Creating a Sustainable Campus

Through Recycling Solutions

An Interactive Qualifying Project

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by

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Abstract

New England Innovation Academy (NEIA) sponsored an interactive qualifying project (IQP) to develop a sustainability plan for their new middle-high school campus. Eventually, the project focused on assisting NEIA in finding a suitable recycling and composting waste management vendor. The primary method of data collection was a multi-criteria decision making methodology consisting of two analytical hierarchy processes: one with stakeholders at NEIA to determine the priorities and goals of the institution, and one to analyze various local recycling vendors according to NEIA's priorities. Through this methodology, an appropriate vendor for recycling and composting was recommended to NEIA. The project also provided a robust problem solving technique for multi-faceted decisions, as well as made recommendations for further sustainability projects and investigation.

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Executive Summary

Introduction

The goal of our project was to help the New England Innovation Academy (NEIA) choose a recycling and composting company service. NEIA is a private middle and high school with 76 students in grades 6-12. Although they are centered in Marlborough, Massachusetts, they are associated with the Wahaha Foundation in Hangzhou, China, and are a sister school to the Wahaha International School—it is for this reason that they are associated with the Hangzhou Project Center. NEIA just recently opened their doors in Fall 2021 as a "human-centered design" school centered around interdisciplinary and project-based learning using real world applications.

Background

Environmental sustainability is a complex issue, and schools and universities are often found as the centers of innovation to increase sustainability and educate people on its benefits. Therefore, using other schools with established sustainability plans, such as Harvard University and Worcester Polytechnic Institute, as role models is an effective way of finding new methods of sustainability to implement in other educational institutions. There are also various recognitions for outstanding environmental sustainability practices that we look for when researching sustainable schools, such as the U.S. Department of Education's Green Ribbon Award for K-12 schools.

Although having physically sustainable practices and amenities is a good first step to become sustainable, fostering a culture of sustainability within the school community is crucial for the school to be a truly sustainable institution. Many college campuses, including those listed

above, implement sustainability into their curricula. There is a consensus among scholars that it is also important to expose students as young as middle school to environmental education, as environmental education is a "lifelong process" and starting earlier in students' development allows more time for this process to mature more completely.

Environmental sustainability also has a positive social impact on communities at large. However, occasionally some organizations choose to participate in environmentally healthy practices for the marketing advantage they bring to themselves over the benefits to the community. For sustainability efforts to continue to be successful, schools and other organizations must be truly committed to improving the community in which they belong.

When it comes to recycling, there are many different methods, two of which include single stream and dual stream recycling. Single stream involves mixing recycled materials in the same bin, while dual stream involves placing recyclables into two categories: paper and cardboard or metals, glass, and plastics. Both have their own benefits and drawbacks: single stream recycling allows for maximum consumer convenience, which increases community engagement, but also allows for more user error, such as people throwing all waste indiscriminately into the recycling bin, which can then contaminate the bin. Dual stream, on the other hand, is less convenient, but also decreases bin contamination due to the user having to sort their recycling themselves. Composting also has several different methods depending on the amount of compostable waste and the specific composting goal. While the method of recycling/composting is important, the most important thing in the case of NEIA is to critically examine various third-party companies that are willing to work with the school.

The vendors for sustainability oftentimes are selected based upon services offered and cost. While this may be an easy way to gauge differences between two companies, it lacks depth when ranking many companies at once. In a decision-making process, each company has different values and needs. While some require the most cost-effective vendor for recycling, others may be willing to spend more money in order to get a wider range of services, or maybe require their services to be scalable for future business expansion.

Methodology

The methods we originally planned on using to develop a sustainability plan for NEIA were archival secondary research, one-on-one surveys, and interviews of sustainability and education experts. However, as the project goal evolved, the methodology also evolved. Instead of surveys, we used multi-criteria decision making and the analytical hierarchy process (AHP) to determine the best recycling company that would fit NEIA's needs. The project became a vendor selection decision based on sustainability dimensions.

Multi-criteria decision making was the primary method for data collection in our study. We first developed a list of factors that we believed were important decision elements to consider, using our archival research and the "triple bottom line" criteria as guides. We then utilized a software called WEB-HIPRE to complete the analytical hierarchy process with decision makers at NEIA. Before the meeting with stakeholders at NEIA to conduct the AHP, we sent a Qualtrics survey to both introduce them to the process as well as for us to gain a baseline understanding of where each stakeholder ranked each factor in a private setting before we held the open discussion. We began the meeting by having an open discussion about the factors to

make sure everyone felt each aspect of their business values were being covered. Next, we explained the software process and began working through the analytical hierarchy process live with the stakeholders. After that, we compiled a list of potential recycling and composting companies considering the same four factors that we ranked with NEIA. Additional crucial details such as operational costs, locality, and certifications were also determined from the companies and secondary sources. Lastly, we completed a second analytical hierarchy process using the vendor information and were able to make an informed recommendation to NEIA based on the data gathered.

We had several limitations to consider when working on the project, the biggest being the time limits of the project itself. We only had seven weeks to contact and set up meetings with our sponsor, analyze existing plans, conduct interviews, conduct surveys, *and* draft a plan. Upon reflecting on this with our advisors and the sponsor, we decided to narrow the scope of the project accordingly.

Results

AHP Process with NEIA Stakeholders:

The four factors chosen to guide the decision-making process were business, environmental, social, and economic. Each factor was composed of several subfactors that detailed different aspects and defined the factor more completely. Before the meeting with stakeholders at NEIA to conduct the AHP, we sent a Qualtrics survey to both introduce them to the process as well as for us to gain a baseline understanding of where each stakeholder ranked each factor in a private setting before we held the open discussion.

At the meeting with the stakeholders, it was determined that the most important factor by far was environmental, with a preference value of 0.633, followed by economic (0.194), and business and social factors tied for last with a score of 0.087 each. The higher the value, the more important the factor is to NEIA.

AHP Process with Recycling Vendors:

Through conducting research on regional recycling and composting vendors, we identified six possible companies local to NEIA that we believed to be good fits: Republic Services, RoadrunnerWM, BP Trucking, E.L. Harvey & Sons, MarlboroughWM, and Orifice Recycling and Refuse. We then began interviewing representatives of the companies through email and phone calls to collect information such as: what types of services they offered, their certifications, and their pricing. Through these interviews, we also learned that RoadrunnerWM does not service the Marlborough area, so they were no longer considered in our rankings.

Based on the information we were able to gather and the factors we had already come up with, we then worked through an additional analytical hierarchy process. We ranked the vendors with four pairwise comparison matrices, one for each individual factor. Because we ranked five potential companies, each matrix was a 5x5 comparison. While Republic Services and MarlboroughWM scored highly in the Business and Economic factors, E.L. Harvey & Sons and Orifice Recycling and Refuse were frontrunners in the Environmental and Social factors. The only company to score well in three factors was BP Trucking, which scored high in Business, Environmental, and Social.

Recommendations and Conclusions

From our AHP analysis of the five vendors and discussion with the NEIA sponsors, we recommend BP Trucking as the best choice for NEIA's current needs and values. Based on the data from our meeting with NEIA stakeholders, the environment is the most important factor to NEIA, so it had a significant weight in choosing a vendor, and BP Trucking scored the highest in the environmental factor.

We also have determined other work that NEIA could do in the future to continue to increase their environmental sustainability. We would recommend an annual waste audit to find the percentage of their recyclable waste that is being recycled, as well as their current and potential recycling rate. We would also recommend our original methodology for use in tackling other areas of the broad sustainability plan, such as greywater usage, energy reduction, carbon neutrality, and much more. This methodology was formulated to see what works at other campuses, how that could be scaled to work at NEIA, and how to go about implementing that plan at NEIA. This work could even be done by future IQP teams at WPI. The AHP process could be used in the future to re-evaluate NEIA's recycling needs. Other groups could also use it to help with other multi-faceted decisions NEIA is faced with. This, in combination with information gained from a waste audit, could give even more detailed insight into NEIA's needs and help them develop as a leader in environmental sustainability among secondary education institutions.

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1.0 Introduction

1.1 General Sustainability Concerns

Sustainability is a concept of ensuring the current creation of goods and services will not impede on the creation of goods and services of future generations. Our environment is an exhaustible resource and it is up to us as a world to ensure its protection. In a perfect world, humans live in harmony with the environment and conserve its resources for future generations to use.

Sustainability is important to society because we all have a moral obligation to each other to ensure its existence. In the big picture, many small actions will very much affect the big picture. When recognizing the human impact on the earth we often find ourselves thinking about sustainability within our own ecosystems, but rarely how that one ecosystem may impact others. For example, if we over hunt a specific kind of animal, say a deer, not only are we depleting the supply and existence of deer, but we are also impacting every organism in their food chain that depends on the deer.

Ensuring that people not only understand their environmental footprint at home as well as in their workplace is very important. In reference to energy usage, nearly 40% of total energy consumption in 2020 was found in the residential and commercial sectors (U.S. Energy Information Administration, 2021). For example, implementing LED light bulbs into your workplace and home can have a large effect on your energy footprint, using 75% less energy and can last up to 25 times longer than incandescent lighting.

Making positive changes in your home and in your workplace will lead to a better and brighter more sustainable future for everyone. This will have not only positive effects on the

environment, people, and atmosphere but in many cases will lead to a more productive society and motivate a greater “circular economy” in which one man's waste can be another man's resource.

1.2 The Sponsor and the Project Goals

The original goal of this interactive qualifying project (IQP) was to develop an environmental sustainability plan for New England Innovation Academy (NEIA), located in Marlborough, Massachusetts. Although they are centered in Marlborough, they are associated with the Wahaha Foundation in Hangzhou, China and is a sister school to the Wahaha International School. It is for this reason that this project became one of the projects for the Hangzhou, China Project Center.

NEIA is a school of grades 6-12 centered around interdisciplinary and project-based learning, utilizing real world applications, and they just opened their doors to students in Fall 2021. As issues with the environment, such as natural resource depletion and air and water pollution continue to develop, it is important for institutions of learning to develop a sustainability plan that outlines practices and habits they can implement to keep their campus as environmentally friendly as possible. In order to accomplish this, our group asked: What types of projects and practices make a more sustainable campus? As we shall see after some revision the project goals evolved and will be stated more explicitly.

To achieve our original goal, we planned to interview knowledgeable individuals in various sustainability positions on educational campuses to learn about practices they have implemented. We then planned to acquire information from students to help set the benchmarks

and baselines through survey distribution in order to help us gain insight into student knowledge and engagement around sustainability and the environment.

In the seven weeks prior to our IQP term, we analyzed existing case studies on the best practices of several other college campuses and high schools. To help NEIA develop a long-term sustainability plan, we benchmarked efficient practices and programs in place on other campuses and drafted a plan on how NEIA can implement similar programs on their campus. We also planned to look into environmental sustainability education on college campuses in order to find ways for NEIA's student population to learn more about environmental sustainability both in a general sense and within their community.

As the IQP progressed, our project evolved quite significantly. This is due to a combination of many different factors, including communications with the sponsor and time constraints. When reviewing which portions of general sustainability NEIA lacked the most, we found ourselves always falling back on the organization's recycling and composting efforts. In brief sustainability conversations with staff, the general consensus was waste management concerns. We asked ourselves: How can we make the greatest sustainability impact at NEIA with the least amount of day-to-day disruption? As a result, we were now tasked with assisting NEIA in choosing a recycling and composting company for their campus. We accomplished our goal using the analytical hierarchy process (AHP) and WEB-HIPRE software.

1.3 Sponsor Background

Although they are located in Marlborough, NEIA is a sister school to the Wahaha International School in Hangzhou, China and is sponsored by the Wahaha Foundation. The school currently has less than 100 students, with 27 teachers dedicated to carrying out the

school's mission: to prepare the next generation of innovators to pursue their dreams and shape a better world.

NEIA's programs can be categorized into three groupings of classes: Innovative Studio Projects, Liberal Arts Programs, and Wellbeing Classes (Curriculum, 2021). Innovative studio projects are where the students partake in hands-on, project-based learning. The Liberal Arts programs are where NEIA teaches more traditional classes, such as humanities, math, science, language, and the arts. Wellbeing classes are courses that address social-emotional learning, functional nutrition, mental health, physical health, life skills, and outdoor skills.

NEIA also offers a handful of extracurriculars and sports. The school encourages involvement in extracurricular activities and has ten sports teams for both boys and girls.

With the goal of wanting to integrate sustainability into the campus culture and programs, our research question aimed to guide both how our group went about drafting a plan to help NEIA achieve a higher level of environmental sustainability, and how NEIA will go about integrating that plan into campus day-to-day life. Because NEIA is a school focused on project-based learning and innovation, we planned to incorporate NEIA's existing infrastructure into our environmental plan.

As part of our plan, the students of the school would get to work on projects to improve their campus's sustainability. With issues involving the environment becoming more and more urgent every year, our research question is something a lot more organizations will be asking about their own communities and workspaces in years to come. Implementing policy around environmental stewardship, such as the type NEIA is looking for, tends to follow the same methodology as previous plans from other establishments: observe where the biggest

environmental impacts can be made on campus, find and create ways for the school to go about making these changes, and establish a plan for integrating these changes into the campus.

1.4 Outline of the Report

To help address the project goal and research question we provide some background from previous attempts at solving this worldwide concern. Using academically backed literature and peer-reviewed articles, we gathered information to assist us in creating an educated methodology to solve NEIA's needs. In doing so, we gathered data into schools of thought. We collected information and combined them into larger ideas that assisted with our problem. These 'ideas' were:

1. Sustainability Practices of Other Schools and Universities
2. Environmental/Sustainability Education and Beliefs
3. Perceptions of Sustainability
4. Methods and Benefits of Composting and Recycling

We collected articles for each idea that backed the robustness of their claims and ensured that our understanding of each was solid. Every idea listed above has numerous peer-reviewed articles backing its claims.

The methodology to get to the particular issue at hand with NEIA was to focus on a multi-factored decision making. Part of our job was to ensure that not only do we provide with them an efficient vendor recommendation, but also provide them with the knowledge to expand their sustainability efforts in the future. We decided to do this by one-on-one surveys and meetings with stakeholders at NEIA. Incorporating what we learned from the four ideas above and making sure our sponsor understood the importance of them was key. Our individual

interviews focused on understanding the needs of NEIA and how they plan to move forward as years progress.

Part of our process was also to speak with key staff at Worcester Polytechnic Institute who would provide us with valuable information pertaining to sustainability efforts on an educational campus.

Using the AHP methodology allowed us to find exactly which portions of the NEIA business that needed sustainability efforts and which factors to focus on when selecting our recommendation for vendor selection. To find these factor rankings, we were required to sit down and meet with important stakeholders in decision making for NEIA and do side-by-side comparisons for each factor. These factors being Environmental, Economic, Social, and Business. To aid with the ranking process, we created sub-factors to further define the main factors for in depth-understanding.

In the recommendations section, we reviewed what was collected in the results section: the data from our interviews with Worcester Polytechnic Institute (WPI) staff, AHP factor ranking with NEIA, and data collected from various possible waste management vendors. We then found the most likely candidate for waste management based on the data measured from each step along the process. We also describe how the AHP methodology can be further used by NEIA for other important multifaceted decisions.

2.0 Background

This section will involve a review of literature related to sustainability practices in school campuses, benefits of sustainability education, perceptions of sustainability, methods and

benefits of composting and recycling, and lastly vendor selection. This will provide the information and understanding that guided our decision making as a group. The information in the following section is based upon the study of archival secondary research. We reviewed previous projects with similar approaches to ours, found their limitations and breakthroughs, and tried to understand how to improve upon them. We also studied peer-reviewed articles and papers that discuss studies that had been done relating to the efficiency of sustainability efforts. Understanding the shortcomings of previous works in the sustainability field allowed us to create a rigid foundation to build our project goals and base our decisions off of.

2.1 Sustainability Practices in Schools and Universities

Practicing environmental sustainability as "Reduce, Reuse, Recycle" is simply not enough anymore. The conventional methods of having recycling bins next to trash cans and replacing plastic straws with paper ones are better than nothing, but the effort cannot stop there. As schools and universities are implementing the newest innovative methods, they can be viewed as role models of increased sustainability.

Harvard University's sustainability plan (Harvard, 2014) gives a very concrete model for upping NEIA's environmental sustainability status. From single stream recycling making it easier for individuals to recycle, to composting programs in their dorms, Harvard's plan is seen as a front runner in the area of college campus sustainability. Smaller schools such as WPI also have sustainability plans in place that incorporate aspects similar to Harvard's plan such as using academics, facilities and operations, research, scholarship and innovation, and community engagement (Mathisen & Tomaszewski, 2020). Using other schools as benchmark references is a

great way of finding new methods of sustainability that can be implemented across educational institutions.

Being able to identify where change can be made on campus is also a factor when implementing new sustainability methods. El-Nwsany et al. (2019) and Zhang et al. (2020) focus on how identifying where the majority of waste (both solid waste and wastewater) can make an impact in ensuring resources are being allocated to the best places. Basically, knowing where on campus the majority of waste is produced allows a school to address said waste. Separate studies on the results of environmental sustainability practices on campuses provide proof that increasing the amount and accessibility of sustainability methods does boost a campus's sustainability. A number of studies with an international perspective and provide case studies of sustainability plans and methods have shown positive results on campuses around the world (Finlay et al., 2012; Ke et al. 2019; Purnell et al., 2004).

One recognition for outstanding environmental sustainability practices at the K-12 level is the U.S. Department of Education's Green Ribbon Award. This is an annual award that is given to schools that highlight excellence in school sustainability practices and resources. Two award recipients from the 2020-2021 school year are the New Roots Charter School in Ithaca, NY and Barrington Middle School in Barrington, RI. Both schools have lengthy lists of items that they uniquely do to make them stand out. Both schools implement the use of EPA Energy Star Portfolio which allowed the schools to have 28% and 40.1% emissions reductions respectively. They also both implement using paper only from certified tree farms to reduce deforestation (Rhode Island Department of Education, 2021; New York State Education

Department, 2021). Practices such as these seem to have wide benefits in sustainability and are common according to the leaders in secondary school sustainability programs.

2.2 Environmental/Sustainability Education and Benefits

While it is important for a school's campus to be physically sustainable, such as through recycling bins and efficient water usage, fostering a culture of sustainability among the student body creates well-rounded, environmentally conscious citizens of the world (Heeren et al., 2016). Many college campuses, such as WPI and Harvard as reported above, have recognized this importance and implemented sustainability into their curricula. Scholars agree that learning about environmental issues in classes not only improves the environmental intelligence of future generations, but also gives them the opportunity to incorporate labs and workshops to improve upon and design new methods and technology for sustainability (Emanuel & Adams, 2011; Finlay et al., 2012; Ruck et al., 2021). The campus can then apply these methods internally, and in this way, the campus starts a virtuous circle of sustainability.

While there is a general consensus that environmental education is important at a college level, it is also equally important to expose students as young as middle schoolers to environmental education (Hudson, 2007; Mouchrek 2017). Similar to higher education, middle and high school students can be involved in sustainability labs and workshops tailored to their age level, and complete projects centered around issues they are interested in. During these labs, relevant science topics can be taught as they come up naturally in the students' problem solving process, and this can help connect what the students are learning in school with their real world experiences (Hudson, 2007). For example, studying the effects of chemical pollutants on water

can lead to discussions on chemical reactions, or studying the durability and lifetime of different materials (such as tires) can lead to lessons on friction (Hudson, 2007).

Other scholars agree that environmental education is a "lifelong process" and can be made more concrete by focusing on students' life experiences and "learning by doing" (Koutsoukos et al., 2015). Starting earlier in students' development initiates this learning process sooner, creating more time for this process to mature. Using innovative and project-based learning in environmental education can also influence both teachers' and students' behaviors towards environmentally sustainable values (Koutsoukos et al., 2015). This makes NEIA uniquely qualified to be an excellent hub for environmental education.

Environmental education is widely considered to be beneficial, however, it is important to note that it must be combined with accessible experimental sustainability methods in order to be the most effective. According to a study in a primary school in Florida: having more knowledge does not automatically mean that a person necessarily takes action to solve environmental problems (Treagust et al., 2016). This pattern continues at the college level, where college students, when surveyed, typically consider themselves environmentally friendly and aware of environmental issues, but do not follow through on these values when it comes to recycling, waste reduction, water conservation, among other practices (Cho, 2019). It is important for campuses to have widely available options to be more sustainable (perhaps more available than the equivalent less-sustainable option) in order to give students the best opportunity to put their knowledge to practical use.

This is especially important when considering which choices NEIA makes as a company because not only will their sustainability efforts affect their campus, but assuming they are able

to optimally produce results from their efforts, these can be used in an educational aspect as well. Showing their students the direct effects of their actions allows for an entirely new level of depth in the learning process. Beyond teaching students cause and effect scenarios, they will understand the importance of sustainability actions and how they can potentially make positive changes in their homes and later on in their lives.

2.3 Perceptions of Sustainability

Environmental sustainability can have a positive social impact on a community (Emanuel & Adams, 2011; Largo-White et al., 2013). Largo-White et al. (2013) specifically considers effects of education on recycling and the direct benefits they have on how much waste will exist on a campus space (Largo-White et al., 2013). They found that taking a direct approach and designing curriculum based around educating students and the effects of students' actions if they do not change their ways had a direct input in increasing total recycling accumulated on a campus (Largo-White et al., 2013). There are differences in perceptions and actions of sustainability and can be different (Emanuel & Adams, 2011). Perceptions of college students differ in willingness to participate in sustainable practices and is likely to occur depending on general social perspectives and demographics and community norms (Emanuel & Adams, 2011).

Outcomes of these studies include that rather than waiting for off-campus initiatives, college administrators must commit and lead the way in establishing sustainable practices on campuses. Students can carry the torch and begin to lead the way for participation in sustainability practices within their peer groups.

Finding the true meaning behind actions can always be difficult. Select people in the environmental and sustainability community have found that there is an increasing number of

organizations choosing to participate in environmental practices not only for the benefits for the community that they bring, but also the marketing advantage that they bring to themselves. College sustainability events have in recent years shifted from student-led events to campuswide plans that are tied into admissions marketing (Breen, 2010). This can bring with it many potential issues that might not seem obvious initially. When an action that was initially intended to bring good to a community becomes a publicity scheme, sooner or later other schools and organizations will catch on and begin to attempt to outdo the others around them to make them stand out. This is a double-edged sword because it still brings with it the advantages of being environmentally sustainable but once it no longer becomes marketable or profitable for an organization, it is possible that events such as these will begin to fall through the cracks (Breen, 2010).

Breen mentions that for these events to continue to be successful in coming years, campuses and schools must be truly committed to improving the community that they belong to (Breen, 2010). This sentiment is directly backed up by Emanuel et al. and Largo-White et al. because they cover studies that have evidence that point to the positive effects of sustainability education on the younger generations (Emanuel & Adams, 2011; Largo-White et al., 2013).

But education is part of the measure, actions will include appropriate selection and decisions by schools to include sustainability in their decision making. This decision making can include decisions related to vendor selection, technology on campus, student and administrative practices, and courses offered. Knowing where to place resources and how to appropriately do it and make a difference is incredibly important. Many schools and organizations make these sorts

of decisions based only on the economic impact they will have, but looking beyond those factors is much more important.

As mentioned above, schools such as the New Roots Charter School in Ithaca, NY and Barrington Middle School in Barrington, RI both are industry leading examples of outstanding sustainable campuses and have been nationally recognized for their efforts. Likewise, the University of Minnesota, implements green ideas into their buildings that are not the cheapest solution but rather assist in making their campus more environmentally conscious. Two of their new buildings use a double-skin facade (made of perforated aluminum) when creating walls which reduces solar heat within the building (Andoko, Andrey, & Niki Prastomo 2021). This choice assists in the long run with reducing energy costs from cooling, but would take a while to see returns on their investment. The key detail in this example is that the University of Minnesota knew that this decision was not necessarily financially focused, but rather geared towards impacting the environment in a positive way by reducing energy consumption.

2.4 Methods and Benefits of Composting and Recycling

Not only is recycling and composting a very simple concept to understand and implement, it is one of the leaders in sustainability efforts for making a large impact with such a small amount of work. When it comes to recycling and composting, one of the biggest questions asked is what specific method should be implemented to increase community engagement. Regarding recycling, the biggest challenges come from determining what method to use. Two of the biggest forms of recycling are called single stream and dual stream recycling (Reeves, 2020), each having their own benefits and challenges. Understanding their differences and independent

advantages to each are important since different waste management vendors may offer one or the other as a part of their services.

Single stream recycling involves mixing recycling materials in the same bin. The bin is then extensively sorted through after pickup by employees at the recycling facility. Once at the material processing facility, it is loaded onto equipment that separates materials by weight and size.

Dual stream, on the other hand, involves the use of placing recyclables into two categories. The first category is for paper and cardboard while the other category is for metals, glass, and plastics. The consumer is tasked with sorting their recyclable goods into the proper bin. The bins are then brought to a recycling facility, and since sorting was done by the consumer, there is no need for sorting at the recycling facility.

Each method comes with its own pros and cons. Single stream recycling allows for the maximum consumer convenience, increasing community engagement. Allowing a consumer to throw any recyclable item into a bin removes the time commitment aspect of sorting your own waste. The biggest issue with single stream recycling comes in contaminating the recycling bins. Allowing any recyclable goods to be thrown into a bin allows for more user error, which can lead to a longer sorting process at the facility, which in the end increases sorting costs.

Dual stream recycling offers less convenience than single stream, but at the decrease of contamination. Making the user sort their recyclable goods themselves already pre sorts the bins, decreasing contamination as well as reducing sorting time at the recycling facility. An issue with dual stream recycling is the increased chance of user error. Tasking the user with sorting their

goods themselves can be seen as more work, which can lead to issues from as small as improperly sorted bins to a decrease in recycling altogether.

One common argument between single and dual stream recycling is which process is more cost efficient. Many people claim that single steam is more costly due to the cost of equipment needed for the separation of recyclables. It could also be argued that dual stream is just as costly due to the collection process requiring more bins and a specialized truck with multiple storage spaces for the recyclable material.

Composting has several different methods, depending on the amount of compostable waste and the goal you have in mind with composting (Hu, 2020). While there are numerous different methods of composting, the specific method isn't as important to NEIA as finding a company that can work with the school is. NEIA wants to work with a third party company, similar to how they'll handle recycling, to deal with composting. Unless NEIA has a preference to the method of composting the company will use (8 Methods of Composting, 2021), finding a company that is the most environmentally friendly for NEIA is the biggest priority.

2.5 Selection of Vendors for Organizations and Factors for Selection

When deciding how to solve a sustainability problem or create new emerging efforts to improve a campus/organization's sustainability, oftentimes companies will seek outside assistance rather than internal solutions to solve its problems. This needed support can be for a variety of reasons, all depending on the size of the organization, or how new they are to the field. Many new companies, similar to NEIA, have limited staff and will look to outside sources to solve smaller problems they face in order for the rest of their employees to focus on other pressing tasks at hand. Either option they chose, they will have a burden to undertake, whether it

be allowing an existing employee(s) to focus on other aspects, taking them away from their previous job, or hiring another worker to solve the new problem.

Hence why companies rely on outsourcing waste management efforts. Instead of taking away valuable time from existing employees, outsourcing allows for them to continue their work as if they never had the problem in the first place. However, with this new decision, comes another burden to undertake, which vendor to select for waste management. According to Humphreys, traditionally, companies solely consider factors like quality and flexibility of services offered when selecting vendors to hire. However, in recent years and the importance of environmental concerns, companies will now measure their suppliers environmental performance when considering partners (Humphreys, 2003).

Additionally, given these new factors for selection, many people correspond these changes due to societal impressions. Today, people often identify businesses as a major source of pollution (Humphreys, 2003). In an attempt to respond, organizations are often using less packaging, reducing pollutants, and decreasing energy consumption among many other alternatives. Furthermore, companies rank their decisions in cause-and-effect scenarios. Placing decisions under lists like pollutant effects and improvement effects. In which if a decision has more negative consequences than positive ones, they will try to balance it by having another decision be more beneficial to the environment (Humphreys, 2003).

Similarly, Guarnieri and Trojan (2019) and Igarashi et al., (2013) agree that allowing the perspective of an outsider and consumer is very important in decision making nowadays. Incorporating both the customers and the decision makers in making business preferences is important (Guarneiri and Trojan, 2019). They also mention that new and emerging companies

tend to focus more on sustainability and social responsibility efforts when making decisions (Igarashi et al., 2013). Public and private sector facing organizations see increasing pressure to consider the environment, they are placing more and more weight on decisions that affect those factors. By doing so, he mentions that as an organization, they will receive more positive press and recognition for their efforts (Igarashi, et al., 2013). These studies place great importance on selecting vendors and suppliers using various sustainability performance measures. We balance some of these measures in this project.

3.0 Methodology

Being originally tasked with creating and developing a sustainability plan, often the best way to do so is to look at the past. Since our task required us to make changes, we needed to look at the methods from the past that did and did not work the best. One way to do this is through analyzing existing research and data. We are able to take a look at the movements and events as well as procedures that campuses across the world have attempted to implement to make their communities more sustainable in hopes of protecting our future.

In addition to archival secondary research, we originally planned to use surveys as well to focus on the knowledge that people around us have. We hoped that through this method, we would be able to analyze what people knew and the information they lacked. Lastly, we interviewed other creators of sustainability plans and those working in the sustainability industry in hopes to gain first-hand knowledge about the challenges we will face in our project.

3.1 Data Collection

Our first method of data collection was planned to be one-on-one surveys. We did this through creating a preliminary survey through Qualtrics. We intended our data collection to be formatted this way in order to reduce paper waste as well as paper trails. We intended for the surveys to target one of the demographics that are present in our proposal (i.e. middle/high schoolers, adults, and college students) and gauge prior knowledge of sustainability among these groups.

Another data collection method we used was the analysis of other case studies involving environmental sustainability practices on high school and college campuses (Harvard, 2014, Mathisen & Tomaszewski, 2020). We looked at multiple different aspects of several different case studies. Looking at sustainability practices of other campuses is a great start, but due to NEIA's student population being significantly smaller than the average high school or university, we analyzed a good amount of case studies that involved making sure each sustainability practice was operating at maximum efficiency (Cho, M. 2019). A school of 30,000 students will have a much different sustainability plan than a school of fewer than 100 students, so making sure the sustainability practices we wish to implement at NEIA work with their unique situation was the top priority. Looking at plans from smaller schools such as Concord Academy (Concord, 2021) gave us a better idea of how the practices and programs we see at larger universities are implemented into smaller ones.

Along with looking at sustainability plans within other schools, our group looked at education practices in middle and high schools regarding environmental sustainability. Scholars have run studies and theorized that greater student activity in science education for sustainable

living can also advance students' understanding of promoting and creating a sustainable existence (Hudson, 2007). The benefits of environmental education among middle and high school students come in the form of a two-pronged approach. Implementing sustainable practices at schools is a good step, but making sure student engagement with these practices is at a maximum is the major factor in how big of an impact these practices will have on campus. Teaching students about the issues with the environment the programs at their school help mitigate can both increase engagement in sustainable practices and instill the importance of environmental sustainability as a key concept of our society.

As part of our data gathering, we interviewed various WPI faculty in the department of environmental sustainability. These experts include professors from the Department of International Development, Environmental Studies, and Sustainability, and staff from the Office of Sustainability. In interviewing these individuals, we were able to gain some knowledge on the types of challenges we would face when developing a plan for NEIA.

The staff from the Office of Sustainability were involved in drafting WPI's Sustainability Plan, from which we were heavily influenced as we developed a program for NEIA, so we asked for first-hand advice on how to draft a sustainability plan for an educational establishment. NEIA also mentioned that incorporating sustainability into their culture and curriculum is very important to them, and interviewing a professor was very useful in learning more about environmental education.

In addition to WPI experts, we interviewed the following staff from our sponsor, NEIA:

- Tom Woelper - Headmaster
- Ayla Gavins - Curriculum, Instruction, and Innovation Manager

- Lily Fu - Acting Assistant Head of School
- Tim McCauly - Science Teacher
- Greg Mertz - Design and Technology Specialist
- Dana Mackenzie - Facilities Manager

Interviewing NEIA staff gave us greater insight into the culture at the school, and what they are hoping to accomplish. Mr. Mackenzie gave us information about waste management at NEIA, which we directly compared to information about waste management at WPI.

For analyzing which recycling companies best suit NEIA's needs, we made use of multi-criteria decision making and the analytical hierarchy process and inputs from the decision makers at NEIA. We first created a list of factors that we as a team believed were the biggest things to consider when trying to bring a new recycling program to NEIA. These factors influenced the decision elements that are considered in the analytical hierarchy process later on. The criteria for choosing these factors - environmental impact, impacts on NEIA as a business, social impacts, and economic impacts - were developed using the "triple bottom line" criteria as a guide (Clarke, 2001). The triple bottom line is a business concept that is used to measure the social and environmental impact, along with the financial performance, of a business decision (The triple bottom line, 2020). AHP, a multi-attribute decision making process developed by Thomas Saaty (Saaty, 1990), requires decision makers to rank a list of different decision elements derived from the decision factors mentioned above. Each factor included a definition describing the main impact it had on NEIA. Along with those descriptions were subfactors tied to each main factor. The subfactors provided a more detailed description of the elements

considered in each main factor. Descriptions of each factor and related subfactors can be found in Appendix A.

The first step in choosing a new recycling company for NEIA to work with was compiling a list of potential companies. After we developed our literature review and read up on the benefits of certain recycling and composting methods versus others, our group looked for companies that could potentially work with NEIA. The same factors used in the AHP process were considered when looking for companies. Operation costs as an economic factor, distance from NEIA as an environmental factor, and company certifications as a social factor were some of the details considered when compiling the list of potential companies. The information on each company was found through their online websites and calls with representatives from the companies themselves.

3.2 Location, equipment, and logistics

We planned for our surveys to take place in one of two locations. Our first location would ideally have been Worcester Polytechnic Institute. Not only is this the school that we are attending, but it is also a culturally diverse location where people of many ethnic and socioeconomic classes are represented (40% non-white and 60/40 male/female ratio). Within WPI, in order for us to get the most diverse and unbiased data, asking people outside of our social circle to reply to our surveys would have been. By standing in a location like WPI's quad or fountain we would have a wide range of possible people to respond to our survey. Both of these areas have very heavy foot traffic, allowing as many people as possible to take one of our online surveys.

Another location for our surveys to take place was the Hangzhou Dianzi University. As we were paired with students in Hangzhou, we had the opportunity to task them for assistance with data collection. Our hope for this addition to our data collection was that the information that we would gain from the HDU campus would create a possible reflection or counterpoint to the way we might treat sustainability practices in the United States.

For analyzing existing case studies, no equipment was needed besides an internet connection and access to the online databases we had been using so far. All information on our archival literature is found above in section 2.0. To mitigate any selection bias, peer-reviewed articles and case studies were the focus of our research. All information we gathered was compared to any other related info to see where our findings agreed and disagreed. The findings from analyzing these case studies were a guiding factor in helping develop our AHP factors as well as the results of the entire project. Interview and survey results were put into both words and graphs, so all relevant info gathered from existing data is present in the report.

In the best-case scenario, we would have liked to conduct all interviews in person, but due to the unpredictability of COVID-19, we developed procedures for in-person and remote interviews. Also, interviews with other schools that are not WPI or NEIA were held over Zoom due to travel restrictions and COVID safety. We wanted our interviews to be semi-structured. The first step was to come up with content for the interview. Because our interviews were semi-structured, according to Berg and Lune, the best way to do this was to brainstorm themes that we would like to cover, and then come up with a few relevant questions under each theme (Berg and Lune, 2017). Then, we sent out the questions to the interviewee beforehand. Example questions for these interviews can be found in Appendix B. With the consent of the interviewee,

for in-person interviews, we planned to use an audio recorder with transcription abilities to record their answers, while for Zoom interviews, we just recorded the Zoom call with the live transcript feature on. For all interviews, one group member took minutes in addition to the recording. Our in-person interviews were conducted on campus at WPI or on campus at NEIA, depending on who we interviewed.

For our surveys, our preliminary intention was to have three surveys. Our first survey was to be a shorter survey with around 11 questions. The first question asked responders to rank their knowledge of sustainability and the environment from 1 to 10, and the following 10 questions checked that response. This allowed us to see if people consider themselves as having a higher perception of their knowledge than they actually do. Another survey that we initially wanted to incorporate into our research was of similar length. We first planned to ask people how often they recycle (once a day, once per week, etc.) and then planned to produce images for them and ask if each of those items can be recycled. There was a potential for bias introduced with questions like these however we discuss this later. Our last survey which could have been potentially broken into multiple quick surveys would have covered smaller topics such as if responders had taken a course in sustainability, if they had participated in a sustainability project/event in the past few months, what was most important thing to do in order to be environmentally friendly, and other things to profile how active our WPI community is. Drafts of these surveys are found in Appendices C, D, and E, respectively.

Data collection of other environmental sustainability plans was the first part of data collection our group worked on. Most of the analysis of these existing plans was carried out by each team member, both in class and on our own time. Since the databases we use are all

available online, all analyses happened from anywhere on or off-campus using personal laptops. These existing sustainability plans also helped us develop our AHP factors.

For the analytical hierarchy process multi-criteria decision methodology, we used a web software called WEB-HIPRE (Mustajoki and Hämäläinen, 2000). WEB-HIPRE is a web version of the HIPRE 3+, a software used for decision analytical problem structuring and multicriteria evaluation and prioritization and can be found at the following website: hipre.aalto.fi. As mentioned in the data collection subsection, AHP has decision makers rank decision elements. These rankings are then evaluated via paired comparisons and matrix math using the WEB-HIPRE software. The software has a user create the "decision hierarchy", and that hierarchy is what is used to rank the different decision elements. The decision hierarchy is described in the findings section—section 4.4.

3.3 Data analysis

Since our surveys and questions were limited to multichoice, ranking, or yes/no format, we were able to quantify and create charts with our data with general ease. By choosing a service such as Qualtrics, we had our responses automatically turned into data as soon as we got our first response out of convenience.

All information we found from existing environmental sustainability plans was transferred to our final report in documents. To allow for each member to work on the report from their own laptop and from wherever they wish, our group used Google Drive. A group folder containing our drafts and final versions of each part of the final report was shared with each member, so everyone could add to documents like our literature review and background chapter as they worked.

The most useful data that came from interviews was recognition of patterns among responses (Berg and Lune, 2017). To analyze our data, the transcript/recordings were first annotated. To mitigate bias, at least two out of the three team members did this.

Once the entire hierarchy is worked through, a comprehensive analysis was conducted to see which factor/factors were the most important based off of the rankings given. This comprehensive analysis illustrates the distribution of each of the general factors, based on stakeholder replies, in the form of a bar graph. A sensitivity analysis was also run to give stakeholders a range of options, allowing them to see which path is best to take when the importance of one factor was changed after seeing the results. If multiple stakeholders ranked the decision elements on their own and get their own results, the sensitivity analysis can also average final scores using weights of 0:100, 25:75, 50:50, 75:25, and 100:0, putting more importance on one stakeholder's answers over another's.

3.4 Ethical considerations

Lastly, we needed to consider some ethical considerations when taking in data in the form of a survey. We needed to understand and account for the fact that participating in an in-person survey would likely make people inclined to lie or inflate their responses in order to appear a certain way. Also worth noting is that memories fade, people might not fully remember all aspects of their day-to-day life (i.e. how many times they throw a can in what bin). Another thing that we needed to consider is that if we did not get a large enough sample size, we would be counting outliers as if they were normal data points. The last thing we needed to do is keep responses anonymous to not link data to anyone that could be used for harm.

While environmental sustainability is a pretty ethically sound practice, some case studies we analyzed highlighted campuses raising their environmental sustainability practices as a publicity stunt more so than for the benefit of the environment (Breen, 2010). Through working with NEIA, we knew their intent behind working with us to draft an environmental sustainability plan was not to make headlines. Both the staff and students of the school are passionate about being environmentally friendly, and are eager to learn how they can help to make their campus as green as possible.

The primary ethical concern to consider when conducting interviews is confidentiality and protecting the interviewee. An important step was to obtain informed consent verbally/in writing from our interviewees prior to the interview (Allmark et al., 2009). We provided an informed consent form similar to Figure 3.1 on page 47 of *Qualitative Research Methods for the Social Sciences* (Berg and Lune, 2017). We also provided a confidentiality agreement similar to Figure 3.2 on page 49 of *Qualitative Research Methods for the Social Sciences* (Berg and Lune, 2017). There were options for the interviewee to select if the interview will be recorded or not, and for them to be anonymous.

3.5 Limitations

Certain limitations that affected our methodologies were factors within our Analytical Hierarchy Process (AHP) meeting. A large proponent of the AHP meeting requires the attendance of major stakeholders in a company to be present. The importance of this is to ensure that all aspects of the business in question has a voice. The technique that we used does not allow for attendance issues because it assumes that each voice is being heard. Without the input from one major portion of factors, its relative weight compared to the rest of the factors will be

unbalanced and it will affect the overall data. In our AHP meeting with NEIA, we were missing their key facilities manager as well as their financial manager. Without the input and understanding of these two managers, the initial data and weights of the AHP factors may have been skewed.

Another potential limitation that we had in our AHP process was our allotted time for the AHP meeting. When creating and defining our project through the AHP process, we created four factors: environment, economic, social, and business. Each of these factors had between three and five sub factors that defined them. In order to truly understand and grasp the knowledge and importance of each factor in the eyes of the NEIA stakeholders, we would have needed to rank the sub factors as well as the factors in our AHP meeting. However, due to time limitations of our meeting, we were only given the opportunity to rank the main four factors.

4.0 Findings

Our research was conducted to help The New England Innovation Academy with choosing a recycling and composting vendor that will work with their school. This section provides the findings of the analytic hierarchy process multiple criteria decision process used to help NEIA stakeholders make a decision on recycling and composting vendors. The analytic hierarchy process results for ranking different vendors based on the factors from the NEIA stakeholder AHP meeting are also presented. We begin with the results from the NEIA AHP meeting, discuss information and findings from primary data acquisition of recycling and composting vendors, then discuss the results of the ranking of vendors, and conclude with the resulting proposal of a recycling and composting vendor for NEIA.

4.1 Choosing Factors for the NEIA AHP Meeting

In order to find a vendor that fits NEIA's current needs, we sat down with stakeholders identified by the head of NEIA and worked through the analytic hierarchy process for ranking the factors involved with working with a new vendor. The four factors chosen to guide the decision making process were business, environmental, social, and economic, each made up of their own subfactors that describe the details of each factor. These include the factors from the triple bottom line approach, along with an extra economic factor. The economic factor allows us to take the money aspect away from the business factor to make its description more focused. Historically speaking, many businesses nowadays solely focus on the "standard bottom line" which is just their ability to generate profit. The triple bottom line can be broken down into the "three P's": profit, people, and planet (Michael, J., & Elser, N, 2019). However, we believed there were other aspects when considering vendors. When assessing the first three factors, we found that everything involved in the businesses profits were way too large. We decided to split the profits factors into business and economic, per the reasoning mentioned above.

Business factors pertain to the impact working with a new vendor would have on NEIA as a school and a business, taking into account subfactors such as the expansion of NEIA's student population in the coming years and disruption brought to the school with setting up the waste management program with a new vendor. A large portion of this is making sure that the vendor chosen or the program created will be scalable, if NEIA doubles or triples in size within the next few years, we need to account for that and make sure that the vendor chosen is able to still take care of the needs of NEIA.

Environmental factors involve dealing with the environment and its broader community, keeping in mind subfactors such as waste minimization and product stewardship (Shah, S., & Sarkis, J., 2003). These factors also take into account the lifespan of equipment that will be used for the recycling and composting program, as well as the possibility of how far away the vendor will be located and therefore travel times and pollution by motorized vehicles transporting said waste. In addition, environmental factors include making sure waste numbers and certifications of said businesses and practices within the program are up to date and in line with regulatory standards.

The social factors relate to the local community, including NEIA staff, students, parents of students, and potential future students. The social subfactors take into account community perception and impact, as well as campus benefits.

The last factor, economic factors, involve the quantitative costs and benefits of working with a new vendor. Supplier and supply costs, as well as potential resale costs are subfactors that were considered.

4.2 Other Considerations Involved

Some ethical considerations that were considered when describing the factors above came from interviews held with individuals who have worked in the sustainability field. While there are obvious things that are taken into account when talking about recycling, there are also items that are overlooked, and covering those bases was the purpose of these interviews. From talking with educated individuals, some things we found that were often overlooked were the equity and long-term aspects of recycling and composting. Making sure long term that the new practices brought to NEIA are advantageous for all on campus is a big part in the success of the

new practice. As time progresses, the biggest thing to keep in mind is assuring the practices of today are still beneficial for those involved years down the road.

Other considerations that we gained from staff interviews were aspects of engagement and education. While adding recycling bins and composting bins to a campus will certainly benefit it, there are other factors that we need to consider too. Making sure that students and staff are placing materials in the right bins as well as knowing what materials are actually recyclable/compostable and not just placing it in landfill waste. Engagement in recycling practices are important, and finding ways to boost that through signage and perhaps transmedia are important, since not every student and staff consume media the same way.

4.3 Introduction Survey Results

Before the NEIA AHP meeting was conducted, we sent out a basic survey for each stakeholder coming to the meeting to get a feel for how the ranking of factors worked using WEB-HIPRE. The results also allowed us to get a baseline idea for where each stakeholder stood on ranking each factor against each other before we sat everyone down in the same room and had an open discussion about ranking each factor. Part of our survey also incorporated making sure that staff and stakeholders at NEIA were comfortable ranking their beliefs on what they felt were important to them and the business. We allowed them to comment in the survey if they felt that the factors and sub factors of the business model we created did not accurately reflect what they as a business deemed important and therefore make changes going forward.

Some results from the survey responses are found below to give an idea of how the format looked.

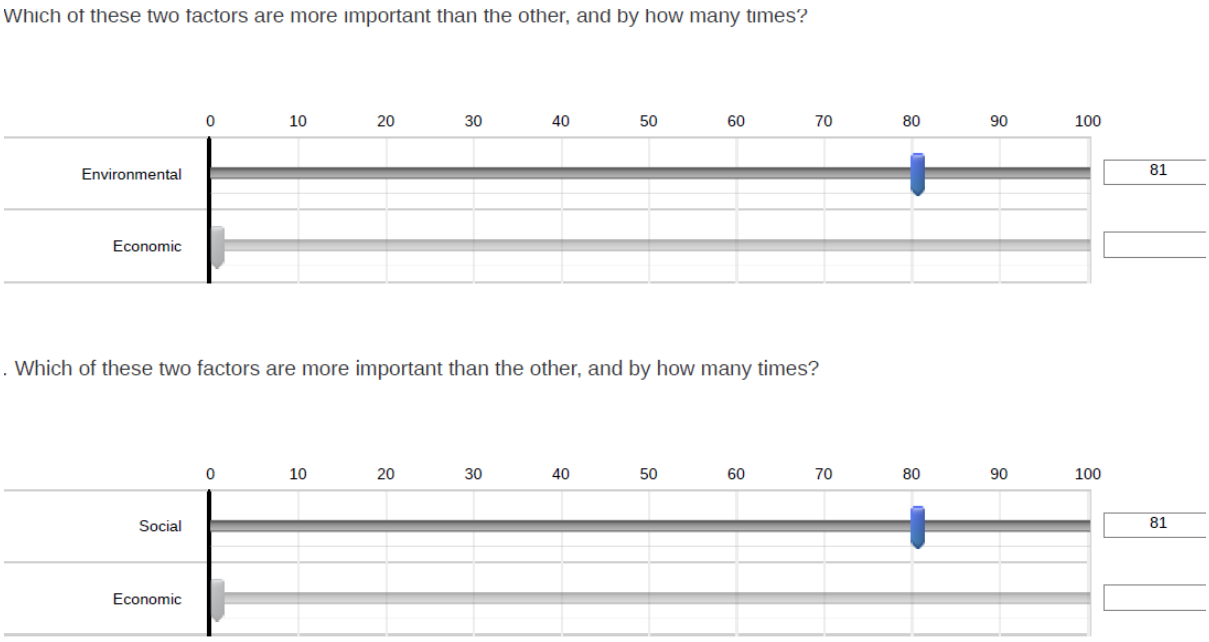

Figure 4.0: Example results from the Qualtrics survey sent to the NEIA stakeholders prior to meeting. The directions to the survey were to drag the bar of the factor that was more strongly valued to the approximate amount more that it was valued. For example, the first question would be interpreted as "This particular respondent to the survey thinks that environmental factors are 80% more important than economic factors."

4.4 Composting and Recycling Vendor Selection using the Analytical Hierarchy Process

Once survey results and feedback on our chosen factors were received, we met with NEIA representatives to introduce them to the WEB-HIPRE software (Mustajoki and Hämäläinen, 2000). We generally discussed the factors to determine which should be included in the evaluation. We wanted to make sure that everyone felt comfortable ranking each of these factors, understood the factors, and if they believed anything was missing. Our goal with this process was to make sure that everyone had ample opportunities to express their knowledge and concerns with the topics and share these concerns with other participants. Gathering staff and

stakeholders from across their business allows us to ensure that for each topic we discuss, we would hopefully have opinions from multiple participants that are well versed in each subject.

We then began to explain and use the software. Part of the ranking process was not only to determine relative factor importance values from NEIA, but it was also to allow them to gain insight into a working and tested method to make multi-factor decisions and to help them discuss their perspectives in a structured way. We had hoped that once we worked through this particular multi-factor decision, they would be able to utilize AHP and apply it to other multi-factor decisions that they would be required to make later on, especially decisions that focused on considering overall strategic goals incorporating business, environmental, social, and economic factors.

Figure 4.1 shows the highest portion of the AHP hierarchy for decision making with the goal to find a recycling and composting vendor for NEIA. To reach that goal using the software, we must consider these four factors of decision making to ensure our result is properly made. Those for factors being Business, Environmental, Economic, and Social.

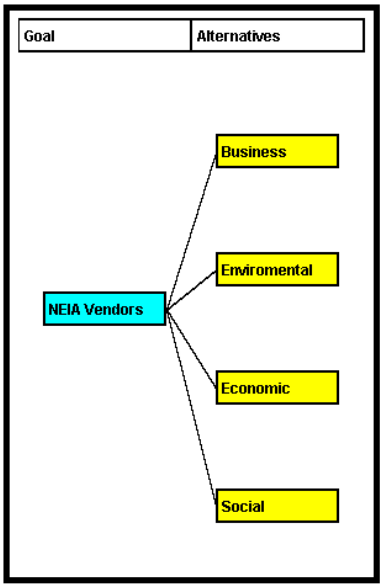

Figure 4.1: This image was from WEB-HIPRE for the relationship between the goal and decision factors. This figure represents the highest portion of the AHP hierarchy.

We met with the participants in a classroom setting and worked through the software. We explained how each factor interacts with the others through pairwise comparisons and the pairwise comparison matrix. We explained how to add more factors and to structure the decision environment. Additionally, we also explained possible ways to make alterations to data once it has been inputted and to add more data if necessary.

Now that everyone was caught up on the software, we began the ranking process. Due to time constraints, we were unable to have every important staff and stakeholder present in this meeting, which may have skewed some of the data collected. The participants for this weighting process included:

- Tom Woelper – Founding Head of School
- Tim McCauley – Science Teacher
- Greg Mertz – Design & Technology Specialist

- Lily Fu – Assistant Head of School

Figure 4.2 shows the completed pairwise comparison matrix for all the major decision factors. Figure 4.3 shows an example of how one cell (the A-B cell) in the pairwise comparison matrix is determined. The purpose of the pairwise comparison matrix is to help value various factors.

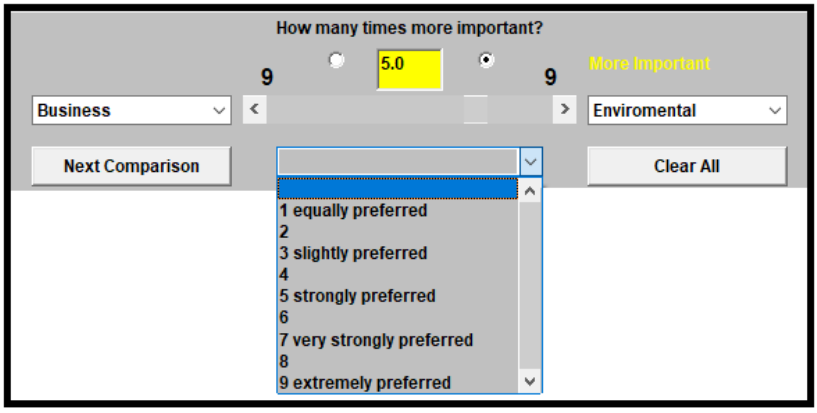

Figure 4.2: The pairwise comparison matrix from NEIA decision makers. The higher the number, the more importance it (horizontal factor) has compared to the factor it is compared to (vertical factor).

Using the software, we began to rank each factor in a pairwise way, comparing one factor to one another factor. Between the two factors, we wanted to understand which the NEIA decision makers preferred and by how much. As outlined in the methodology section, once you chose which of the two factors you preferred, you are then able to declare if it is (1: equally preferred, 3: slightly preferred, 5: strongly preferred, 7: very strongly preferred, and lastly 9: extremely preferred) as recommended by Saaty (1990). Once we completed each individual comparison, we imputed this data into our software. Figure 4.3 shows the pairwise relationship between the Business and Environmental factors.

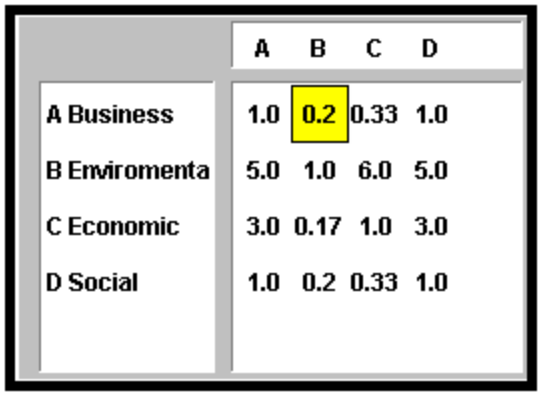

Figure 4.3: An example comparison being made on the importance relationship or preference relationship between business and environmental factors. For example, if the business factor was 'slightly preferred compared to the environmental factor, then a 3.0 value will be assigned to the AxB cell of the pairwise comparison matrix.

After completing the pairwise comparison matrix, the WEB-HIPRE software provides a relative importance value across the factors. Figure 4.4 shows the results of the completed pairwise comparison matrix shown in Figure 4.2.

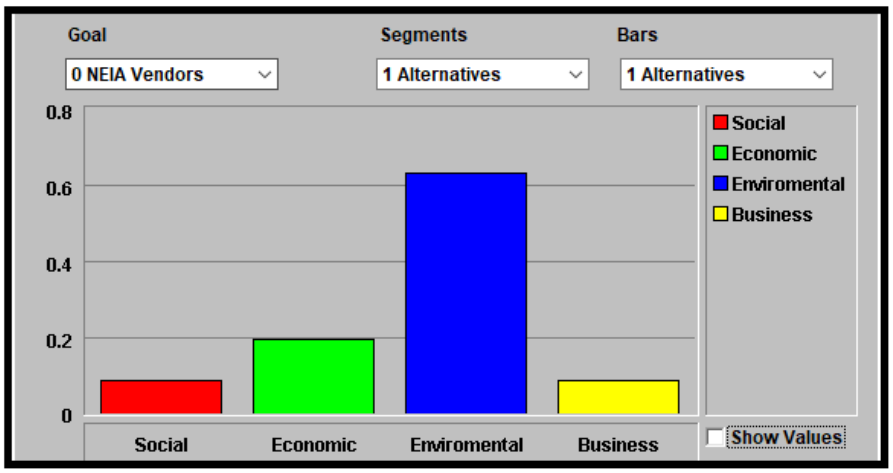

Figure 4.4: The final relative importance weights and results of the factors in making a vendor selection for recycling and composting for the New England Innovation Academy.

As evident from Figures 4.2 and 4.4, NEIA as a business is most concerned with the environmental factors for the recycling vendor decision based on the input from the decision makers. Following environmental factors with a preference value of 0.633, economic factors are the second most important with a value of 0.194. Lastly, the business and social factors are tied for the third most preferred with values of 0.087 (The higher the value the better).

With the results of this data in mind we must incorporate a certain amount of potential bias that could be brought up with collection. To begin, when speaking and collecting data with the major decision makers and staff at NEIA, one member of the group commented on how the factors are intertwined or interdependent with each other. They mentioned: if we make the right choice in terms of environmental factors, business factors, and economic factors; the social factor will follow suit. For example, they mentioned if they chose the company that made the biggest environmental impact, as well as made sense for them financially, they would therefore be displayed in a positive light to their local community. Perhaps this is one reason why their social factors are ranked the lowest based on management's perspective.

Another anecdote from our meeting with NEIA that could showcase possible bias is the attendance from the meeting. Due to time limitations on our project, the only time that worked best for everyone's schedule limited attendance to those that could participate in this study. When we met with them to rank their factors, their key finance staff member and facilities manager were unable to make the meeting. Due to this situation, we could have lost important data as well as perspectives pertaining to these key factors.

Lastly, it is worth mentioning that currently, their number one factor—by far—is the environmental factors and subfactors incorporated into making decisions. While we did not

directly input each subfactor into the software and rank them as well, we did use them to further understand the dimensions of each factor. This result likely occurred because when we began working with NEIA, their intention was to create a more sustainable campus environment—thus the decision to focus on recycling and composting activities. It would make sense that they place the environmental concerns of the campus and its students first.

It is important to realize that creating these weights and understanding how to use this software allows for ease in decision making in the future. While currently NEIA's staff ranked the factors accordingly, they may find themselves looking back and changing their minds or incorporating new perspectives such as those from finance and facilities. In that case, they can adjust as needed. If they decide that they would like to add another staff's perspective into their decision making, they are able to.

4.5 NEIA Recycling and Composting Vendor Analysis

To be able to make a recommendation on which vendor should be chosen or to rank the vendors, research on regional recycling and composting vendors was required. We began our search for vendors almost immediately upon meeting with NEIA. Our goal when collecting potential vendors was to have a wide variety of company sizes, locations, and experience levels to provide a comprehensive set of choices. We believed that with varying sizes and locations, each company could excel at certain aspects of the factors we chose, while having shortcomings in others.

Based on these decisions we initially identified six possible vendors in the local Massachusetts area:

- Republic Services
- BP Trucking

- RoadrunnerWM
- E.L. Harvey & Sons
- MarlboroughWM
- Orifice Recycling and Refuse

Our experience finding vendors was quite standard. Beyond asking NEIA which waste management company they use, we relied upon internet searching to find the highest rated vendors in the area. From there we began to call each company to ensure they were active and willing to take new customers. Upon initial data collection, we found that RoadrunnerWM does service the Worcester and Boston area, but Marlborough is not within its reach.

Moving forward, we began to further call and email each company to find a representative who could supply data for comparison and evaluation purposes. We began our search by collecting data from NEIA as to their trash, recycling, and composting needs. We found that currently NEIA uses two 10-yard dumpsters for trash waste (10-yard being the standard size), one 10-yard dumpster for recycling, and currently no organic composting. We also learned that currently NEIA uses MarlboroughWM for their trash and recycling waste.

From numerous phone calls and emails, we were able to collect information adequate for ranking and making a recommendation to NEIA for the most suitable recycling and composting vendor candidate (see Table 1.0). The initial information we were gathering included what types of services each company provided as well as the certifications they hold. Many of the companies all shared a lot of services due to them being competitors (Left out of table due to redundancy). We found that the majority of differences in companies were their distance from NEIA as well as the pricing for their services since those also are determining traits for the two biggest decision-making factors for NEIA: environmental and economic. The information collected can be found below.

Name and Abbreviation	Service	Distance	Estimated Monthly Price (Weekly Pickup)
Republic Services **(RS)**	Both Recycling and Composting	29 miles from NEIA	**$716.75 initial cost** and $**416.75 monthly**
BP Trucking **(BP)**	Both Recycling and Composting	6 miles from NEIA	**$770/month ($895/month with est. $125/m composting)**
E.L. Harvey & Sons **(EL)**	Both Recycling and Composting	11 miles from NEIA	**No information given**
MarlboroughWM **(MWM)**	Only Recycling	5.5 miles from NEIA	Already servicing NEIA **Does not offer composting.**
Orifice Recycling and Refuse **(ORR)**	Both Recycling and Composting	16 miles from NEIA	**~$1000*[1]**

*[1]We were given pricing for call-by-call basis, weekly pickup, and biweekly pickup which varied in pricing

Table 1.0: Initial information collected on recycling and composting companies. This information was used to compare the vendors on the four factors.

After collecting and analyzing the data from our AHP meeting with NEIA, we began to rank and analyze the vendors depending on the same four factors described in section 4.4. Since we previously gathered data about what NEIA looks for in their own business, we were able to extend those visions upon other companies to see what company worked best for NEIA's factors and relative importance of them.

Working through each factor we began to rank the vendors with four pairwise comparison (PWC) matrices. Each PWC matrix represents one factor. For example, we had a pairwise comparison just for the Business factor and determining the relative performance (importance) of each vendor on business.

Due to us ranking five potential companies, we had to fill out a 5x5 matrix for each individual factor. Beginning with business, we were ranking the vendors between each other and used the four business sub-factors to guide us. These sub-factors were Expansion, Time, Acceptance, and Disruption. Due to NEIA being a new school, we believe that NEIA will grow

in the future especially with their renovated building nearing completion. Therefore, the current waste content of NEIA may dwarf that of the future. Because of this, we focused on ranking the businesses based on how scalable the vendor's services were as well as ease of communication with them. The preference matrix as well as the final weights for the business factor can be found in Figure 4.5 (Vendor abbreviations used from Table 4.0).

Figure 4.5 shows the preference matrix for comparing each companies' business factors. As shown below, BP Trucking was the strongest vendor for this factor due to its ability for their services to be easily scaled. They had a relative weight of 0.366 compared to the other potential recycling and composting vendors. Following them was Republic Services with a 0.255, Orifice Recycling and Refuse with 0.247, EL Harvey and Sons with 0.087, and lastly Marlborough WM with 0.046.

Figure 4.5: Business factor priority matrix for relative performance of each vendor on the business factor. The green bars represent the preference for this factor. The higher the number the better the relative performance of the vendor.

Next up was the Environmental factor. Our assessment of these relied upon the impacts of working with the service as well as the certifications of the business. The subfactors making up the Environmental concerns included waste minimization, regulatory compliance, strategy/policy, and product stewardship. When making our decisions we believed that a large portion of this group deals with the distance from NEIA (pollution from service trucks), as well as what is done to the waste and recycling once it has been picked up. Companies such as BP Trucking and E.L. Harvey & Sons reuse organic waste and give it to local farms for animal nutrition.

The vendor relative performance matrix as well as the final weights for the environmental factor can be found in Figure 4.6. As seen below, BP Trucking leads this factor with a relative weight of 0.335. Following them, Orifice Recycling and Refuse is the second most preferred vendor for the environmental factor with a weight of 0.276. After which EL Harvey and Sons has 0.232, Republic Services with 0.101, and Marlborough WM with 0.056. Being the most preferred factor in NEIA's model, these weights will have a large effect on the final recommendation for NEIA.

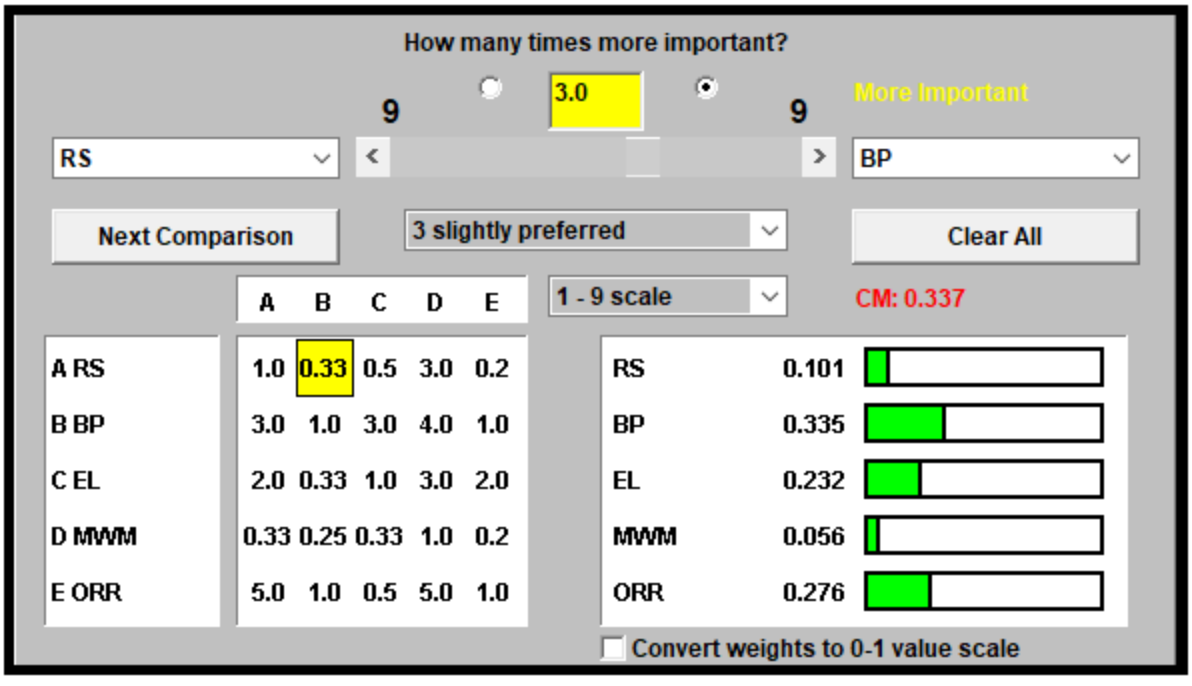

Figure 4.6: Environmental factor priority matrix for relative performance of each vendor on the environmental factor. The green bars represent the preference for this factor. The higher the number the better the relative performance of the vendor.

The third factor for evaluating vendors was the Economic factor. The economic subfactors to guide the vendor comparative evaluation included: Supplier Costs, Supply costs, and Resale Costs. Ranking the vendors for this was quite straightforward. Gathering accurate data for this section was very important. An issue that we ran into when collecting this information is certain vendors have different pricing depending on weekly, biweekly, and on-call basis pickup. To have the appropriate comparison across all the possible vendors, we decided to assume weekly pickup. One interesting note that we found when analyzing pricing is that the larger the company, the less expensive it is. It would make sense that the bigger companies, the more routes they have, the cheaper they can offer their services—they take advantage of economies of scale. While this made sense, it was interesting to note that these differences amounted to nearly half the cost of other services. It is also worth noting that not only were we not able to get pricing numbers from MarlboroughWM, they also do not offer organic composting. Similarly, we were unable to get pricing from E.L Harvey and Sons, however they do offer organic composting.

The vendor relative performance matrix as well as the final weights for the economic factor can be found in Figure 4.7. As seen below, the leading vendors for this factor are Republic services and Marlborough WM. They have relative weights of 0.409 and 0.299 respectively. Following them is BP Trucking, then Orifice, then EL Harvey and Sons with relative weights of 0.131, 0.100, and 0.060 respectively.

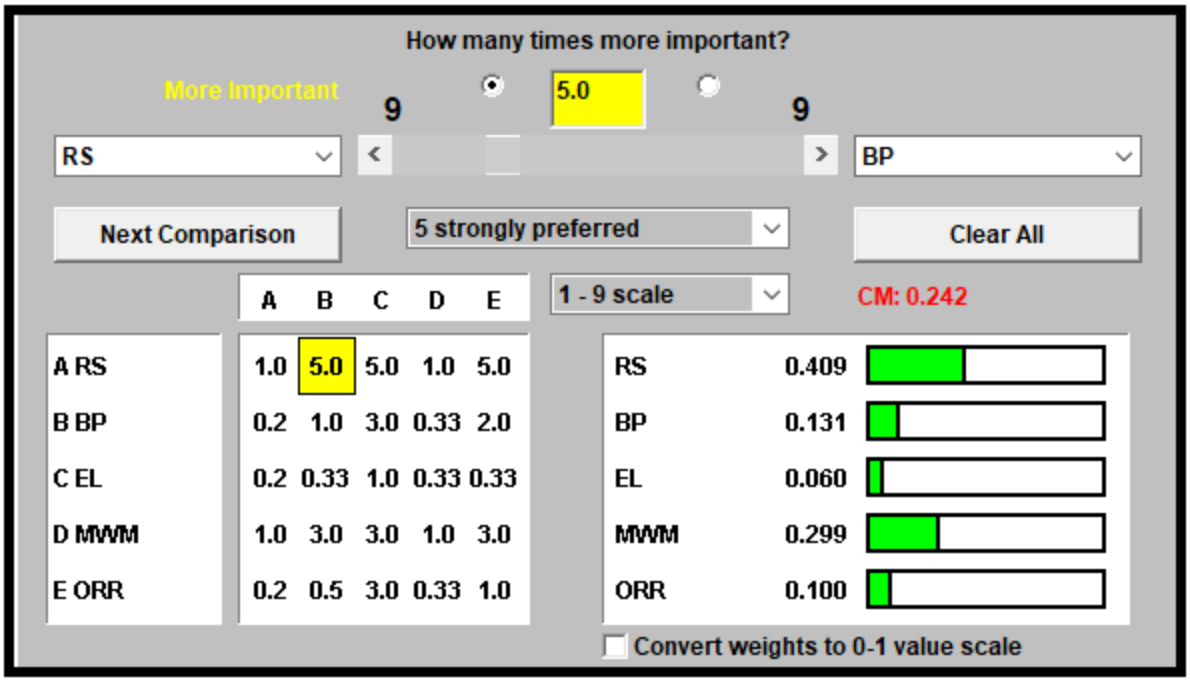

Figure 4.7: Economic factor priority matrix for relative performance of each vendor on the economic factor. The green bars represent the preference for this factor. The higher the number the better the relative performance of the vendor.

Lastly, we have the social factors incorporated into making a vendor recommendation. The sub-factors within this overarching factor are community perception, campus benefits, and community impact. Deciding and ranking the vendors upon these elements is quite qualitative. It is worth noting that since MarlboroughWM does not offer composting, it would make sense that from a campus benefit realm, they would not be the first choice. Similarly, companies such as Orifice Recycle and Refuse are smaller, more local, family-run companies. In many cases, socially it looks better to support local business especially in recent years with Covid-19 making small businesses so difficult to run. Supporting a company like Orifice would have a great deal of positive community perception.

The vendor relative performance matrix as well as the final weights for the social factor can be found in Figure 4.8. Analyzing the bar graphs in the bottom right of the figure, you can

see that BP Trucking and Orifice Recycling and Refuse both lead the social factor. They have preference weights of 0.354 and 0.325 respectively. Following them is EL Harvey & Sons, Republic services, and lastly Marlborough WM with values of 0.171, 0.102, and then 0.048.

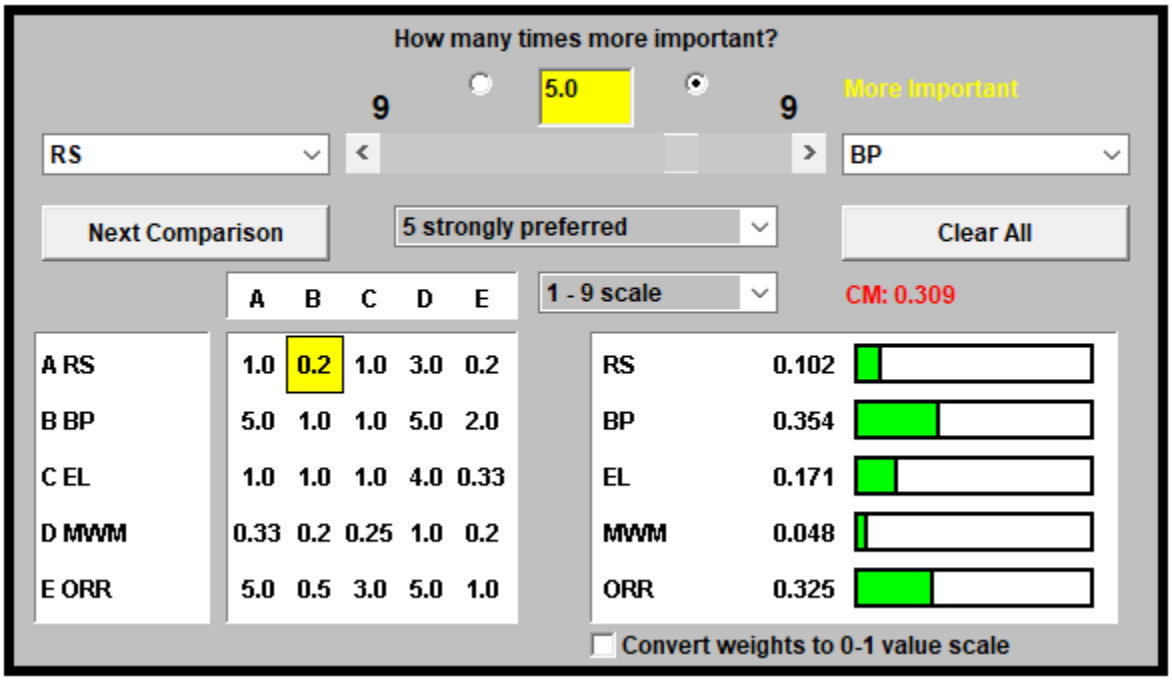

Figure 4.8: Social factor priority matrix for relative performance of each vendor on the social factor. The green bars represent the preference for this factor. The higher the number the better the relative performance of the vendor.

4.6 Results

From the AHP meeting with stakeholders, we learned the environment was the most important factor to NEIA regarding selecting a recycling vendor. While we figured this would be the case, we wanted to see how heavily the other factors were considered before performing the same AHP analysis in order to select a vendor. The same factors were taken into account when ranking the selected vendors against each other. When considering business, the impact on NEIA as an organization was one of the more important aspects we considered. A big part of the environmental factor was each vendor's distance from NEIA, since the further their waste needs

to be transported, the less environmentally friendly that vendor would be. The economic factor was decided mainly with the cost of working with each vendor. The social factor considered aspects that would impact community perception of NEIA. Vendors that stated things like they practiced single stream recycling or their compost was used on farms were weighted greater than vendors that didn't have those aspects.

From our AHP analysis of the five vendors, we found BP Trucking to be the best choice for NEIA's current needs. Although they are a close tie for third among all the vendors when it came to the economic factor, BP Trucking won by a significant margin in the environmental factor. They had all the same aspects of being one of the better vendors when it came to being environmentally friendly, and they were half the distance from NEIA than the next best environmental option. The results from the AHP vendor ranking can be found below.

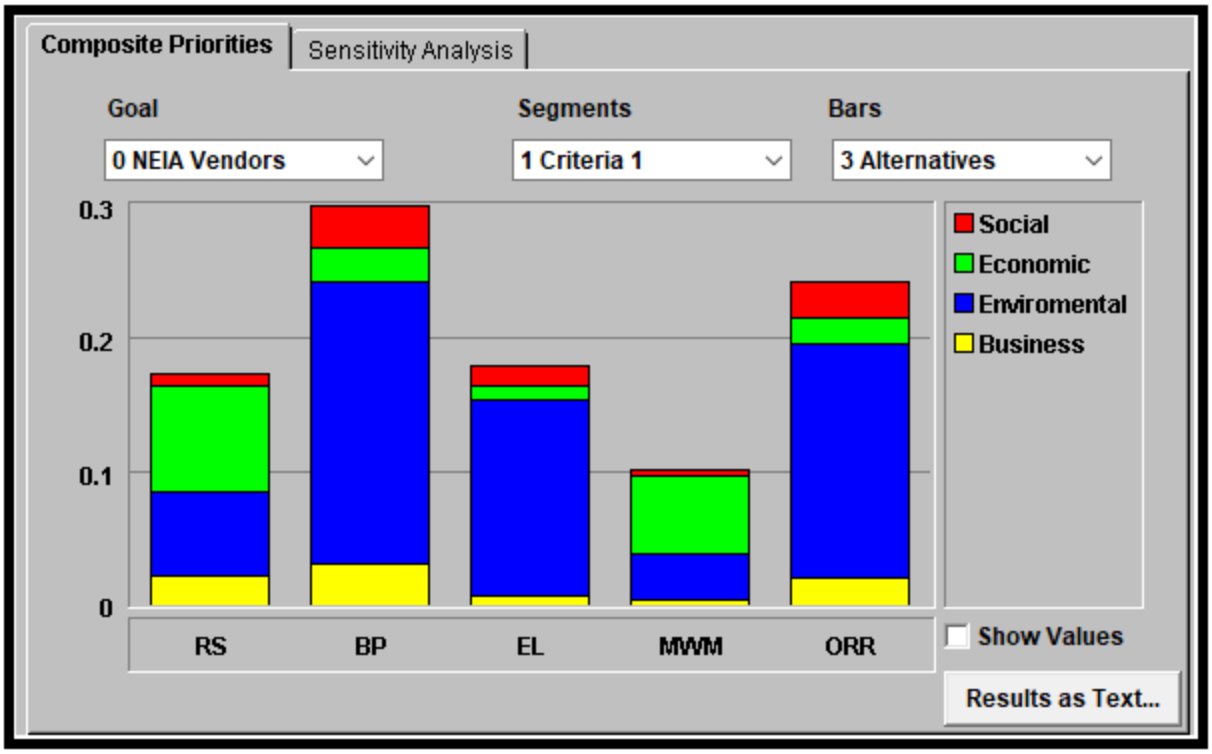

Figure 5.0: The final rankings and results of the factors in selecting a recycling and composting vendor.

BP Trucking is around 6 miles from NEIA's campus, recycles both cardboard/paper waste along with electronic waste, uses single stream recycling at their facility, offers composting, and has a comprehensive list of everything that can and can't be composted on their website to ensure customers are composting correctly.

BP Trucking already has stated their interest in working with NEIA to be the schools recycling and composting vendor. The last step in bringing these practices to NEIA is for the school to set up a new contract with BP Trucking. A meeting can be set up to determine the logistics of the contract, and along with this report, we sent BP Trucking's contact information to NEIA.

5.0 Recommendations

5.1 Introduction

After both of our AHP analysis, along with the other work our group carried out throughout the semester, we came to three total recommendations. The most important being the vendor recommendation for NEIA coming from both of the AHP analysis. Beyond that, we found from archival literature and plans already in place on other campuses steps NEIA can take at their school, to help raise both their level of sustainability and community engagement. Lastly, we explain the importance of the AHP for decision making and how it can be applied to different work in the future, or how it can be used to re-evaluate our work at a later date.

5.2 Complete a Waste Audit

Although the course of the project did change over the seven weeks, our group still found ways for NEIA to increase their environmental sustainability, albeit at a smaller scale than a

whole sustainability plan. Knowing how much of your recycled waste is actually recyclable and how much isn't and was mistakenly placed in the bin recycle is a big step in raising a community's awareness towards recycling. A program we recommend NEIA run is an annual waste audit to find out the percentage of their recyclable waste that is actually being recycled. A report from WPI's Green Team and Office of Sustainability from 2019 outlines both their 8th annual waste audit and how they went about calculating their current and potential recycling rate (WPI, 2019). The Green Team and Office of Sustainability went through the trash and recycling of WPI's Rubin Campus Center, weighing all the total trash and recycling. The groups then separated the recycling between actual recyclable goods and items misplaced into the bin. The formulas and total process of WPI's 8th annual waste audit can be found in their report.

Performing a waste audit will allow NEIA to gauge where their community currently stands on recycling, both as a practice and in knowledge. Seeing how much waste is misplaced into recycling can allow NEIA to take steps to further raise that level of recycling knowledge. As we stated in our literature review, it's important to not only be aware of recycling as a practice in your community, but to also make sure you're educated in the waste that can actually be recycled.

5.3 Future Steps for Sustainability at the New England Innovation Academy

Although the project plan changed from the original goal of a broad sustainability plan to focusing on one aspect of that plan, our research doesn't have to stop there. The same methods we used in the beginning of our term to analyze sustainability plans of other campuses can be applied to tackling other parts of the broad plan that NEIA originally wanted. Whether that part of the plan be greywater usage, energy reduction, or any other aspect, we recommend for future

groups to see what works on other campuses, how that could be scaled to fit NEIA's needs, and how to go about implementing that plan at NEIA. The multi-criteria decision making matrices we used with WEB-HIPRE is a great tool for helping with determining what is and isn't important, regarding whatever decision you're trying to make. Other groups could even take a look at the same work we did a year down the road from now and run the same AHP process to re-evaluate NEIA's recycling needs. That work, combined with information from a waste audit, could give even more insight into NEIA's needs as a school regarding recycling and composting.

6.0 Challenges and Conclusions

6.1 Challenges

There were several limitations we had to take into account while working on the environmental sustainability plan. A large limitation was the timeframe of the project. With seven weeks to work on analyzing the best practices of other schools, interview faculty and staff, conduct surveys, and draft a plan, some aspects we would have liked to incorporate to our project got excluded due to the time element. Making sure the elements of the project's timeframe, such as interview dates and survey data collection, ran as close to schedule was the main way to mitigate this limitation. Even though starting early on interviews and surveys was the best way to reduce the impact of this limitation, we were prepared for some potential interviews to get canceled or to never get scheduled.

Over the course of the last seven weeks, our project changed a decent bit from the original goal. At the beginning of the semester, we planned to work with NEIA to help them draft an environmental sustainability plan for the school. After talking with the sponsors at the

school, the project scope changed into us tackling three different aspects the school wanted help with regarding sustainability. The first of NEIA's three ideas was for us to help them find a vendor or a method to recycle/reuse old office furniture from the previous owners of the building NEIA now owns. The second idea was for us to help them find a new vendor to work with for recycling and composting. NEIA already had a waste removal service in place that worked with solid waste and recycling, but composting was something the school also wanted, so new vendors were considered. The last idea proposed to us was for us to do some work with a bike path NEIA is putting around their campus that runs next to a nearby pond.

After considering the scope of each of those tasks, and the time restraint we had in the semester, our group decided to deal solely with one of those tasks instead of all three. Since proposing a new recycling vendor was the most similar to the original goal, our group settled on that task as the focus for the remainder of our project. Since the work we had already done in our literature review and the prior weeks still closely followed the goal of our new project idea, we hit the ground running, researching into the AHP process and developing the factors mentioned before. We also believe that by tackling this one decision and project, we will be able to shape a methodology for NEIA to make future decisions that arise as they grow as a business.

Another small limitation we ran into was recording Zoom interviews for those who can't meet in person. We used Zoom's screen capture feature to record virtual interviews, and if an interview subject did not wish to have the Zoom call recorded, we took pen and paper minutes of the meeting.

6.2 Conclusions

The New England Innovation Academy's strides towards increasing their level of sustainability on campus is a promising step towards making campus sustainability a major concern for other organizations. Our research showed us that a lot of people have concerns about the environment, but most people don't possess the level of knowledge or the access to programs in order to make a significant difference. Bringing a new third party recycling and composting vendor is just the first step in tackling this issue. Environmental education geared towards students, as well as hands-on programs and projects, will continue to raise the level of sustainability on any campus, not just NEIA's. The best path to follow is to not only bring new programs to a campus to increase sustainability, but to also ensure that the next generation of students is well educated on the environmental issues they will be growing up in.

With the recommendations we have put forth, NEIA can both bring new recycling and composting programs to their campus and educate their students on the issues of today's environmental scene. The education of students stands to make the biggest long term impact. Programs for recycling and composting will always be changing with new technology, but knowing where these issues stem from and how to treat them is a solid way to ensure these problems are addressed at the source and as seriously as they need to be in years to come.

Bibliography

Andoko, Andrey, & Niki Prastomo (2021). "Holistic Approach for Creating Environmentally Friendly Campus." Journal of Sustainability Perspectives, vol. 1, no. 2, https://doi.org/10.14710/jsp.2021.11753

Berg, B. L., & Lune, H. (2017). Qualitative research methods for the Social Sciences (9th ed.). Pearson Education.

Breen, S. D. (2010). The mixed political blessing of campus sustainability. *PS: Political Science and Politics*, *43*(4), 685–690. http://www.jstor.org/stable/40927036.

Cho, M. (2019). Campus sustainability. *International Journal of Sustainability in Higher Education*, *20*(6), 1042–1060. https://doi.org/10.1108/ijshe-06-2018-0107.

Clarke, T. (2001). Balancing the triple bottom line: Financial, social and environmental performance. *Journal of General Management, 26*(4), 16–28.

Curriculum. New England Innovation Academy. (2021, October 26). Retrieved October 28, 2021, from https://neiacademy.org/neia-experience/curriculum/.

Concord Academy sustainability plan. Concord Academy. (2021, March 29). Retrieved September 30, 2021, from https://concordacademy.org/sustainability-2/.

DiMestico, R., Musgraves, E., Wang, L., & Whitworth, T. (2017). (tech.) (pp. 1–104). Worcester, MA: Worcester Polytechnic Institute. Retrieved November 5, 2021, from https://web.wpi.edu/Pubs/E-project/Available/E-project-042717-111233/.

Events. WPI Student Green Team. (n.d.). Retrieved November 5, 2021, from http://greenteam.wpi.edu/events.html.

El-Nwsany, R. I., Maarouf, I., &; Abd el-Aal, W. (2019). Water management as a vital factor for a sustainable school. *Alexandria Engineering Journal*, 58(1), 303–313. https://doi.org/10.1016/j.aej.2018.12.012.

Emanuel, R., & Adams, J. N. (2011). College students' perceptions of campus sustainability. *International Journal of Sustainability in Higher Education*, *12*(1), 79–92. https://doi.org/10.1108/14676371111098320.

Finlay, J., & Massey, J. (2012). Eco campus: Applying the ecocity model to develop green university and college campuses. *International Journal of Sustainability in Higher Education*, *13*(2), 150–165. https://doi.org/10.1108/14676371211211836.

Grisanti, V. (2021, September 13). New England Innovation Academy opens its doors to its first class. NEIA Now. Retrieved December 13, 2021, from https://neiacademy.org/new-england-innovation-academy-opens-its-doors-to-its-first-class/.

Guarnieri, P., & Trojan, F. (2019). Decision making on supplier selection based on social, ethical, and environmental criteria: A study in the textile industry. Resources, Conservation and Recycling, 141, 347-361.

Heeren, A. J., Singh, A. S., Zwickle, A., Koontz, T. M., Slagle, K. M., & McCreery, A. C. (2016, September 5). *Is sustainability knowledge half the battle? an examination of sustainability knowledge, attitudes, norms, and efficacy to understand sustainable behaviours*. International Journal of Sustainability in Higher Education. Retrieved October 1, 2021, from https://www.emerald.com/insight/content/doi/10.1108/IJSHE-02-2015-0014/full/html.

Hu, S. (2020, July 20). *Composting 101*. NRDC. Retrieved November 14, 2021, from https://www.nrdc.org/stories/composting-101#can.

Hudson, P. (2007). Middle school science education for sustainable living. *Middle School Journal*, 38(4), 43–47. http://www.jstor.org/stable/23048057.

Humphreys, P. K., Wong, Y. K., & Chan, F. T. S. (2003). Integrating environmental criteria into the supplier selection process. Journal of Materials processing technology, 138(1-3), 349-356.

Igarashi, M., de Boer, L., & Fet, A. M. (2013). What is required for greener supplier selection? A literature review and conceptual model development. Journal of Purchasing and Supply Management, 19(4), 247-263.

Ke, Y., Choi, M. Y., Didham, R. J., Ayusawa, Y., Chen, Y., Guo, J., Im, H. J., Ko, M. H., Moon, Y. S., Nakahara, H., Pierre, F., Sato, M., Sato, M., & Strecker, M. (2009). The sustainable consumption of green schools in china: A case study on the campus environmental management project in green school. *Education for Sustainable Consumption in Northeast Asia: Strategies to Promote and Advance Sustainable Consumption* (pp. 101–112). Institute for Global Environmental Strategies. http://www.jstor.org/stable/resrep00756.14.

Koutsoukos, M., Fragoulis, I., & Valkanos, E. (2015). Connection of Environmental Education with application of experiential teaching methods: A case study from Greece. International Education Studies, 8(4), 23–28. https://doi.org/10.5539/ies.v8n4p23.

Largo-Wight, E., DeLongpre Johnston, D., & Wight, J. (2013). The Efficacy of a Theory-Based, Participatory Recycling Intervention on a College Campus. *Journal of Environmental Health*, *76*(4), 26–31. http://www.jstor.org/stable/26329712.

Linda L. Cronin Jones. (1992). Strike It Rich with Classroom Compost. The American Biology Teacher, 54(7), 420–424. https://doi.org/10.2307/4449532.

Mathisen, P., & Tomaszewski, E. (2020). (rep.). *WPI's Sustainability Program: 2020-2025*.

Michael, J., & Elser, N. (2019). Personal waste management in higher education: A case study illustrating the importance of a fourth bottom line. International Journal of Sustainability in Higher Education.

Mouchrek, N. (2017). Design-based approaches to engage youth in the transition to sustainability. *Blucher Design Proceedings*. https://doi.org/10.5151/sbds-issd-2017-007.

Mustajoki, J., & Hämäläinen, R. P. (2000). WEB-HIPRE: Global decision support by value tree and AHP analysis. INFOR: Information Systems and Operational Research, 38(3), 208-220.

National Overview: Facts and Figures on Materials, Wastes and Recycling. United States Environmental Protection Agency. (2021, November 14). Retrieved November 14, 2021, from https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials#composting.

New York State Education Department (2021). *New roots charter school: school nominee presentation form*. United States Department of Education. https://www.greenstrides.org/sites/default/files/webform/nomination-package-334.pdf.

Purnell, K., Sinclair, M., & Gralton, A. (2004). Sustainable Schools: Making Energy Efficiency a Lifestyle Priority. *Australian Journal of Environmental Education*, 20(2), 81–91. http://www.jstor.org/stable/44656397.

Reeves, D. (2020, September 14). *Single Stream vs. Dual Stream Recycling*. General Kinematics. Retrieved November 5, 2021, from https://www.generalkinematics.com/blog/the-argument-single-stream-vs-dual-stream/.

Rhode Island Department of Education. (2021). *Barrington middle school: school nominee presentation form*. United States Department of Education. https://www.greenstrides.org/sites/default/files/webform/RI-GRS-2020-21-Application_Barrington%20Middle%20School%20FINAL.pdf.

Rhode Island Department of Education. (2015). *Ponaganset high school: school nominee presentation form*. United States Department of Education. https://www.greenstrides.org/sites/default/files/webform/RI-GRS-2020-21-Application_Barrington%20Middle%20School%20FINAL.pdf.

Ruck, A., & Mannion, G. (2021). Stewardship and beyond? Young people's lived experience of conservation activities in school grounds. *Environmental Education Research*, 27(10), 1502–1516. https://doi.org/10.1080/13504622.2021.1964439.

Saaty, T. L. (1990). How to make a decision: the analytic hierarchy process. European journal of operational research, 48(1), 9-26.

Sarkis, J, Shah, S. (2003). PC Disposition Decisions: A Banking Industry Case Study, 67-84.

The triple bottom line: What it is & why it's important. Business Insights - Blog. (2020, December 8). Retrieved January 7, 2022, from https://online.hbs.edu/blog/post/what-is-the-triple-bottom-line

Topics. Sustainability at Harvard. (2014, January 16). Retrieved September 16, 2021, from https://green.harvard.edu/topics.

Treagust, D. F., Amarant, A., Changrasegaran, A. L., & Won, M. (2016). A Case for Enhancing Environmental Education Programs in Schools: Reflecting On Primary School Students' Knowledge and Attitudes . International Journal of Environmental and Science Education, 11(12), 5591–5612. https://files.eric.ed.gov/fulltext/EJ1115645.pdf.

U.S. Energy Information Administration. (2021, December 22). *Monthly Energy Review*. U.S. Energy Information Administration. Retrieved January 20, 2022, from https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf

WPI Green Team and Office of Sustainability . (2019). (rep.). *8th Annual Waste Audit* (pp. 1–9). Worcester, Massachusetts.

Zhang, D., Hao, M., Chen, S., & Morse, S. (2020). Solid waste characterization and recycling potential for a university campus in China. *Sustainability*, *12*(8), 3086. https://doi.org/10.3390/su12083086.

8 methods of composting. Direct Compost Solutions. (2021, March 14). Retrieved November 5, 2021, from https://directcompostsolutions.com/8-methods-composting/.

Appendix A: Decision Factors and Subfactors from AHP Process

Business Factors: Factors that focus on various operational costs and aspects
Expansion: Will the size of NEIA increasing lead to a need for revamping of the recycling plan?
Time: Time to make decision/time to set up services with a third party company
Acceptance: Acceptance of the decision made among employees/students
Disruption: Disruption of daily activities on account of the decision made/ease to implement a recycling plan

Environmental Factors: Factors that deal with the environment & its broader community
Waste Minimization: Reducing the waste produced by NEIA
Regulatory Compliance: Complying with regulatory standards, including state and federal
Strategy/Policy: The overall environmental strategy of the NEIA, including total commitment from the organization from the top down (faculty and staff down to students)
Product Stewardship: The lifespan of the equipment that will be used to implement recycling

Social Factors: Factors that relate to the local community, including NEIA's staff, students, parents of students,potential future students, and NEIA's surrounding community
Community Perception: The public's perception on bringing a new recycling program to NEIA
Campus Benefits: The benefits to NEIA's campus implementing a recycling plan would bring
Community Impact: The impact NEIA's recycling plan will have on its environment and community

Economic Factors: Factors that relate to the quantitative costs and benefits
Supplier Costs: Those costs of working with a third party company to handle recycling
Supply Costs: Those costs associated with purchasing supplies to implement the recycling plan
Resale Costs: The costs NEIA will save by increasing its recycling rate and lowering the rate of waste produced and brought to landfills

Appendix B: Interview of WPI Office of Sustainability

Purpose: To identify key aspects of a developed sustainability plan

Informed Consent

Hello, welcome to our interview and thank you for choosing to participate in our research. We are part of a term from WPI conducting research on the sustainability practices on educational campuses. This research will be published, but your responses will be anonymous. This interview should take no longer than 20 to 30 minutes, and you are able to skip any question you do not want to answer or stop the interview at any time.

Team Contact: gr-hangzhou21-team6-iqp@wpi.edu

Interview Questions:

1. What are some aspects to keep in mind to make sure you're covering all aspects of sustainability?
2. What do you consider in your research to make sure all fronts are covered?
3. What often gets overlooked when bringing new sustainability efforts to an organization?
4. When measuring the level of sustainability of a place (in our case a school) what do you take into account?
5. Are there any major agreements/disagreements with how we handle recycling/composting at WPI?
6. What are some things to keep in mind when bringing a recycling/composting plan to a new school?

7. Are there things we should avoid when starting a recycling program at a new school?
8. What would you recommend to a new school looking to increase its level of sustainability?
9. Is there any past work you've done that you think would be beneficial to NEIA that we can read up on?

Appendix C: Sustainability Knowledge Survey

Purpose: To identify and understand the general public's knowledge of sustainability practices

Informed Consent

Hello, welcome to our interview and thank you for choosing to participate in our research. We are part of a term from WPI conducting research on the sustainability practices on educational campuses. This research will be published, but your responses will be anonymous. This interview should take no longer than 5 to 10 minutes, and you are able to skip any question you do not want to answer or stop the interview at any time.

Team Contact: gr-hangzhou21-team6-iqp@wpi.edu

Survey Questions:

1. On a scale of 1-10 1 being the least and 10 the most, how would you rank your knowledge of sustainability?
2. How much water does the average showers use per minute?
    a. 1.5 gallons
    b. 5 gallons
    c. 2.1 gallons (answer is 2.1 gallons)
    d. 3.6 gallons
3. How much would you estimate it costs to leave a 60Watt lightbulb on for a straight 24 hours?

   a. 1 cent a day, per bulb

   b. 7 cents per day, per bulb

   c. 23 cents per day, per bulb

   d. 17 cents per day, per bulb (answer)

4. How many gallons of water does it take to produce a pound of beef?

   a. 21 gallons

   b. 43 gallons

   c. 7 gallons

   d. 1,799 gallons (answer)

5. Do you know what LEED-certification is?

   a. Yes

   b. No

Appendix D: Recycling Knowledge Survey

Purpose: To identify and understand the general public's knowledge of Recycling

Informed Consent

Hello, welcome to our interview and thank you for choosing to participate in our research. We are part of a term from WPI conducting research on the sustainability practices on educational campuses. This research will be published, but your responses will be anonymous. This interview should take no longer than 5 to 10 minutes, and you are able to skip any question you do not want to answer or stop the interview at any time.

Team Contact: gr-hangzhou21-team6-iqp@wpi.edu

Survey Questions:

1. Can you recycle bubble wrap?
    a. Yes
    b. No
2. Can you recycle boxboard (Ex: egg cartons)
    a. Yes
    b. No
3. Can you recycle grocery bags?
    a. Yes
    b. No
4. Can you recycle aluminum foil?

   a. **Yes**

   b. No

5. Can you recycle Envelopes?

   a. **Yes**

   b. No

6. Can you recycle Wood?

   a. Yes

   b. No

7. Can you recycle clothing?

   a. Yes

   b. No

8. Can you recycle plastic utensils?

   a. Yes

   b. No

9. Can you recycle a pizza box?

   a. Yes

   b. No

Appendix E: Sustainability Practices Survey

Purpose: To identify and understand the general public's daily engagement in sustainability practices and efforts

Informed Consent

Hello, welcome to our interview and thank you for choosing to participate in our research. We are part of a term from WPI conducting research on the sustainability practices on educational campuses. This research will be published, but your responses will be anonymous. This interview should take no longer than 5 to 10 minutes, and you are able to skip any question you do not want to answer or stop the interview at any time.

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Survey Questions:

1. Rank your personal daily engagement in each of the following sustainable practices 1-10, 10 being actively engaging in the practice daily and 1 being no engagement at all:
    a. Turn off lights in a room when you leave it empty
    b. Own or use reusable water bottles
    c. Take the stairs over the elevator on purpose
    d. Walk or bike somewhere when you can drive
    e. Print using both sides of a sheet of paper
    f. Use reusable grocery bags
    g. Buy second-hand clothes rather than new clothes

2. When was the last time that you participated in a sustainability event?
    a. Last week
    b. Last Month
    c. Last 6 months
    d. Last Year