2018

An Environmental and Cost Comparison Between Polypropylene Plastic Drinking Straws and a "Greener" Alternative: An Oberlin Case Study

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May 9, 2018

Abstract

Plastic straws are one of the most abundant items found in oceans and coastal cleanups around the United States and internationally. Plastic does not decompose over time, so all the plastic we have ever made is still around, affecting every ecosystem on the planet. Drinking straws are made of 100% recyclable material, but because of their small size most recycling plants are not able to process them so they are sent to landfills. Petroleum-based plastic production is also a large source of greenhouse gas (GHG) emissions, making up 1-3% of the United States' carbon emissions alone. By considering green alternatives to PP drinking straws, we can see if there actually are affordable alternatives that can help reduce plastic waste and carbon emissions. This case study focuses on the Feve, a restaurant in the City of Oberlin, and aims to understand the cultural significance of drinking straws in town, and uses that information to suggest ways of changing straw distribution behavior and minimize plastic waste. This study also compares the environmental and financial costs of the Feve using petroleum-based polypropylene (PP) drinking straws versus “greener” alternatives by constructing a modified life cycle analysis to determine if switching to biodegradable polylactic acid (PLA) plastic drinking straws decreases the Feve's carbon and plastic waste footprint. By tracing GHG emissions created in the production of plastic resins, transportation of materials and products, and disposal of plastic straws, I compare the carbon footprint of three products to see if one is better for the environment than the others. I hope this study can be used as a model to help other restaurants make plans to reduce their plastic waste and carbon footprint at an affordable cost.

Keywords: Drinking straw, greenhouse gas (GHG) emission, life cycle analysis, polylactic acid (PLA), polypropylene (PP)

1 Introduction

Plastic drinking straws suck. They are one of the largest contributors to marine plastic waste (Ocean Conservancy, 2017), they cannot be recycled, and they are made out of a material that never decomposes. Instead, these straws are found or ingested by wildlife which often causes starvation or damages vital organs, or straws are broken down into microplastics that permeate through almost every environment today (UNEP, 2014). Plastic production is also a large contributor to global warming, making up between 1 and 3% of the United States' yearly greenhouse gas (GHG) emissions. Plastic drinking straws are one of those products where it seems extremely easy to cut back their use in theory, so why are they still so prominent in restaurants today? My frustration surrounding that question and desire for change are what sparked the following paper.

If drinking straws are going to be used to the same extent that they are today, then there is no reason why the straws have to be made of petroleum-based plastic. Most straws in restaurants are made of polypropylene (PP) whose main ingredient is crude oil, an extremely unsustainable resource to extract. There are many popular websites and campaigns that support going straw free and suggest using straws made from alternative materials such as bamboo, paper, and steel. However, I noticed through my initial research that there seemed to be a lack of sustainable choices that could be bought in bulk by restaurants. Convincing restaurant owners that there are more sustainable alternatives to the standard PP drinking straw, and making sure those alternatives are actually better for the environment and are cost effective for the business, are good ways to incentivize environmental changes.

Life cycle analyses are studies that quantify the environmental impact at every stage in a product's life. This usually involves data collection on the cradle, gate, and grave (e.g. landfill, recycling plant, composting facility, or incineration plant; Figure 1). For the purposes of this study, I used a modified life cycle analysis to measure the GHG emissions for three types of plastic straws, specifically looking at the emissions for material manufacturing, product consumption, and end of life destination stages. Doing this type of analysis allows for a better understanding of how materials that are labeled "green" or "eco-friendly" are actually impacting the environment aside from potentially decreasing plastic waste.

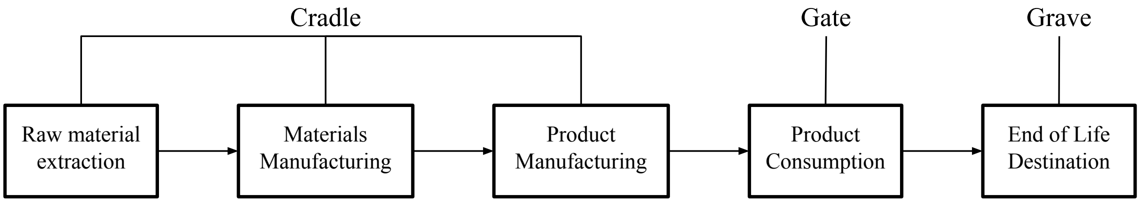

Fig.1. General schematic of factors considered for a full life cycle analysis. Arrows in between life stages refer to physical transportation of focal product from one location to another. All information obtained by literature review.

The goal of this study was to decrease the plastic and carbon footprint of the Feve, a restaurant in Oberlin, Ohio. With the help of a research team, I conducted an observational study and handed out customer surveys to help the owners of the Feve better understand how their customers feel about drinking straws and to gauge what customer reactions might be if the Feve changed the way they distribute straws and/or the type of straw they served. I then collected data for an environmental impact and cost comparative analysis between petroleum-based polypropylene (PP) straws and corn-based polylactic acid (PLA) plastic straws, my pick for the "green" alternative. Using information on straw purchasing and disposing practices provided by the owner of the Feve, I conducted a modified life cycle analysis to track environmental impact through GHG emissions for the production and disposal processes for each straw option, taking into account what happens to each straw at the end of their life cycle in Oberlin specifically. I also compared the cost per piece, per order, and per year for PP and PLA straws to see if there is a larger financial commitment required for purchasing a greener alternative. I tailored all of the information and calculations to the Feve in order to get as accurate information as possible and to best inform their decisions involving drinking straws.

My hypothesis was that the PLA straws would be more expensive than their PP counterparts, but hopefully better for the environment as their "green" alternative label suggests. My research started with addressing and working through the barriers and benefits that the owner of the Feve perceived to making more sustainable choices, and by conducting an environmental and cost comparison between the current straws used by the Feve and a "greener" alternative that would fit their needs. This case study can serve as a model for other restaurants to see if switching to a more sustainable version of their own plastic products would be financially feasible and to ensure that the alternative actually is better for the environment when their taking their access to distributors and disposers into account.

1.1 The plastic problem

There are social and economic reasons for why plastic has become as popular and widespread as it is today. It is extremely cheap to produce, very sturdy, waterproof, and one of the most easily manipulated materials in the world. It can be used in everything from the packaging on microwavable meals to patio chairs, from electronic devices to synthetic fibers in our clothing. We can use chemical additives such as stabilizers, heat retardants, fillers, and colorings to make plastic bags, bottle caps, phone cases, car bumpers, drinking straws, etc. Plastic can help maintain human health by keeping food fresh or protecting sanitary medical supplies. Every year more and more plastic is added to the pile, and while plastic does benefit the economy and consumer products, the excess of plastic in our global cycles is having a negative environmental, social, and economic impact (UNEP, 2014).

Global plastic production increased from 1.7m tonnes to 228m tonnes between 1950 and 2012 (UNEP, 2014). Over 90% of plastics are made from non-renewable fossil fuels—mainly petroleum—which totals to about 6% of global oil consumption, or roughly the same percentage as the global aviation sector (Ellen MacArthur Foundation, 2017). Fossil fuels are made out of dead organisms and take millions of years to build up, but humans have exploited these resources over the course of a few centuries (Šprajcar et al., 2012). If the current growth of plastic production and usage increases as expected, the plastic sector will account for 20% of the total oil consumption and 15% of the global annual carbon budget by 2050 (Ellen MacArthur Foundation, 2017). As the consumer market becomes increasingly reliant on petroleum-based products, the cost and availability of goods like plastic are increasingly susceptible to changes in oil abundance and price. Another issue with using non-renewable resources for plastic production are the major greenhouse gas (GHG) emissions that come from the process of extraction and manufacturing. Carbon dioxide (CO_2) and methane (CH_4) are the two main GHGs that come out of plastic production and disposal. It has been estimated that the production of commodity thermoplastic polymers—plastics such as polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), polyethylene terephthalate (PET), and polyethylenes (PE)—is responsible for around 70 million tonnes of CO_2eq emission per year in the U.S. alone (Posen et al., 2016). Plastic production is responsible for 1% of U.S. GHG emissions and 3% of primary energy use (Posen et al., 2017). It is a huge contributing factor to our country's global warming potential and its contribution will continue to increase if we do not change the source of plastic feedstock to renewable resources or make our manufacturing and disposal processes more efficient.

Depending on the country, somewhere between 22-43% of plastic waste is disposed in landfills and up to 21% goes to incineration plants. Both end-of-life options waste resources that might otherwise be salvageable (UNEP, 2014). Plastic also never decomposes; it just breaks into smaller and smaller pieces. Plastic litter—which is plastic waste that does not ever reach a disposal facility—often makes its way into waterways because wind and storm water can easily carry it into oceans, rivers, or storm drainage that deposits the litter elsewhere. From there it might be decades before plastic begins to break down into smaller particles. It can take up to 25 years for a plastic bag to degrade, up to 450 years for a plastic bottle, and up to 600 years for a plastic fishing net (Detloff and Istel, 2016). While plastic waste can be found everywhere—including the deep sea and Antarctica—it has the most consequential impacts in marine and aquatic ecosystems where it most strongly damages the organisms that live there and the biological resources that human communities depend on. The Ellen MacArthur Foundation (2017) estimated that, "In a business-as-usual scenario, the ocean is expected to contain 1 tonne of plastic for every 3 tonnes of fish by 2025, and by 2050, more plastic than fish (by weight)". Between 1997 and 2012 there was a 40% increase in the number of marine species reported to be affected by plastic ingestion and entanglement (UNEP, 2014). Intentionally made microplastics (5mm in size or smaller) from beauty products or clothing, as well as unintentionally made microplastics from larger waste degradation, can be ingested by plankton, filter feeders, and small fish. This not only harms those organisms feeding on microplastic, but also can harm the rest of the animals in the food chain that prey on those organisms, which potentially includes humans (UNEP, 2014; Detloff and Istel, 2016; Ellen MacArthur Foundation, 2017).

Beyond the environmental impacts of plastic waste, there are also social and economic impacts. The United Nations Environmental Programme (2014), or UNEP, released a report that put a monetary value on the environmental, social, and economic impacts plastic has around the world. They measure natural capital cost as a monetary expression of the net impact plastic can have on a specific sector by damaging important natural resources such as clean air, clean water, and environmental services such as food and climate regulating services. The total natural capital cost of plastic in the consumer goods sector per year alone is over $75 billion. Putting a price on environmental damages is thought to be an effective way of translating environmental damages to companies and the public because it puts the impacts of our actions into a number that is easily understood by anyone. Since economic activity and social well-being can be directly dependent on or affected by the loss of these environmental goods and services, understanding natural capital cost can allow for better corporate decision making and more sustainable business practices.

In the same report, UNEP found that the restaurant sector alone—which is of particular interest in this study—used 4.4 tonnes of plastic in packaging and in the supply chain per $1 million of revenue. They reported that 71% (or $770m) of the environmental impacts from plastic in the restaurant industry happen upstream/during the manufacturing and production processes (which includes resource extraction), and 29% (or $310m) happen downstream/after consumer disposal. The greatest factors affecting the environment from this industry were GHG emissions ($400m) in upstream processes and unmanaged waste (such as chemical additive leaching, terrestrial pollution, and marine litter) in downstream processes. Other industries that are severely impacted by plastic waste specifically around the world include tourism and recreation, shipping, and fisheries and aquaculture. In 2010, for example, the Asia-Pacific Economic Cooperation (APEC) estimated that the tourism, fishing, and shipping industries lost a total of $1.3bn due to plastic waste damaging vessels and coastal cleanup costs (Mouat et al., 2010).

Plastic has become an integrated part of the global economy, but our reliance does not have to strictly be on petroleum-based plastic options. Bioplastics, plastics made from renewable resources, and biodegradable plastic alternatives are starting to get more attention from researchers and the public because they show promising steps towards a more sustainable future.

1.2 The search for an alternative: Biodegradable plastics

If we know that plastic production and waste are harmful to the environment, then why not use more environmentally friendly alternatives? Research dedicated to finding alternative materials to single use plastic has become more prominent over the last several decades, even though many of these materials have been around for longer than that. For example, polylactic acid (PLA)—a biodegradable plastic made from the sugars of crops like corn or potatoes—was discovered in 1890, but was quickly overshadowed by plastics made from synthetic polymers (Rujnić-Sokele and Pilipović, 2017). Many of these plastics cannot be recycled due to the nature of their production, but they can be composted.

Composting is a practice in which bacteria and fungi help break down biodegradable materials, resulting in a collection of gases (particularly CO_2, CH_4, and N_2O), water, and compost (organic matter) which can be used to as a soil conditioner or fertilizer in some agricultural practices (Hermann et al., 2011; Rujnić-Sokele and Pilipović, 2017). Specific industrial composting facilities that are licensed to handle wet food waste and other materials are primarily responsible for processing biodegradable plastic (Platt, 2012), because many biodegradable plastics require extremely hot temperatures to start the decomposition process (Hermann et al., 2011). Industrial composting facilities are starting to get more attention because of their ability to process wet food waste, which recycling plants cannot do (Hermann et al., 2011; Kolstad et al., 2012). This is important because currently recycling plants require the waste being processes to be completely clean while composting facilities do not have that requirement, and because drinking straws count as waste that is mixed with wet food.

For drinking straws in particular, some of the popular alternatives include paper, PLA, metal, glass, and bamboo. While switching to an alternative material seems like a simple solution, there are economic and environmental impacts to take into consideration. One benefit for a restaurant using PP plastic straws is that they are sturdy, disposable, and extremely cheap to supply. Reusable straws, such as steel or glass alternatives, are more expensive and will need to be cleaned individually before they can be reused. Biodegradable alternatives are also on average more expensive than PP drinking straws, and depending on the geographic location of the restaurant, they might end up going to a landfill instead of a composting facility since not all composting facilities can accept food waste or biodegradable plastics. For example, the composting facility in Oberlin can only accept yard waste, so it would not be able to process any biodegradable straws because the straws are mixed with wet food. Depending on the material, some biodegradable options might degrade in landfills (e.g. bamboo and paper). For those that need certain requirements, such as heat, to be met to initiate the degradation process (e.g. PLA), it is likely that they will not degrade in landfills. When looking for more environmentally friendly options that can reduce greenhouse gas emissions and plastic waste, the upstream process and downstream process are extremely important to consider.

1.3 History of drinking straws

Drinking straws have been around for thousands of years. Using straws was an honored method of drinking beer in ancient Mesopotamia. The earliest known evidence for the use of drinking straws is an image of two men using straws to drink beer from a jar engraved on a seal found in a Sumerian tomb that has been dated to 3,000 BCE (Thompson, 2011). The earliest confirmed alcoholic beverage, discovered at Jiahu in the Yellow River Valley of China, dates to the Early Neolithic Period. This drink was made by fermenting rice, so straws were used to drink from the bottom of the cups in order to avoid any floating debris (McGovern, n.d.). Straws have been created out of a variety of materials including reeds, gold, lapis lazuli, metal, ryegrass, glass, and more recently paper and plastic (Thompson, 2011; McGovern et al., 1997; Jamieson, 2001; Hollander, 2014).

Straws are a prominent part of American dining culture, which can be attributed to several factors starting in the late 19th century and early 20th century. At this time, soda fountains were popular social gathering venues. They were places to see and be seen, places to get the latest news on the happenings around town, and places to spend downtime with friends or coworkers. In 1910 alone, when soda cost only a nickel or a dime, Americans spent $500 million on soda, which was more than twice the amount of the U.S. government's annual budget for the army and navy (Funderburg, 2002). Their rise in popularity was sparked by the temperance movement, which eventually became the prohibition movement. Saloons were being attacked for serving alcohol, so soda fountains became a socially acceptable alternative. In the early 1900s, there were growing concerns over the sanitation conditions in the food industry. In 1906, the publishing of Upton Sinclair's book *The Jungle* and increasing magazine and newspaper coverage of the filthy conditions in food processing plants triggered the passing of the Pure Food and Drug Act as well as the Meat Inspection Act. Attempting to maintain their wholesome image, soda fountain operators quickly adapted to the new expectations of cleanliness by bringing in single-use disposable drinking straws and sometimes paper cups. While straws had been manufactured and distributed before these laws were enacted, this change was the beginning of widespread customer demand for straws in America.

For years, rye grass straws were most commonly used. Farmers had to plant rye to feed chickens and cows anyway, so all they had to do to make straws was dry the stalks in a barn and cut them to a uniform length. However, with flu epidemics and the increased frequency of polio and tuberculosis, Americans became even more attentive and concerned about sanitation. Rye grass straws would disintegrate into the beverage, meaning that the glasses would still have to be thoroughly cleaned before being served to another customer. In the late 1880s, an American man named Marvin Stone owned a factory that was using a spiral winding process to make paper cigarette holders. Stone was extremely dissatisfied with the way natural rye grass straws tasted and broke down while drinking, and applied this winding technique to make the first paper drinking straw (Hollander, 2014). He initially made straws by winding strips of paper around a pencil, using glue to hold it together. On January 3rd, 1888, he patented the spiral winding process and started to commercially sell paper straws. By 1890, Stone's factory was making more drinking straws than cigarette holders, and by 1906 the Stone Straw Corporation invented the first mechanism that could machine-wind straws, ending the hand-winding process (Bellis, 2006). Come 1900s, paper straws became synonymous with 'sanitary' since they were machine-made (never touching a human's hand) and were disposable. Some manufacturers would even wrap their straws in tissue or wax paper, allowing the customers to open a straw in the comfort that they were the only people to touch it (Funderburg, 2002). By 1910, straw holders and dispensers were common in restaurants and fountains. These dispensers were usually metal boxes that would protect the straws from dust and airborne germs, and with the press of a lever or turn of a knob a customer could get an untouched drinking straw. Since paper straws were inexpensive to make, easy to supply, and their presence gave credibility to the restaurant or soda fountain owners as well as comfort to their customers, straws became a staple in the American dining experience.

Fast forward to the 1930s, Joseph B. Friedman had taken his daughter out to the soda fountain for a milkshake and watched as she struggled to reach her mouth to the straw from her seat. To help her, he made the first ever ‘bendy straw’ by inserting a screw in the top opening of the straw and tying dental floss around the outside to form corrugations (Broda-Bahm, 2002). The modification allowed for the top of the straw to bend, allowing for his daughter to reach the top opening while not blocking off the beverage. Children were not the only ones who benefitted from the new flexible straw design. The paper flexible straws became exceptionally popular in hospitals, which had previously used mainly glass straws, because the bend allowed their patients to drink while lying down (Broda-Bahm, 2002). By September 28, 1937, Friedman had patented a bendable paper straw known as the “drinking tube” (Friedman, 1937). In 1939, he created the Flexible Straw Company (later renamed Flex-Straw Company) and by the 1940s the production process quickened with machinery that Friedman invented to add the bends in the straws (Broda-Bahm, 2002). With World War II came a large increase in U.S. petroleum-based plastic production because of how sturdy and cheap it was compared to other types of materials (Rujnić-Sokele and Pilipović, 2017). While the paper straws did not disintegrate as fast as their rye grass counterparts, they did still disintegrate and plastic straws did not, so by the 1960s plastic straws had almost completely replaced paper straws (Smith, 2017). As the presence and franchisement of fast food chains like McDonald’s and Dunkin’ Donuts increased in the 1950s and 60s, so did the distribution and use of disposable utensils such as plastic silverware and straws (History of Fast Food, 2018).

1.4 Drinking straws today

In the Ocean Conservancy’s 2017 International Coastal Cleanup Report, straws and stirrers were the 7th most commonly found items around the world and the 6th most common finds in U.S. coastal cleanup zones. There were 125,973 straws and stirrers found in U.S. coastal and marine areas alone (almost 31% of the global total), with the second largest number being 46,700 straws from sites in Puerto Rico, some 80,000 fewer straws than the U.S. (Ocean Conservancy, 2017). A study done by Ecocycle (2016) estimated that Americans alone now use around 500 million drinking straws every day, which is enough to fill over 127 40-foot long school buses. The U.S. has developed this cultural dependency on straws that started during a time when illnesses were being spread by unknown means and the low level of factory sanitation was being exposed. To this day, we use more straws than any other country in the world.

Straws are usually made from polypropylene (PP), a 100% recyclable petroleum-based plastic, but are too small in diameter to be recycled. Therefore, PP plastic drinking straws have to go to either landfills or incineration plants, which is a big waste of potentially salvageable resources (UNEP, 2014). If they do end up at a recycling plant, their light weight allows for the possibility that they accidentally land in the wrong silo, contaminating batches of other material, e.g. paper or aluminum (personal correspondence with VaLori Sciarrillo, Operations Administrator and Educational Tour Guide at Republic Services Recycling Plant in Oberlin, Ohio). Their light weight and durability also contribute to their role in marine and aquatic litter. In cities and near open water sources, straws can easily fall out of drinks, be blown out of trash cans, or picked up by an eager animal looking for food and/or objects to build nests or shelters. Even in landlocked cities, plastic waste over several years is likely to eventually make its way into major water systems because it is easily carried away by wind or storm water (UNEP, 2014). PP plastic straws do not decompose over time, once they are created they are not destroyed unless put through an incinerator. Instead of decomposing in landfills or oceans straws break down into microplastics which further contribute to global environmental damages. And drinking straw production contributes to global warming by being a part of the plastic problem. As mentioned in Section 1.1, raw material extraction and plastic production are very large contributors to global warming, and the low levels of resource recycling that can happen with drinking straws furthers those issues.

Because disposable plastic straws increase accessibility for drinking beverages and satisfy a sanitation requirement held by many Americans, it is unlikely that getting rid of straws all together will be a suitable societal change. As restaurants are some of the largest contributors to plastic straw waste, they should be targeted when thinking about how to change our cultural dependency on straws. There is not a requirement that our straws be made out of non-renewable, petroleum-based plastic, and not everyone needs or prefers to use straws. Changing the behavior of restaurants and customers so that the minimum number of straws are used can help reduce our national plastic waste footprint, and using their consumer power to support straws made from renewable resources will put pressure on plastic producers to start taking steps towards sustainability. Putting the time into working with restaurant owners can also help further environmental causes. If a restaurant owner decides to use straws made from renewable resources, or only offers straws per customers' request, they become part of a larger sustainable dining culture in the U.S., creating space discussion about how plastic is damaging the planet and the ways in which straws are complicit in that damage.

Some restaurants, cities, and even a few countries have started banning single use plastic products like straws. With the impacts of marine pollution and global warming receiving increasing amounts of attention from popular culture—some examples are the viral YouTube video of a sea turtle with a straw up its nostril, documentaries like *A Plastic Ocean* that can be found on Netflix, and editorials from popular news sites—there has been a recent push from the populace to do something about plastic waste and global warming. In the United States, cities like Seattle, WA; Malibu, CA; Davis, CA; and Fort Myers, FL have put legislation into place that bans plastic straws completely (Victor, 2018). Scotland is planning ways to cut down on nationwide single-use plastic waste, and is aiming to be completely free of petroleum-based plastic drinking straws by 2019 (Gabbatiss, 2018). These bans help put pressure on drinking straw manufacturers to make straws that are better for the environment. Because some customers need straws to drink beverages, manufacturers that use renewable resources or biodegradable materials now have a market where their products are more competitive. My goal with this paper is to help one restaurant in Oberlin, OH, the Feve, find a way to cut back on its plastic waste and carbon footprint, and to help gather information that can inform their decisions on sustainable actions. If one restaurant can start the trend of trying to cut back on plastic waste and/or decreasing their carbon footprint, then maybe the City of Oberlin will be next to join the fight.

2 Methods - The Feve as an Oberlin case study

The Feve is a popular restaurant and bar in downtown Oberlin. The owners, Matt and Jason Adelman, firmly believe in buying locally sourced and ethically produced food, as well as providing a place for people to come and enjoy themselves. I chose the Feve for this case study for three reasons. First, with their dedication to sustainably sourcing their food, I hoped that they would be susceptible to learning more about potential alternatives to petroleum-based plastic straws. Second, they have previously tried to reduce straw waste by providing straws only on request, which proved inefficient since the servers would too often have to put down the beverages, go and get a straw for the customer. They also have considered putting straws on the tables for customers to take when desired, but decided against it because the straws would clutter the small tables. Finally, the Feve's bar is a particularly popular spot during the weeknight specials. On these nights, there is an increase in the number of beverages being ordered, leading to increased straw use.

Working with one restaurant allowed me to tailor my environmental and cost comparative analysis to their specific needs and location. I suggested alternatives and new distribution behaviors based on preferences listed in the interview section below. Focusing on one restaurant as a case study meant that I was able to build a general framework for how these types of analyses could be done for other restaurants. I believe that keeping the specific needs and the perceived barriers and benefits of the restaurant owners in mind was very important to the completion of this study. The project became collaborative because Matt was very eager to be involved and to hear the suggestions I had to make based on the data we collected from their customers and their preferences for alternative straws.

2.1 The interview

I talked with Matt Adelman many times over the course of this project, the first meeting taking the form of an informational interview. I learned that the Feve picks up most of their disposables—including disposable silverware, takeout boxes, and straws—from either Restaurant Depot or Joshen Paper at their respective Cleveland locations. They spend on average

$30.71 for a case of 5,000 unwrapped straws, which is roughly $^1/_2$ of a cent per straw, and he estimated that they buy around 15 boxes per year. Depending on the drink, the Feve will provide a customer with either a regular drinking straw (the straws that usually come with soft drinks or juice at most restaurants), bar stirrers for alcoholic beverages served in tall glasses, or cocktail straws for alcoholic beverages served in short glasses. Many of the alcoholic drinks will come with two bar stirrers or cocktail straws, which are much smaller in diameter than regular drinking straws, to help mix the contents of the beverage. The small size also helps customers control how much alcohol they are drinking at once. All straws are served to the customer already in the drink for the sake of efficiency, and when the tables are being cleaned, whatever remains of the beverage (including the straw) gets poured into a slop bucket that eventually gets taken to the dumpster.

When I asked Matt about potentially switching straw types to reduce GHG emission, he consistently emphasized that he would not mind switching straws as long as he is still providing a positive experience for their customers. That is the top priority taken into consideration when decisions are being made. The potential benefits that giving customers more environmentally friendly straws could have for the Feve, as identified by Matt, include reducing their overall landfill contributions and bolstering their reputation as a sustainable restaurant. He was reluctant to use alternative straws made out of materials such as paper or bamboo because they run the risk of disintegrating into the customer's drink. They had previously tried using paper straws and received reports of the straws giving off weird tastes and textures. Having this information about straw material preferences and past attempts to cut back on straws allowed me to narrow my search for an alternative drinking straw to ones made of bioplastics, which were ultimately less likely to compromise customers' experiences.

I then talked with Matt about ways of reducing the Feve's plastic footprint. Some examples of ways to do this were putting straws in cups on the tables for people to grab on their own, or to serve the drinks automatically without straws and provide straws per request. He mentioned that they had thought about and/or tried methods like these in the past and met some resistance. Some of the tables at the Feve are relatively small (a two-person table might be roughly 2x3 ft), so Matt was concerned that putting straws out on the table might clutter the space. They had also tried serving drinks without straws in the past, but a lot of customers would request straws and it ultimately took too much time for the waiters to go back and get straws for every customer that asked for them. The other concern was that even if Matt told his staff to stop serving straws, it has become muscle memory for those that have worked there for upwards of a decade. With very little staff turnover, especially with bartending, he expressed concerns for having to break that deeply ingrained habits.

In sum, by far the largest perceived barrier to changing the straw policies in any way was compromising the customer's experience at the restaurant. If the alternative straws reduce customer satisfaction or their beverage drinking experience then it is not worth the change for the Feve.

2.2 Data collection on customer straw use

A research team comprised of four students and myself took turns observing Feve customer straw use. I confirmed days and times with Matt a few days before going to observe so that the staff would be aware of our presence. Usually Matt would tell the staff to not serve straws at all on the days we were planning to observe the customers. For each session, one or two members of the research group sat at a table on the first floor of the Feve. Upon the team's arrival, the waitstaff would be notified that an observation session was starting. While remaining seated at a table, the team took notes on a spreadsheet counting the number of people at each table, the number of those people using straws, and noting the time of day. We did not count customers that sat at the bar because it was very difficult to see what they were drinking and we did not want to risk including incorrect information. Paper surveys were also given to the Feve, and the waitstaff were instructed to hand out surveys along with customers' receipts. The customers were not given any information about the purpose of this study, nor that its goals were to work on reducing the Feve's carbon and plastic waste footprint. The surveys asked the following four questions and then were collected and analyzed by the research team:

1. How often do you use straws? (almost always/often/rarely/almost never)

2. What is good about NOT using straws?

3. What is good about using straws?

4. Would you ask for a straw if you were not offered one? (almost always/often/rarely/almost never)

2.3 Data collection for the environmental impact comparison

I looked online for alternative straw options made of biodegradable material that could be sold in bulk to restaurants and noted the location of the nearest suppliers to the Feve. Based on those options and Matt's preference for an alternative with similar textures as PP plastic straws, I chose to compare True Choice Pack compostable straws[1] (PLA_{TCP}) and Green Paper Products PLA resin drinking straw[2] (PLA_{GPP}). Both of these suppliers sell straws made from Ingeo™, which is brand-name corn-based PLA plastic.

Where industrial composting facilities are able to process biodegradable plastics, PLA plastic is a better option environmentally than PP plastic because using biodegradable materials can minimize plastic waste in landfills. If there are no such facilities, PLA has to go to a landfill or an incineration plant because it cannot be recycled. Since PLA needs temperatures between 50-60^oC to start breaking down (Hermann et al., 2011), it is unlikely to biodegrade in landfills where temperatures typically reach 21-35^oC (Krause and Townsend, 2016). This means PLA will contribute equally to plastic waste in the Lorain County Landfill as does PP. Since the amount of plastic waste will remain constant, I conducted a modified life cycle analysis to track the GHGs being emitted by each product because GHG emissions are a large contributor to current environmental problems. Therefore, the environmental comparison analysis in this study will focus solely on the total GHG emissions of each product's life cycle.

To do a full life-cycle analysis (Figure 1), I would track the CO_2-equivalent (CO_2eq) from cradle to grave. This process generally includes emissions from resource collection or extraction, energy used by the buildings and machines that are producing the plastic resin, fuel used by trucks taking shipments to straw producers, the straw-making process, the distribution of

[1] Product details:
`https://www.biogreenchoice.com/ProductDetails.asp?ProductCode=BGC-401&CartID=1`

[2] Product details:
`https://greenpaperproducts.com/diposable-biodegradable-straws-st775.aspx`

straws to restaurant owners, the transportation from the restaurant to the disposal site, and the disposal process. Due to the time and resource restrictions on this project, and that commercial data is not readily available, I collected as much information as I could about the life cycle of each drinking straw option. I could not locate detailed information on specific straw production and disposal processes. Instead, I used data from sources that had calculated the total GHG emissions of specific types of resin for the comparison (Kolstad et al., 2012; Vink and Davies, 2015; Posen et al., 2017). This data omits GHG emissions for the drinking straw production, and lacks information on any additives or wrappers that might be included during production.

For the PP plastic straws, I started with the information given during my interview with Matt, focusing only on the soda straws. I used the locations of the suppliers, number of cases purchased per year, and disposal method to get an idea of the general framework of these straws' life cycle. All of the refuse in Oberlin is taken to Lorain County Landfill (Lorain County Solid Waste Management District, 2015) so I used the distance from the Feve to the landfill for gate-to-grave transportation calculations. It is assumed that collection trucks make more stops than just one to the dumpster closest to the Feve, but because I was unable to find specific collection routes I just used the GHG emissions for direct transport to the landfill. This means the values for transportation to the landfill are overestimates of the GHG emissions for each straw. I then conducted a review of the literature to find the general GHG emissions of PP plastic in landfills.

From a study published by NatureWorks (Vink and Davies, 2015), I was able to find the global warming potential (GWP) of PLA and PP production. Similarly to the PP research, this information did not include GHG emissions released in turning the PLA and PP resin into straws, so I only included the GHG emissions released during the production of each resin. I used Lorain County Solid Waste Management District (2015) to determine where the PLA alternative straws would go. Since there is not an industrial composting facility around Oberlin that can accept biodegradable plastics, the PLA straws would still go to Lorain County Landfill. I used the same information for the Feve-to-landfill transportation. I then similarly conducted a review of the literature to find the GHG emissions and of Ingeo™, and PLA plastic in general, in landfills.

For both types of straws, I found the reported GHG per 1 kg (converted to 2.205 lbs) of plastic produced, the distance (in miles) between the Feve and the suppliers as well as between the Feve and the Lorain County Landfill, the number of straws per case, the number of cases ordered per year (Matt purchases one case at a time), the method of transportation for getting straws from the supplier to the Feve, and the method of transportation for getting the trash to the landfill. I used the U.S. national average miles per gallon (MPG) for personal vehicles and trucks—because the make and model of the personal vehicles being used by the Feve and trucks by suppliers/disposers is unknown—to later use in transportation carbon emission equations (EPA, 2018). I used average pounds of carbon dioxide equivalent (lbs of CO_2eq) emission data for personal vehicles using gasoline (E10), which is normally 10% ethanol and 90% gasoline, and trucks using diesel (B20), which is normally 20% biodiesel fuel and 80% diesel fuel in the U.S. (EIA, 2017). To find the number of gallons of fuel used during all transportation routes, I used the following equation:

$$x = \frac{\text{miles between A and B} \times 1 \text{ gallon}}{\text{average MPG (in miles)}} \tag{1}$$

Where x is the number of gallons of fuel used for a one-way trip. I then multiplied x by the average lbs of CO_2eq released per 1 gallon of fuel—respective to each vehicle (EIA, 2017)—to find how many lbs of CO_2eq were emitted during each transport. If the vehicles were making round trips, the total lbs of CO_2eq emitted was doubled. Again, because it is assumed that each transportation event involves either making multiple stops or the simultaneous purchasing of items that are not straws, these are maximum estimates lbs of CO_2eq values. Each type of straw's CO_2eq emissions from the production, transportation, and disposal processes were totaled and compared to give the GHG emissions for one order of straws. I also calculated yearly GHG emissions for each straw by multiplying the transportation from supplier to the Feve by the number of cases needed per year (since Matt only buys one case at time), and multiplied the transportation from the Feve to the landfill by 52 because the trucks pick up refuse once a week. Since I was unable to find information about how much plastic is needed to make one drinking straw, I left the emissions from production the same for the straw options in both the one order and yearlong calculations. If that information becomes available in the future, the calculations should be modified accordingly.

2.4 Data collection for the cost comparison

Products made from biodegradable plastics are usually more expensive than their PP plastic counterparts. To make sure switching to an alternative straw was financially feasible for the Feve, I conducted a cost comparison analysis of all expenses involved with purchasing each straw option. I looked at the purchasing and transportation costs specific to the Feve for each type of straw. By summing those values, I found the costs of buying one order of each straw type and the costs over the course of a year. For PP plastic straws, Matt gave me an estimate of how many cases per year they use, the number of straws per case, average cost per case (which was used to find the price per piece, or the price for one straw), the location of the suppliers, and the method of transportation used to get the straws to the Feve. I then found the corresponding information for the PLA straws.

Currently, the owners of the Feve drive to the supplier to pick up the straws whenever they are running low. Because the make and model of the car might differ depending on who is running the errand, I used the average MPG found in the previous section and most recent national average retail fuel price for gasoline, which is $2.50 per gallon, to approximate how much money is being spent on gasoline to pick up the PP straws (Bourbon, 2018). Both of the PLA straws would have to be shipped to the Feve rather than being picked up in the store. The shipping cost for the PLA_{TCP} straws were included in the price per case. Green Paper Products offers free shipping if an order is over $89, so because I am recommending that Matt orders 3 cases of 2,000 straws at a time, there is no shipping cost associated with the PLA_{GPP} straws. I added each straw option's price per case, and found what the Feve's total costs for one order and for a whole year would be for each product.

3 Results

3.1 Observation sessions and surveys

Over the course of three weeks, we held four observation sessions lasting between one and two hours each. The research team observed a total of 112 customers, 35 (31.25%) of which asked for straws when one was not automatically served with the drinks. 113 customers responded to the paper surveys. 33.8% of those reported that they almost never use straws and 23.6% reported to almost always use straws (Fig. 2). When asked if there was anything good about not using drinking straws, 53% responded with answers about how they are bad for the environment and 11.5% reported that there is nothing good about not using drinking straws, meaning that they prefer to use them (Fig. 3.). 30.9% and 28.2% believed that using drinking straws is good because they increase accessibility and sanitary conditions respectively, while 10.9% responded that there is nothing good about using a straw (Fig. 4.). Finally, 48.1% of customers reported that they would almost never ask for a straw if they were not initially given one, while 18.9% said they would almost always ask for a straw if one was not provided (Fig. 5.).

3.2 Environmental comparison

As mentioned earlier, I chose to focus solely on regular drinking straws, the straws that are served with water and fountain drinks, because many of the alternative suppliers did not sell tall or short stirrer straws. The Feve gets their straws from either Restaurant Depot or Joshen Paper, both of which are 36 miles away from the Feve's location. A maximum of 15 cases of straws are needed throughout the year. They are picked up one case at a time by someone from the Feve using a personal vehicle, possibly along with other disposables. Each case has 5,000 unwrapped PP straws. All of the straws go to a dumpster behind the Feve and a collection truck comes once a week to bring refuse to Lorain County Landfill, which is 3.1 miles away from the Feve (Table 1).

Both PLA straws would have to be ordered online and shipped to the Feve via truck. The PLA_{TCP} straws would be coming from Dayton, OH, the specific location being 192 miles away from the Feve. These straws are wrapped and are only sold in packages of 10,000 which means

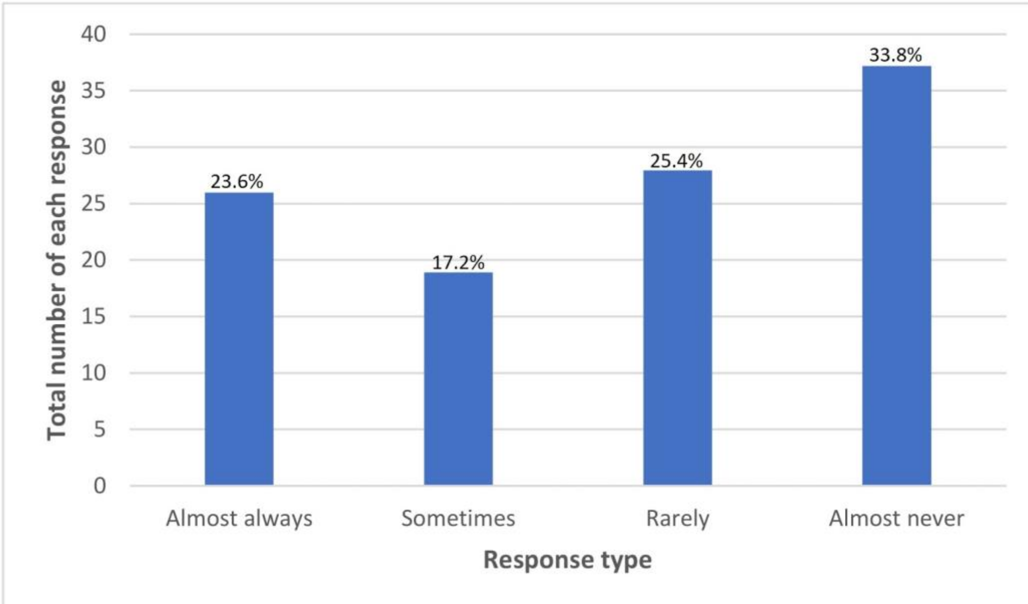

Fig. 2. Responses to the survey question "How often do you use straws?" A total of 110 customer responses were collected.

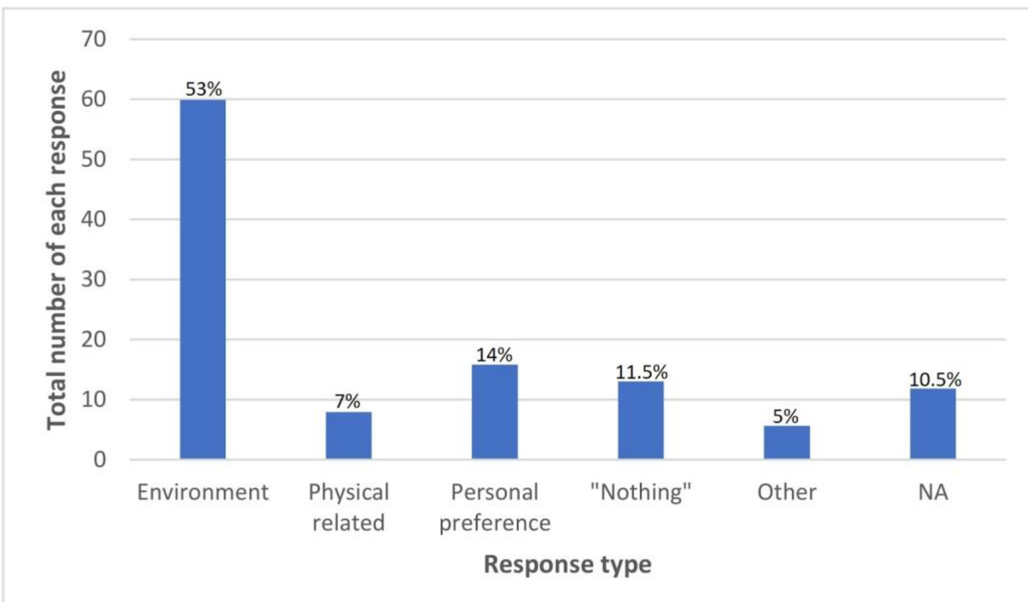

Fig. 3. Responses to the survey question "What is good about NOT using straws?" A total of 113 customer responses were collected. *Environment* included all the responses that mentioned environmental health and well-being. *Physical related* was a broad category that included anything people said about their own bodies in relation to straws (e.g. "The mouth feel of the glass", "less air in stomach", and "risk of injury is low").. *Personal preference* referred to customers who reported preferring not to use straws in the first place. *"Nothing"* is a category because some people thought there was no good reason to not use a straw, and often wrote "Nothing" in response to the question. *Other* included unique responses that were not similar to any others collected, and *NA* were when customers gave no response.

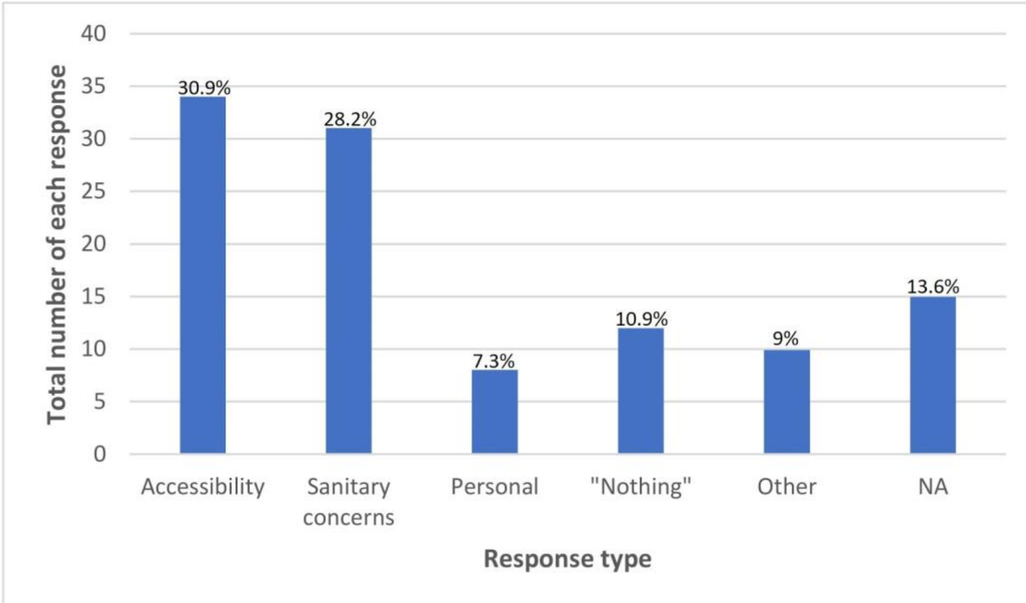

Fig. 4. Responses to the survey question "What is good about using a straw?" A total of 110 customer responses were collected. *Accessibility* included answers that mentioned ease of access to the beverage (especially for children or people with mobility impairments), preventing tooth aches, not spilling ice/beverage, etc. *Sanitary concerns* included answers expressing concern for touching their mouths on a glass that other customers have used. *Personal* included answers that expressed that it was a personal preference/they had personal reasons for wanting to use straws. *"Nothing"* included answers where the customers wrote "Nothing" or something similar in response to the question. *Other* included unique responses that were not similar to any others collected, and *NA* were when customers gave no response.

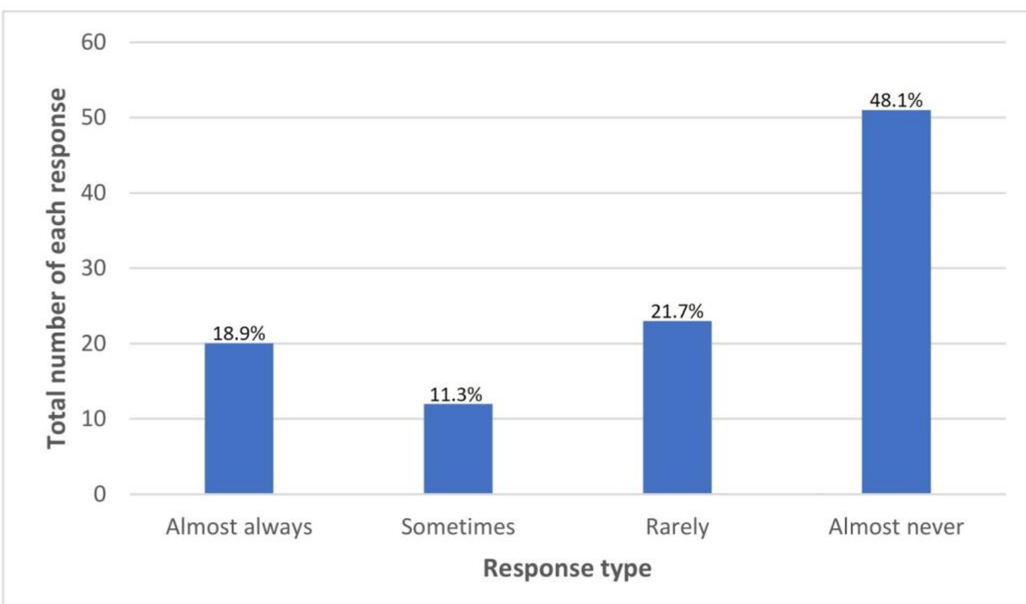

Fig. 5. Responses to the survey question "Would you ask for a straw if you were not offered one?" A total of 106 customer responses were collected.

the Feve would only need to order approximately 7 cases per year. The PLA_{GPP} straws are coming from Cleveland, OH, 51 miles away from the Feve. The cases come in multiple sizes with the largest containing 2,000 wrapped straws. Multiple cases of PLA_{GPP} straws should be purchased at one time, and for the purpose of this comparison I will use 3 cases (giving a total of 6000 straws per order) to make the number or straws per order as similar to current purchasing practices as possible. Since there are no industrial composting facilities that can accept PLA plastic mixed with food waste in Lorain County (Lorain County Solid Waste Management District, 2015; Platt, 2016), the PLA straws would also have to go to the Lorain County Landfill (Table 1).

Production

Through my literature review, I found that the total GHG emissions for the production of corn-based PLA is between 0.6-1.3 kg CO_2eq/kg polymer resin and the total GHG emissions for the production of PP is between 1.6-1.9 kg CO_2eq/kg polymer resin (Vink and Davies, 2015). I converted these production values to lbs of CO_2eq per 2.205 lbs (1 kg) of polymer resin to match the units for the rest of the data. I was unable to find how much plastic resin is needed to make drinking straws, so I kept the production values the same for one order (Table 2) and a year's worth of orders (Table 3).

Transportation to Feve

The PP straws are picked up from the supplier in Cleveland by one of the owners of the Feve using their personal vehicles, and are brought back to the Feve. The average miles per gallon for personal vehicles in the U.S. is 24.7mpg (EPA, 2018), and the average emission is 18.9 lbs CO_2eq per gallon of E10 (EIA, 2017). Using Equation 1, I found that 1.457 gal E10 is used to drive from the Feve to the supplier. This value was then multiplied by 2 (equaling 2.914 gal E10) because this is a round trip. I then multiplied 2.914 gal E10 by 18.9 lbs CO_2eq to get the total lbs of CO_2eq emitted during the drive to the supplier and back. The result was 55.09 lbs CO_2eq/gal E10 for one trip to the supplier (Table 2) and 826.35 lbs CO_2eq/gal E10 for 15 trips (Table 3). This method assumes that the Feve is only buying straws from the suppliers

Table 1
Data collection on PP straws and PLA alternatives based on the interview with Matt, supplier product options, and Lorain County municipal waste information (Lorain County Solid Waste Management District, 2015).

Life Cycle Comparison	PP straws	PLA_{TCP} straws	PLA_{GPP} straws
Number of straws per order	5,000	10,000	2,000
Cases needed per year	15	7	37
Distance (Supplier to Feve)	36 mi	192 mi	51 mi
Transportation (Supplier to Feve)	Personal vehicle	Truck	Truck
Type of disposal	Dumpster	Dumpster	Dumpster
Distance (Feve to Disposal)	3.1 mi	3.1 mi	3.1 mi
Disposal facility	Lorain County Landfill	Lorain County Landfill	Lorain County Landfill
Transportation (Feve to Disposal)	Truck	Truck	Truck

during these shopping trips, but if they were buying other supplies at the same time the carbon footprint burden would be divided amongst the products.

A similar process was used for both of the PLA straws. The average miles per gallon for trucks in the United States is 21.2mpg (EPA, 2018), and the average truck emits 17.9 lbs CO_2eq per gallon of B20 (EIA, 2017). It can be assumed that both shipping trucks make other stops when they are delivering straws to the Feve, but because I do not have access to that information I estimated the GHG emissions for a scenario in which the trucks are only delivering to the Feve. Therefore, the values listed below are the minimum amount of GHGs each truck would emit in their respective transportation scenarios. Equation 1 tells us that a truck shipping PLA_{TCP} straws will use 9.057 gal B20 to get from the supplier to the Feve, and then that is multiplied by 2 since the truck has to return to Dayton (equaling 18.114 gal B20). I then multiplied 18.114 gal B20 by 17.9 lbs CO_2eq to find the total number of lbs of CO_2 used during these transports. The result is that 324.23 lbs CO_2eq is emitted for one order of straws (Table 2) and

2,269.61 lbs CO_2eq are emitted for 7 trips (Table 3). A truck delivering PLA_{GPP} straws will use a total of 4.812 gal B20 to get to the Feve and back to Cleveland, resulting in the emission of 86.122 lbs CO_2eq (Table 2). Because of the small number of PLA_{GPP} straws per case, and because orders over $89 from Green Paper Products receive free shipping, I would recommend that Matt orders 3 cases of 2,000 straws at a time (or more) rather than one case at a time like he would for the other two straw options. This means there are 6,000 straws per order, which is more similar to their current PP straw purchasing practices. In this case, the trucks would be travelling to the Feve 12 times a year, so their total GHG emissions for a whole year would equal 1,033.464 lbs CO_2eq (Table 3).

Transportation to disposal

To estimate the carbon impact of disposal, I used the average truck mpg and lbs CO_2eq/gal B20 from earlier, and that Lorain County Landfill is 3.1 mi away from the Feve. The trucks use 0.142 gal B20 to take refuse directly from the Feve to the landfill. Because I was unable to find information on collection truck routes in Lorain County, I used the direct route from the Feve to the landfill. This meant that 2.533 lbs CO_2eq is the minimum amount of GHGs emitted while taking straws from the Feve to the landfill (Table 2). The collection trucks come by once a week for the whole year (total of 52 weeks), so the trucks emit 131.716 lbs CO_2eq going between the Feve and the landfill all year (Table 3).

Disposal

Through my literature review I found that the mean GHG emissions due to landfill end of life scenarios for both PP and PLA plastic were 0.04 kg CO_2eq/kg plastic (Posen et al., 2016). These values were converted into lbs CO_2eq/2.205lbs of plastic, again to match the units for the other data (Table 2 and Table 3). Because I was unable to find how much plastic is needed to make drinking straws, I left this value the same for both Table 2 and Table 3. Ideally, if Oberlin had the capacity to process biodegradable plastics, this value would have differed because the PLA straws would have gone to a different facility to be composted. However, because there are no such facilities in Lorain County, all straws would go directly to the landfill.

Table 2
Life cycle emissions of PP straws and PLA alternatives for one order of straws.

Life Cycle Stage	PP straws (lbs CO_2eq)	PLA_{TCP} straws (lbs CO_2eq)	PLA_{GPP} straws (lbs CO_2eq)
Production	3.527-4.189	1.323-2.866	1.323-2.866
Transportation to Feve	55.09	324.23	86.122
Transportation to Disposal	2.533	2.533	2.533
Disposal	0.088	0.088	0.088
Total GHG	84.035-84.697	328.264-329.807	90.066-91.609

Table 3
Life cycle emissions of PP straws and PLA alternatives for a year's worth of orders.

Life Cycle Stage	PP straws (lbs CO_2eq)	PLA_{TCP} straws (lbs CO_2eq)	PLA_{GPP} straws (lbs CO_2eq)
Production	3.527-4.189	1.323-2.866	1.323-2.866
Transportation to Feve	826.35	2,269.61	1,033.464
Transportation to Disposal	131.716	131.716	131.716
Disposal	0.088	0.088	0.088
Total GHG	961.681-962.343	2,402.737-2,404.280	1,166.591-1,168.134

3.3 Cost comparison

I found the cost per piece for each straw option by dividing the cost per order by the number of straws per order. The cost per piece serves as a standardized comparison between the straw options because it shows the cost of buying one straw. The cost per piece for PP straws is less than \$0.01 (specifically it is \$0.006142) while the cost per piece for the PLA_{TCP} straws is \$0.02 and PLA_{GPP} straws is \$0.03. The cost of making one PLA straw is over three and four times the cost of making a PP straw respectively, which is one of the reasons cost can be such an influential part of decision making for restaurant owners that are considering switching to "greener alternatives for PP plastic. The rest of the cost comparison focuses on the cost of one order of straws and the costs for an entire year.

Fuel

By multiplying the average cost of gasoline in the U.S. by the average number of gallons E10 used to transport to and from the supplier, I found that it costs the Feve approximately $7.29 worth of fuel each time they buy a case of straws from their current supplier. For the year-long prediction, I multiplied the fuel cost by 15 because Matt reported that they purchase one case at a time and need around 15 cases per year. The cost then for gasoline used to purchase PP straws over the course of a year is $109.35 (Table 5). Similarly to the environmental comparison, this method is assuming that they are only going to the supplier to buy straws, but if they are buying other disposables along with straws then the cost is split amongst the products. This means that the values found in this study are maximum costs and would be lower if other products were being bought simultaneously. Since the Feve is not directly responsible for paying for the diesel used by the shipping trucks, the PLA straws' costs for fuel are $0 each (Table 4; Table 5).

Cases of straws

The prices for one case of straws were taken from Matt's interview, True Choice Pack's online catalog, and Green Paper Products' online catalog respectively (Table 4). One case of 2,000 PLA_{GPP} straws costs $47.60, but because I am assuming that a minimum of 3 cases of the PLA_{GPP} straws be purchased at a time, that number is tripled (Table 4). Those prices were then multiplied by the number of cases the Feve would likely need over the course of one year (Table 5).

Shipping

The PP straws are not being shipped to the Feve and the PLA_{GPP} straws have no shipping fee if the price of the order exceeds $89, so the cost of shipping in both of these scenarios is $0 each (Table 4; Table 5). PLA_{TCP} straws have a shipping fee of $11.91 for all orders in the zip code

44074, which includes the City of Oberlin. This is a fixed price and does not change depending on how many cases are ordered at a time (Table 4). If Matt is ordering 7 cases a year, the total amount for shipping will be $83.37 (Table 5).

Table 4
Cost comparison for buying one order of PP straws or PLA straws.

Costs for the Feve	**PP straws**	**PLA_{TCP} straws**	**PLA_{GPP} straws**
Fuel	$7.29	$0	$0
Straws	$30.71	$190.60	$142.80
Shipping	$0	$11.91	$0
Total	$38.00	$202.51	$142.80

Table 5
Cost comparison for buying a year's worth of PP straws or PLA straws.

Costs for the Feve	**PP straws**	**PLA_{TCP} straws**	**PLA_{GPP} straws**
Fuel	$109.35	$0	$0
Straws	$460.65	$1,334.20	$1,713.60
Shipping	$0	$83.37	$0
Total	$570.00	$1,417.57	$1,713.60

4 Discussion

4.1 Observation sessions and surveys

The goal of these observations and surveys was to get a better sense of what the culture surrounding straws is like in Oberlin specifically and to use that information to gauge how customers might react if the Feve changed straw type or distribution policies. This was important information because customer satisfaction was Matt's expressed top priority. If the customers were going to be overwhelmingly unhappy with the Feve distributing fewer straws then we would have had to focus purely on finding a suitable drinking straw alternative. The results showed that a total of 59.2% of customers reported that they rarely or almost never use a straw, and 69.8% reported that they would rarely or almost never ask for one if it was not initially provided. This suggests that the majority of the customers would not have strong negative feelings towards the Feve if straws were not automatically given.

Without being informed of purpose of this study, over half of the customers surveyed acknowledged that using fewer straws would be better for the environment. This means that many customers were already aware of the damage that plastic straws can cause to our environment and understand that not using them is one way to help mitigate the problem. Since one of the benefits that Matt identified was bolstering the Feve's reputation as being a sustainable restaurant, this information was reassuring. If the Feve attributes any future change in straw distribution practices to reducing its environmental impact, many customers will likely understand and support the decision.

The two main benefits of using straws that were addressed by the customer surveys were that straws increase accessibility, particularly for children and people with some mobility impairment, as well as that they minimize sanitary concerns. These are both benefits that relate back to the history of drinking straws. In the 1930s, hospitals were one of the largest consumers of single-use disposable drinking straws because they helped patients drink their beverages and decreased the risk of spreading diseases. Because of this history, accessibility and sanitation were the two benefits of using straws that I expected to see from the customer surveys, and these results confirmed that those are still important cultural issues to take into consideration. Removing straws altogether would make it more difficult for some customers to drink their beverages, which would have a negative impact on their experience at the Feve and might damage the Feve's reputation. The same is true for sanitation; if a customer is worried about drinking out of a glass that others have used before, they will have a more negative experience than they would have if they had been given a straw.

Something to think about should more observational studies be conducted in the future is the way in which the observations are set up. We briefly considered putting cups out on the tables with a set amount of wrapped straws, letting customers grab straws on their own, then counting the number of straws left in each cup at the end of the observation session. If we had done this instead the waitstaff serving straws per request, there may have been a difference in the number of customers that used straws. Based on conversations I have had with family members, friends, and coworkers, there are people who prefer to use straws, but do not feel the need to ask for one. In situations like these, I would expect to see more people choose to use straws compared to what was found in this study if there were cups of straws out on the tables. Having the straws in front of the customers—so they know straws are available—and not having to ask the waitstaff to bring them a straw would possibly lead to higher straw use. We did not use this method of observation because Matt had expressed not wanting to put straws on the table as part of a long-term solution, and because we did not have a chance to buy wrapped straws in order for the studies to be finished on time. Having the waitstaff provide straws per request was more aligned with what I imagined possible distribution changes could be, which is ultimately why our method was used. However, if more unbiased information about the number of people who really prefer to use straws is needed in the future, I would recommend using the cup on the table strategy as a point of comparison.

Based on the results from these observations and surveys, I believe it will be important for the Feve to find a balance between lowering the number of straws distributed and keeping straws readily available to customers who prefer them. During the observational study, we noticed that all the waitstaff wear aprons that have large pockets in them. My recommendation is that drinks be served automatically without straws, but have waitstaff carry wrapped straws in their apron pockets. The pockets are short, so the straws would likely be seen by the customers, letting them know that straws are available. This would be more efficient solution than waitstaff bringing out drinks and having to go back to get straws for customers, which is a practice that the Feve has tried in the past.

4.2 Environmental impact comparative analysis

The CO_2eq emissions were greater for both PLA straws in this modified life cycle analysis. The PLA_{TCP} option emitted a between 244.229 and 245.11 lbs CO_2eq more than their PP counterparts for one order, and between 1,441.056 and 1,441.937 lbs CO_2eq more for a year's worth of orders. The difference between GHG emissions for the PLA_{TCP} and PP straws for a year is roughly equivalent to driving a car non-stop for 25.46 hours or watching a 42in LCD TV for a little over 163 days consecutively (YouSustain, 2018). The PLA_{GPP} option only emitted a between 6.031 and 6.912 lbs CO_2eq more than the PP straws for one order, and between 204.910 and 205.791 lbs CO_2eq more for a year's worth of orders. The difference between GHG emissions for the PLA_{GPP} and PP straws for a year is roughly equivalent to driving a car non-stop for 3.63 hours or watching a 42in LCD TV for a little over 23 days consecutively (YouSustain, 2018). PLA is made from corn which is a CO_2 sink and a renewable resource, so the production emissions from PLA are lower than those of PP, but that did not make up for the GHG emitted during transportation from the supplier to the Feve. Buying PP straws had a lower carbon footprint because of the location of the supplier, even though petroleum extraction is less sustainable on a global scale. Ultimately, the Feve will have to decide if they would rather give PP straws and have a lower carbon footprint or support the companies working to make straws out of renewable resources and have a slightly larger carbon footprint until "greener" alternatives become more widespread and easier to compost.

Because this life cycle analysis had to be modified to reflect the information I could find, there are several life cycle stages that were not included that could influence the true carbon footprint of each straw option. First, I have no way of knowing where the petroleum used to make these PP straws in particular came from or how many lbs CO_2eq were emitted through the extraction process. The PLA straws that I chose were made from corn that was grown in the United States, but similarly I do not know where specifically it was made and what agricultural practices were used for managing these resources. Second, I was unable to find straw manufacturers that were willing to share information about straw production. I do not know how much resin is needed for, or if there is a difference between, the production of straws made out of PP and those made out of PLA, but it does take energy to create straws so those processes do contribute to their true carbon footprints. Third, the location of the manufacturer for each specific product in this study was unknown. The distance and method of transportation between manufacturer and supplier would also significantly impact the GHG emissions of each product.

Despite these limitations, this model serves as a tangible starting point that other restaurants owners, independent researchers, or any other business looking to decrease their carbon footprint can use on their own. The information that was the most crucial for calculating these GHG emissions were all found on government websites or websites ran by organizations that believe in open access documentation and transparency. Anyone with access to the Internet is able to conduct a similar modified life cycle analysis, and while the analysis might not be perfect every time, it can serve point of comparison that interested parties can use to inform sustainable decision.

4.3 Cost comparative analysis

The price per piece is useful, standardized information for finding out which straws are inherently more expensive to buy. Petroleum-based plastic tends to be the cheapest type of plastic to make, which is reflected by the price per piece found in these results. Financial feasibility is one potential barrier to why restaurant owners are unable to make sustainable decisions. When I interviewed Matt, he said that cost would become a factor if they would have to increase the prices of drinks to cover the costs of the alternative straw. The results showed that, as expected, the PP straws were by far the cheapest option for the Feve for everything between price per piece to a year's worth of orders. PLA_{TCP} straws were more expensive than the PLA_{GPP} straws for one order, but because Matt would have to order fewer cases of the PLA_{TCP} straws over the course of a year, they ended up being cheaper than PLA_{GPP} straws by almost $300 per year.

All of these calculations were made under the assumption that the Feve continues its current practice of buying one case of straws at a time. The PLA_{GPP} option is the only scenario in which multiple cases are being purchased at once, but that was so the number of straws per order could remain as close as possible to the number of PP straws per case that are currently being used. One factor that might affect the cost of the PLA_{GPP} straws specifically would be buying more than the assumed 3 cases that I used in this study. Should Matt decide to use this product and purchase 5 cases at one time (giving the same amount of straws per order as the PLA_{TCP} cases come with), then he would only have to make 7 orders a year. This would mean the cost of one order is instead \$238.00, and \$1,666.00 for a whole year. This would not make PLA_{GPP} straws less expensive than the other options, but it does decrease the cost of this specific option. Alternatively, if the Feve changes their habit of automatically putting a straw in every drink and only offer straws per request, they could save money on any of the three straw options because they would need fewer straws per year.

The Feve will have to decide if buying biodegradable drinking straws and supporting the green market is worth the monetary commitment that is found in this study given that the "greener" alternatives contribute equally to plastic waste and have higher total GHG emissions. If they decide they cannot afford to make the switch, then there are still ways of decreasing the size of their plastic footprint that do not involve losing profits. If they decide that they can afford to use one of the PLA straw options, they will be using their power as consumers to support a market that is trying to come up with more sustainable practices to plastic production. The reason it is currently more expensive to buy "greener" plastic alternatives is because not nearly enough resources have gone into making the production and disposal processes more accessible and efficient, and there is not yet a strong enough demand from consumers to convince manufacturers that providing more petroleum-based plastic alternatives is needed. Choosing to pay more for biodegradable plastic alternatives now is a good way to show support for the green market and for those manufacturers that are looking to focus on making sustainable products in the future. Eventually, if enough consumers choose green alternatives over petroleum-based plastic products, we can get to a point as a society where industrial composters and the use of renewable resources as feedstock become a norm.

5 Conclusions

In the future, should the Feve or any other restaurant wants to replace their PP straws with a different "greener" alternative, they can use this study as a model. The important aspects to keep in mind are the materials being used in the production, the way the product gets to the restaurant location, and where the product will be sent for disposal. The types of alternatives considered should also reflect the needs and perceived barriers of the restaurant owners, otherwise they will not be incentives to change distributing or purchasing behaviors to ones that favor minimizing environmental impact. Biodegradable alternatives seem like a great way to cut back on plastic waste, but unless the necessary facilities are available to compost the materials, the alternative will contribute just as much to landfills as petroleum-based plastic. The decision to support manufacturers and suppliers of biodegradable materials is one that restaurants should consider, because part of the reason we do not have the right facilities everywhere is because biodegradable plastics are not as commonly used. Putting pressure on the markets to make more renewably sourced, biodegradable plastic products can change how global plastic production functions and can spark efforts to make industrial composting facilities that are capable of processing biodegradable plastics more common.

This model can be applied to any plastic items for which restaurants, businesses, or independent researchers might want to find suitable replacements. Businesses like restaurants are good places to start promoting sustainable decisions because they can share the reasons behind their decisions with their customers and help educate the public. The cultural and economic dependency that the world, and particularly the United States, has on single-use petroleum-based plastic items is unsustainable. Drinking straws are small things that many people can easily cut back on and that could have immense impacts on the amount of plastic waste and GHG emissions produced in the U.S. Making sustainable practices the norm has to start somewhere, and with the information in this study the Feve can help contribute to the growing group of restaurants, cities, and countries that are working towards that goal.

6 Acknowledgements

I would like to thank Professor Cindy Frantz and Professor Roger Laushman for all their guidance and feedback over the course of the year, and to the Oberlin Environmental Studies department for giving me a platform to do this research. I would also like to thank my research team, Emily Barrow, Suzie Su, Kate Hall, and Daniel Pardee for helping me conduct the observational studies and make/analyze the surveys. And a special thanks to Matt Adelman and the Feve waitstaff for letting me use your restaurant for this case study and for being so accommo-

dating and accessible throughout this whole process.

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