waste:

One of the greatest benefits of recycling is the reduction in the amount of total waste that ultimately ends up in landfills or incinerators. With such a reduction, disposal capacity needs, emissions from landfills and incinerators, and litter and improper disposal of materials can all be similarly reduced. ${ }^{4}$ In the 1980 s, public interest in recycling grew in response to a "landfill crisis," where people assumed that the creation of any new landfills would be a huge expense and enormous environmental burden. ${ }^{5}$ While this has since been shown to be less of a crisis than expected, optimizing land usage by minimizing landfill creation still remains important. In addition to potential land degradation, atmospheric emissions also are harmful effects of landfills. Landfills and incinerators produce emissions that are detrimental to environmental and human health. Gases emitted from landfills are composed of roughly $50 \%$ methane and $50 \%$

[^0]carbon dioxide, along with a small proportion of non-methane organic compounds. ${ }^{6}$ Methane is a potent greenhouse gas and is 28 to 36 times more effective than carbon dioxide at trapping heat in the planet's atmosphere. ${ }^{7}$ Reducing the amount of waste we send to landfills and incinerators always provides a benefit and incorporates a lens of sustainability into waste management.

## Environmental Justice:

Minimizing the impact of landfills and incinerators is also important from an environmental justice standpoint. An overall reduction of landfill and incineration space, paired with careful placement of subsequent recycling processing centers, is an important factor to sustainability in recycling. Waste management facilities, and their related harms, are often disproportionately centered in communities of color and low income areas, potentially exposing the marginalized and vulnerable to environmental toxins and emissions. ${ }^{8}$ This is problematic due to the harmful effects these facilities have on the communities they are located in and around.

## Reducing Toxics:

Toxics, which generally refer to toxic or hazardous substances defined by the Toxics Use Reduction Act, are a common and dangerous byproduct of industrial processes, including waste management. ${ }^{9}$ Recycling has the potential to mitigate the pollution that would otherwise be created by landfills and incineration. Both landfills and incinerators are significant sources of carcinogens, ${ }^{10}$ greenhouse gases, toxic heavy metals, and other harmful pollutants. ${ }^{11}$ By minimizing the amount of waste that goes to landfills and incinerators, recycling reduces the harms associated with these facilities. Finally, recycling is less energy intensive than the creation of new materials, and thus reduces the greenhouse gas and fossil fuel demand, the latter of which can have its own hazardous byproducts. ${ }^{12}$

[^1]
## Conserving Resources:

Recycling also contributes to the long-term conservation of raw materials, as many recyclable products are made out of non-renewable resources. Therefore, creating another usable object through recycling makes the use of these non-renewable resources more sustainable. If the growth rate of materials production remains high, recycling will unfortunately not be enough to prevent the total depletion of such natural resources. ${ }^{13}$ However, the recycling industry addresses the reuse of myriad different materials besides plastics, and the production of certain raw materials in turn requires multiple other source materials. Take, for example, Pennsylvania Department of Environmental Protection's statistics on steel: by recycling over 1.2 million tons of steel in 2005, Pennsylvanians saved 1.4 million tons of iron ore, 829,786 tons of coal, and 71,124 tons of limestone. ${ }^{14}$

## Maximizing Energy Efficiency:

Recycled materials usage in industrial practices has its own benefits, including energy use, industrial extraction, and manufacturing reductions. While the recycling process does consume energy, the process of of extracting new resources and processing them requires greater energy consumption. For example, it is $92 \%$ more energy efficient to recycle an aluminum can than it is to produce a new one. ${ }^{15}$ Metals are the least "downcycled" recyclable product, meaning that the material isn't degraded by continued recycling; energy efficiency for paper and plastics is likely lower, though still significant. One study determined that one ton of recycled paper saves 17 trees. ${ }^{16}$ Because recycling reduces energy consumption, it concurrently reduces greenhouse gas emissions. ${ }^{17}$ In 2013, recycling reduced potential carbon dioxide emissions by 186 million metric tons. ${ }^{18}$

## Economic Benefits:

An Environmental Protection Agency Recycling Economic Information (REI) Study in 2016 found that the recycling industry in the United States accounted for a total of $\$ 36.6$ billion
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in wages and $\$ 6.7$ billion in tax revenues. ${ }^{19}$ Economic benefits are not only measured in monetary figures. The 2016 study also reported that the recycling industry accounted for 757,000 American jobs, or more than 1.5 jobs for every 1,000 tons of material recycled. ${ }^{20}$ Overall, recycling jobs make up $0.52 \%$ of the US economy. ${ }^{21}$ In the state of Massachusetts, recycling is responsible for 13,905 jobs and $\$ 4.98$ million in wages. ${ }^{22}$ Investments in recycling collection support a strong, diverse recycling industry, creating one link in a long chain of economic activity. ${ }^{23}$ Recycling businesses are not in a closed loop, and provide indirect benefits by purchasing goods and services in support of other businesses. Additionally, the sorting and processing of recyclable materials creates ten times as many jobs as if the same materials were put into the ordinary waste stream. ${ }^{24}$ While these employment statistics refer to recycling facilities statewide, the management of Wellesley College's on-campus recycling does require the employment of a number of facility workers and custodians.

In terms of economic benefits for the College, there is an opportunity to get paid significantly for well-sorted or high-quality recycling (such as cardboard or metals) as opposed to garbage, which costs money for Wellesley to send. This provides Wellesley College with the opportunity to profit from its waste. However, the price of commingled recycling, our current system, and the price of glass recycling is often quite high, due to processing costs. The College will have to take these pricing conventions into consideration when adopting a recycling and waste disposal procedure.

[^2]
### 1.2 Background: Life Cycle of Recyclables

Prior to making recommendations for improvements to Wellesley College's recycling system, it is essential to understand the recycling process of each material recycled at Wellesley. For the purpose of this section we will only examine the most common recycled materials: glass, metal, plastic, and paper.

## Glass

After collection, glass is taken to sorting stations where contaminants (ceramics, light bulbs, etc.) are removed and the glass is sorted by color. After sorting, there are four major steps in the recycling process: purification, fining, cullet melting, and forming. In the first step, purification, glass is cleaned of any contaminants. During the next step, fining, glass is shattered into small pieces which are then crushed to uniform size and mixed with sand, soda ash, and limestone. ${ }^{25}$ They then pass through a trommel, where the labels and other items that did not shatter (lids, caps) are removed. After fining, the glass undergoes an additional purification process before progressing to cullet melting. ${ }^{26}$ Different types of glass are cullet melted at different temperatures according to their respective melting points. Finally, in the forming process, melted glass is molded into new products such as bottles and jars.

Glass can be recycled multiple times without degrading in quality and purity. ${ }^{27}$ According to a study done by the Environmental Protection Agency (EPA), the greenhouse gas equivalent of energy savings attributable to recycling glass (compared to glass being disposed as trash) is roughly $150 \% .^{28}$

## Metal

Metals, like glass, can be recycled multiple times without a change in properties. Although aluminum and steel are the most common recycled metals, there are other metals that are just as valuable and recyclable, such as silver, gold, brass and copper.

After collection of the metal there is a sorting process. In large recycling facilities, a magnet is used to locate metals. Sometimes eddy currents and high-pressure air flows also assist with sorting. After the metals have been sorted by similar characteristics, the metal scraps are processed, which involves squeezing and compacting. Some metals are also shredded and broken down into small pieces so they require less energy to melt. Not all metals are shredded. For example, aluminum is compacted into flat sheets and steel is turned into steel blocks. After all metal scraps are in their proper shapes, they are melted. ${ }^{29}$ Each furnace varies in temperature, depending on the metal's properties and its melting point. For example, the temperature required to melt aluminum is around $1220.58^{\circ} \mathrm{F}$. The melting process wastes less energy than the melting

[^3]of raw materials. This process varies in time depending on the volume of the metal and the size of the furnace. After the metals have been melted, they are taken to a cooling area. Chemical additives are combined with the metal to ensure that the final material is free of impurities and is high quality. As the metals are solidifying, they are designed into various shapes and sizes, usually metal bars that can be easily transported. ${ }^{30}$ Recycling metals can save 67.2-153.3 million Btu/Short ton Waste, ${ }^{31}$ as compared to landfilling, which is equivalent to roughly $75 \%$ of GHG savings.

## Plastic

After collection, plastic is sorted by type at the facility (e.g. 1: PET, 2 HDPE...). The sorting process occurs by hand and by various machines that divide the plastic based on resin contents. Plastics are then shredded into tiny pieces and divided by weight of flakes, which are used to make different types of end products. ${ }^{32}$ The plastic pieces are washed with detergents to remove any leftover contamination and then are ready to be melted. ${ }^{33}$ After melting, the plastic pieces are molded into pellets which can easily be used to create various plastic products. Recycling plastic can save 39.8 million Btu/Short ton Waste compared to being thrown in a landfill. This is roughly a $75 \%$ of GHG benefits attributable to energy savings from recycling. ${ }^{34}$

## Paper

Once paper has reached the recycling facility it is separated into several types and grades (newspaper, magazine paper, computer paper). Then it's mixed with water and chemicals to create a slurry called pulp. The pulp is taken through screens made up of different shapes and sizes to remove any contaminants such as glues and plastics. To take out staples and other contaminants the pulp is spun around cone-shaped cylinders, allowing the heavy items still in the pulp to migrate to the center of the cone and then be collected. After this is complete, the paper is de-inked. The pulp is then taken through a refining stage, where it is beaten to make the fibers swell. ${ }^{35}$ If needed, color is added to the paper. Otherwise, the paper is bleached with chlorine dioxide to make the pulp whiter. New wood fibers are added to give the pulp more strength. The pulp is then mixed with hot water and chemicals and the slurry is sprayed continuously into wire mesh screens until the water in the mixture begins to drain, forming a layer of new recycled paper. ${ }^{36}$

[^4]Energy savings of paper recycling varies since it depends on how many times the paper has been recycled. ${ }^{37}$ For newspapers the savings are roughly 16.9 Million Btu/ Short ton of waste and for other papers it can range from 20.6-21 Million Btu/Short ton of waste. These energy savings correspond to $10-30 \%$ reduction in greenhouse gas emissions relative to landfill. ${ }^{38}$

These four categories help us understand the life cycle of the majority of recyclables collected at Wellesley College. It is important to note that although recycling requires a lot of energy, it is often still more energy efficient than relying on new raw materials for products.

## Resource and Land Conservation Through Recycling

Recycling is one example of sustainable management as it encourages the reuse of existing products in order to avoid the need to extract and process new materials. There are significant environmental and economic benefits of resource conservation through recycling of paper products, plastic, glass, and metal. The economic benefits include discounts or cost savings to recyclers as well as energy savings across multiple phases of product life cycles. The environmental benefits include reduced soil erosion, improved air and water quality, avoided deforestation, and increased carbon sequestration due to the decreased need to cut down trees for paper products. ${ }^{39}$

As an example, recycling materials such as metals and plastic, commonly found in ewaste, helps to conserve precious metals such as copper that require intensive energy to mine and manufacture. The EPA gives the following estimates for resource conservation per one ton of paper, plastic, aluminum, and glass: one ton of paper recycled saves 17 trees (recycled newsprint saves 4.6 cubic yards of landfill space and 60 pounds of air pollutants from being released), one ton of plastic saves 16.3 barrels of oil and 30 cubic yards of landfill space, one ton of aluminum saves 4 tons of Bauxite Ore, 40 barrels of oil, and 10 cubic yards of landfill space, and one ton of glass saves one ton of mixed limestone, soda ash and sand as well as preventing 7.5 pounds of air pollutants from being released. ${ }^{40}$

[^5]
### 1.3 Background: Wellesley College

Wellesley College was founded in 1870 with the purpose of providing advanced education opportunities for women. It is a private, four-year women's college located in Wellesley, Massachusetts, with about 2,300 students enrolled. The College has a liberal arts curriculum, offering over 50 majors. ${ }^{41}$

Since 1968, Wellesley College has offered cross-registration programs with other schools in the Boston area, including the Massachusetts Institute of Technology, Babson College, and Olin College. Some of Wellesley's most famous alumnae are Madeleine Korbel Albright '59, the first woman to become the United States Secretary of State, and Hillary Rodham Clinton '69, former Secretary of State, senator, First Lady of the US, and the first woman to be nominated for president by a major U.S. political party. ${ }^{42}$

[^6]
### 1.4 Background: History of Recycling at Wellesley College

Recycling awareness on Wellesley College's campus began as early as Earth Day, April 1970, when a group of students presented about the benefits of waste recycling to the College and their peers. ${ }^{43}$ The recycling movement continued to build momentum on campus with student group efforts to recycle beginning in October 1974. At this time, the Wellesley Environmental Concerns Group (WECG) began sponsoring a recycling program on the Wellesley College Campus. Their intent was to expand to a "campus wide recycling program," because at this time (October 11th, 1974), recycling was only present in Green Hall, a building in the Academic Quad. It was limited to paper only. WECG began urging for paper recycling programs to begin within residence halls and held high hopes for them to begin soon. ${ }^{44}$ In February, 1975, WECG sent out a recycling policy to the House Councils, the voting bodies of Wellesley's residential halls, in an attempt to get them to begin implementing a process for recycling paper in each hall. According to WCEG's plan, certain selected students in each hall would be responsible for carrying filled recycling boxes down to the basement once a week. Then, custodial staff would call for pickup once the quantity was large enough for collection. However, two months later, many House Councils had still not replied to the letter sent by WECG, which indicates that getting a grassroots recycling program to stick on campus was likely a slow and challenging process. ${ }^{45}$

In 1989, Wellesley took an important step forward in efforts to recycle by forming a task force of students, staff, and administrators charged with the goal of increasing recycling and conserving paper on campus. Following the recommendations of that task force, the College began recycling on an institutional level in April 1990. By the fall of 1990 the College's recycling program expanded from white paper and cardboard to include colored paper, aluminum, and glass. The College introduced collection bins in residential, academic, and administrative buildings. ${ }^{46}$ To encourage student participation, House Councils elected conservation and recycling representatives, who held a role similar to the position of Ecorepresentative that still exists in residence halls today. ${ }^{47}$

Since then, Wellesley has sought to refine its recycling programs. As in the 1970s, student organizations have been crucial to the expansion of the College's recycling programs. In the early 2000s, student members of Wellesley Energy and Environmental Defense (WEED) engaged in what the organization referred to as "guerrilla recycling," collecting recycling at large

[^7]campus events like the Ruhlman and Tanner conferences, and taking it themselves to the Town of Wellesley Recycling and Disposal Facility. ${ }^{48}$ In 2008, WEED took notable efforts to expand recycling on campus, leading to a $43 \%$ decrease in recyclables thrown in the trash by 2009. ${ }^{49}$ The College continued to try new approaches to increase engagement in recycling on campus. In 2011 Wellesley installed a Greenbean Recycle machine on campus, which allows students to earn money while they recycle. ${ }^{50}$ In the following years the College joined local and national recycling competitions between universities, such as Recyclemania. ${ }^{51}$

Today, Wellesley continues to collect and recycle traditional materials such as mixed paper, cardboard, metal, glass, and plastics, and has expanded to recycle nontraditional materials including styrofoam and electronics. ${ }^{52}$ Beyond recycling, Wellesley has also worked to reduce the amount of durable goods entering its waste stream by creating the Move-In Sale and the Sustainable Move-Out Collection that occur at the beginning and end of each school year, providing an opportunity for unwanted items (such as furniture) to get reused instead of thrown away. ${ }^{53}$


Figure 1.4.1: Recycling practices at Wellesley in the 20th century. Image courtesy of the Wellesley College Archives.

[^8]
### 1.5 Background: Current Recycling Practices at Wellesley College

Recycling at Wellesley College is collected from each academic, residential, and administrative building, placed in dumpsters, and then transported to a disposal facility. Collection bins are located in all campus buildings, although bin styles and configurations vary widely across campus. Most residence halls have large bins on each floor for both mixed paper/cardboard recycling and commingled recycling, but these are not always close together or easy to find. In the East Side residential buildings, recycling is instead collected using a four bin system. Recycling in academic buildings is even less standardized, with substantial differences between floors of the same building. The location of paper recycling bins is more predictable than commingled bins. Paper recycling bins are usually located near printers and in hallways, and there is typically at least one bin per floor. Commingled recycling bins, on the other hand, cannot be found on every floor of every academic building. Before now, there has not been centralized information on recycling bin locations across campus. We have created maps of current recycling bin locations for academic and residential buildings on campus in order to better understand our current system, and to provide a resource for those who may implement recycling changes across campus (see: Appendix B: Current Wellesley Campus Recycling Map).

Custodians collect recycling daily or as needed from their assigned buildings. They may do some sorting by hand to remove trash or contaminated recycling before leaving it at outdoor collection sites. Custodians may place bags with a high level of contamination, often food, in the trash at their own discretion. At collection sites, recyclables are divided into three streams: mixed paper, commingled recycling, and clean corrugated cardboard. Cardboard boxes from AVI Fresh dining service and other large-scale sources are compressed into bales at two sites on campus. The College pays (or is paid) a different price to recycle each stream (Figure 1.5.1). Mixed paper and cardboard are significantly more valuable than commingled recyclables since the raw material is more easily recycled and less often contaminated.

The College pays Wellesley Trucking Service $\$ 150$ per dumpster load to pick up trash and deliver it to a disposal facility. Until February 2018, all recyclables went to the Town of Wellesley Recycling \& Disposal Facility (RDF), using college-owned vehicles. This facility is only three miles from campus, and serves the residents and businesses of Wellesley. In February, the RDF raised its rates on certain types of recyclables to reflect the recent changes in Chinese national policy (see: Background: China and U.S. Recycling) that limit imports of recyclables from abroad for processing. Under the RDF's new fee structure, the College would pay more to recycle commingled recyclables than it would to dispose of them with its trash. As a temporary solution, the College is using Wellesley Trucking to take its commingled recycling to the Covanta Recycling Station in the town of Holliston, ten miles from campus, where the College also sends its trash. The fee for recycling here is approximately $\$ 95$ per ton. ${ }^{54}$ Wellesley College will need to make a longer-term decision on where to transport recyclables collected on campus in the near future.

[^9]| Material/Stream | Cost/Revenue before Feb. 2018 | Cost/Revenue after Feb. 2018 |
| :--- | :--- | :--- |
| Mixed Plastics | No cost | No cost |
| Cardboard | $\$ 15 /$ ton revenue | $\$ 15 /$ ton revenue |
| Paper | $\$ 5 /$ ton revenue | $\$ 5 /$ ton revenue |
|  <br> Cardboard | $\$ 5 /$ ton revenue | $\$ 5 /$ ton revenue |
| Mixed Metals | No cost | No cost |
| Glass | $\$ 10 /$ ton cost | $\$ 125 /$ ton cost |
| Single-Stream | $\$ 60 /$ ton cost | Stream not accepted |
| Commingled | $\$ 60 /$ ton cost | Stream not accepted |

Figure 1.5.1: The costs and revenues for Wellesley to dispose of recycling. Cost to the College for recyclables taken to the Wellesley Recycling and Disposal Facility, before and after February 2018. ${ }^{55}$

[^10]
### 1.6 Background: China and U.S. Recycling

Since undergoing economic reforms in the 1980s, China has emerged as a global superpower. China's enormous manufacturing and exports sector powered this growth, increasing the internal demand for labor and raw materials. ${ }^{56}$ High production costs and insufficient supply of raw materials encouraged industrial usage of waste materials. As a result, China began importing wastes, a cheaper alternative, from international sources. China is now the world's largest importer of waste and scrap. The United States is the world's largest exporter of waste, with $30 \%$ of US recycled scrap exported to China. ${ }^{57}$

In recent years, growing concerns over imported waste quality have forced China to reconsider its status as "the world's dumping ground. ${ }^{" 58}$ China has historically accepted waste from the European Union, North America, Japan, and other neighbouring countries. China sharply increased its waste imports from these countries in 2000 and import levels have continued to rise ever since. ${ }^{59}$ This increase in imports resulted in higher levels of illegal, falsely labelled shipments and more highly contaminated and poorly sorted low quality waste. ${ }^{60}$ In response to growing domestic concerns over public health, growing pollution levels, and environmental impacts, China began a campaign against its yang laji, "foreign garbage," ${ }^{61}$ notifying the World Trade Organization in July 2017 that it would no longer accept imports of 24 categories of waste, including plastic, unsorted paper, metal, and glass. ${ }^{62}$ Additionally, China set goals to replace all solid waste imports with domestic sources by 2019, and China's Ministry of Environmental Protection set a maximum contamination rate of $0.3 \%$ for current scrap imports, effectively banning imports due to difficulty for countries to achieve such low contamination levels. ${ }^{63}$

These policy changes in China will have lasting effects around the world. If China's waste market fully closes in 2019, the US faces a loss of more than $\$ 5$ billion annually in

[^11]unexported waste. ${ }^{64}$ Currently more than 40,000 jobs in the US are supported directly by the waste export industry, with another 94,000 jobs supported indirectly. More than $\$ 3$ billion in tax revenue from waste exports are collected at the federal, state, and local levels. ${ }^{65}$ Since the ban's announcement, the monetary value of domestic recyclables has declined and domestic waste processors have been forced to consider alternatives for their waste. While the US attempts to develop markets in other countries, many local waste and recycling processing centers have begun to limit the amounts and types of waste they will accept, leading to increased dumping at landfills. ${ }^{66}$ Companies have also been trying to address and enhance trash sorting processes at local levels by changing curbside systems and using robots within facilities. ${ }^{67}$ As recycling piles up instead of being shipped to China in many municipalities across the US, disposal facilities have stopped accepting certain types of waste and recycling. ${ }^{68}$

At Wellesley College, the effects of China's waste ban are already being felt. In February 2018, the Town of Wellesley RDF changed its prices to reflect the low demand for commingled recycling streams, as outlined above in Background: Current Recycling Practices at Wellesley. Similar price increases have occurred at other facilities across Massachusetts. ${ }^{69}$ These ripple effects will likely continue until the US can find an alternate market for its recyclables or limit its product consumption, and address the source of its waste problems.

[^12]
### 1.7 Background: Massachusetts Recycling Laws

Although China's recent policy change makes recycling more difficult and expensive, Wellesley College is still bound by Massachusetts laws that require us to recycle. By implementing waste bans on select items, Massachusetts law indirectly mandates recycling, with the hopes that improved recycling rates will rescue resources, save energy, reduce greenhouse gas emissions, support thousands of jobs, and generate millions of dollars for the economy of the Commonwealth. ${ }^{70}$ By law, banned items cannot be discarded into the trash. The list of banned materials has grown since its introduction in 1990. Items banned from landfills and incinerators include metals, glass, plastics, paper, and cardboard, as well as large appliances, lawn waste, and construction materials. ${ }^{71}$

While all Massachusetts citizens and institutions must comply with the waste ban (310 CMR 19.081), regulation to ensure compliance operates at the waste-facility scale. Landfill, transfer, and combustion facilities cannot accept banned items and are subject to inspection by third parties. ${ }^{72}$ The Department of Environmental Protection (DEP) may allow a facility or person to dispose of restricted materials temporarily if the material is contaminated or the regular recycling facility cannot accept the material as a result of an administrative or judicial order. ${ }^{73}$ Because waste facility operators are responsible for ensuring that banned materials are removed from disposal and properly recycled, they retain the right to charge fines/handling fees, reject waste, and restrict waste disposal. ${ }^{74}$

In response to leveled-off recycling rates following an increase from $10 \%$ to $47 \%$ after the implementation of the 1990 Solid Waste Master Plan, MA Bill S454 (2015-2016) requires that cities/towns report the amount of solid waste disposed annually to the DEP. If the municipalities are not meeting DEP target waste reduction levels, they must report reasons why. ${ }^{75}$

Wellesley College, as a private institution within Massachusetts, must comply with state waste bans. The Town of Wellesley does not implement any other laws related to recycling. The town waste disposal system requires residents to personally drive their trash and recycling to the Town of Wellesley RDF. Disposal is paid for through tax dollars, but in order to use the RDF, residents must carry a valid permit, which they must apply for and then adhere to the windshield of their vehicle. Residents must agree to register the permit to a single vehicle, and cannot transfer the permit to other vehicles. ${ }^{76}$ The RDF classifies Wellesley College as 'Commercial Customers,' charging the College per ton of waste and recyclables.

[^13]
### 1.8 Background: Waste and Recycling Profile of Wellesley College

Wellesley College produces an approximate 1,000 tons of trash per year. In 2017, the college produced 174.7 tons of recycling, which corresponds to a $17.5 \%$ recycling rate. Of these 174.7 tons, Wellesley collected 94.7 tons of commingled recycling and 80 tons of mixed paper recycling. ${ }^{77}$

In 2012, the ES 300 class conducted a waste audit of trash collected from the Bates, Freeman, and McAfee residence halls, as well as the Bates Dining Hall. ${ }^{78}$ A substantial portion of the waste the 2012 class sorted was recyclable, with large quantities of paper, plastics, metals, and glass in the trash (Figure 1.8.1). Other recyclable materials such as e-waste and styrofoam were also thrown out. $33.9 \%$ by weight of the materials disposed of as trash are mixed paper and commingled that could be recycled. Based on this estimate, Wellesley College has the potential to recycle an additional 323 tons.


Figure 1.8.1: Percentage of waste comprised of recyclable materials (2012 waste audit).
Contamination from incorrectly discarded items can also pose a problem for recycling rates. If a particular bag of recycling has too many incorrectly recycled items - such as dirty food containers or un-emptied plastic bottles - the recycling may be too contaminated to be accepted by a recycling facility. Bags with high levels of contamination are commonly thrown in the trash by Wellesley College custodians. ${ }^{79}$

Fortunately, the contents of recycling bins coming from residence halls and academic buildings on campus is relatively uncontaminated (see: Experiments). The recycling profile of

[^14]Wellesley College has the most room for growth with respect to decreasing the amount of recyclable materials that end up in the trash. However, in pursuit of this goal, we must be mindful of the potential to unintentionally increase the number of incorrectly recycled items that contaminate our recycling.

### 1.9 Background: Methods for Experiments

In order to test which behavior-based and infrastructure-based changes increased recycling rates, we conducted several experiments in buildings on campus. In each experiment, we collected trash and recycling from each of our experimental locations once per week for three weeks. We established baseline measurements in the first week, then applied treatments and took measurements over the next two weeks.

Prior to beginning our experiments, we conducted a baseline measurement of all experimental and control locations to determine the typical recycling and trash behaviors in each location. The week after first implementing interventions is uniformly referred to as "Week 1 ," and the subsequent week is referred to as "Week 2." Each experiment had at least one "treatment" floor and one "control" floor to account for various circumstances/events (parties, lectures, etc.) that might influence recycling and trash rates week to week.

With the exception of one experiment that sorted through trash to find potentially recyclable objects, we exclusively weighed trash and then disposed of it. For each floor that was a part of our experiments, including controls, we collected all trash except for trash in bathrooms for health and safety reasons. Once we collected trash and recycling, we took it to the Cazenove Hall kitchen and dining space (no longer in use as a functional dining hall) to be sorted, weighed and disposed of.

All measurements are reported in pounds (lbs). The scales used in these experiments are unable to measure anything less than 0.2 lbs . After weighing total recycling, we separated recycling into paper, plastic, glass, aluminum, other and non-recyclable objects. Non-recyclable objects are referred to as "incorrect" recycling.


Figure 1.9.1: Sorting recycling collection during experiments. Commingled recycling was sorted into plastic, glass, and aluminum. Each type of material was then weighed separately.

## Limitations:

Limitations of our data collection methods could have altered our results' accuracy to some degree, particularly in how we weighed commingled recycling. One limitation was that waste and recyclables were weighed instead of counted. To calculate the percent incorrect recycling, for example, we weighed the total collection sample, then separated the incorrect recycling from the correct recycling and weighed the incorrect recycling to create a value of incorrect recycling as a percent of total recycling. We did not count the number of items incorrectly disposed of in the recycling bins. This could cause misleading percentages of incorrect recycling in certain cases. For example, there could be massive amounts of paper in the commingled recycling bins (which would count as "incorrect recycling"), yet as a percentage of the total weight it would not seem like there was a significant amount of incorrect recycling because paper is much lighter than glass. Our data also does not account for how some materials are more harmful than others when recycled incorrectly. Food and contaminated recycling, for example, may be a smaller percentage of the weight of incorrect recycling than the incorrect recycling caused by the misplacement of glass in a paper bin, but are more of a concern because of the potential to contaminate an entire bin of recycling. Contamination is more likely in plastic food containers, which are relatively light, and many students do not wash them before recycling. This has implications for our weight measurements and could influence interpretations of our data.

It is also important to note that in cases where paper recycling appears lighter than other types of recycling, more individuals may have contributed to the paper recycling. We believe that the weight of recycling is not always representative of the recycling participation rates, and that there are events on campus that contribute to peaks in recycling by smaller groups or individuals. For example, in almost all residential experiments, we noticed a peak in recycling during one week, which we believe to be due to an on-campus party that caused an increase in recycled glass and aluminum containers. In academic spaces, lectures and events tend to increase the amount of recycling and waste generated. While these types of events vary in frequency, it is important to take into consideration formal and informal events in residential and academic spaces that contribute to a large volume of waste.

## 2. Behavior

### 2.1 Experiment: Recycling Pledges Are Hard to Get, and Have Little Influence

## Overview

Pledges have been shown to be a useful tool to increase participation in desired behaviors. This experiment examined whether the use of public or private recycling pledges could increase positive student recycling behaviors on campus. We hypothesized that if the student living in residence halls took pledges-either publicly or privately-to recycle properly, they would feel more accountable for their waste disposal decisions and therefore recycle more often and more accurately. To test this hypothesis, we introduced public and private pledges to floors in the Bates Hall and Freeman Hall, and measured the properly sorted recycling over three weeks. We found that neither public nor private pledging increase recycling rates, and they do not reduce trash production either. Pledging participation was too low to fully reflect changes to recycling behavior on participating floors. As participation was greater with public pledges, we encourage methods emphasizing community to be considered when trying to increase positive recycling behavior.

## Background

Behavioral studies have shown that after individuals agree to an initial request or commitment, they are subsequently more likely to engage in a substantial activity. The creation of a pledge has potential to trigger behavioral change by utilizing the "foot-in-the-door effect." 80 Pledges can initiate behavioral change by using a commitment technique to overcome barriers that might hinder a desired goal. Some studies have shown that those who sign a pledge promising a certain behavior will feel compelled to follow through with the behavior in order to see themselves in a positive light. ${ }^{81}$ While the results of these studies could be applied to improve many human behavioral issues, the use of pledges for achieving sustainability goals proves compelling.

We hypothesized that a behavioral change campaign, such as a pledge, could potentially benefit our recycling behavior at Wellesley. This experiment sought to test the efficacy of inciting positive behavioral change through social norms (which could be assessed through the making of a public pledge) and individual perceptions of responsibility (which could be assessed through the making a private pledge). This type of approach to change behavior is more behaviorally based than approaches changing the infrastructural design of our recycling system.

## Methods

We collected private and public pledges in two residence halls - Bates Hall and Freeman Hall - because of their identical construction, number of residents, and well-defined recycling areas. We conducted experiments on the first through third floors of each building where the first floor was given public pledges, the second floors private pledges, and the third floors a control treatment of no pledges.

[^15]Both pledges in this experiment were identical (Figure 2.1.1), but some participants were asked to take it publicly while others were asked to take it privately. A "public" pledge would be taken in the view of others, or posted where anyone could see who had pledged, whereas the names of signers of the "private" pledge were only to be seen by the pledge's creator. In the control treatment, no pledge system was introduced.


Figure 2.1.1: Recycling pledge distributed to residents of experimental floors. Participants filled in their name, signature, and date of taking the pledge for both the public and private pledges.

For the public pledges, we worked in coordination with the student Residential Assistant (RA) of each floor to plan a small floor event based around informing residents of the pledge. Part of the duties of the RA include holding regular gatherings in the floor's common space to encourage community growth. We offered attendees freshly baked cookies as a way to encourage attendance. At the event, we explained the need to improve recycling on campus, offered the residents paper copies of the pledge to sign, and thanked them for their participation. The signed public pledges were then pasted on a decorative wall (created by the RA at the beginning of the year) behind the recycling bins on the floor, in order to further publicize the effort and create a visual representation of the new social norm (Figure 2.1.2).


Figure 2.1.2: Public pledges pasted above Bates and Freeman first floor recycling bins.
For the private pledge, RAs distributed the pledge to their residents via a Google form, and we paralleled the cookie incentive by pinning cookies to the doors of those who participated. However, the RA of the private pledge floor in Freeman never distributed this electronic information to her floor and did not respond to follow up inquiries, so we interpreted the data collected on that floor as equivalent to data from control treatments.


Figure 2.1.3: Collection and sorting of recycled materials and trash in Cazenove Hall kitchen.

Trash and recycling were collected weekly. Following collection, recyclables were sorted and weighed by material. Commingled recycling was sorted as plastic, glass, cans, and incorrect (garbage or contaminated materials), and paper recycling as paper, cardboard, and incorrect (Figure 2.1.3). On the first collection date, we also sorted through the trash to determine the percentage of potentially recyclable material that was being diverted from the recycling stream. This gave us a general idea of the amount of recyclable material in the trash at the time of collection. For the remaining collection dates, we only continued further sorting of recycled material. However, we were concerned that some materials we considered to be contaminated recycling, or trash, had not originally been in that state when they were initially disposed of. Thus, our measurements may not fully reflect the amount of recyclable material being thrown into the trash.

During data processing, we found an additional, unexpected weight value for commingled recycling collected on March 4th; though we were ultimately unable to determine whether this was value was a valid data point or the result of human error, we chose to include it in our analysis, noting 1.1 kg of "wrong" material in the trash.

## Results

Generally, pledge participation was low for both public and private pledges. Participation in pledges ranged from $10-32 \%$ of residents on each floor (Figure 2.1.4). Baseline levels of recyclables in the trash by mass were approximately 6-10\% in Bates, and approximately 20-30\% in Freeman. These levels may be underestimated, given the number of contaminated materials in the trash that were designated as no longer recyclable and, thus, excluded from the measurement of recyclables in the trash.

| Building and pledge type | Number of participating residents | Percentage of participants |
| :--- | :--- | :--- |
| Bates Hall, public | 10 | $32 \%$ |
| Freeman Hall, public | 8 | $26 \%$ |
| Bates Hall, private | 3 | $10 \%$ |

Figure 2.1.4: Pledge participation rates by building and treatment. Percentages were calculated as the number of participants relative to the total number of residents on each floor.

On average, the weight of recycled material decreased over time on floors with residents that took the private and public pledges, as well as floors that did not participate in the pledge system (Figure 2.1.5). These results suggest that the use of pledging does not significantly impact recycling behavior compared to no pledging.


Figure 2.1.5: Average weight (lbs) of recycled material before and after pledge commitments. Public and private pledges were taken after making baseline measurements. The weights of all recycled material combined (commingled and paper) were averaged for floors receiving the control ( $n=2$ ), the public pledge treatment ( $n=2$ ), and the private pledge treatment ( $\mathrm{n}=1$ ).

Separately considering each floor reveals an initial decrease in the mass of items recycled between the baseline and week 1, but also great variation in recycling mass at baseline and over time (Figure 2.1.6). We observed an increase in the weight of recycled material between the first and second week following participation in recycling pledges for both the control floor in Bates Hall and the public pledging floor in Freeman Hall (Figure 2.1.6). All other trends illustrated small or large declines in recycling weight. Additionally, the percent of total waste output that was comprised of recycling slightly increased in both private and public pledge residence halls, but also increased in the control residence halls (Figure 2.1.7). These results also suggest that pledging does not significantly impact recycling compared to no pledging.

| Building / Treatment |  | Change in Amount Recycled |  |
| :---: | :---: | :---: | :---: |
|  |  | Baseline to Week 1 | Week 1 to Week 2 |
| Bates Hall | Control | -42\% | 118\% |
|  | Public | -28\% | -51\% |
|  | Private | -71\% | -18\% |
| Freeman Hall | Control | -14\% | -79\% |
|  | Public | -55\% | 15\% |

Figure 2.1.6: Percent change in total amounts of correctly recycled items. The percent change in weights of all recycled material combined (commingled and paper) were calculated by floor between the baseline and Week 1 and between Week 1 and Week 2. Negative percentages reflect decreases in amounts of items recycled.


Figure 2.1.7: Recycling as a percent of overall waste in both residence halls combined. The percent of the total amount of waste output (trash and all recycling streams) that was comprised of recycling in the different experiments was calculated.

The percent of material mistakenly recycled showed no trend in both public and private pledging, as well as in the control treatment (Figure 2.1.8). This result suggests that pledging does not significantly impact rates of incorrect recycling.


Figure 2.1.8: Total non-recyclables found in both commingled and paper recycling bins as a percent of total overall recycling.

The average weight of trash decreased steadily over the course of experimentation (Figure 2.1.9). The private floors exhibited consistently higher masses of garbage than that of the floors that participated in the public pledge, although the two demonstrated similar rates of decrease in garbage mass (Figure 2.1.9). These results suggest that private pledges do not reduce trash generation as well as public pledging.


Figure 2.1.9: Average weight of trash before and after pledge commitments. Public and private pledges were taken after making baseline measurements. The total weights of trash produced on each floor were averaged for floors receiving the control ( $\mathrm{n}=2$ ), the public pledge treatment $(\mathrm{n}=2)$, and the private pledge treatment $(\mathrm{n}=1)$.

## Discussion and Conclusion

We sought to determine the effects of using public and private pledging to increase recycling behavior. We expected the pledge to create an increase in properly recycled materials and, concurrently, a decrease in the amount of trash placed in recycling bins. By specifically disseminating information about proper recycling through the floor events and e-mails, we sought to change student recycling behavior through education and exposure to a set of established rules and norms. We also sought to compel people to follow through on their promises of having better recycling behavior through pledging, and hypothesized that this behavioral change would be reflected in the cleaning of bottles and cans, throwing out of contaminated food containers, and correct separation of paper and commingled recyclables, and ultimately in recycling and trash generation levels.

We found that neither public nor private pledges consistently increased the amount of material recycled. However, given low pledge participation, we were not confident that the full effect of pledging on recycling behavior was reflected in this study. After measuring baseline trash and recycling production and subsequent recycling and trash production following pledging, we observed steady decreases in both trash and recycling mass across treatment groups and the control. This trend may reflect weekly variability in waste production across residence halls and floors within residence halls.

The public pledge was shown to have little effect at reducing incorrect recycling levels (Figure 2.1.8). For the private pledge, there was only data for one floor (Figure 2.1.8), making the accurate assessment of the effect of the private pledges on recycling difficult.

The greatest challenge of this study was insufficient participation in the public and private pledges to confidently correlate the response in waste disposal patterns from the pledge treatments. Because rates of participation ranged from $10-32 \%$, the small fraction of residents actually participating in the pledges may not have been significant enough to produce a measurable effect on the floor's recycling profile. However, while participation rates were low, more than twice as many people took the pledge on floors that offered public pledges than those that offered private pledges (Figure 2.1.4). This result suggests that the greater social visibility of the public pledge could increase the number of people willing to pledge to improve recycling behavior. Although we could not confidently measure the subsequent effects of pledging on recycling rates, we do suggest public pledging as a way of engaging residents in recyclingpositive behaviors. Because acquiring participation for pledges was difficult, however, we would not advocate offering a pledge system as a primary method to encourage proper recycling, but we would suggest some system of communal participation in increasing recycling efforts. This approach is likely transferable to other residence halls, and in concept may be implemented in academic buildings as well.

Finally, we observed a significantly larger percentage of recyclables in the garbage bins in Freeman Hall, at 2-3 times as much as that in Bates Hall. This effect may be related to the neat and proper signage on the recycling stations in Bates Hall, as opposed to the unclear signage on recycling stations in Freeman Hall, suggesting that signage and infrastructure may also affect behavior.

Ultimately, the amount of recycled material did not increase nor did the amount of trash decrease in response to private or public pledging. The results of this study are largely inconclusive given the low pledge-participation rates and low number of replicates. Nonetheless, the greater participation in public over private pledges suggests a potential use of social encouragement or pressures to promote recycling-positive behavior.

### 2.2 Survey: Recycling Motivation/What Inhibits Recycling?

## Overview

To identify specific ways in which on-campus recycling could be improved, we decided to dive deeper and discover the recycling motivations of Wellesley College's students, faculty, and staff. We created and disseminated a survey, composed of demographic, Likert Scale, and short answer questions focusing on individual and institutional barriers to recycling, as well as potential improvements to recycling behaviors. After collecting responses over a week-long time span, we found that uncertainty over what items can be recycled, lack of accessibility to recycling bins, and contaminated recyclables were the primary barriers to recycling.

## Methods

Our goal was to gauge on-campus barriers to recycling and find potential ways to increase recycling. The survey facilitated our understanding of on-campus circumstances and sentiments that complicate or preclude recycling. Since this is a behavior survey, our answers are a combination of multiple choice, Likert Scale, and 'check all that apply' questions. In the Likert Scale series, our survey provided respondents with five ranks to choose from, ranging from 'Strongly Disagree' (1) to 'Strongly Agree' (5). Initial survey questions asked for respondent's background information (student, staff, faculty) and graduation year (if a student), followed by a Likert scale question with various statements about why respondents might not have recycled (Figure 2.2.1).

In the last month, recall a time when you didn't recycle and rank the following factors as reasons why you didn't recycle. *


Figure 2.2.1: Survey question measuring reasons respondents did not recycle when they could have. Responses to 6 statements were given using a Likert scale.

All these options required respondents to choose whether they agreed or disagreed with a particular statement. We picked questions to pinpoint where exactly we needed to focus most of our efforts on, whether it be educating our community about recycling or adding more bins around campus. We included an optional short answer component where responders could choose to express any other reason they do not recycle as much as they should.

Finally, in order to identify what options would motivate individuals to recycle more, we made a 'check all that apply' question on what factors they believed would increase their likelihood of recycling, with the options listed in Figure 2.2.2. Our last question was open ended, which allowed responders to express any additional thoughts they had about recycling on Wellesley campus.

What would help you to recycle more? Select all that apply *More recycling bins around campus
$\square$ A personal recycling binMore information about what can be recycledBetter signageIncentives (\$ for each bottle recycled)Disincentives (punishment for incorrect recycling)Competitions (by class year, res hall, or department)Other:

Figure 2.2.2: Survey question where respondents could identify ways that would help them recycle more. Respondents could select as many options as they wanted and were given the opportunity to add their own.

## Results

We analyzed results to the first question (Figure 2.2.1) as a positive, negative, or neutral response. Positive responses were ones in which the respondent answered that they "Somewhat Agree" or "Strongly Agree." Negative responses were ones in which the respondent answered that they "Somewhat Disagree" or "Strongly Disagree." The positive responses were totaled by statement to create a percent positive and a percent negative response.

We collected a total of 187 responses: 23 faculty members, 53 staff members, and 111 students. These responses were aggregated by community group in Figure 2.2.3, 2.2.4, and 2.2.5 to identify trends in responses that might be different due to the varying roles filled by each group on campus.


Figure 2.2.3: Reasons faculty respondents $(\mathbf{n}=23)$ did not recycle. Red/pink colors indicate a positive response to the prompt, meaning that respondents agreed that the statement was a reason they did not recycle. Yellow colors indicate a negative response to the prompt, meaning that respondents did not agree that the statement was a reason they did not recycle. Grey indicates neutral responses.


Figure 2.2.4: Reasons staff respondents $(\mathbf{n}=53)$ did not recycle. Green colors indicate a positive response to the prompt, meaning that the respondent agreed that the statement was a reason they did not recycle. Blue colors indicate a negative response to the prompt, meaning that the respondent did not agree that the statement was a reason they did not recycle. Grey indicates neutral responses.


Figure 2.2.5: Reasons student respondents $(\mathbf{n}=111)$ did not recycle. Blue colors indicated a positive response to the prompt, meaning that the respondent agreed that the statement was a reason they did not recycle. Green colors indicate a negative response to the prompt, meaning that the respondent did not agree that the statement was a reason they did not recycle. Grey indicates neutral responses.

All three groups indicated that the three most common reasons they did not recycle were "I didn't know if it could be recycled," "I couldn't find a recycling bin," and "My recyclable was dirty."


Figure 2.2.6: A breakdown of the three most popular responses by campus group.

While all three groups responded with agreement to the prompt "I didn't know if it could be recycled," there was variation in the percentage of respondents in each group that agreed. $76 \%$ of students agreed that they didn't know if something could be recycled compared to only $53 \%$ of staff and $43 \%$ of faculty (Figure 2.2.6). This indicates that recycling information campaigns should be targeted primarily at students.

For the statement "I couldn't find a recycling bin," $68 \%$ of student respondents agreed, compared to $43 \%$ of staff and $52 \%$ of faculty (Figure 2.2.6). This result might indicate that we should focus on making recycling bins more clearly available in student spaces, such as residence halls, rather than faculty offices.

While a significantly smaller group overall responded positively to the statement "I didn't think it would make a difference," the students had a more positive response to this statement, indicating that they agreed that "[recycling] wouldn't make a difference." Faculty and Staff positive responses ( $9 \%$ and $11 \%$, respectively) were lower than students (17\%) (Figure 2.2.6).

In the second question (Figure 2.2.2), respondents indicated that the top three things that would help them recycle more include: more information, more bins, and better signage (Figure 2.2.7).


Figure 2.2.7. Aggregated responses to "What would help you recycle more?" Students, faculty, and staff selected which options they thought would increase their personal recycling habits.

## Discussion

Our results indicate that three major obstacles to recycling on Wellesley College campus are uncertainty around what can be recycled, lack of recycling bin access, and soiled recyclables.

The confusion surrounding whether or not an item is recyclable can be ameliorated by providing greater information regarding possible recyclables to our campus community, potentially in electronic (website, email) or print (campus-wide posters and infographics) form. Additionally, annual orientations for incoming first-years can provide a space for recycling education, equipping all new students with proper recycling knowledge and behaviors. Including information on what to recycle and not to recycle, as well as other sustainability focused programming could be a useful introduction to Wellesley's standard recycling behavior. Although many other events also occur during orientation, this will serve to normalize recycling and sustainability on campus. This information could be repeated for first years and reintroduced to upper class students by including recycling information on the agenda for the first floor meeting led by RAs that takes place in the first week of classes.

Second, lack of recycling bin access remains a pressing problem. Profound bin variation exists across the academic, residential, and administrative buildings. Differences in bin size, capacity, shape, and distribution (within buildings) create cross-campus inequalities in recycling ease and accessibility. For example, numerous faculty and staff respondents reported a lack of inoffice recycling bins, and student respondents noted a dearth in glass/aluminum/plastics bins in Clapp Library. A smaller, yet commonly identified issue related to bin distribution and accessibility was inconvenience. Sparsely-distributed recycling bins inhibit immediate recyclable disposal. Instead, individuals must carry around their waste materials until finding a recycling bin. Establishing more recycling bins across all buildings, possibly even including students and staff who desire individual bins, would increase the number of on-campus recycling bins, making recycling a more accessible and convenient task.

Dirty recyclables pose a third major challenge. Individuals with sullied containers may feel reluctant to place their unclean items in recycling bins. Taking time to clean potential recyclables poses an inconvenience. Instead, discarding the item in the trash could be, for some, an easier option. Identifying a dirty recyclable could serve as a challenge, itself, for "dirty" is highly subjective; what may be considered too dirty to be recycled by some may be still viewed as clean and recyclable by others. Insufficient knowledge of the features defining "proper" recycling leads to not only the disposal of unclean recyclables, but also the incorrect handling of the College's recycling overall.

Some respondents believed that items diverted into Wellesley College's recycling stream were not even being actually recycled, but rather thrown away with the trash; these sentiments were also repeated by members of Wellesley's custodial staff. To assuage doubts about Wellesley's recycling practices, the College could be more transparent about the requirements of the conditions of recyclables, and the College's process of, and support for, recycling. Knowledge of how the College handles its recycling, if provided to all Wellesley College community members, could assure individuals that recycling is handled properly, and not merely discarded as trash. Further confirmation that the College stores recycling securely, with no access to insects or vermin, matters as well.

Overall, increasing recycling will require action on both individual and institutional levels. Providing information on what items can and cannot be recycled on campus, placing greater numbers of uniform, large-capacity bins around campus, and improving recycling signage were identified by our respondents as the most preferred improvements to on-campus recycling. On the contrary, recycling competitions, disincentives/punishment for improper
recycling, and the dissemination of personal recycling bins would not help Wellesley to increase recycling, according to respondents, though some desired their own individual bins.

## 3. Infrastructure

### 3.1 Custodians

Custodial staff and facilities are important stakeholders in recycling at Wellesley College. We conducted interviews with several custodians across campus, some of whom had served in several buildings before and could speak to the differences between buildings. We aggregated custodian commentary by topic so as to preserve anonymity.

## Incorrect Recycling

Because several of our experiments measured incorrect recycling, we asked custodial staff to share observations about recycling practices. One custodian in an administrative building said that students place food in the recycling stream more frequently than staff. Another custodian expressed similar concerns, saying that though custodians often take out some of the incorrect recyclables out of the bins, they have to throw out a whole recycling bag if food contaminates it.

Another takeaway from our conversations with custodians was that there needs to be a uniform system to recycle cardboard. With the rise of online shopping, more cardboard is coming back to residential spaces that had not previously seen such high volumes of cardboard recycling. One custodian reported that students often put cardboard boxes in the paper recycling, which makes the bin fill up faster and causes other paper products to be thrown away. One custodian had issues with cardboard boxes filling up the paper bins, so this particular staff member created a sign for the hallway that asked students to break down boxes and put them behind the trash bins. Most custodians seemed to agree that this was the best system for cardboard recycling in residential spaces.

## Sorting Recycling and Deposits

Many custodians reported sorting the recycling themselves, but that the process was not easy. Several custodians that we spoke with told us that custodians, themselves and others, often collected and redeemed recyclables for their deposit value. This is an important source of income for custodial staff, and many expressed that they wanted this option to remain available to them. The College has to pay a per ton value to dispose of recyclables (including plastic and aluminum), whereas custodial staff can dispose of the recycling for supplemental income at no cost to the College. A recycling setup that separates metals from other recycling would facilitate this collection, and would benefit the College by reducing the amount of recyclables needing to be sent off campus.

## Streams

Two custodians that we interviewed indicated that having more streams would improve accuracy of recycling and would not have a big impact on the amount of work they would have to do. One custodian mentioned that more streams would not be more work because emptying trash and recycling bins was already a part of their daily schedule and adding a few more bins would not lead to a large change of this schedule. Custodians who sorted recycling themselves commented that it was not an easy process and that it caused them many difficulties. Another custodian who has worked in both residence halls with four separate recycling bins and residence
halls with two recycling bins prefered the multi-stream system because recycling was more accurate.

## Signage

One custodian believed that students ignored current recycling signage, and suggested that larger, bolder signage may be useful to capture students' attention.

## Misinformation and Improved Communication

Through our interviews with custodians we were able to better understand the importance of communication with facilities in making the recycling process as efficient as possible. One custodian, who was working in a building in which we conducted an experiment, expressed an interest in becoming better informed of recycling initiatives around campus since custodians are the people primarily responsible for disposing of recyclables. We found that it was important to consult with custodial staff to ensure that our efforts were not undermined by breakdowns in communication. We spoke to one custodian who indicated having been instructed to discard commingled recycling as trash due to China's ban on recycling imports. Since Wellesley is legally required to recycle, and custodians do most of the actual recycling of materials, it was concerning to us that this misinformation was being shared. Incorrect information about recycling can contribute to a perception that recycling does not make a difference, and it might also lead to a diminished interest in recycling and increased skepticism of Wellesley's overall commitment to sustainability. We advocate for clear, accurate information sharing across all levels so that everyone along the recycling chain knows what is happening with our recycling and why.

### 3.2 Experiment: Specialized Recycling Bins Work

## Overview

This experiment tested whether color-coded specialized bins would increase on-campus recycling rate and accuracy. We believed that people being confused about how to sort their recyclables led to negative recycling behavior, and hypothesized that recycling bins with specialized, color-differentiated lids would help people correctly determine which bin they should place their recyclables. We tested this hypothesis by replacing decentralized recycling containers with centralized, color-coded recycling units in one residential building and one academic building. By 'centralized', we refer to a group of bins that are spatially close together or all in one central location, and by 'decentralized', we refer to bins that are more spatially spread apart. We found that recycling yield increased when centralized, specialized bins were available.

## Background

The goal of this study was to determine whether changing recycling infrastructure could increase recycling rates and accuracy. A study conducted by Binder at Western Michigan University found that replacing classroom bins with centralized integrated waste receptacles in the hallways of an academic building decreased the amount of recyclables thrown in the trash. ${ }^{82}$ In Wellesley College's residential buildings, there is no uniform recycling system. Some buildings have standardized built-in recycling on each floor, while others have labeled, movable bins (Figure 3.2.1). Even within a building, these bins are not always placed in the same location on each floor. Reid showed that moving containers to locations near common activities increased recycling, ${ }^{83}$ while Duffy showed that placing specialized lids that matched the shape of the recyclable object onto recycling bins increased the beverage-recycling rate by $34 \%$ and reduced the number of contaminants by $95 \% .{ }^{84}$ Ofstad et al. similarly found that implementing separate, specialized recycling bins helped students recycle more. ${ }^{85}$ We hypothesized that centralizing and standardizing waste and recycling receptacles and adding specialized lids would increase recycling accuracy. Centralized systems have already been implemented in some other parts of campus, including the Science Center and the Lulu Chow Wang Campus Center.

Based on these experiments done by previous researchers, we decided to focus on two on-campus buildings, one academic and one residential, to determine whether the addition and removal of specialized bins influenced recycling rates differently based on the type of building.

[^16]

Figure 3.2.1: Built-in recycling bins in an East Side residence hall. These standardized recycling bins are on each floor of the East Side dorms: Bates, Freeman, and McAfee.

## Methods

In order to test the significance of specialized bins, we removed specialized bins from one location on campus and added them to another space. We removed the centralized waste disposal bins on the ground floor of the Science Center, near the elevator and Science Library. In these locations, we replaced the centralized waste disposal bins with three separate bins of different shapes and sizes. The new bins at each location consisted of one lidless grey round bin on wheels for trash, one blue rolling bin with a black flip lid for recycling paper, and one square, blue bin with a lid with a circular hole for recycling plastics and commingled items.

In Shafer Hall, a residential building, we removed the decentralized recycling bins on the second and fourth floors. Decentralized bins were not located next to one another. We replaced the removed bins with a centralized recycling station with three separate, but identically-sized recycling units for recycling paper, plastics, and glass/aluminum. The paper bin had a blue lid with a thin paper slot, the plastics bin had a grey lid with a circular hole, and the glass/aluminum bin had a black lid with a rectangular opening (Figure 3.2.2).


Figure 3.2.2: Specialized bins in a residential Building. The new recycling bins featured three identical bins, with specialized lids and labels. The grey bin with a thin paper slot was for paper, the blue bin with a circular hole was for plastic, and the black bin with a rectangular opening was for glass and aluminum. The trash cans were kept the same.

We identified control areas in each building against which we compared our changes. In the Science Center, our control areas were the bins on the first floor near the stairwell and the Leaky Beaker, a popular study spot and retail location. In Shafer Hall, we established the first and third floor, with bins unchanged, as our control floors. The second and fourth floors were our treatment floors. We did not measure recycling in Shafer Hall's basement or fifth floor because significantly fewer residents inhabit those floors.

We removed and replaced the pre-treatment bins on a Sunday evening. Afterwards, we collected and weighed the contents of each bin in both our treatment and control groups as baseline measurements. Collections took place every Sunday evening for two weeks after the bin changes had been made.

We sorted the recycling collected from our treatment and control groups to determine a percent accuracy for each bin. In order to do this, we weighed each bag, then separated commingled and paper bags into paper, plastic, aluminum, glass, and incorrect materials (trash). We then weighed separately each particular grouping of recyclables (plastics, aluminum, glass, paper) from the bags to determine the percent composition of the bag. Since our residential experiment asked individuals to separate their recyclables into paper, plastic, and glass and aluminum streams, we measured the experimental bags by weighing the bags individually, then sorting out incorrect recyclables and weighing the incorrect amount. The scales used for this experiment did not capture the weight of an item less than 0.2 lbs , so items that did not register were listed in the notes of the datasheet.

## Results

Both Science Center floors exhibited lower incorrect recycling yields than Shafer Hall's floors, and Shafer Hall had higher total recycling yields than the Science Center. When comparing the average weight of recycling yields across bin treatment and building type (academic and residential), baseline weights across the buildings were slightly greater than the manipulated floors (Figure 3.2.3, Figure 3.2.4). The residential building, Shafer Hall, exhibited higher recycling yields than its academic counterpart, the Science Center.

## Shafer



Figure 3.2.3: Weight of recycling before and after introduction of specialized bins in Shafer. Week 1 and 2 are aggregated together for control and experimental floors.

The removal of specialized bins on the ground floor of the Science Center led to a decrease in overall recycling, though there was also a decrease in our control (Science Center 1st) (Figure 3.2.4).

Science Center


Figure 3.2.4: Weight of recycling before and after removal of specialized bins in the Science Center. Week 1 and 2 are aggregated together for control and experimental floors.

Two of our Week 1 treatment recycling yields (Shafer second and fourth) increased in comparison to their respective baseline measurements. Both of Shafer Hall's treatment floors saw a decrease in total recycling from Week 1 to Week 2 (Figure 3.2.5).


Figure 3.2.5: Changes by location in total recycling weight before and after introduction/removal of specialized bins. Specialized bins were removed on Science Center Ground floor (SCI G) and added to Shafer Hall Second floor (SHA 2) and Shafer Hall Fourth floor (SHA 4). Science Center First floor (SCI 1, specialized bins), Shafer First floor (SHA 1, non-specialized bins), and Shafer Third floor (SHA 3, non-specialized bins) acted as control groups. Data was not collected for Week 2 in both Shafer First and Shafer Third.

The second floor of Shafer Hall had the lowest baseline measurement at 6 lbs , while Shafer fourth floor had the highest, at around 12 lbs . Week 1 measurements were highest among the treatment floors, 14 lbs and 18 lbs for Shafer Hall second and fourth, respectively. All floors had consistently low amounts of incorrect recycling yields (Figure 3.2.6). While total weight varied across the floors, the introduction of specialized bins on the treatment floors reduced the amount of recycling overall and the amount of incorrect recycling (Figure 3.2.6).


Figure 3.2.6: Changes in total recycling weight before and after introduction of specialized bins in Shafer Hall. Data was not collected for Week 2 in both Shafer first and Shafer third floors.

The amount of incorrect recycling decreased from the original amount of incorrect recycling with the introduction of specialized bins in our experimental group (Figure 3.2.7). Figures 3.2.7 and 3.2.8 illustrate a decline in incorrect recycling across both the academic and residential buildings.


Figure 3.2.7: Incorrect recycling over time in Shafer Hall. Data was not collected for Week 2 on both of our control floors (Shafer First and Shafer Third).

While the control recycling bins (specialized bins) in the Science Center remained at $100 \%$ correct recycling throughout the experiment, incorrect recycling showed no clear trend over the two week period with the removal of specialized bins (Figure 3.2.8).


Figure 3.2.8. Incorrect Recycling Over Time in the Academic Building.

## Discussion and Conclusion

Our data shows that the introduction of specialized bins improved recycling yields and accuracy. Less than $10 \%$ of the recyclables we collected and measured were placed in the incorrect specialized bin. Furthermore, incorrect recycling declined over the course of the experiment, suggesting that Shafer Hall residents grew accustomed to the new, specialized system and were knowledgeable of proper separation and disposal techniques.

Although the recyclables sampled from the Science Center and Shafer Hall showed relatively low inaccuracy, incorrect and unclean recyclables, along with plain detritus, were present in the recycling stream. If this experiment were hypothetically scaled up to an entire residential or academic building, the College would have to implement measures, such as larger specialized bins and/or more numerous bins, to enable greater recycling and reduce inaccuracies and trash-stream diversion. Nevertheless, the introduction of specialized bins was successful at increasing correct recycling, demonstrating the usefulness of specialized bins. If specialized bins were implemented across campus, recycling yields may increase as they did during our experiment, yet incorrect recycling may still occur.

During our experiment, we also increased the number of recycling streams from two (paper/cardboard and commingled) to three (paper, plastic, and glass/aluminum). The specialized bins separated glass and aluminum from the commingled stream, creating a third stream. Based on the results of this experiment, we conclude that collecting in more streams encourages more accurate and frequent recycling choices.

### 3.3 Experiment: Convenience Matters, But Only Modestly

## Overview

Convenience has been shown to have important influences on recycling behavior. We hypothesized that people might place recyclables in the trash because of the relative ease of discarding objects in trash bins compared to the relative difficulty of properly disposing of recyclables in recycling bins. To determine if recycling rates at Wellesley College were influenced by convenience of disposal, we conducted experimental interventions in Claflin Hall and Lake House, two residential halls on campus, and measured changes in the amount of waste production. We implemented two interventions in each hall. In the first intervention, we added lids to trash bins to increase the difficulty of waste disposal in trash bins. In the second, we gave students reusable tote bags to store recyclables in their rooms to increase ease of recycling. We hypothesized that recycling rates would increase due to these interventions. Our results show that while total recycling rates modestly increased in both cases, trash disposal rates were not greatly affected by our interventions.

## Background

The effects of convenience on recycling behavior and rates has been widely documented. Past studies have found a link between proximity of recycling locations, considered here as a factor of convenience, and high participation rates in curbside pickup programs. ${ }^{86}$ Additionally, Wellesley College Sustainability Coordinator, Dorothea von Herder, indicated that experiments on Harvard University's campus have shown that residential student recycling rates increased when students were instructed to hang a recycling tote bag on their dorm door. ${ }^{87}$ We mirrored the Harvard University study and assessed the influence of convenience on recycling rates at Wellesley College by hanging a recycling bag on each dorm room's door knob. Based on the findings described previously, we predicted that the use of a bag would alter students' recycling behaviors because they were convenient, clearly labeled as recycling bags, and residents may not have had recycling receptacles prior to the intervention. Further, the bags were simpler to use than conventional bins because they had handles and could easily be carried down halls to recycling bins.

Making trash disposal more difficult has also been studied as a way to increase recycling participation. Research on garbage disposal patterns in Portland, Oregon found that increasing garbage disposal fees leads to an increase in recycling program participation. ${ }^{88}$ Similarly, a weight-based garbage disposal fee encouraged higher recycling rates. ${ }^{89}$ These trash deterrents were financially based and made trash disposal more challenging by raising the cost. Rather than financial deterrents to trash disposal, we chose to implement a physical deterrent: trash can lids.

[^17]We tested the effectiveness of increasing physical barriers to trash disposal by adding lids to trash bins. Most trash bins on campus currently do not have lids.

The relevant literature suggests that making recycling bins more accessible and trash bins less accessible should increase recycling rates. We decided to test this hypothesis at Wellesley College to see effects on the specific infrastructure, lifestyle, and behavior of Wellesley's community members.

## Methods

We implemented the experiment on the first, second, and third floors of Claflin Hall and Lake House. The first three floors of Claflin Hall have an average of 30 residents each, with a student RA on each floor. Lake House is a freestanding building (not attached to a dining hall) with an average of 23 residents per floor and no student RAs. While we mainly wanted to study waste disposal rates of residents in their respective halls, we noted that in both residence halls, trash and recycling bins on the first floor were likely to be more accessible to the entire campus community than bins on the second and third floors.

We collected trash and recycling from residence halls between 5 and 7 pm on Sundays. We chose to collect at this time because trash is not collected by custodians between Friday and Sunday, meaning bin contents would be largest and least disturbed. Following baseline measurements, we placed round lids on every trash bin on the first floor of Claflin Hall and Lake House (Figure 3.3.1). We placed signs on the bin lids that read: "This lid is intended to be on this trash can. Please replace it after use! If you have any questions or concerns, please contact Sustainability Coordinator Dorothea Von Herder."


Figure 3.3.1: Trash bin lid intervention on the first floor of Claflin Hall. The picture shows a lidded trash bin on the first floor of Claflin Hall.

On the third floors of Claflin and Lake House, we hung tote bags on each room's door with a note explaining how to use them, as shown in Figure 3.3.2. The totes were blue and said "We Recycle." The notes inside the tote read: "Dear Resident(s), We are implementing a new recycling system on your floor. Please keep this bag on your door and place all your recyclables inside it. When the bag is full, sort your recyclables into the appropriate bins on your floor. If you have any questions, contact Sustainability Coordinator, Dorothea von Herder. Thank you for your cooperation!"


Figure 3.3.2: Recycling tote intervention on the third floor of Claflin Hall. The image shows a Wellesley "We Recycle" tote placed on the door of a room on Lake House's third floor.

For the two weeks of intervention, we sorted and weighed bags of recycling. For paper and cardboard recycling, we removed and weighed trash items and incorrectly recycled commingleds separately, and weighed the remaining correctly recycled paper and cardboard. For commingled recycling, we sorted and weighed trash and incorrectly recycled paper products separately. For both paper/cardboard and commingled recycling, we measured and recorded the total weight of the bag.

To assess the effectiveness of our interventions, we measured total waste disposal, and recycling rates as a percentage of total waste disposal in Claflin Hall and Lake House. Because we calculated trash weights by subtracting empty bin weights from the combined bin and content weight, some weights were approximated rather than directly measured. For bins whose weights we approximated, we assumed the content weight to be 1 lb if the weight of the empty bin was greater than the approximated weight. For bins which were heavy enough to trigger a scale reading (i.e. weight was not approximated), but had an empty bin weight greater than the measured weight, we assumed the content to be 1.5 lb . We collected waste between 6 and 7 pm during the first two weeks of our experiment, and at 4 pm during the third week.

## Results

Total waste production
Across both residence halls, total waste disposal did not change significantly following two weeks of intervention treatments (Figure 3.3.3). Similarly, there were no appreciable changes to either trash or recyclable disposal. Disposal levels remained similar to baseline measurements across all treatments (Figure 3.3.3).

Total Waste Production


Figure 3.3.3: Total waste production following bin/lid interventions in two residential buildings. Weekly recyclable and trash disposal weights (lbs) in Lake House and Claflin Hall. In the bags treatment, trash and recyclable disposal rose in Week 1 but fell in Week 2. In the control and lid treatment, trash and recyclable disposal decreased from the baseline.

Although we saw no appreciable trends across the data, we noted some minor trends within residence halls. In Claflin Hall, we observed an increase in correctly recycled material following the addition of trash bin lids (Figure 3.3.4A). Lake House produced similar levels of total waste compared to Claflin Hall (Figure 3.3.4B), despite having 10 fewer residents on average per floor compared to Claflin Hall. Additionally, while waste disposal in Claflin Hall remained similar across treatments (Figure 3.3.4A), there was greater variation in waste disposal across different treatments in Lake House (Figure 3.3.4B).


Figure 3.3.4: Total waste disposal in both Claflin Hall and Lake House. Measurements of total amount of trash, incorrectly recycled material, and correctly recycled material A) Claflin Hall and B) Lake House residence halls. In Claflin Hall, we observed a small increase in correct recycling following the trash bin lid treatment. Lake House disposal weights on the control and treatment floors were more variable and inconclusive.

## Trash Disposal

We observed that baseline levels of trash disposal on treatment floors were low compared to those on control floors (Figure 3.3.5). However, we also found that these levels generally stayed low during the experimental period (Figure 3.3.5), suggesting that the interventions may have helped to maintain low levels of trash production on the experimental floors.

Combined Total Trash Production


Figure 3.3.5: Total levels of trash production in Claflin Hall and Lake House. The total weight of trash produced in both Claflin Hall and Lake House during the experimentation period were measured.

Recycling Rates
Following two weeks of intervention, total recycling rates increased across all treatments (Figure 3.3.6), but levels of correct recycling remained consistent with baseline measurements (Figure 3.3.6). This suggests that more items were being incorrectly recycled each week following interventions.


Figure 3.3.6. Rates of A) total and B) incorrect recycling in Claflin Hall and Lake House. Total and correct recycling rates, calculated as a percentage of total waste production and total recycled material by weight, for Claflin Hall and Lake House residence halls during baseline, Week 1, and Week 2. Across the treatments and control we observed an increase in total recycling. In the lid treatment, incorrect recycling in Week 1 and Week 2 were lower than the baseline percentage. Weeks without bars indicate $0 \%$.

## Discussion and Conclusion

Our results supported our hypothesis that total recycling levels would increase with the implementation of recycling tote bags and lids on trash bins (Fig. 3.3.6). Our results show a total increase of recycling in both treatments, with Claflin Hall experiencing a greater effect than Lake House. Our interventions did not have a significant effect on trash disposal, as overall trash production was comparable to pre-intervention values (Fig. 3.3.5). This could have resulted from
natural variation in recycling patterns, or due to on-campus events that altered the amount of overall waste, much of it recyclable, that was produced. There was a popular campus-wide party the day before trash collection in Week 2, which may have influenced waste generation levels generally. Our baseline measurements indicated that recycling behavior was quite varied, between residence halls and even between floors. Subsequent measurements indicated that these distinctions generally persisted throughout the experiment period, suggesting that the interventions did not significantly influence recycling or trash production rates (Figure 3.3.4). Though recycling rates were seemingly larger than our baseline measurement, there was also a noticeable increase in recycling production on the control floors of both buildings, thus indicating that increase in recycling on treatment floors might have been affected by natural variations in the recyclable disposal rather than a result of the interventions.

Though our interventions were successful, our observations revealed some challenges to permanently implementing them. Differences in bin locations and lack of uniformity between buildings, and even between floors, potentially affected our results. Though there is relative uniformity in the locations of trash cans in Lake House, there is less uniformity between floors in Claflin Hall. Some of the trash and recycling bins on the first floor are located in common areas, which could have influenced the amount of material collected from each source. Additionally, some large trash cans in Claflin Hall were located inside bathrooms, which we could not collect for sanitary reasons. On the first floor of Claflin Hall, the trash can in the kitchen area was a different size and shape than all other trash cans. We did not weigh waste from this bin because it did not have a counterpart on Claflin Hall's other floors. Furthermore, we collected waste three hours earlier in Week 2 than in baseline collection and Week 1, which could have also potentially altered our results.

The addition of lids to previously open trash bins was met with resistance by custodians, who removed the lids each day throughout the length of each experiment because it created extra work for them. Lake House custodians removed the trash bin lids in the early days of Week 1 due to inconvenience. If we permanently add lids to trash bins, we should clearly communicate with custodians about the changes and gather their input before implementing new standards and rules.

We do not recommend the implementation of lids on trash cans due to their difficult implementation. Apart from custodian complaints that we received from the onset of our experimental setup, we also learned that trash bin lids had previously been phased out by order of the Facilities Department. In the past, lids had been on trash cans throughout the campus, but facilities chose to remove them due to the physical hassle for custodians and the inconvenience presented when the lids got dirty and had to be washed. We recommend providing recycling bags for dorm rooms as it is easy to implement and shows potential to increase correct recycling rates. Wellesley College's Sustainability Coordinator, Dorothea von Herder, supports the distribution of recycling bags throughout campus, granting institutional support. Overall, we do not recommend lids on trash cans, and we recommend providing recycling bags to students arriving during move-in.

### 3.4 Experiment: Messaging Does Not Change Recycling Rates

## Overview

We were concerned about low recycling efficiency on the Wellesley College campus due to individuals disposing of recyclables in the trash and incorrectly recycled waste. This experiment evaluated the effect of implementing signs as reminders to recycle on recycling behavior. We hypothesized that placing signs over trash bins with messages reminding people to recycle would increase recycling rates, decrease the amount of recyclables thrown in the trash, and decrease the amount of recycling thrown in the wrong container. Our experiment took place in a residence hall (Beebe Hall) and an academic building (Clapp Library). We created signs with different messaging strategies and placed them over every trash bin on three treatment floors per building. We weighed trash and recycling once per week for three weeks, sorted the recycling, and measured how much waste was incorrectly recycled. We found that signs with "invalidating" messages led to a slight increase in recycling rates and decrease in incorrect recycling while "validating" and "social norm" message treatments had no impact or a negative impact.

## Background

Recycling infrastructure varies across buildings on Wellesley College's campus. In Clapp Library, recycling bins are spatially further apart. Trash cans are similarly dispersed. All floors have unique bin arrangements. Students, faculty, staff, and guests to the College use the space for academic or professional purposes between 8 am . and 12 am . In Beebe Hall, a residence hall, each floor has a nearly identical setup: two large garbage bins placed next to a large commingled recycling bin and a large paper recycling bin, located in a common space. This setup is typical for most residence halls on campus.

Recycling signage is inconsistent across the College campus. For this experiment, we investigated only the effects of signs intended to remind people to recycle, not provide information on what to recycle. Although student groups (including Residence Life, the campuswide network of student and professional staff that manage community-building in residence halls) and professional offices have introduced signs reminding people to recycle and what to recycle in some locations, many areas around campus simply have hand-made signs with varying levels of clarity. The lack of clarity in signage makes it difficult for even enthusiastic recyclers to locate bins and, when they do, determine which items belong in each one. We believe this ultimately lowers recycling rates across campus. Trash cans that exist without a nearby recycling bin may perpetuate the problem of community members throwing recyclables in trash if recycling is not an instinctive habit and there is no reminder-to-recycle signage. ${ }^{90}$

In addition to confusion, many individuals throw their recyclable materials in the trash because they do not think to recycle. In this study, we placed signs directly over trash cans in Clapp Library and Beebe Hall to remind waste producers about the option to recycle directly before throwing away possible recyclables. Shifting the messaging on signs from a neutral message such as simply "Recycle!" to messages that validate the added inconvenience of

[^18]recycling have been shown to increase recycling rates even when recycling was inconvenient. ${ }^{91}$ Signs that use eye-catching features, such images and unique designs, have been shown to increase the likelihood that people will not only notice the signs, but actually stop to read them. A study by White et al. (2002) found that signs that validate the difficulty of recycling, but persuade people to recycle anyways, were effective at increasing recycling. ${ }^{92}$ Similarly, Cialdini et al. (2006) found that injunctive norm-based signage can positively increase compliance to messaging. ${ }^{93}$ We predicted that noticeable signs with effective messaging strategies, especially validation and social norms, would improve recycling on the Wellesley College campus.

## Methods

We conducted our experiment in Clapp Library, an academic building, and Beebe Hall, an average-sized residence hall. We designated one floor per building as a control floor and three floors per building as treatment floors. We applied a different signage treatment to each treatment floor. As shown in Figure 3.4.1, one treatment involved the placement of a "validating" sign, similar to the validating signs used by White et al. (2002). ${ }^{94}$ The validating sign acknowledged the additional inconvenience of recycling and encouraged individuals to recycle despite this inconvenience. It stated "PLEASE RECYCLE! It may be inconvenient, but it saves money and the environment."

The second treatment used an "invalidating" sign, which used shaming language. The invalidating signage read, "PLEASE RECYCLE! It's not that hard to save money and the environment."

A third "social norm" treatment used a social norm-based message, as shown to be effective by Cialdini et al. (2006). ${ }^{95}$ Social norm signage said "PLEASE RECYCLE! Wellesley recycles! Please do your part."

All sign treatments used the same font, color, and images. The only difference between the sign treatments was the language. Signs were placed above each trash bin on the treatment floors (Figure 3.4.2), with arrows drawn in black ink pointing to the nearest recycling bins. The control treatment did not include any signs other than to distinguish trash and recycling bins.

[^19]
## Validating



It may be inconvenient. but it saves money and the environment.

Invalidating


## Social Norm

## PLEASE RECYCLE!

Wellesley recycles!
Please do your part.

Figure 3.4.1: Signs created for messaging experimental treatments. We created signs with messages communicating (from left) validation, invalidation, and social norms.


Figure 3.4.2: Messaging experimental treatments in Clapp Library (left) and Beebe Hall (right).

We collected trash and recycling for a baseline measurement on a Sunday evening and put up signs the following Tuesday morning. We implemented each of the three treatments on three different floors of each building (Figure 3.4.3). The entry-level floor of each building was designated as the control floor, with no signs.

| Floor | Treatment |
| :--- | :--- |
| Beebe 1st | Control |
| Beebe 2nd | Validating |
| Beebe 3rd | Invalidating |
| Beebe 4th | Social Norms |
| Clapp 1st | Validating |
| Clapp 2nd | Control |
| Clapp 3rd | Invalidating |
| Clapp 4th | Social Norms |

Figure 3.4.3: Floor treatment designations for Beebe Hall and Clapp Library.
Over three weeks, we collected data each Sunday afternoon. In total, we measured one baseline and two experimental measurements per floor. We calculated the weight of each bin's incorrectly recycled contents, such as garbage in a commingled bin or plastic in a paper bin, to create a measurement of the percentage incorrect.

We compared the treatment values to the baseline values and to the control treatment to measure changes in recycling and trash disposal. In addition, we focused on how the percentage of incorrect materials in the recycling changed in response to the treatments we introduced. Total waste is defined as combined trash and recycling weight per bin location.

Some of the sorted recycling weighed less than 0.2 lbs and did not register on the scale. In cases where there was waste present but the scale did not register a weight, we noted the weight as 0.1 lbs .

## Results

Recycling as a percentage of total waste in Beebe Hall showed few observable trends for any treatments, and remained at roughly $40 \%$ throughout the experiment. The weight of trash disposal varied substantially over time, and recycling as a percentage of total waste also varied. We observed a rise in recycling as a percentage of total waste in the control and invalidating treatments (Figure 3.4.4). In the social norm treatment, recycling's percentage of total waste dropped over the experimental period, with a more pronounced drop in Week 1. The validating treatment experienced a rise in percent recycling of waste in Week 1, but then decreased in Week 2.


Figure 3.4.4: Recycling as a percentage of total waste in Beebe Hall.
Beebe Hall's percentage of incorrect recycling rose substantially in the validating treatment, and to a lesser degree in the social norms treatment, though overall recycling levels did not increase greatly in those treatments. Percentage of incorrect recycling decreased each week in the control treatment. The invalidating treatment resulted in a temporary drop in incorrect recycling, but the percentage rose again in Week 2 (Figure 3.4.5).


Treatment
Figure 3.4.5: Percent incorrect recycling in Beebe Hall under different messaging. Incorrect recycling decreased in the control, increased greatly in the validating treatment, and increased to a lesser degree in the social norm treatment.

In Clapp Library, recycling as a percentage of total waste was higher than in Beebe Hall (Figure 3.4.6). Over the course of the experiment, the recycling percentage decreased in the control and in every treatment with the exception of the invalidating treatment. In total, we collected less waste from Clapp Library, so the small amounts of incorrect recycling varied widely as a percentage (Figure 3.4.7). We saw a sharp increase in incorrect recycling in the social norm and invalidating treatments, and a decrease in the control and validating treatments. In the second week of the experiment we found nothing recycled incorrectly in any treatment.


Figure 3.4.6: Recycling as a percentage of total waste in Clapp Library under different messaging. Recycling as a percentage of total waste increased in the invalidating treatment and decreased in both the validating and social norms treatments.


Figure 3.4.7: Percentage incorrect recycling in Clapp Library under different messaging. There is large variation in the amount of incorrect recycling. In the social norm treatment, the percentage significantly increased during Week 2 . No bar is equivalent to $0 \%$.

## Discussion and Conclusion

We found that "validating" and "social norm" signs reminding and encouraging people to recycle do not result in increased rate or quality of recycling. In some treatments they even had the opposite effect.

We expected to find a higher percentage of recycling with respect to total waste in each treatment after putting up signs, with the control remaining the same each week. In Beebe Hall, only the invalidating treatment and control measurements showed clear increases above the baseline (Figure 3.4.4). In Clapp Library, following validating and social norms treatments, recycling quantity decreased as a percentage of total waste after our first collection, as did the control. Only the invalidating signs had a positive effect on recycling quantity (Figure 3.4.6).

We expected to see the percentage of incorrect recycling decrease after the sign implementation, indicating that people were paying more attention to the bin types, but in Beebe Hall this also did not happen except in our control (Figure 3.4.5). Not only did incorrect recycling increase, but the validation and social norms treatments also saw less recycling overall and more that was incorrectly recycled. These types of signs were clearly not as effective as hypothesized. Clapp Library had so little overall recycling that even one plastic or glass bottle in a paper bin could make a large percentage of the weight incorrect, so the variability in percentage of incorrect recycling (Figure 3.4.7) was largely not informative.

In both Beebe Hall and Clapp Library, the only treatment that showed consistent improvement in recycling rate and accuracy was the invalidating treatment. This was surprising
because previous studies have shown that validating and social norms messaging are more effective.

Overall, variability in data sets with low sample size made it difficult to pinpoint distinct trends and determine the most effective treatment. Two weeks may not have been enough time to see if the observed changes in recycling rate and accuracy were lasting or just due to random variation. Part of the efficacy of signs relies on novel shapes and colors that attract people's attention at the moment when they are thinking about disposing of items. So, signs should have the strongest effect when they are new. However, we saw little impact in our first two weeks, when the signs were relatively new. Thus we question whether signs would be more effective in later weeks.

Having more baseline measurements would have more accurately demonstrated typical waste level in our buildings of study. When we conducted our baseline collections from Beebe Hall we observed significant disposal of alcohol bottles, leading us to suspect that students held parties on one or more floors that weekend, skewing the recycling weights with heavy glass bottles. This would make recyclable disposal from weeks without parties appear lower in comparison.

Waste collection in Clapp Library is less regular than in the residence halls, so we were not sure how many days' worth of waste each data point represented. Paper recycling may have been in the bins for weeks before our first collection day, while trash may be taken out more frequently. This would account for the large amount of recycling versus trash in our baseline measurement for Clapp Library, and the lower amount in following weeks (Figure 3.4.6). If so, the increase in recycling on the floor with invalidating signs is even more significant.

Residence halls, like Beebe Hall, generate more waste than the library. This experiment demonstrated that an intervention in the residence halls, if effective, could have more of an impact on the College's waste stream than a similar intervention in academic buildings. The larger amount of waste produced in Beebe Hall also makes the results from the residence hall more reliable, as percentages of incorrect disposal are thus less likely to be skewed by a smaller number of items. Here, our experiment shows little to no benefit to recycling rate or accuracy when signs are placed over trash bins.

Our results demonstrate that changing messaging is not an effective means of increasing recycling quantity and correctness. We suggest that the College not prioritize signage in its efforts to increase recycling. Even considering the limitations of our experiment, it is difficult to say that there is any useful application of using signs as reminders to recycle as a means of increasing recycling behavior.

### 3.5 Experiment: Single-Stream Does Not Help

## Overview

In some cases, switching from multi-stream to single-stream recycling has been shown to dramatically increase recycling rates. Additionally, many local Boston schools use a singlestream system. We sought to determine whether transitioning from multi-stream to single-stream recycling at Wellesley College would result in a higher recycling rate. To gain a better understanding of how the transition might affect recycling rates, we measured recycling in two buildings on campus: an academic building (Pendleton Hall East) and a residence hall (Pomeroy Hall). Each building had control floors, which remained dual-stream (paper/cardboard and commingled) and treatment floors, which we converted to single-stream. We collected data twice per week in Pomeroy Hall and once per week in Pendleton Hall. Our experiment revealed a minor increase in incorrectly recycled items (contaminated items, garbage, non-paper) in Pomeroy Hall during single-stream collection. In contrast, in Pendleton Hall, we observed a minor decrease in the amount of incorrectly recycled items during single-stream collection. These results suggest that simplifying recycling provides no clear advantage for increasing correct recycling at Wellesley when compared to using multi-stream recycling.

## Background

Throughout the twenty-first century, communities across the United States have increasingly embraced single-stream recycling as an alternative to dual-stream and multi-stream recycling. ${ }^{96}$ The number of single-stream facilities in the U.S. has grown at an average rate of fourteen per year between 1995 and 2008. ${ }^{97}$

Numerous studies have demonstrated the benefits of switching to single-stream recycling. Transitions from dual-stream to single-stream recycling often result in increased collected tonnage. Single-stream curbside recycling programs were found to have dramatically increased participation and volume collected because they increased the ease of recycling. ${ }^{98}$ When singlestream collection is used in communities, recycling rates tend to increase by anywhere between $10-100 \% .{ }^{99}$ Additionally, changing from dual-stream to single-stream recycling was found to result in approximately a $50 \%$ increase in production of recyclable commodities, or avoiding the global warming effects of $710 \mathrm{~kg} \mathrm{CO}_{2}$-equivalents per metric ton of collection. ${ }^{100}$

Single-stream collection leads to higher recycling rates and expedited collection. However, having to separate the single-stream recycling into separate streams during processing

[^20]is more difficult and energy intensive. The process requires more sophisticated automated equipment. ${ }^{101}$ Single-stream collection results in higher residue rates and likely leads to increased down-cycling, as single-stream plants tend to produce lower-quality output streams than multi-stream plants. ${ }^{102}$

Wellesley College has, until recently, sent its commingled recycling to the Wellesley Recycling \& Disposal Facility (RDF) in Wellesley, Massachusetts. Due to China's recent ban on imports of many classes of recyclables, ${ }^{103}$ the RDF stopped accepting the College's commingled recycling and raised its recycling prices effective February 2018. ${ }^{104}$

This change raises questions over where the College should send its recyclables and some of the potential options include facilities that accept single-stream recyclables. The relevant literature demonstrates that switching to single-stream may be an effective way to boost recycling at the College. However, besides the process of collection, conversion to single-stream has numerous implications for how the College recycles. Conversion to single-stream would mean switching to a recycling facility that accepts single-stream recycling, which could potentially change the costs of sending recycling. Alternatively, the College could elect to separate the collected single-stream recycling into multiple streams on campus and then send the separated streams to a multi-stream facility. This option would require not only space to separate the recycling but also wages to pay those who would be separating the recycling. In light of the literature findings and changes at the Wellesley RDF, we decided to test whether switching to single-stream recycling would impact the quality and quantity of recycling and be a viable recycling option for the College.

We conducted our experiment in an academic building (Pendleton Hall East) and a residence hall (Pomeroy Hall). We analyzed recycling in Pomeroy Hall, a student-centric space, to track and understand student recycling behavior. We also analyzed recycling in Pendleton Hall to understand how not only students, but also faculty, staff, and members of the public recycle on the College's campus. By measuring in these buildings, we sought to understand how various types of campus users interact with the buildings' recycling bins.

## Methods

In Pomeroy Hall, the first and third floor were control floors while the second and fourth floors were treatment floors. The first floor of Pomeroy Hall contained four paper and two commingled bins prior to experimentation, while the second, third, and fourth floors each had one paper and one commingled recycling bin (Figures 3.5.1) The first floor differed from other floors as it was entry-level and received higher traffic, primarily due to non-residents of Pomeroy Hall using the first floor dining hall. The first floor also differed in that there were 4 bins on the floor while on the other floors there was only 1 bin. This discrepancy was accounted for by averaging the weight of the trash for the 4 bins on the first floor for each week. In Pendleton Hall, the first floor was the control floor and the second floor was the treatment floor. Prior to

[^21]experimentation in Pendleton Hall, each floor contained 3 paper recycling bins and 2 commingled recycled bins (Figure 3.5.2).

To convert to single-stream collection, we repurposed the existing bins, removing the bins' lids and signage on treatment floors. We collected Pomeroy Hall's recycling on Sundays and Thursdays at 6:00 pm We collected from Pendleton Hall on Thursdays starting at 6:00 pm, as custodial staff did prior to the start of our experimentation. We collected and weighed paper and cardboard bins' recycling together, and collected and weighed commingled items (glass, metals, and plastic) together. We noted any incorrectly recycled items in each bin.

During the experimental phase, we collected a greater amount of recyclable materials during Week 2. An event appeared to have been held on the second floor of Pendleton Hall, which may have accounted for the higher amount of materials collected on that day.

| TYPE OF BIN | 1st Floor <br> (Control) | 2nd Floor <br> (Treatment) | 3rd Floor <br> (Control) | 4th Floor <br> (Treatment) |
| :--- | :---: | :---: | :---: | :---: |
| PAPER | 4 bins | 1 bin | 1 bin | 1 bin |
| COMMINGLED | 2 bins | 1 bin | 1 bin | 1 bin |

Figure 3.5.1: The number and types of bins in Pomeroy Hall by floor prior to conversion to single-stream. Floors marked "treatment" were converted from multi-stream (paper and commingled) to single-stream.

| TYPE OF BIN | 1st Floor (Control) | 2nd Floor (Treatment) |
| :--- | :---: | :---: |
| PAPER | 3 bins | 3 bins |
| COMMINGLED | 2 bins | 2 bins |

Figure 3.5.2: The number and types of bins in Pendleton Hall by floor prior to conversion to single-stream. Floors marked "treatment" were converted from multi-stream (paper and commingled) to single-stream.

## Results

In Pomeroy Hall's commingled recycling bins, the weekly percentages of incorrect recycling varied on the treatment floors. The incorrect recycling percentage increased over 20\% from the baseline in Week 1 of treatment, but decreased to $0 \%$ by Week 2 of treatment. By the end of the experimental period, percentage of incorrect recycling on treatment floors had decreased (Figure 3.5.3). Conversion to single-stream recycling did not cause a clear, consistent decrease in incorrect recycling. Baseline incorrect recycling percentages were low across all experimental floors (Figure 3.5.3).

Pomeroy Hall Incorrect Recycling


Figure 3.5.3: Incorrectly recycled items as a percentage of total recycling in Pomeroy Hall recycling per week by number of streams. Incorrectly recycled items include contaminated items, garbage, and recyclables placed in the wrong bin. Control bins were left as multi-stream recycling after the baseline data collection. Changed bins were converted from multi-stream recycling to single-stream. Orange bars represent originally paper bins and blue bars represent originally commingled bins. No bar is equivalent to $0 \%$.

Similarly, we observed a decrease in the percentage of incorrect recycling in Pendleton Hall's commingled bins once they were converted to single-stream recycling (Figure 3.5.4). Incorrect recycling decreased from baseline levels on the single-stream treatment floor, from $15 \%$ incorrect to $3 \%$ incorrect (Figure 3.5.4). In bins that were left as multi-stream recycling bins, we consistently found incorrect recycling in the bins throughout the experimental period. In these bins, incorrect recycling in paper recycling bins decreased each week. However, incorrect recycling in commingled bins decreased from the baseline in Week 1, then increased above baseline levels in Week 2. Other than during the baseline week, incorrect recycling was consistently lower on single-stream floor compared to the multi-stream control floor (Figure 3.5.4). Generally, Pendleton Hall had very little incorrect recycling in the paper bins, which primarily consisted of unclean pizza boxes.

## Pendleton East Incorrect Recycling



Figure 3.5.4: Incorrectly recycled items as a percentage of total recycling in Pendleton Hall recycling per week by number of streams. Incorrectly recycled items include contaminated items, garbage, and recyclables placed in the wrong bin. Control bins were left as multi-stream recycling after the baseline data collection. Changed bins were converted from multi-stream recycling to single-stream. Orange bars represent originally paper bins and blue bars represent originally commingled bins.

Switching to single-stream recycling also did not have a positive impact on the total amount of recycling in either Pomeroy Hall or Pendleton Hall (Figure 3.5.5, Figure 3.5.6). In Pomeroy Hall, the total amount of recycling decreased throughout the course of the experiment (Figure 3.5.5), suggesting that in residence halls, single-stream recycling would likely not result in an increase in overall recycling. In Pendleton Hall, there was no consistent trend in the amount of recycling (Figure 3.5.6).

There was little incorrect recycling in dorms or academic buildings using the current multi-stream recycling system. While there was some incorrect recycling (Figure 3.5.3, Figure 3.5.), it did not comprise a high percentage of the total amount of the recycling overall. Additionally, there was no notable increase in the total amount of recycling in either Pomeroy Hall or Pendleton Hall (Figure 3.5.5, Figure 3.5.6), suggesting that switching to single-stream recycling would likely not dramatically increase participation in recycling.


Figure 3.5.5: Total amount of recycled items in Pomeroy Hall by number of streams. Total amount of recycled items included all of the paper/cardboard and the commingled products.

Total Recycling in Pendleton East


Figure 3.5.6: Total amount of recycled items in Pendleton Hall by number of streams. Total amount of recycled items included all of the paper/cardboard and the commingled products.

## Discussion and Conclusion

We found that switching to single-stream recycling has little effect on the extent to which items are correctly recycled. Additionally, we also found a general decrease in the amount of incorrect recycling in single-stream treatment, although it was comparable to the decrease observed in the control multi-stream treatment. These results suggest that switching to singlestream recycling does not significantly impact the amount of recycling overall. Notably, there was not a high percentage of incorrect recycling in the baseline measurements, suggesting that
students, faculty, and guests at Wellesley College were largely recycling correctly prior to experimentation.

In interpreting the Pendleton Hall results, one must consider the high number of events held on the 2 nd floor the building. Much of the incorrect recycling was comprised of items produced at events, including large quantities of pizza boxes. We recommend that the College prioritize making on-campus events sustainable and communicate to campus users that pizza boxes are not recyclable.

We expect our results would hold for most other residence halls and academic buildings throughout campus. Pomeroy Hall is similar to most other on-campus residence halls, being of average size and with floors representing all class years. Pendleton Hall houses various academic departments and is similarly trafficked by students of all class years, in addition to faculty and staff.

If our single-stream experiments had positively impacted recycling, there would have been evidence for Wellesley to seriously consider converting to a single-stream system. This would require changing how collection is carried out and finding a facility that accepts singlestream recycling. However, our results indicate that single-stream recycling did not cause a significant improvement to the quality or quantity of the College's recycling. Our results suggest that there is no clear advantage of converting to single-stream recycling and that simplifying the College's recycling system to one collected stream would not be beneficial at Wellesley. Though we found no advantages to using single-stream, we did not find it to be disadvantageous. We did not observe an increase in incorrect recycling or a significant decrease in total recycling. Thus, our experimental findings still leave open the possibility of the College switching to a singlestream system dependent on other factors, such as pecuniary cost of sending recyclables to a single-stream facility.

### 3.6 Analysis: How Many Streams? (Collecting/Sending)

## Background

Recycling can be collected in a variety of streams, where streams are defined as groupings of similar recyclable materials. Some educational institutions, including Boston University, Harvard University, and Babson College, collect all recyclable materials in the same bin, a system referred to as single-stream recycling. Wellesley College currently collects recycling in two streams on campus: commingled (plastics, metals, and glass) and mixed paper/cardboard. Potential alternatives to this dual-stream collection system include collecting recycling in more streams or sorting recycling into those streams post-collection. In this analysis, we will compare Wellesley's various collection and sorting options using the criteria of ease (both individual and institutional), cost (monetary), and effectiveness (relative recycling rate and accuracy).

## Many Streams: Separate at collection

One option for recycling at the College is to increase the number of streams currently being collected for recycling. The primary benefits of utilizing this option are lower processing costs and contamination rates as the number of streams collected increases. Additionally, due to recent changes in the recycling market, commingled recycling is becoming much more expensive, and some recycling centers no longer accept this stream. ${ }^{105}$ Multi-stream collection is therefore more cost efficient than collecting in one or two streams (see: "Analysis: Recycling Motivation/What inhibits recycling?") We have identified a potential option for the College: collecting recycling in four streams, rather than the current dual-stream system. These four streams would be: mixed paper/cardboard, plastic, metal, and glass.

In terms of individual ease, this additional level of sorting for a multi-stream system should not pose substantial difficulty for individuals disposing of their recyclables. Rather, a difficulty may be that individuals may not be equipped to sort their recycling due to lack of information on proper disposal and exaggerated preconceptions of inconvenience. ${ }^{106}$ At Wellesley College, limited bin availability and lack of clear information seem to be greater deterrents to recycling than preconceptions of inconvenience, suggesting that a multi-stream recycling program on campus may actually promote acceptable levels of participation if infrastructure is sufficient (see: "Analysis: Recycling Motivation/What inhibits recycling?")

Institutionally, implementing a multi-stream system may pose logistical and monetary expenses for the College compared to maintaining the current dual-stream system. Current recycling bin distribution around campus is sparse and inconsistent, and a wide variety of signage and recycling bin set-ups exist. This means the College has no standardized campuswide set of signage or bins. Implementing multi-stream collection would require additional bins, updated signage, and the potential removal of existing bins at many locations on campus. This would require a large upfront cost: a standardized four-stream recycling bin set costs from $\$ 1000-\$ 2500$ per set, depending on the bins' durability. At minimum, if a new set of

[^22]standardized bins were to be installed on every floor of major academic buildings and the more heavily-occupied floors (i.e. 20+ residents/floor) of every residence hall, the estimated total cost would range from $\$ 78,000-\$ 195,000,{ }^{107}$ although this only reflects the purchasing of entirely new bins; installing additional bins to supplement existing bins instead would be also be a feasible and cheaper option, though this might also hamper the standardization process. However, this initial installation of a new bin system would be a one-time cost, and likely the only major cost incurred by implementing this system. Space is required for the addition of more bins, thus making the setup of bins for multi-stream collection infeasible at some campus locations. However, if bins were to be installed primarily in the larger, highly-trafficked areas of campus, the issue of finding sufficient space would be minor.

Ultimately, implementing multi-stream collection may be one of the most effective options in terms of cost and reducing the College's waste output. While there would likely be initial upfront costs for bin installation, it may reduce long-term costs by eliminating the need to pay a third-party to sort waste. Additionally, if Wellesley continues using its current recycling facility, but begins sending recycling in more streams, the College will generate greater revenue than it does currently. Sending plastics and metals separately is free for the College, as opposed to sending it commingled with glass, which currently costs the College $\$ 125$ per ton ${ }^{108}$. Sending glass separately will still incur a cost of $\$ 125$ per ton cost, but sorting out plastics and metals means the College would pay less per tonnage. ${ }^{109}$ There are also many other recycling facilities around Wellesley that accept multi-stream recycling, should the College choose to switch facilities. ${ }^{110}$ Additionally, collecting in more streams may help Wellesley to reduce its waste production overall: although collecting in fewer streams generally has higher total rates of recycling, ${ }^{111}$ multi-stream recycling programs generally have lower rates of contamination (see "Experiment: Single-stream does not help."), ${ }^{112}$ and less material being sent to landfill. ${ }^{113}$

This option requires minimal individual effort and either slight to major infrastructural changes from the institution, depending on how many new bins should be installed. It will also require some new infrastructure for storing the streams separately once the custodians have collected them, and before they travel to the recycling facility. Despite a potentially high onetime cost for the purchase of new bins, there will be a short return on investment as Wellesley does not need to pay a third-party for processing recycling and will be sending out cleaner, more valuable recycling. In terms of efficacy, multi-stream recycling has also been shown to reduce overall waste and contamination levels, leading to a potentially large reduction of Wellesley's waste production. It should be noted that having adequate clear signage is important for this option to be truly effective.

[^23]
## Many Streams: Sort post-collection at Wellesley

The second option is to collect recyclables in our current dual-stream system, and then sort into further streams on campus before sending to recycling facilities. In terms of ease, this option requires no behavioral changes for individuals, and instead relies on institutional changes. Implementation costs to hire staff and find a location to sort recyclables are the most important considerations. The analysis of this option assumes that sorting would be done manually, as we did during our experiments, and would require large open spaces. Thus, no additional spaces or infrastructure are taken into account in our cost analysis or difficulty of implementation.

Based on how long it took us to sort and separate the collected recycling, our calculations estimate that it would take approximately 100 person-hours per week to sort through Wellesley College's recycling. This estimate includes residential and academic buildings and assumes that this labor would be distributed amongst a larger group of people. Based on the Massachusetts state minimum wage, the College would have to pay a collective minimum of $\$ 1,150$ to sorters each week. This wage calculation assumes that the sorting work would be provided as a way for current custodial staff or employees to pick up extra hours, and therefore does not take into account benefits that would be added if there were to be new people hired specifically to perform only the sorting.

In theory, this option could be easily applied on Wellesley College campus, as it requires no additional infrastructure or change in collection systems. The only things the College would need to ensure would be the availability of workers and space to separate materials. Additionally, transportation of recycling from Wellesley College to the recycling facility would need to account for the different collection sites and times across campus. Locating sorting spaces in each central residential and academic location could reduce transportation burdens. This way, it would mostly mirror recycling as it is currently processed on campus, requiring fewer changes.

This option would create a highly accurate recycling system, as each individual piece of material that is recycled would pass through a second set of hands, and thus be placed in the right category, or disposed of, if necessary. Additionally, it provides the College with the opportunity to sort its recycling in as many categories necessary, depending on current, and often changing, market prices, to lower transportation costs and/or increase its potential revenue. This presents an interesting economic opportunity for Wellesley College to adapt with market fluctuations. Therefore this dual-stream to sorting system might be worth considering at least as a transition phase. It would also enable the College to take advantage of the unusually high number of categories into which the Wellesley RDF separates its recycling, and thus lower our costs at the RDF as much as possible.

## Two Streams: Collect and send to recycling facility in two streams (current practice)

Wellesley currently collects its recycling in two streams: paper and commingled. Ease would be maximized by maintaining this system. The College as an institution, and students, faculty/staff, and custodians as individuals, would not need to change anything or do any more work to maintain the status quo.

Examining cost, this method is becoming unsustainably expensive. The Wellesley RDF raised the price of accepting Wellesley College's commingled recycling to $\$ 125$ per ton in February, ${ }^{114}$ and ceased to accept it altogether in April. Wellesley's commingled recycling is for
${ }^{114}$ Von Herder, Dorothea. "Data to Show in Class Today," February 14, 2018.
the time being sent to Covanta Recycling, where it costs $\$ 95$ per ton. ${ }^{115}$ Based on the knowledge that Wellesley produces about 174.7 tons of recycling per year, with $54 \%$ of that being commingled recycling, ${ }^{116}$ we can extrapolate that continuing to send our recycling to facilities in two streams would cost Wellesley $\$ 8,962.11$ annually. This price is far from stable, having undergone dramatic fluctuations in the past few months alone.

As the efficacy of Wellesley's current system is not optimal, maintaining current methods would neither improve nor hinder current recycling rates and accuracy.

## Single-Stream: Sort at recycling facility

Another potential recycling stream option would be to switch to single-stream and send to a recycling facility to be sorted. This option maximizes ease for individual behavior. This method is also increases ease for Wellesley College as an institution; it would involve fewer bins, and therefore likely less work for custodians. It would also allow students to take less time in terms of sorting out their paper and plastics/aluminum/glass. However, in terms of effectiveness, it has been shown to increase recycling only by an average of $6 \% .{ }^{117}$ But on Wellesley College campus, the ES 300 class experiment showed that switching to single-stream recycling does not increase the level of recycling overall. It also has little effect on the extent to which items are correctly recycled (see: "Experiment: Single-stream does not help.").

As of April 2018, Eoms Inc, Casella Waste Services, Save that Stuff Inc., and Orifice Recycling and Refuse accept single-stream recycling from customers generally, so we assume they would accept it from Wellesley College, making it a viable option, in theory.

Costs for single-stream may be prohibitive. Single-stream appears to be the most expensive stream option due to the intensive seperation work for recycling facilities. For reference, the most expensive RDF option is single-stream at $\$ 125$ per ton. ${ }^{18}$ Additionally, contamination, which typically incurs a fee, also tends to be highest for single-stream recycling. On average, a quarter of the total weight of single-stream recycling ends up in the landfill. ${ }^{119}$ Therefore, there will also be significant costs that incur from contamination. ${ }^{120}$

Many recycling facilities have been hesitant to cite costs for single-stream recycling because of large fluctuations in price due to the recent Chinese laws preventing many countries from continuing to send their waste there any longer. Regardless of any benefits of single-stream systems, it is likely that this system may pose unnecessary financial risk due to the constant pricing changes, and lack of transparency, in the waste industry. Our experiments already concluded that implementing single-stream practices did not increase recycling rates. ${ }^{121}$ This,

[^24]combined with the reduced acceptance, and increased cost of single-stream by recycling facilities (such as the RDF), ${ }^{122}$ makes the single-stream system a poor option for Wellesley College.

## Final Recommendations

Based on these analyses, we conclude that separating recycling at collection in a fourstream system is the best recycling option for Wellesley College. Despite a higher upfront cost to purchase and install the new bin system, long term cost is minimized via the elimination of the need for a third-party to process the recycling. Additionally, sending recycling to a facility in more streams than we do currently will lower the costs of recycling over time. Out of the available multi-stream facilities in the surrounding area, we recommend sending recyclables to the RDF due to cost considerations (See: "Analysis: Where Can/Should We Send our Recycling?). The cost-effectiveness of recycling at the RDF reinforces our recommendation to use a four-stream system. Based on the prices to recycle and the potential revenue at the RDF, it currently costs substantially more to recycle commingled recyclables than it would cost to send glass, metals, and plastics separately.

An important aspect of this recommended system is the need for standardization. In order for it to be as effective as possible, this system must be implemented uniformly throughout the Wellesley College Campus in order to ensure that individuals can easily learn and become accustomed to it. Thus, the ideal set up would implement the same bins in academic, residential, and public spaces. Though determining the exact placement of and spatial availability for these new bins would be a considerable task, we do not believe that it would be a prohibitive factor in implementing the new system. We also hope that our map of current recycling locations on campus could be helpful in this process (See: Appendix B).

Though, in the long-term, separating at the source is our top recommendation, it is important to keep in mind the potential benefits that a system with post-collection separation on campus could provide. With manual sorting, there is the possibility of sorting into as many categories as is financially beneficial. Since, ideally, the College would send its recycling to a multi-stream facility such as the Wellesley RDF, the College could maximize financial benefits by sorting into a large number of accepted categories.

Further separation can maximize revenue for the College. One of the categories that has the potential to increase revenue at the RDF is cardboard. Currently, and with the recommended four-stream system, the College sends its recycled paper in one stream as mixed paper, which earns a revenue of $\$ 5$ per ton. However, if the College separated cardboard from that mixed paper category, its revenue could increase substantially, as each ton of cardboard earns $\$ 15$ of revenue. This serves as an example for other categories in the four-stream system that could be separated further to increase revenue (i.e. plastics).

In the long term, however, it is likely that this four-stream system is more financially viable for the College, as it consists of mostly upfront costs, with much smaller continuous costs compared to the option of separating post-collection on campus.

The chart below summarizes our comparison of Wellesley's four main options moving forward (Figure 3.6.1). Each option is ranked on a scale of 1-5 for individual ease, institutional ease, cost, and efficacy (Figure 3.6.2). A ranking of one is considered to be the most difficult to

[^25]implement, most expensive, or least effective. A ranking of five was found to be the easiest to implement, cheapest, or most effective.

| Metric (1-5) | Many Streams: <br> Separate at <br> collection | Many Streams: <br> Sort post- <br> collection at <br> source | Two Streams: <br> Collect \& send <br> off in two <br> streams | Single-Stream: <br> Sorting at <br> facility |
| :--- | :--- | :--- | :--- | :--- |
| Individual Ease | 2 | 5 | 5 | 5 |
| Institutional <br> Ease | 3 | 1 | 5 | 3 |
| Cost | 2 <br> $\$ 78,000-$ <br> $\$ 195,000$ (one- <br> time upfront <br> cost) | $\sim \$ 50,000$ per <br> year | About $\$ 8,962.11$ <br> per year | 1 |
| Efficacy | 4 | 4 | 1 |  |

Figure 3.6.1. Ranking of each of Wellesley's options for sorting recycling. Each potential recycling option for the College was ranked on a scale from 1-5 based on individual ease, institutional ease (extent of infrastructural change needed), cost (monetary cost for the College to implement), and efficacy (extent of increasing recycling rate and accuracy).

| Metric/Rating <br> scale | 1 | 2 | 3 | 4 | 5 |
| :--- | :--- | :--- | :--- | :--- | :--- |
| Individual <br> ease | No sorting <br> required |  | Some/minimal <br> sorting <br> required |  | Most sorting <br> required |
| Institutional <br> ease | No additional <br> changes to <br> infrastructure <br> needed to <br> adopt option |  | Some/minimal <br> changes to <br> infrastructure <br> needed to <br> adopt option | Short return <br> on investment, <br> low <br> maintenance <br> costs | Major <br> infrastructural <br> changes <br> needed to <br> adopt option |
| Cost | No/minimal <br> additional <br> costs needed <br> to <br> implement/m <br> aintain |  | Some <br> improvement <br> to recycling <br> rate/accuracy | Long return <br> on investment, <br> high <br> maintenance <br> costs |  |
| Efficacy | No change to <br> or reduces <br> recycling <br> rate/accuracy |  |  | Very high <br> improvement <br> (>70\%) to |  |

Figure 3.6.2. Definitions of metrics and rankings for recycling options. Each metric for assessing recycling options for the College was defined at 5 levels.

### 3.7 Background: RDF Background

Until recently, Wellesley College transported all its recycling to The Wellesley Recycling and Disposal Facility (RDF), located approximately 2.7 miles from campus. It is located at 169 Great Plain Avenue, Wellesley, MA 02482 and is the closest recycling recycling facility to campus. The RDF was founded in 1970 and is operated by the Wellesley Department of Public Works. ${ }^{123}$ The current Superintendent is Jeff Azano-Brown. The RDF accepts commercial recycling Mondays through Saturdays. ${ }^{124}$ It is a multi-stream facility that accepts a wide array of items for recycling and reuse. Such items include: household recyclables (boxboard and chipboard, brown paper bags, cardboard and corrugated cartons, mixed office paper, mixed paper, newspapers, refundable containers, glass, steel/tinned cans, plastic bottles, plastic nonbottles, rigid plastics, aluminum foil and trays, aluminum cans, cell phones, electronic media, eye glasses, household batteries, and inkjet cartridges), metals (aluminum, copper, and metal/light iron), and special/hazardous materials (appliances, automotive batteries, computers \& monitors, fluorescent bulbs, paint, propane tanks, tires, and waste oil). It also accepts compost and wood waste. ${ }^{125}$ The RDF has a reusables area where individuals can donate and take items. ${ }^{126} \mathrm{~A}$ map of the RDF is below (Figure 3.7.1). ${ }^{127}$


Figure 3.7.1: Wellesley Recycling \& Disposal Facility.
The RDF is funded by taxpayer dollars allocated at town meetings, and it returns its revenue to the Town General Fund. In the Fiscal Year 2012, the RDF turned $\$ 877,000$ back to

[^26]the Town General Fund. ${ }^{128}$ Its recycling generated $\$ 400,000$ in the Fiscal Year 2016, ${ }^{129}$ and over $\$ 285,000$ in $2017 .{ }^{130}$ Additionally, the RDF purchases trash and recycling from five other communities and sells it for profit. ${ }^{131}$ The RDF leadership monitors the official monthly board market prices of its accepted materials to determine where to sell its recyclables and trash for the most money. It sends waste both internationally and domestically. ${ }^{132}$

The RDF currently pays Wellesley College and other commercial organizations $\$ 15$ per ton for cardboard, and $\$ 5$ per ton for mixed paper and cardboard together. They charge $\$ 125$ per ton for glass recycling, and accept mixed plastic and mixed metals at no cost. ${ }^{133}$ Because of China's recent ban on imports of many recyclables, the cost of recycling glass increased in February 2018. Prior to February 2018, it cost $\$ 10$ per ton to recycle glass, rather than the current $\$ 125$ per ton. ${ }^{134}$ The RDF previously charged $\$ 60$ per ton for commingled recycling. Now it no longer accepts Wellesley College's commingled recycling. These changes at the RDF raise questions about whether Wellesley College, which primarily uses a dual-stream system (paper/cardboard and commingled streams), should continue to send its recyclables to the RDF, and if so, whether Wellesley should restructure its collection system to adapt to the RDF's new pricing scheme.

[^27]
### 3.8 Background: Recycling at Boston Colleges

The recycling practices of educational institutions in the Boston area show an overall consensus in methods of waste collection and integration of recycling processes into student and faculty life on campuses. The colleges and universities examined here are the following: Babson College, Brandeis University, Boston University, Boston College, Emerson College, Northeastern University, Harvard University, Massachusetts Institute of Technology, Tufts University, and University of Massachusetts Boston. Within this group of institutions, there were many similarities in collection and processing systems, but also a range of strategies in community involvement, or what can be termed as "recycling culture."

All of these institutions collect recycling in a single stream on their respective campuses. This single-stream collection gathers paper, plastic, glass, and metal within one container in dorms, academic buildings, and public spaces. Many schools cite ease of individual contribution and decrease in participant confusion to be a major factor in transitioning to single-stream collection. Northeastern University, for example, includes this aim of simplicity within its threestep recycling mission, which states its goal is to "keep the design of the program simple and convenient to maintain university wide commitment." ${ }^{135}$ This same simplicity-oriented mentality is present in institutions like Babson College ${ }^{136}$ and Harvard University, ${ }^{137}$ which claim that single-stream collection helps decrease the amount of recyclable materials that end up in the trash due to confusion. Some schools, such as Boston College, have waste systems in which there is a recycling bin next to every trash bin, discouraging individuals from throwing recyclable materials in the trash. ${ }^{138}$

Uniformity and standardization appear to be the main incentives for most institutions' single-stream collection systems. This goal also drives many efforts to make collection bins visually standardized within campuses. Having the same colored recycling bins helps simplify Boston College's waste system, with blue bins in public spaces and maroon bins in residential areas. ${ }^{139}$ Having the same type of lid on every bin-one which enables all recycling, yet constricts some non-recyclables-is the strategy at Tufts University. Their "UFO-shaped" lids are the same all across campus and are shaped in a way that visually and physically facilitates the single-stream process (Figure 3.8.1). ${ }^{140}$

[^28]

Figure 3.8.1: Example of "UFO-shaped" lid used at Tufts University ${ }^{141}$
Tufts University, along with Boston University, has adopted the Trash Buddy Program, in which the office and dorm recycling bins provided by the university are accompanied with an attached small trash can inside. ${ }^{142}$ This program intends to reduce the amount of space that a trash and recycling bin would take beside a desk, while still providing both recycling and trash options.

Many schools also provide alternative options for their students to dispose of recyclable materials that do not fit in the single-stream categories of paper, plastic, glass, and metal. This particularly applies to E-Waste in many institutions. There is a range of how students can dispose of these harder-to-recycle materials, including submitting work orders for someone to pick up the device, ${ }^{143}$ taking it to a location on campus, ${ }^{144}$ or providing outside-source information of companies or stores that could dispose of the device for students or faculty. ${ }^{145}$ For confused students or faculty, many institutions provide campus-specific guides to recycling ${ }^{146}$ or short online courses so that students or faculty can become comfortable with the recycling process. ${ }^{147}$

Though not all institutions provide information in post-collection processing, most of these schools send their single-stream collected recyclables to a processing company or facility to later be sold to separate sources. Two of these institutions, Boston University and Boston

[^29]College, are clients of the Save That Stuff Inc. processing facility. This facility, whose slogan is "The One-Stop-Shop," collects all types of recyclables and trash, taking it to locations in which is it separated and "prepared for the market." ${ }^{148}$ Save That Stuff Inc. also provides preinstallment audit services to evaluate current systems and give recommendations, as well as offering education programs for staff and custodial services. ${ }^{149}$

Other schools, like Babson College, sell their single-stream recycling to processing facilities where they are separated and sold. ${ }^{150}$ Some institutions have relationships with companies that provide student organizations with the opportunity to be members, and thus be an on-campus outlet for certain hard-to-recycle materials. One example of this is Tufts University's relationship with the TerraCycle program, in which hard-to-recycle and non-recyclable materials are sent to the company to be made into new, usable products. ${ }^{151}$

In order to engage the on-campus and off-campus community, institutions utilize both permanent incentives and temporary, annual events to encourage recycling participation. Boston University, for example, provides discounts in their on-campus dining operations to students who use their own reusable mugs instead of the single-use ones provided. ${ }^{152}$ Some institutions employ students in their recycling management offices, and maintain strong relationships with oncampus student organizations to encourage student and faculty involvement in the recycling processes and improvement. ${ }^{153}$ Recycling competitions, both within and between campuses, are a strategy that is widely used in campuses across the Boston Area. Emerson College has oncampus competitions and student pledges to encourage participation and personal interest in increasing the percentages of total campus recycling. ${ }^{154}$ In addition, Emerson College and Boston University ${ }^{155}$ participate in RecycleMania, a nationwide competition sponsored by large corporations like Coca-Cola, in which college and university campuses record their recycling statistics for an 8 week period in the spring semester and are then ranked according to who recycles the most. ${ }^{156}$

On March $6^{\text {th }}$ of 2018, the yearly RecyclingWorks conference took place at Boston College, and many of the Boston institutions included in this analysis participated. ${ }^{157}$ This 2018 College \& University Forum hosted by RecyclingWorks is a place where professionals in the

[^30]area get together to discuss ways to improve recycling systems in their respective educational institutions. This year's conference was focused on the particular topics of furniture reuse programs on college and university campuses, as well as the recycling and recovery of food in everyday processes and special events within campuses in the Boston Area. Inter-campus collaboration and accountability is an ongoing process essential to the optimization of educational institutions' recycling systems.

## 4. Analysis: Where Can/Should We Take Our Recycling?

## Introduction

There are a wide variety of recycling and transfer facilities in the state of Massachusetts, ranging from highly specialized facilities that only accept a few materials to larger facilities that accept all materials in a range of streams. We assessed a selection of these facilities that accept commercial recycling based on the following factors: distance from the College, ability to accept single-stream or multi-stream recycling, cost, and variety of materials accepted. We called and emailed representatives from local facilities to gather information. After analyzing these factors, we propose that Wellesley College take its recycling to the Town of Wellesley Recycling and Disposal Facility (RDF).

## Methods

We identified 73 of the recycling and transfer facilities closest to Wellesley College. We filtered out facilities that were mistakenly identified as recycling facilities, those that would not serve businesses or out-of-town/city locations, and those that were too specialized (i.e. solely construction waste facilities) from our consideration. We prioritized those that appeared to offer the required services and had the capacity to conduct business with an institution of Wellesley College's scale. Out of the list of 73 , we narrowed down a list of 22 high priority facilities who appeared to accept commercial recycling. We contacted representatives from those facilities.

We gathered information by asking representatives to answer the following questions over phone or email:
a. Are you currently accepting new clients? Are there are restrictions on whose recycling you do accept?
b. Which recycling streams do you accept?
c. If you accept commingled, would you accept them in plastic bags or would they need to be loose?
d. What is the cost of recycling for each stream for a client that produces approximately 60 tons of commingled, 80 tons of office paper, 10 tons singlestream, 24 tons unbaled corrugated containers, and 2 tons baled corrugated containers per year? (Or: What are your facility costs per stream?)
e. Do you sort or process recyclables? Or where do you send your recycling for processing?

We rated each of the locations based on the parameters of ease and cost. Ease addressed the distance of the facility from the college, whether the facility sorts or transfers, and whether separate waste streams are accepted. Cost addressed the fixed and variable costs, including penalty fees for recycling contamination. Other important parameters included greenhouse gas emissions (e.g the use of more efficient equipment) and environmental justice considerations. However, these factors could not be easily assessed by phone and e-mail interviews and were therefore not primary considerations in our assessment.

## A Review of the Recycling Facilities Contacted

All facilities are in the state of Massachusetts.

Casella Waste Services' Bunker Hill facility is located 19.8 miles from campus in Boston. Casella is a larger waste service company with multiple sites across the country. The Bunker Hill location is a "Zero-Sort Processing" facility, where "Zero-Sort" is the companywide term for single-stream collection. The facility accepts paper, cardboard, plastic, glass, and metal cans. Casella also offers collection services. Casella's facilities have partnered with over 70 colleges and universities in the Northeast, and the company advertises its ability to create an efficient and integrated system for collection for all campuswide facilities, including dining, athletics, administration, and housing.

Covanta Holliston is located 8.4 miles from campus in Holliston, and is a transfer facility through which Wellesley College is currently managing its commingled recyclables. The College began sending its commingled recycling to Covanta when the Wellesley Recycling and Disposal Facility (RDF) stopped accepting the College's commingled recyclables due to China's waste import ban. It was also convenient for the College to send its commingled recycling to Covanta because Wellesley Trucking already takes the College's trash to the facility. ${ }^{158}$ Currently, Covanta accepts the College's commingled plastic, glass, and metal cans, but not paper or cardboard, which continues to go to the Wellesley Recycling and Disposal Facility. Covanta Holliston declined to offer pricing information. According to the College's Sustainability Coordinator, Dorothea von Herder, Covanta's tipping fee is $\$ 95$ per ton for commingled recycling. ${ }^{159}$

Conigliaro Industries is located 6.4 miles from campus in Framingham. ${ }^{160}$ The facility accepts multi-stream recycling. It currently accepts commingled recycling but is in the process of phasing it out. Conigliaro offers collection services and also accepts dropped-off recyclables. It requires a minimum cost of $\$ 80$ per drop-off under $1,000 \mathrm{lbs}$ and $\$ 150$ per drop-off over 150 lbs . Plastics cost $\$ 50$ per ton, cardboard is free, glass costs $\$ 150$ per ton, and paper costs up to $\$ 30$ per ton. The facility also accepts electronic waste. It costs $\$ 50$ to recycle monitors and $\$ 70$ to recycle television sets. Computer recycling costs about $\$ 5$ per piece. Conigliaro does not accept fluorescent bulbs or standard batteries. Its sorting and processing practices vary depending on the material. The company separates metals and plastics and makes bales of paper, cardboard, and plastic. Workers take apart recycled electronics but do not process them. Where Conigliaro sends its recycled products depends on market conditions, but the company mostly confines itself to domestic markets. ${ }^{161}$

Northeast Material Handling is a single-stream and multi-stream recycling provider located 30.5 miles from campus in Ayer. The facility is committed to low-cost sustainable
${ }^{158}$ Von Herder, Dorothea. Interview. April 24, 2018.
159 Von Herder, Dorothea. "Info for Es 300," March 21, 2018.
160 "Conigliaro Industries." Conigliaro Industries. Accessed April 15, 2018. http://www.conigliaro.com/.
${ }^{161}$ Representative from Conigliaro Industries. Interview. Phone, April 12, 2018.
recycling and operates a program called North East Single Source Recycling (NESSR) that tracks the amount that an organization recycles with Northeast Material Handling and provides credits to the organizations. Additionally, Northeast Material Handling collects e-waste and processes all of the electronics on site manually. Nothing is sent internationally, which is unique in e-waste recycling, ${ }^{162}$ and has positive environmental justice implications. Northeast Material Handling has a recycling pick-up service. Northeast Material Handling is engaged with the local community, sponsoring local sports teams and hosting community recycling days. ${ }^{163}$

The Town of Wellesley Recycling and Disposal Facility (RDF) is located just 3 miles from campus and has accepted Wellesley College recycling in the past. The site accepts both single-stream and multi-stream recycling. The Wellesley RDF is extremely well developed, and accepts and processes a wide range of recyclable materials. Due to the changes in materials being accepted by China, the RDF increased its prices for single-stream, commingled, and glass recycling. The RDF currently pays commercial organizations $\$ 15$ per ton for cardboard, $\$ 5$ per ton for mixed paper and for mixed paper and cardboard together, while charging $\$ 60$ per ton for single-stream recycling, and $\$ 125$ per ton for glass. It accepts mixed plastic and mixed metals at no cost. ${ }^{164}$ The prices for single-stream, commingled, and glass recycling were previously $\$ 10$ per ton, $\$ 60$ per ton, and $\$ 60$ per ton respectively. The RDF has stopped accepting the College's commingled recycling and it will not accept single-stream recycling from the College, though it continues to accept sorted materials. Waste is sold both domestically and internationally and generates profit for the town of Wellesley. ${ }^{165}$

Waste Management (WM) Foxboro is a single stream only recycling facility located about 17 miles from campus in Foxborough. The facility is a large processing facility that sorts the recycling and ships it to processing and remanufacturing plants. WM requires the use of their collection services. WM Foxboro is able to accept a wide variety of materials to be recycled. They do offer campus recycling programs for colleges and universities to help meet institutional sustainability goals, such as offering both single-stream and dual-stream programs. The website provides some case studies of institutions that have incorporated some of WM recycling programs to achieve specific recycling rates. ${ }^{166}$

Orifice Recycling and Refuse is a small-scale recycler, located 7.3 miles from campus in Natick. It accepts single-stream and multi-stream recycling as well as various speciality streams including compost, appliances, and demolition waste. It provides both residential and commercial collection services but its status on accepting drop-offs is unclear. ${ }^{167}$

[^31]Eoms Inc. is located 27 miles from campus in Bridgewater. It is a family-run, locally owned and operated, full-service recycling and waste removal company. It focuses on cardboard, paper, and single-stream recycling as well as business recycling programs, organics and food waste recycling, composting organic materials, solid waste/trash removal waste services, ewaste, and construction and demolition waste disposal services. They also provide balers and compactors. It services most areas except western Massachusetts and Cape Cod. Fees are based on size of container and frequency of collection. Cardboard is the least expensive ( $\$ 15-\$ 20$ per ton). As for contamination rate, this fee can vary anywhere from $\$ 45-\$ 85$ per ton and is directly charged to the customer. ${ }^{168}$ The cardboard is shipped to Canada. They also ship other recyclables to China.

77 Recycling is located 30 miles from campus in Clinton. It specializes in recycling plastics; however, it also provides cardboard, glass, metal, and paper recycling services. They collect and process post industrial scrap and do not handle any commingled items. They are currently working on a system that will handle commingled scrap. They were not able to offer exact pricing, but did discuss some of the variables they use when providing pricing to customers, such as distance and frequency that items need to be shipped. For example, the higher the weight per load, the less it costs per pound to ship. This is a fixed cost and is not dependent on material type. Currently, the facility offers the following pricing: White ledger office paper is around $\$ 250$ per ton baled and cardboard is about $\$ 95$ per ton baled. In addition, they process plastics on site and and send paper products to surrounding mills in the area. Metals are collected and sold. ${ }^{169}$ The representative also suggested to contact EL Harvey, another local recycling center, as they might be able to answer pricing regarding single-stream collection as this particular facility, El Harvey specializes in single-stream sorting and collection.

Miller Recycling is a family-run facility located 29 miles from campus in Mansfield and specializes in commercial recycling. The facility processes and recycles paper, metal, plastic, electronics, and organic materials. It also provides services such as equipment (balers, compactors, air systems, as well as on-site trailers, and transportation), material pick-up, shredding, data and product destruction, and salvage cleanouts. The facility requires prior inspection of material before committing to new suppliers. It only accepts clean material (i.e. properly sorted and marketable) and does not accept commingled materials. ${ }^{170}$ A price quote was not generated from this facility, but as with other facilities, handling and transportation costs are a major factor in determining prices or charges. There is minimal sorting since they do not accept commingled items.

Save That Stuff is located 20 miles from campus in Boston. The facility accepts single stream, paper, cardboard, metal, electronics, and compost. Recyclables are hand sorted at the facility, however, single-stream is not processed on-site. It is sent to Casella Waste Services. A recycling rate was not provided, but this cost is dependent on factors such as pick-up mode, type of compactor/dumpster used, as well as frequency of collection. A representative from the

[^32]facility did indicate the range in which it charges a contamination fee which varies anywhere from $\$ 25-\$ 200$.

The above eleven facilities responded to contact attempts or had sufficient information on their website to answer some, most, or all of our questions. A few facilities did not respond to our inquiries despite multiple attempts at contact over phone and email. The nonresponsive facilities were Braintree Technical Services, E.L. Harvey and Sons, Greenworks, and Surplus Technology Solutions.

We excluded seven different facilities from our ultimate analysis because their services proved too niche to be reasonable. Earthworm Recycling only takes recycling from small businesses. ${ }^{171}$ Northside Carting, Inc. will not accept recycling from the town of Wellesley. ${ }^{172}$ Stoughton Recycling Facility only accepted construction and demolition recycling. ${ }^{173}$ Wheelabrator Saugus does not accept recycling. ${ }^{174}$ Salem Recycling Plant accepts commercial recycling, including most varieties of paper and some plastics, but the main grade of plastic it accepts is low-density polyethylene (LDP) plastic from distribution centers. ${ }^{175}$ Mr. Trashman was solely a hauling company, in the same vein as our currently contracted Wellesley Trucking haulers. Strategic Materials, Inc. in Franklin accepts only glass and industrial plastics. ${ }^{176}$

## Recommendation

Based on the information we obtained, we recommend sending our recycling to the Town of Wellesley RDF in multiple streams.

We deemed eleven facilities high priority. Out of these facilities, seven accept single stream recycling: Casella Waste Services, Northeast Material Handling, the Wellesley RDF, WM Foxboro, Orifice Recycling and Refuse, Eoms Inc., and Save that Stuff. Covanta Holliston, Conigliaro Industries, (though phasing it out), and WM Foxboro accept commingled recycling. Conigliaro Industries, Northeast Material Handling, the Wellesley RDF, Orifice Recycling and Refuse, 77 Recycling, Miller Recycling, and Save that Stuff are multi-stream facilities.

Most companies could not give us estimates of recycling costs, given that we were student researchers collecting data rather than potential clients requesting a quote. Moreover, many facilities were unresponsive to calls or emails. Many that were responsive could not, or would not, answer many of our questions. Several representatives we spoke with declined to answer questions on their facilities' environmental efforts, either because they could not speak with authority on the matter or because they sent their materials for processing at other facilities whose environmental efforts were outside of their control. Ultimately, these barriers to collecting information made comparisons across facilities based on our metrics challenging.

Representatives from none of the eleven contacted facilities shared information on their facilities' environmental considerations and initiatives. Only three facilities offered information

[^33]on pricing per stream: the Town of Wellesley RDF, Conigliaro Industries, and Eoms Inc. Eoms only provided pricing information for cardboard recycling despite also accepting paper and single-stream recycling.

We recommend sending out the College's recycling in multiple streams (see Analysis: How Many Streams?). Because of this recommendation, we prioritized multi-stream recycling facilities. A comparison of facilities is shown in Figure 4.1 below.

| Metric | Conigliaro <br> Industries | Northeast <br> Material <br> Handling | Wellesley <br> RDF | Orifice <br> Recyclin <br> g and <br> Refuse | 77 <br> Recycling | Miller <br> Recycling | Save that <br> Stuff |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| Accepts <br> commingled | Yes, but <br> phasing out | No | No | Unknown | No | No | No |
| Pricing <br> Available | Yes | Unknown | Yes | Unknown | Unknown | Unknown | Yes, for <br> contamination <br> fees only |
| Accepts e- <br> waste | Yes | Yes | Yes | Unknown | No | Unknown | Yes |
| Environmental <br> Initiatives | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown | Unknown, but <br> do hand-sort <br> recycling |
| Processes <br> recycling | Depends on <br> the material | No | Unknown | Unknown | Unknown | Unknown | No |
| Material <br> Destination | Largely <br> domestic | All <br> domestic | Domestic <br> and <br> international | Unknown | Unknown | Unknown | Unknown |
| Accepts drop- <br> off | Yes | Unknown | Yes | No | Unknown | Unknown | Unknown |
| Offers <br> collection <br> services | Yes | Yes | Unknown | Unknown | Unknown | Unknown | Unknown <br> Distance from <br> Wellesley <br> College <br> 6.4 miles <br> (Framingham) |
| (Ayer) |  |  |  |  |  |  |  |

Figure 4.1: A comparison of multi-stream recycling facilities.
Due to the general lack of environmental information, we based our recommendation primarily on pricing. Since Conigliaro Industries and the Wellesley RDF were the only facilities which made costs per its multiple streams available, we narrowed down our analysis to those two facilities. There was no compelling reason to include the other five multi-stream facilities among
our leading contenders as they did not offer information on environmental or social initiatives that outweighed cost concerns. We included Covanta Holliston in our price analysis, as the College currently sends recyclables there, but we based our estimate of $\$ 95$ per ton of commingled recycling on previous communication with the Office of Sustainability (Figure 4.2).

| Stream | Wellesley RDF | Conigliaro Industries | Covanta Holliston |
| :--- | :--- | :--- | :--- |
| Mixed Plastics | No cost | $-\$ 50 /$ ton | Unknown |
| Cardboard | $+\$ 15 /$ ton | No cost | Unknown |
| Paper | $+\$ 5 /$ ton | Up to $-\$ 30 /$ ton | Unknown |
|  <br> Cardboard | $+\$ 5 /$ ton | Unknown | Unknown |
| Glass | $-\$ 125 /$ ton | $-\$ 150 /$ ton | Unknown |
| Single-Stream | Stream Not Accepted | Stream Not Accepted | Unknown |
| Commingled | Stream Not Accepted | Unknown ${ }^{177}$ | -\$95?/ton ${ }^{178}$ |

## Figure 4.2: Cost comparison between the Wellesley RDF, Conigliaro Industries, and

Covanta Holliston. " + " indicate revenue and "-" indicate costs to the College.
Conigliaro Industries charges higher prices overall. Its cost per ton recycled is higher for mixed plastics, glass, and paper. The Wellesley RDF accepts cardboard or mixed paper and cardboard rather than paper alone, and the revenue of those streams are $\$ 15$ per ton and $\$ 5$ per ton respectively, which is cheaper than Conigliaro Industries' $\$ 30$ cost per ton for paper. These pricing differences are significant because Wellesley College's largest streams were commingled recycling and mixed office paper in 2017, which encompass mixed plastics, glass, and paper. The College recycled 56.04 tons of commingled recycling, 82.99 tons of mixed office paper, 24 tons of unbaled corrugated containers, and 2.06 tons of baled corrugated containers (boxes) that year. ${ }^{179}$ We did not find that Conigliaro Industries offered any clear advantages in other non-cost based metrics.

We recommend sending the College's recycling to the Wellesley RDF because it is the most cost-effective multi-stream option. The Wellesley RDF has a diverse array of sorting categories compared to similar municipal facilities. While single-stream recycling is a common option for educational institutions in the surrounding region, ${ }^{180}$ single-stream in general will likely be phased out due to expense in wake of the recycling situation in China. It will be to our advantage that we establish a source separation standard here at Wellesley College in preparation for that shift. Keeping recyclables in Wellesley is not only most economically advantageous but

[^34]will also generate the lowest environmental costs of fuel generated GHG emissions associated with transporting waste to recycling facilities.

## 5. Analysis: Reducing Waste and The Need For Recycling

## Introduction

The previous pieces of this report consider materials only at the very end of their use on campus as they enter the waste stream. Another way to change the College's waste profile is to reduce the total amount of materials entering the campus in the first place. With this goal in mind, we examined typical recyclable materials found on campus: plastics 1-6, glass, steel, aluminum, cardboard, and paper. For each material we considered five factors: 1) environmental impacts of its life cycle, 2) where on the College's campus this material is found and in what quantities, 3) what functions on campus this material provides, 4) more sustainable replacements to these materials, and 5) how feasible replacement is.

This analysis allows us to make recommendations for reducing or replacing the materials often purchased for use on campus. These recommendations take into account the following metrics: cost (direct fees and revenues), resource conservation, greenhouse gas emissions, toxicity, and both individual and institutional ease.

## Life Cycle Analysis of Materials

To understand each material's environmental impacts, we completed life cycle analyses (LCA). An LCA calculates the environmental impacts of a product or process through each stage of its production, use, and disposal. We used the computer software SimaPro to complete our LCAs, because it has a comprehensive database of materials and is the industry standard for making business and design decisions.

We compared the life cycles of 1 pound of each target material using SimaPro's TRACI 2.1 V1.01 / US 2008 method and normalized the results. We constructed our analysis using lifecycle data for newly produced material, that is, made from virgin components rather than recycled, that is conventionally discarded. Essentially, we analyzed the environmental impacts of not recycling our target materials by considering the costs of needing to produce new, virgin units of that substance.

Because our analysis was based on a standard unit of weight, these results do not necessarily translate to a fair comparison of products. One pound of plastic \#1 produces far more bottles than one pound of glass. Our analysis compares the relative impacts of using one material versus another, in whatever form, in order to identify which common materials are particularly environmentally harmful. When discussing each material, we will translate 1 lb of material to functional units.

We focused our analysis on five impact categories: global warming, ecotoxicity, carcinogenic emissions, non carcinogens, and respiratory effects. We rated the relative impacts on a scale of 'Low' to 'Very High.'

The normalized metrics we used for our rating are:

| Low | $0-0.0005$ |
| :--- | :--- |
| Medium | $0.00025-0.0005$ |
| High | $0.0005-0.001$ |
| Very High | $>0.001$ |

Assigning these qualitative values allows us to consider the results of our LCAs alongside other concerns.

## Purchasing Behavior on Wellesley College's Campus

A substantial portion of waste is brought to campus by departments and offices, instead of individuals. To get a sense of the purchasing decisions currently being made and what types of materials are being disposed, we identified: the Economics Department, Library and Technology Services (LTS), and AVI Fresh. We chose these three groups to represent different types of institutional decision makers on campus: academic departments, library and technology, and dining services.

AVI Fresh is the food service provider the College contracts to run five dining halls and three retail centers, serving food to students, faculty, staff, and guests. It serves an essential function to the College and is a major contributor to the waste stream. ${ }^{181}$ We interviewed Michael Stecklair, Director of Operations for AVI Fresh, and Keith Tyger, Executive Chef. The great majority, estimated $80 \%$, of the packaging waste from AVI Fresh is cardboard, which is one of the cheapest materials for packaging. Cardboard is mostly taken to the Wellesley Recycling and Disposal Facility (RDF). A small percentage of the cardboard, estimated 5\%, is wax-coated for products like chicken. This cardboard is not recyclable and must be thrown away. After cardboard, the next most prevalent packaging material is plastic for products such as oils and vinegars. Cans, a mix of aluminum and steel, are also recycled. Styrofoam doesn't seem to be used except in packaging fish, which is more difficult to store.

The Economics Department is the largest academic department at the College, and it mirrors the structure of most academic offices on campus. The department provides administrative support to faculty and students, coordinates and publicizes relevant events, and stocks the department's office with basic supplies. We interviewed Sheila Datz, the Academic Administrator for the department. She estimated that some of the department's most common purchases are printer paper, printer toner, blue books for exams, paper coffee cups, and compostable paper plates. When the department has control over the disposal of these items, they try to recycle all of them appropriately. Blue books are handed out to students, who may recycle them or not, and coffee cups have to be thrown away.

LTS provides resources for teaching, research, and administration. They run four libraries on campus, and are responsible for purchasing and maintaining technology in classrooms and offices. We interviewed Gerard Euell, the Operations Manager. Since electronic waste is outside this project's scope, he told us that their relevant waste products are mainly cardboard and other packaging materials, printer paper and toner, and coffee supplies. LTS buys K-Cup coffee pods and paper coffee cups for its office staff. Cardboard and paper are recycled, as are toner cartridges (returned to the manufacturer), so the department's largest source of trash is K-Cups and coffee cups.

[^35]
## Plastics



Figure 5.1: Comparison of environmental impacts of making plastics 1-6.

| Material | Global <br> Warming | Carcinogens | Non <br> Carcinogens | Ecotoxicity | Respiratory Effects |
| :--- | :--- | :--- | :--- | :--- | :--- |
| Plastic 1 | Low | Low | Low | Low | Low |
| Plastic 2 | Low | High | Low | Low | Low |
| Plastic 3 | Low | Low | Low | Low | Low |
| Plastic 4 | Low | Low | Low | Low | Low |
| Plastic 5 | Low | Low | Low | Low | Low |
| Plastic 6 | Low | Low | Low | Low | Low |

Figure 5.2: Ratings of environmental impacts of making plastics 1-6.

## Plastic 1

$1 \mathrm{lb}=44.4500 \mathrm{~mL}$ plastic bottles ${ }^{182}$
Plastic 1 is polyethylene terephthalate, shortened to PET or PETE. It is a clear, sturdy material used for water and soda bottles, and other food containers like peanut butter. ${ }^{183}$ Producing plastics from raw materials creates greenhouse gas emissions and carcinogenic effects, but the impacts are low compared to other plastics (Figure 5.1). This is the most commonly recycled plastic, accepted in nearly all recycling programs. ${ }^{184}$

On campus, the main source of PET is drink bottles. The Emporium and the Leaky Beaker sell drinks in PET bottles, and individuals bring more in from off-campus. Some academic departments buy plastic water bottles for guest speakers and event receptions.

Bottled water could be replaced in many ways. Cost-effective options are reusable water bottles, reusable water jugs, washable cups at events, and water filters on sinks and fountains. Other drinks, like sodas and juices, are available to students in the dining halls but without the convenience and portability of a bottle. To reduce PET waste on campus, the Emporium and Leaky Beaker could address these functions by selling drinks from a soda machine with a discount for bringing a reusable cup or bottle.

When people on campus talk about reducing plastic waste and changing purchasing behavior to be environmentally-friendly, they often think about plastic bottles. The culture in some departments has started to change so that disposable bottles are not the norm, but other departments and many students still find the convenience worthwhile. The College has made an effort to shape students' habits by handing out durable water bottles to first-year students during Orientation, and by installing "Well on Wheels" bottle-filling stations in outdoor spaces from spring to fall. ${ }^{185}$

## Plastic 2

$1 \mathrm{lb}=7.5$ 1-gallon milk jugs ${ }^{186}$
$1 \mathrm{lb}=82$ plastic shopping bags ${ }^{187}$
Plastic \#2, HDPE (high density polyethylene) is used for food containers, especially jugs and bags that have to be shelf-stable, as well as plastic shopping bags. The lifecycle of this plastic is more harmful than others, especially due to the carcinogens that are released at various points through production (Figure 5.1). Since it is made with energy from fossil fuels, there is

[^36]some global warming impact from production, but the impacts to non-cancer-related human health, ecotoxicity, and respiratory effects are small. Recycling or replacing this plastic instead of making it from raw materials would have an important benefit to the global environment.

This type of plastic may be brought to campus by individuals more than by organizations, when students buy laundry detergent, shampoo, and anything from a store that uses plastic shopping bags. The town of Wellesley banned plastic check-out bags in 2017, making them less common in the campus waste stream. ${ }^{188}$

HDPE may be challenging to replace with other materials. The important functions of this plastic include carrying things, as in bags with a high strength-to-weight ratio; staying flexible and not cracking when old; and either keeping out air and moisture or keeping in hazardous chemicals.Some of these functions will be replaced more easily than others. Paper and cloth shopping bags have proven to be an acceptable substitute for plastic in most cases, though Wellesley (the town) and other communities with bag bans still allow plastic bags for produce, garbage, and other uses. Other properties that make this plastic useful make it difficult to substitute. Glass is equally good as an impervious, long-lived storage container, but can easily crack. (see Figure 5.8 for how glass scores on other metrics.)

## Plastic 3

$1 \mathrm{lb}=1 \mathrm{ft}$ pipe $(21 / 2 \text { inch diameter })^{189}$ $1 \mathrm{lb}=90$ disposable gloves ${ }^{190}$

Polyvinyl chloride, or PVC, is labeled as plastic \#3. The term PVC is used most often to refer to the pipes and other durable construction materials it can be made into, but PVC can also be thin and clear, used for bags, shrink wrap, single-use gloves, and clamshell food packaging. ${ }^{191}$ It is difficult to recycle, meaning energy-intensive and therefore expensive. Items made with PVC are designed for uses that generally leave them dirty or mixed with other materials, so they're not recycled even when it is an option. ${ }^{192}$

PVC is different from other plastics in that it is not made primarily from petroleum. Around $60 \%$ of the raw material is chlorine derived from salt, and production of the plastic uses $20 \%$ less energy than other plastics. ${ }^{193}$ However, separating chlorine from salt using an

[^37]electrolysis process takes more energy, ${ }^{194}$ and many PVC products have chemicals added for flexibility or other properties, making the net environmental and human health impacts higher. The PVC industry is working to reduce their use of controversial additives. ${ }^{195}$ For construction materials, PVC's lightness and durability may make it environmentally better than substitutes, like metals which are heavy and rely on mining.

Much of the PVC thrown away on Wellesley College's campus comes from shrink wrap, used in the dining halls, and disposable gloves, which are used in the dining halls by custodial staff, Health Services, and science labs. Shrink wrap protects food from drying out and from contamination, so it stays fresh longer and won't be wasted. Single-use gloves in the kitchens also protect food from contamination, and they also protect the user's hands from getting dirty or potentially harmed. Gloves save water and time by reducing the need to wash hands after each task. The functions of thin, flexible plastic film are challenging to replace, and replacements would significantly increase cost and reduce ease.

## Plastic 4

$1 \mathrm{lb}=2096 " \times 3 " \times 12 " .65 \mathrm{mil}$ bread bags ${ }^{196}$
Items labeled as plastic 4 are made out of low-density polyethylene (LDPE). It is typically used in packaging such as transparent bags, coating or film for packaging liquids, shrink wrap, and squeeze bottles. ${ }^{197}$ Compared to the other types of plastic we analyzed, new LDPE has a relatively low impact throughout its life cycle, with the majority of its environmental impact falling into the LCA's global warming category (Figure 3.7.1). Although LDPE has lower life cycle impacts than other types of plastics, it is difficult to recycle.

The ability to recycle LDPE varies depending on its form. Bags and packaging film made from LDPE can be recycled but they must be both clean and dry in order to be processed. Also, they are often not accepted in conventional recycling schemes, though both items can be brought to specific collection sites such as grocery stores. ${ }^{198}$ Other products that contain LDPE film, such as those used to package liquids, can often be broken down and recycled by component, but the LDPE is typically too contaminated to be recycled and put into the waste stream. ${ }^{199}$ So although LDPE products can be recycled, they often are not. Just as with Plastic 2, many LDPE products such as bags and product packaging are likely brought onto campus by individuals and therefore out of the scope of this analysis.

Much of the LDPE that is purchased by the College is found in food packaging used by AVI Fresh. Milk and milk substitute containers are a major source of LDPE in the College's waste stream and should be a focus of reduction. In these types of containers LDPE is used to

[^38]line the paperboard container so that it can hold liquid. Each dining hall on campus offers a range of milk substitutes such as Lactaid Milk, rice milk, almond, and soy milk. Typically, the dining halls offer these substitutes by purchasing several quart-sized containers of each and keeping them in a separate, labelled fridge. Some dining halls also serve milk substitutes in large dispensers similar to those used for standard milk. These dispensers are used for soy milk and, in some locations, for almond milk. Even when these dispensers are in place, dining halls still offer several other varieties of milk substitute in the quart-sized containers.

The ES 300 waste audit in 2012 estimated that each student discarded on average 3.24 of these containers annually, all of which were thrown in the trash. ${ }^{200}$ Even if these containers were recycled, the LDPE would likely be too contaminated to be processed as recycling. ${ }^{201}$ It is worth auditing current consumption rates of milk substitutes in each dining hall and exploring whether it is feasible to offer more milk substitutes in dispensers in order to minimize the amount of packaging used. This would be a relatively easy replacement for AVI Fresh to make as it would require few structural changes.

LDPE is also used for plastic laboratory equipment like pipettes, wash bottles, and carboys in laboratories on campus. ${ }^{202}$ These products are difficult to substitute as they typically handle chemical material and must be treated with certain health and safety precautions that make them difficult to clean on a large scale. Additionally, the products would have to be reliably sterilized in order to avoid contamination in subsequent projects. We do not recommend the College pursue purchasing changes for these materials.

## Plastic 5

$1 \mathrm{lb}=150$ bottle caps $^{203}$
Polypropylene, or plastic \#5, is often used in opaque food containers, medicine containers, straws, and bottle caps. This plastic ranks low in all five impact categories, and does relatively little harm in comparison to other plastics (Figure 5.1; Figure 5.2).

We are likely to find plastic \#5 in food-distributing centers on campus. Straws are located in many of the dining halls. Opaque food containers and bottle caps can be found in places that sell packaged food or drink, such as the Emporium, the Leaky Beaker, and Collins Cafe.

Straws could easily be eliminated from the dining halls without the need of a replacement. Some students do use the plastic straws in the dining halls; however, straw-users make up a relatively small portion of the student body. Alternatively, plastic disposable straws could be replaced with reusable straws, made from plastic, metal, or wood, that are treated like

[^39]any other dining hall dish or utensil. The cost of purchasing reusable straws is not unreasonable, and would be a worthwhile investment in the long run, both in reducing waste and from a cost standpoint. However, reusable straws would be additional dishes for dining hall workers to wash and put out for use. It would be far simpler to eliminate straws from the dining halls. Straws can also be found in the Emporium. It is less practical to replace or eliminate these straws because the lids of some of the drinks made in the Emporium necessitate straws.

Opaque food containers, as found in the Emporium and the Leaky Beaker, could be replaced by other plastics or in some situations by paper or cardboard. Plastic, when recycled, is often downcycled, while paper can more often be used in a similar way after being recycled. Therefore, it may seem more sustainable to use paper packaging. Some of these opaque containers store liquids or other substances that could not be usefully held by a paper container. In addition, plastic \#5 is a relatively harmless plastic compared to other plastics, and ranks lower on our impact factors than does paper (Figure 5.6). We do not recommend replacing plastic \#5 with another material for the purpose of food packaging.

Bottle caps are necessary for preserving the liquid inside plastic bottles. The plastic could be replaced by another type of plastic or by metal; however, it is likely difficult to find vendors who sell bottles capped with a different kind of material. In addition, plastic \#5 scores fairly well on the impact factors, and therefore it does not make sense to replace this material in the case of bottle caps.

## Plastic 6

$1 \mathrm{lb}=1$ cubic foot of Styrofoam ${ }^{204}$
Plastic \#6 (polystyrene) is a cheap, lightweight, and insulating material, most commonly known by the brand Styrofoam. It is used in packaging, takeout containers, cups, and other disposable dining materials. SimaPro results show that it has the lowest impact on the five measured categories. Apart from these metrics, polystyrene is known to leach nervous system toxins and carcinogens during use, increasing toxicity to humans. ${ }^{205}$ In terms of environmental effects, polystyrene production may create minimal GHG production, but it is difficult to recycle, non-biodegradable, and toxic. Also, its lightweight structure lends it to transport by wind, making it an environmental contaminant. ${ }^{206}$

Use of polystyrene for dining purposes at Wellesley College is very low, and our interviewees did not report high amounts of polystyrene use. For example, when AVI Fresh provides disposable dishware it is a compostable paper product, and cardboard packaging is preferred to foam. It is possible that polystyrene enters Wellesley from student purchases, as packing peanuts in department shipments, or foam packaging containers. A relatively inexpensive replacement for packing peanuts may be newspaper or shredded paper filling. Another replacement is biodegradable packing peanuts, though they do have a higher cost. ${ }^{207}$

[^40]These replacements would still create waste, but are more recyclable and biodegradable, reducing toxicity to the environment and humans. Replacements would likely have to be made at the distributor level, which may be difficult to enforce, but both replacements are easily available for purchase in larger quantities.

Metals
$1 \mathrm{lb}=34.6355 \mathrm{~mL}$ aluminum cans ${ }^{208}$


Figure 5.3: Comparison of environmental impacts of making aluminum and steel.

| Material | Global <br> Warming | Carcinogens | Non <br> Carcinogens | Ecotoxicity | Respiratory <br> Effects |
| :--- | :--- | :--- | :--- | :--- | :--- |
| Aluminum | Low | Very High | Very High | Very High | Low |
| Steel | Low | Very High | Very High | Very High | Low |

Figure 5.4: Ratings of environmental impacts of making aluminum and steel.
Steel and aluminum cans allow food to be safely stored for long periods of time in an easily transportable container without exposure to oxygen, moisture, or light. Of the materials analyzed here, results of a SimaPro analysis of metal material creation demonstrate that metals represent the highest risk for carcinogens, non-carcinogenic toxins, and ecotoxicity. This means if we are attempting to mitigate total toxicity from material creation, reducing metal purchasing is very important. Steel is more durable than other recyclables, and its use is less likely to release

[^41]harmful toxins than plastic use, for example. ${ }^{209}$ It has the highest recycling rate and retains material quality through multiple recycling processes. ${ }^{210}$ This can offset some of the harmful impacts of mining and smelting virgin material.

According to the ES 300 Waste Audit "Waste Not Want Not" (2012), metal represents a small portion of Wellesley College's total waste, and the majority ( $91 \%$ ) of recycled metals is steel cans. The majority of these steel cans likely come from AVI Fresh and - to a smaller degree - student purchasing of personal beverages and canned food items. Most steel products are made from about $60 \%$ recycled material. ${ }^{211}$ Rather than seek out a replacement for steel cans in dining services, purchasing products that are packaged in recycled steel cans is more likely to reduce toxicity to the environment and humans. The best option to remove steel from the waste stream is to avoid purchasing materials in steel cans.

## Paper

$1 \mathrm{lb}=100$ sheets $^{212}$


Figure 5.5: Comparison of environmental impacts of making recycled and virgin paper.

[^42]| Material | Global <br> Warming | Carcinogens | Non <br> Carcinogens | Ecotoxicity | Respiratory <br> Effects |
| :--- | :--- | :--- | :--- | :--- | :--- |
| Paper - <br> Recycled | Low | High | Medium | High | Low |
| Paper - <br> Virgin | Low | High | Low | Medium | Low |

Figure 5.6: Ratings of environmental impacts of making recycled and virgin paper.
The production of both virgin and recycled paper are sources of concern for carcinogens and ecotoxicity, though more so for recycled paper than for virgin paper. This, along with the fact that paper cannot be recycled indefinitely into exactly the same material, suggests that recycling paper is not the best way to reduce environmental or health impacts. The SimaPro results, however, do not take into consideration land use. Recycled paper is beneficial in that it avoids deforestation and its subsequent environmental concerns. Paper recycling is also beneficial to minimize use of landfills, and the associated impacts on ecotoxicity.

The largest sources of paper use on campus are likely in academic and in administrative departments, and student printing with office paper for course readings and resources. The College currently supports free black-and-white printing for students with no page cap. This year, LTS expanded printing services by introducing printers into residence halls, making student printing more convenient. Both the Economics Department and LTS reported recycling used paper. The best way to minimize paper use, and subsequent disposal, is through reducing consumption. This can be done by 1) creating an accessible library of student's course readings or accessible electronic copies that are easy to use and don't require printing, and 2) encouraging more electronic distribution of department resources, readings, and spam either through information campaigns or printing limits. Reducing paper use may be initially difficult to implement and may temporarily decrease both institutional and individual ease, but would reduce cost and toxicity in the long run.

## Cardboard

$1 \mathrm{lb}=1.8(31 \times 31 \times 21 \mathrm{~cm})$ cardboard boxes ${ }^{213}$

| Material | Global <br> Warming | Carcinogens | Non Carcinogens | Ecotoxicity | Respiratory <br> Effects |
| :--- | :--- | :--- | :--- | :--- | :--- |
| Car <br> dboard | Lo | High | Low | Medium | Low |

Figure 5.7: Rating of environmental impacts of making cardboard

213 "Overview of Standard Industrial Packaging Weights." Val-I-Pac. Accessed April 17, 2018. http://www.valipac.be/Belgium/members-info/pdf/OVERVIEW-OF-STANDARD-WEIGHTS.pdf.

Cardboard production has a low impact rating in global warming, non-carcinogens, and respiratory effects. It creates a medium level of ecotoxicity and a high level of carcinogens. Although its rankings in some of these impact categories are concerning, cardboard is a widely used, convenient packaging material. About $80 \%$ of AVI Fresh's packaging waste is cardboard, most of which is recycled, with the exception of a small amount that is wax-coated. LTS and the Economics Department also purchase items packaged in cardboard.

Cardboard could feasibly be replaced by re-usable plastic packaging. If a thin plastic were to be used, the packaging may break if a heavy item is being carried. A thicker plastic designed for re-use as a container could be used. This container would be heavier than a cardboard box, which would make carrying it more difficult. In addition, the containers would have to be returned to the distributor, which adds complexity and fuel consumption. Although reusable packaging would certainly decrease the amount of cardboard waste coming to campus, it would require substantial packaging changes on the part of the distributor.

In addition, if the plastic were disposed of and recycled it would likely be downcycled, whereas cardboard can be recycled to make more cardboard. Cardboard is the most valuable material to recycle in terms of revenue for the college--Wellesley receives $\$ 15$ per ton of cardboard from the RDF. ${ }^{214}$ Therefore, although cardboard comprises a large amount of the waste brought to campus by distributors, it may not be practical to replace it with another material.

## Glass

$1 \mathrm{lb}=0.9750 \mathrm{~mL}$ glass bottles ${ }^{215}$

| Material | Global <br> Warming | Carcinogens | Non <br> Carcinogens | Ecotoxicity | Respiratory <br> Effects |
| :--- | :--- | :--- | :--- | :--- | :--- |
| Glass | Low | Medium | Low | Low | Low |

Figure 5.8: Rating of environmental impacts of making glass.
Glass production has a relatively low environmental impact compared to other materials (Figure 5.8) although it has a relative medium carcinogenic impact. Glass is highly efficient to recycle, as it can be repeatedly recycled without loss of quality. ${ }^{216}$ However, infrastructural changes to recycling facilities have made glass recycling prohibitively expensive, ${ }^{217}$ so cost is an especially relevant metric when considering the College's purchasing behavior for glass. Currently, it costs the College $\$ 125$ per ton to recycle glass at the Wellesley RDF. ${ }^{218}$

[^43]Glass is primarily used on campus for food and beverage containers, although it is also laboratory equipment. ${ }^{219}$ AVI Fresh purchases food and beverage products packaged in glass bottles for sale in its retail locations. It would be easy to substitute these products with items packaged differently and would require no structural changes. It would be much more difficult to substitute glass laboratory equipment with comparable products. Replacing laboratory equipment should be lower priority because it is typically only thrown out when it breaks, in which case the glass is disposed in specific collection boxes that are not treated as recyclable material. ${ }^{220}$

Importantly, our observations revealed that the majority of glass products recycled on campus are alcoholic beverage containers brought onto campus by individual students. Federal, state, and local laws restricting the sale of packaged alcohol limit the College's options to how to change individual purchasing behavior. ${ }^{221}$ We recommend that the College partake in an information campaign to encourage students to purchase alcohol in aluminum cans rather than glass bottles.

## Conclusion \& Recommendations

We are recommending that the College take several actions to change its purchasing behavior and reduce the total amount of recyclables entering the campus.First, we recommend that the College focus especially on removing glass from the purchasing stream and reducing paper and plastics and also offer a number of other suggestions to shift on-campus purchasing behavior.

Next, we recommend that a set of purchasing guidelines be integrated into the Sustainable Office Certification as carried out by the Office of Sustainability. Any group that self-identifies as an office can apply for this certification and pledge to follow a list of guidelines. Third, we propose that additional purchasing guidelines be added into this document that discourage the purchase of glass and of items such as paper cups.

We offer our recommendations in three categories: high, medium, and low priority. We sorted ratings into categories considering the following metrics: environmental impact, recycling efficiency, institutional ease, and cost.

## High Priority

We recommend that AVI Fresh cease purchasing beverages packaged in glass bottles for sale at retail locations on campus. If possible, we suggest purchasing identical products in aluminum can packaging, which can be recycled without loss of material quality. If that is not possible, we suggest purchasing similar products packaged in aluminum cans. This action does not impose significant changes in cost and it removes a substantial cost incurred by recycling glass. We recommend that the College make these

[^44]stock changes at the beginning of a semester to lessen impact of change felt by consumers.

We recommend that LTS impose a cap on free printing for students and faculty. The College can discourage printing on campus by either eliminating free printing altogether or introducing a cap on free printing. This action would reduce costs associated with purchasing paper and toner. It would not require the College to stop using its printing service provider, Papercut. The College would likely receive considerable pushback for this change. We recommend that academic departments create policies to ensure that the cost of printing would not create a financial burden that prohibited students from academic engagement. Additionally, we suggest academic departments maintain accessible libraries of all course readings in physical copies and/or in electronic copies. Electronic copies should be offered in a format that allows students to annotate the readings.

## Medium Priority

We recommend that AVI Fresh cease purchasing beverages packaged in plastic bottles for sale at retail locations on campus. If possible, we suggest purchasing the same products with aluminum packaging, which can be recycled without loss of material quality. If that is not possible, we recommend that AVI Fresh purchase similar products with aluminum packaging. This action does not impose significant changes in cost. We recommend that the College make these stock changes at the beginning of a semester to lessen impact of change felt by consumers.

We recommend that the College install filtered water dispensers in every building on campus and publicize both the location of the dispensers and the fact that they have filters installed. We recommend this action be taken in step with removing plastic water bottles from retail locations on campus.

We recommend that the College build on previous efforts and cease purchasing bottled beverages for events. At campus-wide events such as the Tanner and Ruhlman conferences, this could save the College over 2,750 bottles per event previously supplied to each faculty member and student.
This action would only require only minor purchasing changes and offer a reduction in costs. We suggest the College provide easy-access refill stations and encourage individuals to bring a cup or reusable bottle.

We recommend that academic departments cease purchasing single-use paper cups for use in their offices. We suggest that departments maintain collections of department-owned, communal mugs and cups or require students and faculty to provide their own. This action would require only minor purchasing changes and offer a reduction in costs.

## Low Priority

We recommend that academic departments cease purchasing single-use coffee pods, commonly referred to as K-Cups and used in Keurig coffee machines, and replace them with reusable ones. K-Cups are made of non-recyclable plastic. There are plastic cups available for purchase, which are the proper size for a Keurig and are reusable and dishwasher safe. The lid of the cup opens and can be filled with coffee grounds. This reusable alternative allows users to make the beverage they prefer while reducing waste. This action would require only minor purchasing changes and likely not affect costs, although it would reduce the convenience of using the Keurigs.

We recommend that the College implement an informational campaign to inform students to purchase alcohol and other beverages in aluminum packaging rather than glass bottles. At a cost of $\$ 125$ per ton, glass is currently the most expensive recycling stream at the Wellesley Recycling and Disposal Facility, and many of the same beverages (beer, cider, soda, hard alcohol) can be purchased in a material that is cheaper for the college to recycle such as plastic or aluminum. Though student purchasing behavior may be more difficult to alter, this information can be easily incorporated into first year orientation material. This action would require little structural change although it could incur some costs.

## 6. Ideal Recycling Setup

## Four Stream Collection

The ideal recycling setup for Wellesley College includes four streams: plastic, paper, glass and metal. These four streams will have specialized lids to encourage accuracy in recycling. From our specialized bins experiment, we found that color coding bins with specialized lids and labels yielded an increase in recycling rate and a decrease in incorrect recycling. In our experiment, we only divided recycling into three streams (See: Section 3.2, Figure 3.2.2). We suggest the addition of glass and metal streams because there are different charges for metal and glass in the recycling facilities, and separating them beforehand allows the College to save money. Our interviews with custodial staff indicate that the addition of two streams campus-wide will not greatly affect the amount of work custodians do, and that some custodial staff favor this system because it improves recycling accuracy.

While the paper stream will officially be mixed paper and cardboard, we recommend the separation of large cardboard (such as that from packages) to be broken down and placed behind trash/recycling bins. This separation is already practiced by parts of campus that frequently receive cardboard packages as well as many students per recommendation of custodial staff. Custodians expressed the value of separating bulk cardboard from paper to prevent quick-filling of paper recycling bins and the subsequent improper recycling of paper when the bins are too full. Moreover, by separating paper and cardboard, the College would receive three times as much revenue per ton than that generated by submitting the two streams as mixed (a difference of $\$ 15$ rather than $\$ 5$ per ton).


Figure 6.1: Proposed four stream system. The recycling is divided into three streams (Glass and Aluminum, Plastic and Paper). The bins are also located right next to the trash bins.

## Bin Location

Each trash bin inside a building on campus should have four streams of recycling bins located next to it, as this will improve consistency across campus. We recommend that recycling bins be located next to trash bins so that someone who is going to throw something away thinks twice about whether that item can be recycled instead. This will also decrease the likelihood that
students are unable to find a recycling bins, which the motivation survey identified as a problem, since the bins will be next to the trash can.

## Consistency

We recommend consistency across campus, and we propose that the trash cans be consistent throughout the College and the color of each recycling stream be as well. This consistency will make it simple and allow for students, faculty and staff to associate a color with the stream it is being recycled. We want to make this process as easy as possible. By implementing uniform sets of specialized bins, eventually the Wellesley Community will learn which color stands for which stream.

## Informational Signage

To further increase the accuracy in recycling we recommend educational signage to be placed on top of each bin, as prepared in Appendix A: Proposed Signage. This signage will give people more knowledge on and confidence in what can and cannot be recycled. This signage should include mention of the non-recyclability of things like pizza boxes that people frequently incorrectly recycle. We also recommend increasing campus awareness of the online Wellesley's Waste Disposal Guide where you can find out more about what can/can't be recycled. The availability of this website should be listed on signage above recycling bins. Additionally, during orientation week, we suggest that when students receive their water bottles, inside will be an educational brochure with all the items that can be recycled and which bins they belong to. We hope to teach first-year students about the importance of recycling from the very beginning so they can then change their behaviors accordingly.

Finally, in the floor plan map that is placed in each residential and academic building, which denotes bathroom locations and room numbers, we recommend the addition of a recycling symbol to signify where a recycling bin is located in that building floor (See: Appendix B) This will hopefully allow people to find recycling bins easier, and as a result, increase recycling on campus.

## Conclusion

The College's current dual-stream recycling system-which collects mixed paper and cardboard in one stream, and commingled in the other-may no longer be feasibly sustainable. The effects of China's July 2017 ban on certain foreign waste imports has led to a decline in the number of waste facilities that accept commingled recycling. Increased separation of recycling streams will not only expand the number of facilities to which the College may send recycling, but it will also generate revenue if the College sends recycling to the RDF.

After performing extensive research, review of the academic literature, implementing numerous experiments, and comprehensive analyses, we found that standardizing a four-stream recycling system across campus coupled with informational signage will most improve recycling practices. To maximize revenue and decrease the greenhouse gas emissions associated with transportation, we also recommend that Wellesley College resumes sending its recyclables to the Town of Wellesley RDF.

The four streams of this system would include mixed paper and cardboard, mixed plastics, metals, and glass. Additionally, if the system standardizes separating paper and cardboard into two separate streams-as is already done in parts of campus that frequently receive cardboard packages-and sends it to the RDF, the College would receive three times as much revenue per ton than would be generated by submitting the two streams as mixed (a difference of $\$ 15$ rather than $\$ 5$ per ton). Mixed plastics would generate neither revenue nor costs. Glass, on the other hand, costs $\$ 125$ per ton to recycle. We recommend reducing the amount of glass waste on campus by replacing glass products with cans at retail locations, and encouraging students to do the same.

Our approach to improving recycling on campus is fundamentally based on converting recycling infrastructure into a form that prompts individuals to separate waste accurately and intuitively. Experimentation illustrated that efforts to involve students in active pledging to recycle or posting messaging to encourage recycling were neither successful nor sustainable. A survey of students, faculty, and staff demonstrated that the most common reasons for why people do not recycle are rooted in infrastructure and information. Namely, people on campus expressed not being able to locate recycling bins, not knowing if items were recyclable, and carrying dirty recyclables as major impediments to recycling.

Of the infrastructural changes with which we experimented, specialized bins with informational signage improved rates of recycling most significantly. Single-stream recycling did not improve recycling and may have contributed to increases in incorrect recycling. This pattern further supports the anticipated success of a four-stream system, which may increase both yield and accuracy. Discussions with custodial staff garnered further support for this four-stream recycling model. Custodians commented on the benefits of separating bulky cardboard from paper to prevent rapid filling of paper recycling bags, separating recyclables with redemption values that custodians in turn deposit, and improving recycling accuracy with specialized bins reducing the amount of sorting by custodians.

While upfront costs associated with installing standardized four-stream bins across campus must be considered, the yield, accuracy, and subsequent revenue will likely offset many of these costs in the longer-term. With Wellesley College's 10 -year commitment of $\$ 300,000$ per
year to sustainability initiatives, a standardized four-stream recycling system with informational signage should be implemented over time to improve recycling across campus, moving our community to a more sustainable future.

## Appendices

## Appendix A: Proposed Signage

Signs (five of them- four streams \& one trash)


Plastics \#6, plastic straws, unnumbered plastic, napkins

Download here.

## Metal



Aluminum and steel cans


Clean Aluminum Foil and Trays

## All metals

Download here.

## Glass



All white, green, and brown glass

Download here.

## Plastic

Soda bottles, milk jugs, laundry detergent,
shampoo bottles, margarine tubs, yogurt cups, etc


All plastics \#1-5
Check bottom of container for plastic \#

Download here.


Wire, clips, staples, and rubber bands do not need to be removed
No paper towels, pizza boxes, napkins, tissues, food

Download here.

## Handout on recycling (in first-year water bottles)



Download here.

## Appendix B: Current Wellesley Campus Recycling Map

Locations of recycling bin sets for most buildings on campus are marked with red X's. Areas without recycling bins or not accurately mapped are noted.

## Academic buildings



Figure B.1.1: Science Center 1st Floor Recycling Bin Locations.


Figure B.1.2: Science Center 1st Floor Recycling Bin Locations.


Figure B.1.3: Science Center 2nd Floor Recycling Bin Locations.


Figure B.1.4: Science Center 3rd Floor Recycling Bin Locations.


Figure B.1.5: Science Center 4th Floor Recycling Bin Locations.


Figure B.1.6: Science Center 5th Floor Recycling Bin Locations.


Figure B.2.1: Founders Ground Floor Recycling Bin Locations.


Figure B.2.2: Founders Hall 1st Floor Recycling Bin Locations.


Figure B.2.3: Founders Hall 2nd Floor Recycling Bin Locations.


Figure B.2.4: Founders Hall 3rd Floor Recycling Bin Locations.


Figure B.2.5: Founders Hall 4th Floor Recycling Bin Locations.


Figure B.3.1: Clapp Library 1st Floor Recycling Bin Locations.


Figure B.3.2: Clapp Library 2nd Floor Recycling Bin Locations.


Figure B.3.3: Clapp Library 3rd Floor Recycling Bin Locations.


Figure B.3.4: Clapp Library 4th Floor Recycling Bin Locations.


Figure B.4.1: Jewett Arts Center 1st Floor Recycling Bins.


Figure B.4.2: Jewett Arts Center 2nd Floor Recycling Bins.


Figure B.4.3: Jewett Arts Center 3rd Floor Recycling Bins.


Figure B.4.4: Jewett Arts Center 4th Floor Recycling Bins.


Figure B.5.1: Pendleton Hall 1st Floor Recycling Bins. Locations not noted in Pendleton Hall West in current and subsequent figures due to recent renovations not reflected in available floor plans.


Figure B.5.2: Pendleton Hall 2nd first floor recycling bins.


Figure B.7C: Pendleton Hall 3rd first floor recycling bins.


Figure B.7D: Pendleton Hall 4th first floor recycling bins.

## Residential halls



Figure B.1.1: Beebe Hall 1st Floor Recycling Bin Locations.


Figure B.1.2: Beebe Hall 2nd Floor Recycling Bin Locations.


Figure B.1.3: Beebe Hall 3rd Floor Recycling Bin Locations.


Figure B.6.4: Beebe Hall 4th Floor Recycling Bin Locations.


Figure B.6.5: Beebe Hall 5th Floor Recycling Bin Locations.


Figure B.7.1: Pomeroy Hall 1st Floor Recycling Bin Locations.


Figure B.7.2: Pomeroy Hall 2nd Floor Recycling Bin Locations.


Figure B.7.3: Pomeroy Hall 3rd Floor Recycling Bin Locations.


Figure B.7.4: Pomeroy Hall 4th Floor Recycling Bin Locations.


Figure B.7.5: Pomeroy Hall 5th Floor Recycling Bin Locations.


Figure B.8.1: Shafer Hall 1st Floor Recycling Bin Locations.


Figure B.8.2: Shafer Hall 2nd Floor Recycling Bin Locations.


Figure B.8.3: Shafer Hall 4th Floor Recycling Bin Locations.


Figure B.8.4: Shafer Hall 5th Floor Recycling Bin Locations.


Figure B.9.1: Stone-Davis Hall 1st Floor Recycling Bins.


Figure B.9.2: Stone-Davis Hall 2nd Floor Recycling Bins.


Figure B.9.3: Stone-Davis Hall 3rd Floor Recycling Bins.


Figure B.9.4: Stone-Davis Hall 4th Floor Recycling Bins.


Figure B.10.1: Tower Court 1st floor recycling bins.


Figure B.10.2: Tower Court 2nd floor recycling bins.


Figure B.10.3: Tower Court 3rd floor recycling bins. Representative image of 3rd, 4th, and 5th floor recycling bin locations in Tower Court. There are no recycling bins on the 6th floor.

Lake House
First Floor


Figure B.11.1: Lake House 1st floor recycling bins. Representative of 1st, 2nd, and 3rd floor recycling bin locations in Lake House.


Figure B.12.1: Claflin Hall ground floor recycling bins.


Figure B.12.2: Claflin Hall 1st floor recycling bins.


Figure B.12.3: Claflin Hall 2nd floor recycling bins.


Figure B.12.4: Claflin Hall 3rd floor recycling bins.


Figure B.13.1: Severance Hall ground floor recycling bins.


Figure B.13.2: Severance Hall 1st floor recycling bins.


Figure B.13.3: Severance Hall 2nd floor recycling bins.


Figure B.13.4: Severance Hall 3rd floor recycling bins.


Figure B.13.5: Severance Hall 4th floor recycling bins.


Figure B.18.1: Freeman Hall 1st floor recycling bins. Representative of 1st-4th floor recycling bin locations in Freeman. There are no recycling bins on the 5th floor.


Figure B.19.1: Bates Hall 1st floor recycling bins. Representative of 1st-4th floor recycling bin locations in Bates. There are no recycling bins on the 5th floor.


Figure B.20.1: McAfee Hall 1st floor recycling bins. Representative of 1st-4th floor recycling bin locations in McAfee. There are no recycling bins on the 5th floor.


Figure B.17.1: Dower Hall 1st Floor Recycling Bins.


Figure B.17.2: Dower Hall 2nd Floor Recycling Bins.


Figure B.18.1: Munger Hall Ground Floor Recycling Bins.


Figure B.18.2: Munger Hall 1st Floor Recycling Bins.


Figure B.18.3: Munger Hall 2nd Floor Recycling Bins. Representative of recycling bins on the 2nd and 3rd floors of Munger.


Figure B.19.1: Lulu Chow Wang Campus Center 1st Floor Recycling Bins. Representative of recycling bins on the 1 st floor of the Wang Campus Center.


Figure B.19.2: Lulu Chow Wang Campus Center 2nd Floor Recycling Bins. Representative of recycling bins on the 2 nd floor of the Wang Campus Center.


Figure B.19.3: Lulu Chow Wang Campus Center 3rd Floor Recycling Bins. Representative of recycling bins on the 3rd floor of the Wang Campus Center.


Figure B.19.4: Lulu Chow Wang Campus Center 4th Floor Recycling Bins. Representative of recycling bins on the 4th floor of Lulu.


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    \%20Waste \%20Management\&rft.volume=320\&rft.issue=1\&rft.spage=43\&rft.epage=50\&rft.date=2012-10-
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