Glass Recycling in Caño Martín Peña

by
Afthim, Julia M.
Barthold, Tatyana A.
Carrillo, Eduardo A.
Le, Newton N.

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Glass Recycling in Caño Martín Peña

An Interactive Qualifying Project
submitted to the faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfilment of the requirements for the
degree of Bachelor of Science

by
Afthim, Julia M.
Barthold, Tatyana A.
Carrillo, Eduardo A.
Le, Newton N.

Date:
May 2, 2022

Report Submitted to:

Francisco De La Cruz
Project ENLACE Corporation

Carlos Muñiz Pérez
Project ENLACE Corporation

Professor Alex Sphar and Professor Brigitte Servatius
Worcester Polytechnic Institute

ABSTRACT

The pollution of Caño Martín Peña, a natural tidal canal, prompted a plan to dredge its entire length of 3.7 miles. This plan is a part of Caño Martín Peña Restoration Project. We evaluated the feasibility of glass recycling in the Caño Martín Peña area for our sponsor, Caño 3.7. We concluded that glass recycling is especially difficult on an island but is possible with support from local businesses. Our team developed a guidebook in both English and Spanish to provide ENLACE with active ways to implement glass recycling, recommendations for uses of locally recycled glass to complete the dredging project as supported by our feasibility calculations, and recommendations for future research.

ACKNOWLEDGEMENTS

Our team would like to acknowledge the contributions of the following individuals for their role in helping us complete our project. First, we would like to give a huge thank you to Francisco De La Cruz for his continual support and guidance. We are grateful to Francisco for connecting us with individuals and organizations that gave us valuable information for our project.

We are thankful for Professors Brigitte Servatius and Alex Sphar, our advisors, for pushing us to work harder. They helped shape our project and set a writing standard that continued until its completion. We would also like to acknowledge Scott Jiusto and John-Michael Davis for their contribution to the initial stages of our project.

ENLACE provided input and assistance along the way including but not limited to: Carlos Muñiz Pérez who worked with Francisco to shape our project; José Bauza for assisting us in our research on the glass circular economy; Estelí Capote, Miguel Naveira, Kimberly Perez, and Estrella Santiago who all provided input to our project proposal; and José Caraballo for assisting us during our surveys around the Caño.

OLIN Labs was very open to sharing their research with our team. We would like to thank Rebecca Popowsky for sharing her work on innovating projects such as soil-less soil.

We would like to thank José Mercado Quintana, a manager of Bloques Caribe, and Rubén González Abreu, an owner of Reciclaje Del Norte, for taking time out of their schedules to share their initiatives for glass recycling.

Finally, we would like to thank the businesses around the Caño that provided us with enlightening and detailed survey responses.

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EXECUTIVE SUMMARY

Summarized Background Information

Environmental justice is the fair, unbiased treatment of people regarding environmental regulations; a lack of environmental justice has been shown to cause detrimental effects to communities with high rates of poverty and/or high populations of minority ethnicities (United States Environmental Protection Agency, 2017). In many cases, environmental injustice means that the government does not provide protection from environmental and health hazards in an equal and fair way. Therefore, communities that fall in the previously mentioned groups must support themselves with the resources that they do have. A community that has had to support themselves are the neighborhoods surrounding the Caño Martín Peña (Canal Martin Pena in English) in San Juan, Puerto Rico. Since its formation in the 1930s, the area has not had an appropriate drainage system to prevent flooding, an appropriate sewage system for waste management, or suitable infrastructure to house its residents (De La Cruz, 2022). From these foundational issues came an idea to use the canal as a resource for trash disposal; residents would dump their sewage and trash into the canal to eliminate it from piling up in their neighborhoods. However, this pollution caused environmental issues for the communities when the canal no longer flowed freely and flooded when it rained. Law 489 was enacted in 2004 to address the poor conditions and flooding in Caño Martín Peña; this law includes plans to dredge the canal to avoid flooding in the nearby residential areas. To ensure this plan becomes a reality, Caño 3.7 was formed. Caño 3.7 is made up of three community organizations, each with specific goals regarding the canal dredging process: ENLACE, the G-8, and the Caño Martín Peña Community Land Trust (CMPCLT). ENLACE manages the projects regarding environmental efforts towards the canal and has recently received funds from the Puerto Rican government to prepare for dredging the canal. The G-8 is a group of eight community leaders, one from each neighborhood of the Caño Martín Peña area, which works to include community input into the canal dredging process. The CMPCLT oversees the land within the Caño Martín Peña area.

Summarized Project Description

Francisco De La Cruz, a project coordinator from ENLACE, believes that an appropriate waste management system is essential for the Caño Martín Peña to remain unpolluted post-dredging (De La Cruz, 2022). One aspect within this waste management system is the recycling of materials. Martín Peña Recicla, INC. (MPR) is a recycling company that has been working with ENLACE since 2011 to improve the environmental state of the Caño Martín Peña area, as well as the community's knowledge on recycling (Naveira, 2022). However, Miguel Naveira, one of the two employees of MPR, explained that their reach has been limited because they lack employees and funding. José Bauza, from the economic division of ENLACE, recommended that our project team investigate the feasibility of glass recycling in the Caño Martín Peña area. After walking around the community, our team observed multiple businesses selling glass beer bottles that were then left in trash cans or throughout the streets. These glass materials could be used for several of the current projects at ENLACE, including landfill cover material, construction materials, or even art materials for local microbusinesses. Our team planned to understand the current state of glass recycling and glass-waste in the Caño Martín Peña area and analyze potential uses for recycled glass. The team explored the number of weekly glass bottles

being sold in the Caño Martin Peña area by surveying businesses that sell glass bottled beverages. We also interviewed companies around Puerto Rico that currently recycle glass to understand their procedures and costs related to glass recycling. Along with working on-site to gather information, we researched potential uses for glass recycling to provide recommendations to ENLACE. Finally, we created a guidebook for ENLACE to understand the steps we took to understand glass recycling and its uses. This guidebook provides our suggestions to ENLACE on how to implement a glass-waste recycling initiative in the Caño Martín Peña.

Summarized Results, Conclusions, and Recommendations

For this project, a series of interviews and surveys were completed by our team; four companies participated in these interviews. To learn more about recycling practices in the Caño Martín Peña area, we interviewed Martín Peña Recicla INC. (MPR). MPR is a local recycling company for just the Caño Martín Peña area; Miguel Naveira from Martín Peña Recicla INC. explained that MPR collects recycling materials from the Caño neighborhoods and helps to promote recycling. To gain more of a broad perspective on recycling in Puerto Rico, our team interviewed Rubén González Abreu from Reciclaje del Norte (RDN). Through this interview, we gained an understanding on why glass is recycled much less than plastics, cardboard, and paper materials, since González Abreu sees glass recycling as "unprofitable." To see the potential uses of glass, our team interviewed companies who currently work on projects that use pulverized glass. Bloques Caribe Inc. is a construction company that incorporates glass cullets in a mixture for cement blocks; José Mercado Quintana, the administrator of Bloques Caribe Inc. (BC) in Guaynabo, Puerto Rico, uses glass in the cement mixture for both environmental and economic purposes. Rebecca Popowsky, the OLIN Labs external research coordinator, provided our team with information about a research project currently underway. OLIN Labs is hoping to spread knowledge about the uses of glass aggregate as an alternative to sand. Both Bloques Caribe Inc. and OLIN Labs specified that they use Andela products to pulverize their glass bottles. From the interviews and surveys conducted, glass recycling appears to be economically feasible in the Caño Martín Peñaa. The surveys concluded that majority of businesses in the area would recycle their glass bottles and sell enough glass bottles to be used in a microbusiness that pulverizes glass. The Andela GP mini is used in Bloques Caribe Inc., this machine has potential to be implemented in the Caño Martín Peñaa area. The businesses we surveyed produce an estimated annual 44.35 metric tons of glass bottles. Through our calculations, we concluded that dumping these 44.35 metric tons into a landfill would cost approximately $1,863. By using this glass in for new products, like cement blocks or soil-less soil, the Caño Martín Peña would economically benefit. For example, we estimated that Bloques Caribe Inc.'s annual savings for substituting glass into their cement block mixture is approximately $507,892, based on the weight of an *8"x8"x16"* block and the estimated 11% glass in weight per block.

From both the interviews and surveys, conclusions and recommendations were made by our team for ENLACE to continue researching glass recycling in the Caño Martín Peña area. Our team came to the following conclusions:

- Businesses and residents around the Caño Martín Peña are willing to recycle if they understand the purpose behind it and the process is feasible.
- Recycling in Puerto Rico relies primarily on non-profit organizations and/or environmental groups because there is a lack of support from the local government.

- Glass recycling is arduous to implement since, unlike plastics and metals, unrecycled glass has no monetary value.

Our team has the following recommendations for ENLACE:

- We recommend that ENLACE encourages businesses in the Caño Martín Peña area to recycle their glass bottles through an incentive program.
- We recommend that ENLACE and Bloques Caribe Inc. come to an agreement to recycle glass from the Caño Martín Peña area.
- We recommend that ENLACE collects glass waste from businesses around the canal and starts a micro-business operating a glass pulverizer to produce glass cullets. Uses for the glass cullets should be explored further.

CHAPTER 1: INTRODUCTION

The Caño Martín Peña is a 3.75-mile-long canal that connects the San Juan lagoon to the San Juan Bay in Puerto Rico. The community was self-started in the 1930s; consequently, the Puerto Rican government has not provided the Caño Martín Peña area with proper environmental support (De La Cruz, 2022). The canal is a natural body of water that provides a beauty to the community of the Caño Martín Peña; however, due to improper waste removal practices by the surrounding community, the canal has become extremely polluted (De La Cruz, 2022). To address this pollution, Caño 3.7 is working with the United States Army Corps of Engineers (USACE) towards dredging the canal, in ordinance with Law 489. Caño 3.7 is made up of three community organizations, each with specific goals regarding the canal dredging process: ENLACE, the G-8, and the Caño Martín Peña Community Land Trust (CMPCLT). ENLACE manages the projects regarding environmental efforts towards the canal and has recently received funds from the Puerto Rican government to prepare for dredging the canal. Before this dredging occurs in late 2023, ENLACE has many projects to complete to be ready for the USACE; one of these projects is to assist in the community's views of waste disposal (De La Cruz, 2022). To our team's knowledge, it seems that some members of the Caño Martín Peña community are not aware of the environmental impacts of their trash-disposal methods. One way to manage waste is to recycle. Martín Peña Recicla, INC. (MPR) is a recycling company that has been working with ENLACE since 2011 to improve the environmental state of the Caño Martín Peña area, as well as the community's knowledge on recycling (Naveira, 2022). José Bauza, from the ENLACE corporation, suggested that our team investigate the feasibility of glass recycling to determine if and how recycling glass could occur in the Caño Martín Peña area.

CHAPTER 2: BACKGROUND/LITERATURE REVIEW

This background chapter discusses some history and current information related to our glass recycling initiative project within Caño Martín Peña.

2.1: History of Environmental Justice

Environmental justice is defined by the United States Environmental Protection Agency as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" (United States Environmental Protection Agency, 2017). The environmental justice movement originated around the Civil Rights Movement in the 1960s, when African Americans and Native Americans were demanding equal environmental conditions from the United States government, for "poverty-pockets" in rural areas, urban ghetto neighborhoods, and Native-American reservations (United States Environmental Protection Agency, 2017). All these neighborhoods lacked the environmental protections of primarily white neighborhoods in the United States. The first public account of the environmental justice movement in the US was the Memphis Sanitation Strike for the city of Memphis, Tennessee in February of 1968 (United States Environmental Protection Agency, 2017). There were several public protests for the improvement of environmental and economic conditions for the men who picked up and disposed of garbage in the area, which were led by Dr. Martin Luther King Junior. Several members of the Memphis community were protesting the unequal pay and inhumane work conditions after the deaths of two garbage collectors, Echol Cole and Robert Walker, caused by severe injuries from a garbage compactor (Estes, 2000). The protest began with about 1300 African American men from the Memphis Department of Public Works (MDPW) but expanded to several other groups of the Memphis community over just a few weeks (Estes, 2000). The slogan for the cause was "I Am a Man" which was written on placards that the MDPW protestors wore for the duration of the strike (just over two months); these signs symbolized the demand for the MDPW to treat these workers with "humanity and dignity" (Estes, 2000). Figure 1 shows the placards held by protestors, all of which in this photo are black (Conover, 2018). This protest did not have the legal effect that protestors desired, due to the polarizing time that it took place in. However, this may have been the first public record of an environmental justice strike in the US, but it was not, by far, the last.

Figure 1: National Guard troops point rifles at Memphis Sanitation Strike protests on Beale Street on March 29, 1968 (Conover, 2018).

2.2: Environmental Justice in Puerto Rico

Issues related to environmental justice are found throughout the island of Puerto Rico, which is demonstrated by the government's efforts towards recovery after Hurricane Maria. Hurricane Maria, hit Puerto Rico in mid-September of 2017, this natural disaster had devastating environmental impacts on the entirety of Puerto Rico; several buildings were destroyed by the treacherous waves, floods, and tornadoes at high winds (Acevedo, 2020). However, Gustavo A. Garcia-Lopez, writing in *Environmental Justice*, believes that the government actions since the natural disaster have been the "real catastrophe" (2018). Although the entire island experienced the effects of the hurricane, only certain areas are still feeling these effects in 2022. Specifically, these include the northern and western areas which are more rural and have greater poverty levels than the metropolitan, urban area (García, 2018). Environmental injustice can affect many aspects of daily life, including contaminated water, poor food conditions and options, and a lack of electricity in some areas. As for clean water, 36% of Puerto Ricans did not have access to clean water via the public water supply for about one month after the hurricane. The same report signified that "although 80% of clients in the metropolitan area had water by that time, in the west it was only 45% and in the north 32%" (García, 2018). This uneven spread may be understandable immediately after the hurricane because the metropolitan area has the highest population, but after one month of recovery it is understandable for those in the western and northern areas to be upset by the previous statistic. One of the negative results from this one aspect of the aftermath of Hurricane Maria is the "total lack of environmental monitoring of water quality by the government," the water became contaminated in many of the communities in poverty because 40% of the sewage plants were not functioning properly (because they require a public water system) which resulted in an increase of untreated discharges, and therefore water contamination (García, 2018). A similar story can be told about electricity in some Puerto Rican areas: the municipalities that lacked electricity following Hurricane Maria were in the central mountainous and south-eastern regions, which are the poorest of the country and the areas that

were hit hardest by the hurricane (García, 2018). Even within the metropolitan area of San Juan, there were differences in government support based on wealth: “the poorest communities, such as those in the Caño Martín Peña region, were still without electricity as of mid-December” (García, 2018) although the hurricane hit in mid-September (Acevedo, 2020). The government even suggested that those without clean water should boil their water before drinking, meanwhile many of these individuals did not have access to electricity and generators were too expensive for them to afford (García, 2018). However, according to a 2020 *NBC News* article, there have been improvements made to the environmental problems caused by Hurricane Maria, just not by the government. Puerto Rican native, Angel Perez, stated (in Spanish) that "As a community social worker, I can tell you that Puerto Rico's recovery, if it can be called that, didn't come thanks to the government. It came from non-profit associations; it came from the neighbors themselves. It came from foundations. It came from the hands of other people who supported the families that suffered the most,” (Acevedo, 2020). Perez also hints to the fact that this is a general opinion of those in his community, which is understandable based on the injustice that many of these areas have experienced (Acevedo, 2020).

2.3: History and Current State of Caño Martín Peña

Many farmers fled to find work in the Caño Martín Peña area after their farms were destroyed from Okeechobee Hurricane in 1928 (Padilla, 1978). During the 1930s, the areas around the Caño Martín Peña provided work and settlement for the people of Puerto Rico, which at the time was scarce in the major cities and other urban areas. The Caño Martín Peña was referred to as the “ideal place to live” in the 1930s by Modesto F. Padilla in a development project written in 1978. The residents’ houses were built from whatever material could be found and were tightly packed together. An example of one of these homes from the 1930s is shown below in Figure 2, which shows a house built on stilts. Because the area was self-started in the 1930s, the residents were not supported by the government after the economic conditions in Puerto Rico were favorable (De La Cruz, 2022). In the 1940s, those who had money lived in more urban areas like San Juan, while those in poverty and in the working class stayed in areas around the city known as the “slums” (Padilla, 1978). The communities around the Martín Peña canal were characterized as “the worst of the slums in Puerto Rico” due to their poor living conditions (Padilla, 1978). Compared to the residents of government-supported areas, people living around the Caño Martín Peña were statistically less educated and developed sickness and diseases (Padilla, 1978).

Figure 2: 1930s Martín Peña community home (Padilla, 1978).

The Caño Martín Peña community has been dumping their sewage waste and garbage into the canal for almost a century (Padilla, 1978). The pollution in the canal has built up to the point where the canal no longer flows from the San Juan Bay to the San Juan lagoon (World Habitat, 2016). When walking through the community, our group has observed lots of trash on the ground within the neighborhoods and commercial areas. This trash then ends up in the canal when it floods in the rain because of the poor water circulation in the area (World Habitat, 2016). An image of this trash in the canal area is shown in Figure 3, where you can see mostly plastic waste on the edge of the polluted body of water. Animals in this ecosystem can struggle to get the resources they need because this pollution is in the way. Consequently, they can develop diseases that can spread to the community when the canal floods (World Habitat, 2016). The community's health has been negatively affected by this pollution based on a Health Impact Assessment (HIA) report from the Annals of Global Health (AGH); the HIA describes the environmental and health related results if the current conditions are to continue (Sheffield, 2014). The organization determined that "flooding and negative environmental exposures, such as mold, limits to physical activity, stress, chemical toxicants, pathogenic bacteria, and pests, are worsening. The higher rates of diseases, such as asthma and diarrhea, in the community compared with elsewhere in Puerto Rico appear to be attributable to these factors" (Sheffield, 2014). They also provided recommendations for the Puerto Rican legislature on how to move forward, which included a strong endorsement to dredge the canal and relieve the nearby communities of the poor living conditions they experience (Sheffield, 2014). Aside from the HIA report, a Zika virus study was conducted by the Eco Health Alliance in 2016. When a person contracts the Zika virus, the symptoms include high fevers, body aches, rashes, and headaches. Though these symptoms are not long term, a big health risk that arises from the Zika virus is birthing defects in the fetus of pregnant women, like Guillain-Barre syndrome (Center of Disease Contro, 2021). This study reported that because of the flooding, there has been an increased population of Aedes aegypti (Zika carrying) mosquitoes in the Martín Peña area than other areas around San Juan Bay (Yee, 2019). The Puerto Rican government came to recognize these health

issues in 2004, which involved the issuance of Law 489. This law provides government resources towards the environmental restoration of the Caño Martín Peña and the rehabilitation of the eight communities bordering the canal; an organization was created to ensure these resources are used efficiently, which is the community group Caño 3.7.

Figure 3: Trash in the Caño Martín Peña taken on April 6th, 2022, by our project team.

2.4: About Caño 3.7

Caño 3.7 is made up of three community organizations planning to take actions to combat the current environmental and health problems for the Caño Martín Peña community. The name "Caño 3.7" stands for the length (3.75 miles) of the canal. Law 489-2004 was put into effect to address the health issues present in the Caño Martín Peña area and to revitalize the communities and promote a healthy relationship between the environment and the developing communities. Three organizations were created because of Law 489: ENLACE, G-8, and the Caño Martín Peña Community Land Trust (CMPCLT). These organizations are to work towards completing the ENLACE Project, which is responsible for coordinating the efforts of the state, the private sector, and the community to advance Law 489. ENLACE manages all the individual projects and efforts towards redeveloping the communities around the Caño Martín Peña and was the company that our team primarily works with for our project. ENLACE has several different areas within their organization, such as the environmental, economic, infrastructure, housing, and budgeting departments that work together to progress the canal dredging project. The CMPCLT was established as a response to the displacement of families surrounding the Caño Martín Peña; this organization owns about 25 acres of the public land along Caño Martín Peña and ensures this land will be used for the advancement of Law 489. El Grupo de las Ocho Comunidades Aledañas al Caño Martín Peña (G-8) is a non-profit run by community members; G-8 is to ensure community involvement in the ongoing projects led by ENLACE. These three organizations together form Caño 3.7, our sponsor for this project. When our project team first arrived in

Puerto Rico, we wrote personal reflections on our first meetings with ENLACE to explain more about the intricacies of the corporation, which are in Appendix A.

The "Caño Martín Peña Restoration Project" is the biggest project currently worked on by Caño 3.7. This project was agreed upon by the Puerto Rico Commonwealth and the United States Army Corps of Engineers, or USACE (Summa, 2018). The restoration project deals with all the preparation and actions towards dredging the canal. Caño 3.7 is working together with the USACE to prepare for and eventually dredge the canal (Hale, 2022). The project is estimated to cost $285,000,000; the USACE is expected to contribute $163,000,000 and the rest will be allocated from government funding (Hale, 2022). The dredging is expected to begin in the late months of 2023; in the meantime, there are preparation processes to be completed, such as finding contractors and getting documents like agreements and contracts in order (Hale, 2022). This dredging process will also require the Caño Martín Peña community to relocate, which requires lots of planning from the infrastructure division of ENLACE (Hale, 2022). Francisco De La Cruz was working with our team directly on our project, which was focused the area in and around the Marina neighborhood, which is circled in blue on the map below in Figure 4. More information specific to the Marina neighbourhood is located in Appendix E.

Figure 4: The map of the Caño Martín Peña community with the Marina neighborhood circled (Corporation of the ENLACE Project of the Martín Peña Channel, 2016).

To carry out their vision, ENLACE has drafted a document describing the actions they plan to take for the development of the community. The name of the document is "Plan de Desarrollo Integral y Usos del Terreno del Distrito de Planificación Especial del Caño Martín Peña" which loosely translates to "Integrated Development Plan for the Caño Martín Peña." The development plan proposes rational strategies for urban development that are based on the active participation of community members (*Plan de Desarrollo Integral y Usos del Terreno del Distrito de Planificación Especial del Caño Martín Peña.* (2008). In addition, the plan proposes strategies for construction and rehabilitation of housing in areas of high population density and poor sanitary conditions. The development plan mentions that community trash bins were previously placed along certain parts of the communities. However, these bins quickly filled up and were not emptied often enough, causing them to overflow. As a result, community members opted out of the community bins and proceeded to dump their waste into the canal (*Plan de Desarrollo*

Integral y Usos del Terreno del Distrito de Planificación Especial del Caño Martín Peña. (2008).

2.5: Recycling in Puerto Rico

Recycling is defined as the process of converting waste materials into new materials and objects, which can be "challenging" on islands (Glatsky, 2019). The American Society of Civil Engineers completed a study in 2019 that reported only 9%-14% of waste in Puerto Rico is recycled, even though 35% of materials are recyclable (Cruz, 2021). There are several reasons for this low recycling rate, which Genevieve Glatsky from *WasteDive* believes are "due to their geographic isolation from end markets and lack of sufficient quantities to support processing investments. Industry professionals indicate shipping off island is expensive, with increasingly low profits, and say recycling activity is limited" (Glatsky, 2019). Francisco De La Cruz indicated that although his apartment complex has designated recycling areas for paper, plastic, and landfill; when these materials are collected, they are all thrown into one garbage truck, which he assumed goes to a landfill (De La Cruz, 2022). Therefore, although some Puerto Rican residents may be diligent about recycling, their materials are not kept separate by the government-supported trash collection for recycling. It is required by law for Puerto Rican municipalities to recycle, but 20 of the 78 municipalities do not have any sort of a recycling system (Glatsky, 2019). Currently, 86% of waste in Puerto Rico goes to one of twenty-nine landfills on the island – "most of which are over capacity and noncompliant under RCRA Subtitle D, or otherwise referred to as 'open dumps'" (Glatsky, 2019). Residents of Toa Alta, Puerto Rico have seen the effects of overfilled landfills; the area has been building up with pollution in the past decade, which residents suspect has led to foul odors and increased illnesses (Cruz, 2021).

2.5.1 IFCO Recycling Inc.

IFCO Recycling is one of the main recycling companies in Puerto Rico. IFCO has four recycling plants located in Caguas, Bayamón, Gurabo, and Guayanilla, with a fifth one in planning stages for the southern part of Puerto Rico (IFCO Recycling. (2015). IFCO recycles and processes twenty-four classifications of materials, which include cardboard, mixed papers, magazines, plastics, and glass, and has been in business for over forty-five years. Their mission is to "offer clients the most competitive, efficient and complete recycling service in Puerto Rico always guided by the sustainability of our environment" (Refsnes, 2015).

2.6: Recycling Glass

Unlike the Caño Martín Peña area, places like the United Kingdom and Maryland, US have a history of glass recycling. In 1999, only 38% of glass containers in the United Kingdom were recycled (Dyer, 2014). Companies like British Glass have worked on initiatives in the past twenty years to increase glass recycling in the UK. They have identified that green wine bottles make up 68% of the glass waste in the UK and provided methods to the community on how to recycle and repurpose the glass (British Glass, 2020). Through the initiatives of British Glass, 81% of glass containers were recycled by 2010 (Dyer, 2014). In Maryland, the implementation of glass recycling processes has reduced the costs of their landfills. Each ton of crushed glass that is recycled saves 1.2 tons of raw materials in the manufacturing of new glass (O'Malley, 2014). With the average tipping fee for Maryland landfills being $58 per ton, the Maryland

municipality has been able to avoid nearly $173 million in tipping fees in 2012 (O'Malley, 2014). Recycling has also allowed for conserving landfill capacity. In 2012, Maryland recycled three million tons of material, which saved an estimated 6 million cubic yards of landfill space. Recycling also creates more jobs in the recycling industry. In a 2011 paper by the Natural Resources Defense Council, it was estimated that the reuse and processing of glass created 9 jobs per 1,000 tons of material recycled.

2.6.1: Methods of Glass Recycling

Analyzing the different glass recycling methods can help us determine which would be best for Caño Martín Peña. There are two main types of recycling: closed-loop recycling and open-loop recycling. Closed-loop recycling of glass focuses on recycling glass waste, also known as cullet, by melting it and mixing it with other raw materials to produce a new rendition of the same product that the glass previously was. The process of remelting glass is something that can be repeated multiple times. For closed-loop glass recycling, color sorting is important before melting the glass; assorted colors of glass have different tolerance levels on contamination; as a result, assorted colors should not be melted together (Dyer, 2014). Open-loop glass recycling can also include remelting glass but does not produce the same product. Open-loop glass recycling focuses on alternative products that the glass can produce (Dyer, 2014). Both processes are beneficial for the environment and aim to eliminate glass waste, however open-loop recycling has been seen to provide more economic benefits to communities due to the unsteady market price for cullets (Dyer, 2014). Open-loop glass recycling has many different resultant products that could be beneficial to Caño Martín Peña. One alternative product is simply using glass to create a new and different glass product, such as landfill cover material.

2.6.2: Recycling Glass into Landfill Cover and Construction Materials

Glass can be used as an aggregate for landfill cover materials. From a recycling center in Seattle, Washington, an evaluation was done on the properties of recycled glass landfill covers. Landfill covers with recycled glass excelled in their performance as a supplement or replacement for gravel landfill covers (Shin, 2003). Since glass contains amorphous silica rather than crystalline silica, it did not pose the health risks associated with sand. No appreciable environmental impact could be detected with the use of glass. The costs were competitive with or less expensive than conventional aggregates (Shin, 2003). Another open-loop glass recycling process is using glass as a cement component, specifically soda-lime silicate glass. These building materials could be used in the infrastructure projects that ENLACE has envisioned within their master development plan. To create crushed waste glass (CWG) for construction material in an open-loop process, the glass waste must be a certain chemical composition which is determined by the glass type. There are four distinct types of glass waste: soda-lime glass, lead crystal glass, borosilicate glass, and electric glass (Mohajerani, 2017). The most common type of glass that can be found in the Caño Martín Peña area are glass bottles that are used for soft drinks and beer. These glass bottles are commonly created with the soda-lime glass type, which is well suited to recycle into construction aggregates due to its inert properties and non-biodegradability (Lee, 2007). This allows for the glass to be used in more useful applications while freeing up valuable space for biodegradable materials in landfills. Recycled glass can also assist in highway construction by incorporating glass in bituminous highway pavement. Glass can be used on the surface, the base, as well as the

binder of the structure. The benefit of using glass in bituminous highway pavement is that it provides skid resistance. By adding the glass into the pavement, it becomes more permeable, meaning the surface allows for liquid to pass through; this is a safety benefit for when it rains, the water has an easier time flowing through it meaning flooding is less likely (Dyer, 2014). This form of glass recycling could be beneficial to the Caño Martín Peña area because of the frequent flooding of the canal.

2.6.3: Recycling Glass into Art

Recycled glass can be transformed for art, a company that has been working with glass waste is Xaquixe, located in Mexico. This company uses glass bottles to produce glass products such as glasses, jugs, and mezcaleros. The Xaquixe pro-environmental process (PPX) is a team working on sustainable technologies to create innovative pieces of artwork, they partner and collaborate with small artisan companies. In the PPX Impact and Learning report of 2014-2016, they reported that each month 1100kg of glass waste was transformed into new products. Additionally, the report indicates that Xaquixe reformulates 95% of raw materials into crystal-quality glass (Xaquixe, 2020).

CHAPTER 3: METHODS TO ACHIEVE OUR PROJECT GOAL

This chapter contains the methodology that our team followed when completing our project on the feasibility of glass recycling in Caño Martín Peña. The methodology is separated into four objectives, which are listed below. These objectives are discussed in-depth throughout the chapter.

1. To understand what recycling currently looks like in Caño Martín Peña.
    a. To review ENLACE's documents on plans, meetings, and interviews related to recycling information.
    b. To interview Martín Peña Recicla, INC. on current recycling procedures in place, including how often recycling is occurring, how much of each material is recycled, and what the current uses of these recycled materials are.
2. To investigate and document the amount of glass bottles being sold per week by businesses in and around the Marina neighborhood
    a. To speak with community members and business owners to get a general idea of glass waste in the area.
    b. To survey restaurants, bars, and convenience stores on their number of one-way bottles sold and waste management policies.
3. To explore potential uses for recycled glass that are feasible and profitable for Caño Martín Peña.
    a. To research methods of glass recycling in other areas of the world.
    b. To speak with community members and business owners to understand what recycling methods would be feasible and profitable.
    c. To investigate the amounts and costs of these glass recycling methods.
4. To provide deliverables to ENLACE and Martín Peña Recicla, INC. to support the implementation of glass recycling in Caño Martín Peña.
    a. To provide recommendations of methods to recycle glass to ENLACE
    b. To provide an outline of steps that the team completed to produce these deliverables for ENLACE to apply these methods to other aspects and neighborhoods surrounding the Caño Martín Peña.

3.1: To understand the current state of recycling in Caño Martín Peña.

The first step in obtaining this understanding was to read and markup the quantitative and qualitative data that ENLACE has collected regarding recycling. After reviewing these documents, our team toured Martín Peña Recicla, INC. (MPR), a recently developed recycling company in the Marina neighborhood, and spoke to leaders of MPR to understand what current processes are in place for waste management. This tour and interview provided more specific information on recycling materials and processes in place today. This understanding allowed us to develop relevant questions for the following objectives of determining the weekly number of glass bottles being sold per week by businesses in and around the Marina neighborhood, and exploring potential uses for the recycling of glass that would be feasible for Caño Martín Peña.

3.2: To investigate and document the number of glass bottles being sold per week by businesses in and around the Marina neighborhood.

The second objective within the project goal was to investigate and document the number of weekly glass bottles being sold within the north side of the Caño Martín Peña. The purpose for this was to assess the project's feasibility and if it is beneficial for ENLACE. To assess the weekly number of glass bottles being sold in the community, the team took two major steps. First, we wanted to collect information on the communities' opinions surrounding recycling and if they would be willing to participate in recycling. Our team entered in conversations with community representatives and shop owners to assess their willingness to recycle, using the Informed Consent Script in Appendix B. Second, our team sought to find out the weekly number of glass bottles being sold in the community. Our team surveyed business owners that sell single-use glass bottles. The survey focused on questions surrounding how many glass bottles they sold weekly. The survey used can be found in Appendix C.

3.3: To explore potential uses for recycled glass that are feasible and profitable for Caño Martín Peña.

The third objective within our project goals is to explore potential uses for the recycling of glass that are feasible and profitable by investigating different uses and costs recycled glass can offer to the Caño. One potential use that recycled glass can provide is construction materials, specifically landfill materials. This would benefit the OLIN development plan since ENLACE will need to cover the rubble created throughout the construction and demolition from numerous projects. For the next 10 years, the Caño will be undergoing the dredging process. By reviewing the future construction projects with ENLACE, we estimated the total landfill cover needed. The landfill cover then can be created with pulverized recycled glass from the Caño. Glass use to be pulverized at Reciclaje Del Norte, a company in San Juan that collects recycling, but they have stopped crushing glass since Hurricane Maria. By interviewing Reciclaje Del Norte, we determined the maintenance, training, and initial costs to purchase machines to crush glass. The information can then be used as an idea for a future glass crushing startup business. Our team would need to find whether this plan would be profitable to enact through the investigation of the total cost it would take to create the needed amount of fill material with recycled glass versus traditional landfill cover material. We will also need to determine if Caño produces enough glass waste to create a realistic amount of fill material. Determining the amount of glass produced in Caño will have been completed in the second objective. However, construction materials are not the only uses for recycled glass. Alternative recycled glass uses for the Caño besides construction material for ENLACE is important due to the inevitable dissolution of the ENLACE corporation after the dredging is completed. However, it may be difficult for ENLACE to implement these changes if the infrastructure to collect and recycle glass is not established within the Caño. Our team plans to offer multiple uses for recycled glass that would benefit the Caño community.

3.4: To provide deliverables to ENLACE to support the implementation of glass recycling.

Our team provided ENLACE with suggested methods on what to do with the glass once obtained. A project idea presented to us was using pulverized glass in soil to help with the

agriculture and gardening in the community. By surveying the community and businesses, we gained an estimate on the number glass bottles being sold in the north side of Caño Martín Peña. We then determined if these projects presented by our sponsor were feasible in the community, as well as any recommended projects of our own through the research we conducted. On top of the research we conducted, the information the team gathered from the surveys and interviews conducted will also be provided to ENLACE. After the team's research was completed, a guidebook was provided to ENLACE for them to apply these methods to other aspects and neighborhoods surrounding the Caño Martín Peña. Due to the limitation of time that we had in Puerto Rico, our team only focused on the North side of the Caño Martín Peña; however, we believe that similar methods can be implemented to the other communities around the Caño Martín Peña as well. The guide captures all the work and data obtained in these past seven weeks and locates them in one area so that it is easier to read. The reason for this guide is to ensure that once our project team has finished our time here in Puerto Rico, the glass recycling initiative will continue and spread throughout the Caño Martín Peña. This guide was provided in both English and Spanish and allows our sponsor to continue working on the glass recycling initiative even when our team’s time in Puerto Rico ends.

CHAPTER 4: RESULTS AND ANALYSIS

This chapter will discuss the results from the surveys and interviews conducted by the team while in Puerto Rico. Our team focused on the northern side of the canal, where the majority of the local bars and businesses are located. However, we hope the results from this report can be extended to other parts of Caño Martín Peña. Since we surveyed the most visited establishments on the northern side of the canal, the estimations from our data should account for more than 50% of the glass bottles sold in the northern Caño Martín Peña areas.

4.1: Interview with Martín Peña Recicla INC.

Martín Peña Recicla, INC. is a community organization that believes recycling may be one method of removing pollutant waste in the Caño Martín Peña. We met with one of their employees, Miguel Naveira, who has a background as an environmental scientist. We spoke with Miguel Naveira on March 25th, 2022, and our team learned much more about the history and current state of recycling in the Caño Martín Peña area. Martín Peña Recicla, INC. was created in 2011 to collect plastic types one and two, paper, cardboard, and aluminum via collection bins, and then recycle them by crushing or crushing the materials to be sold throughout Puerto Rico or overseas. According to Miguel, the community is engaged with the efforts for recycling, however the challenge lies in educating them on how to recycle since often the trash set aside for recycling can be contaminated with other substances. To address this issue, Martín Peña Recicla has provided the community with detailed instructions on how to set aside trash for recycling, for example plastic containers must be clean and cardboard must be dry. In the future, Martín Peña Recicla seeks to educate children on environmental consciousness, collect and recycle materials that would instead go to landfills, create jobs, and most importantly increase the environmental value for the community surrounding the canal. As of 2020, the microbusiness of only two employees has recycled about 90,000 pounds of raw materials. However, most of these materials are paper and cardboard because recycled plastic and aluminum are difficult to process and sell in the San Juan area. Martín Peña Recicla, INC. has a contract with the San Juan municipality, which provides them with about $4,000 a month. The small business has won several awards to recognize their environmental efforts; one of these awards is the World Quality Award from the Environmental Protection Agency. Although Miguel is proud of the environmental efforts that his company has been able to achieve, he hopes to improve community awareness of waste and recycling within the canal area. Our team has learned from Martín Peña Recicla's environmental actions and has found the education of community members necessary to implement glass recycling.

4.2: Interview with Bloques Caribe Inc.

On April 22, 2022, our team interviewed José Mercado Quintana, the administrator of Bloques Caribe Inc. (BC) in Guaynabo, Puerto Rico. Bloques Caribe Inc., is a construction company that produces concrete blocks, specifically made from limestone and pulverized glass. Each glass bottle collected is pulverized by a glass pulverizer, the pulverized glass is added with limestone

grains to produce a concrete mixture. After this mixture is created, it is then formed into block-like shapes and dried for 24 hours. These concrete blocks are then shipped to the desired customer. Each cement block is sold for 89 cents wholesale and $0.98 retail when manufacturing cost is equal to 50 cents per block. In the past year, they sold approximately 9.7 million cement blocks across the island of Puerto Rico. There is a demand for Bloques Caribe Inc.'s cement blocks, José informed our team that Bloques Caribe Inc. has attended multiple meetings with the municipalities in Puerto Rico, however the government officials were not interested in assisting with the company's environmental efforts.

A glass pulverizer, like the one Bloques Caribe Inc. pulverizes glass to a maximum size of 3/8 inch in each direction. The glass pulverizer is able to crush 1 ton of glass per hour but is only running for about 20 hours a week; therefore, the glass pulverizer pulverizes 20 tons of glass per week. These cement blocks contain 10-12% weight of pulverized glass, of the total 30lbs per block. Bloques Caribe Inc. gets their glass from nearby communities that want to recycle their glass bottles instead of disposing them into landfills. These nearby communities have verbal agreements with BC to ensure a constant supply of glass is being brought to the facility. In our interview with Quintana, he explained that the main purpose behind using glass in the cement block mixture is to help the environment; utilizing pulverized glass is also economically beneficial for the company.

Figure 5: A handful of pulverized glass at Bloques Caribe Inc., image taken by our project team.

Figure 6: A piece of pulverized glass at Bloques Caribe Inc., measured to be 10.16 mm.

4.3: Interview with Reciclaje Del Norte

Figure 7: The Reciclaje Del Norte Santurce Distribution Center, image taken by our project team.

On April 22, 2022, our team interviewed Rubén González Abreu, one of the owners for Reciclaje Del Norte (RDN) in Santurce. RDN has recycling centers across Puerto Rico that have been in operation since 1996. The role of RDN is to collect recyclable materials from businesses and

homes, then prepare the materials to be either exported off the island or sold domestically to clients. For example, RDN has exported recyclables, such as plastic, to processing plants in Guatemala or Costa Rica. Some more images of RDN's recycling facility are in Appendix F. As for glass recycling, Reciclaje del Norte charges community members to drop off glass at their facility. RDN then donates glass to businesses that produce concrete blocks (like Bloques Caribe Inc.), since RDN cannot find anyone that wants to purchase un-recycled glass-waste. To sustain the glass recycling operation, which operates at a revenue loss, RDN charges $0.25 per pound (approximately $550 per ton) of glass to people who bring their glass to their distribution centers. RDN also charges a custom fee to private companies that hire RDN to collect recycling from nearby businesses. According to González Abreu, an obstacle that RDN faces is that the government does not support glass recycling programs. People do not want to pay a fee to get their glass recycled which disincentivizes glass recycling. Previously, RDN crushed glass in 2011-2012 by driving a truck over bottles; however, RDN discontinued this service because their crushing method provided inconsistent glass sizes and damaged their recycling trucks. González Abreu mentioned that RDN would be open to crushing glass again to cater to specific clients, but it does not make sense for them as of April 22, 2022.

Figure 8: Reciclaje Del Norte's glass bottle pile to be donated

4.4: Interview with OLIN Labs

On April 26, 2022, our team interviewed Rebecca Popowsky, the OLIN Labs external research coordinator. At OLIN Labs, they are currently conducting research to further the development of their soil-less soil project. OLIN hopes to pulverize glass as a substitute to sand; the soil is a 60/20/20 mix of sand, compost, and natural soil, respectively. In the 60% sand mixture, OLIN has researched different glass-to-sand ratios that provide preferable properties such as water infiltration. Currently, OLIN is working with a 50/50 mixture of glass and sand. Glass has a higher pH and is more hydrophilic than natural sand, so increasing the glass content in the

mixture changes the property of the soil by retaining more water. An increased amount of glass in the mixture can be useful for greenhouse applications where soil that retains more water would benefit plants, but it would be less desirable for stormwater infiltration purposes where water flowing through soil is necessary. OLIN Labs has been researching soil-less soil since 2018 and has conducted two studies on the use of the soil in greenhouse applications by analyzing the performance of glass soils versus natural soils. From these studies, the glass soil had either excelled or performed as well as natural soils. OLIN sources their recycled glass from the Philadelphia municipality, and the glass is shredded to the same size distribution as ASTM C33 concrete sand, as shown in Table 1.

In 2023, OLIN plans to open a pilot factory to begin pulverizing glass at a larger scale in Philadelphia. To pulverize glass, OLIN is using an Andela GP-MegaMini, which is the same brand pulverizer at Bloques Caribe Inc.. These machines pulverize glass to a maximum of 3/8", which is falls within the ASTM C33 distribution. To create the soil-less mixtures, they seek local soil blending businesses. The overall goal is to make the costs to purchase soil-less soil as competitive as traditional soils.

Table 1: ASTM C33 Gradation Specifications for Fine Aggregates (United States Department of Agriculture)

Sieve	**Percent Passing**
9.5 mm (3/8")	100
4.75 mm (No. 4)	95-100
2.36 mm (No. 8)	80-100
1.18 mm (No. 16)	50-85
0.60 mm (No. 30)	25-60
0.30 mm (No. 50)	10-30
0.15 mm (No. 100)	0-10

Popowsky mentioned other OLIN projects that have the potential to use pulverized glass or soil-less soil; one of these projects is to use glass as a dredging material for shoreline restoration in Baltimore Harbour. This research is still in the initial stages of development, so further studies are required to determine the possibility of utilizing glass across other OLIN projects.

4.5: Survey Results

The team surveyed local businesses in the Marina and Barrio Obrero Oeste neighborhoods on the number of glass bottles they sell. Our team explained the intentions of our survey using the Informed Consent Script in Appendix B. The businesses surveyed can be found in Figure 9 below. The survey presented to the different businesses can be found in Appendix C. The results of the survey show that 100% of businesses are willing to recycle glass if an incentive is presented to them, but 0% are involved in recycling of any sort. 4 out of the 8 businesses that participated in this survey said that they would prefer business promotion over any other incentive to recycle. The data quantifying the number of glass bottles thrown away weekly by each business surveyed can be seen in Table 2, all other results from the survey can be found in Appendix D.

Table 2: Weekly number of glass bottle sales per establishment.

Name of establishment	Average number of bottles sold by establishment per week
El Retorno	163
La Esquina de Eli	138
La Milagrosa	500
Father and Son	1,250
Colmado cuchilandia	188
Colmado and liquor store Cibao	1,375
Agencia Hipica 217	450
Copa del Chevere	200
Total	4,264

The map in Figure 9 indicates the location of the businesses surveyed by our team. The map is color-coded to display the number of glass bottles sold per week, as well as different symbols to show the different types of establishments we visited.

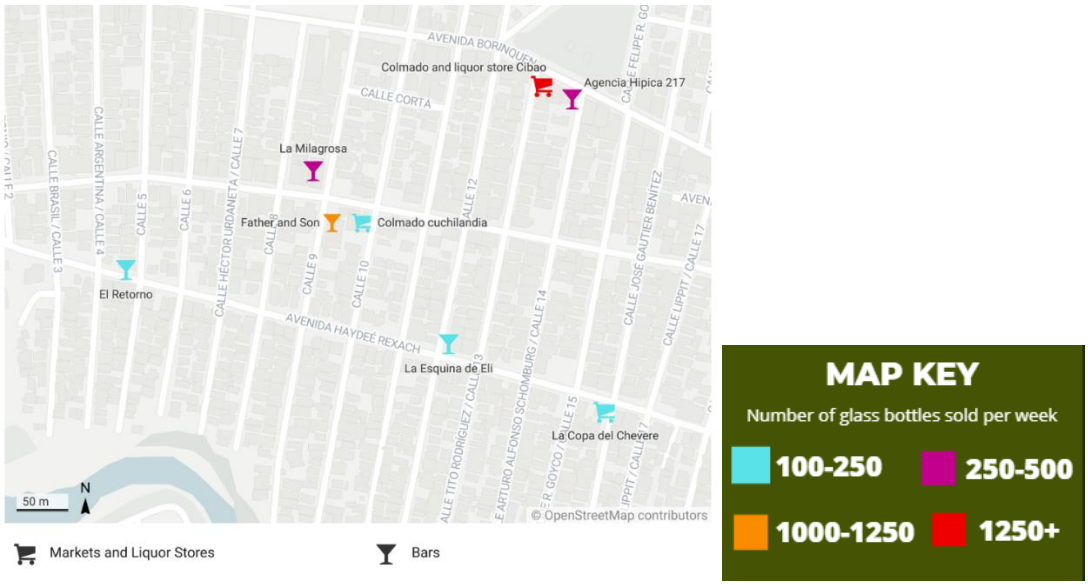

Figure 9: Map of businesses that our project team surveyed.

4.6: Estimated Number of Glass Bottles Sold Annually

Feasibility studies are commonly done on yearly estimates. For that reason, we have derived yearly estimates of the number of glass bottles sold. By multiplying the values in Table 2 by 52, the number of weeks in a year, the estimated yearly number of glass bottles sold by surveyed establishments were found on Table 3.

Table 3: Estimated number of bottles sold per year per establishment.

Name of establishment	Number of bottles sold per year
El Retorno	8,450
La Esquina de Eli	7,150
La Milagrosa	26,000
Father and Son	65,000
Colmado cuchilandia	9,750
Colmado and liquor store Cibao	71,500
Agencia Hipica 217	23,400
Copa del Chevere	10,400
Total	**221,650**

In addition, we derived the estimated yearly weight of glass bottles sold by surveyed establishments. We estimated the weight of each glass bottle to be 200 grams and multiplied it by the yearly number of bottles sold. The resulting value was then converted to metric tons using the conversion: 1 metric ton is equal to 1,000,000 (10^6) grams. The estimated yearly weight of glass bottles sold in metric tons by surveyed establishments can be found on Table 4.

Table 4: Estimated metric tons of glass sold per establishment.

Name of establishment	Metric tons of glass sold per year
El Retorno	1.70
La Esquina de Eli	1.44
La Milagrosa	5.20
Father and Son	13.00
Colmado cuchilandia	1.96
Colmado and liquor store Cibao	14.30
Agencia Hipica 217	4.68
Copa del Chevere	2.08
Total	**44.35**

4.7: Glass Recycling Calculations

The following calculations resulted from the above survey data. The spreadsheet used to calculate this data is in Appendix G.

4.7.1 Landfill Costs

The rate to send materials to the San Juan landfill site is $42 per ton of material; the rate was inquired from the San Juan County Landfill Management Facility. If the glass bottles surveyed from the businesses were transported to the landfill, it would cost $1,863 in landfill tipping fees to send approximately forty-four tons of glass bottles to the landfill per year.

4.7.2 Glass Pulverizer Data: Andela GP-Mini

The cost to purchase and ship an Andela GP-Mini to San Juan, Puerto Rico is $38,450. The cost was directly quoted from Andela Products. The specifications of the GP-Mini can be found in Appendix H. The GP-Mini uses 4.1 kW of electricity to run the motors. With the commercial electricity rate in San Juan at 24 cents per kWh as of 2022, Bloques Caribe Inc. pays $1024 per year operating the GP-Mini for 20 hours a week and 52 weeks a year. Bloques Caribe Inc. uses 4265 kWh of electricity to run the GP-Mini for the year, which equates to 1.8 tons of CO_2 emissions per year.

4.7.3 Cement Block Data at Bloques Caribe Inc.

From our interview with Bloques Caribe Inc. we know the weight of an *8”x8”x16”* block is 13,600 grams, and we know that its weight is 11% glass aggregate. We calculated the weight of glass per block to be 1,496 grams. This number was then converted to tons which yields 0.0015 tons of glass per block. The savings per block were calculated to be $0.05 based on the cost per ton of limestone. Based on Bloques Caribe Inc.’s 9.7 million blocks sold last year, the total savings in raw materials were calculated to be $507,892 from using glass aggregate for their cement blocks in 2021.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

This chapter will explain the conclusions and recommendations that our team defined once we analyzed our results and findings. In the limited time that we were investigating the feasibility of glass recycling, we were able to only scratch the surface of glass recycling purposes in the Caño Martín Peña area. However, we believe that our results and conclusions can provide a framework for ENLACE to recycle glass for the environmental and economic benefit of both themselves and the Caño Martín Peña. These conclusions and recommendations were provided to ENLACE via a guidebook located in Appendix I.

5.1: Key Conclusions

Businesses and residents around the Caño Martín Peña are willing to recycle if they understand the purpose behind it and the process is feasible. Our team found that the only companies that recycle glass in Puerto Rico utilize glass aggregate in cement blocks. Otherwise, glass waste is donated to other countries, littered, or dumped into landfills. However, throughout our surveys and interviews, all the businesses we spoke with were interested in glass recycling (see survey data in Appendix D, and interview summaries in sections 4.1-4.4 for more information). Miguel Naveira from Martín Peña Recicla, INC. emphasized this recycling interest when explaining the importance of education in the recycling process. According to Naveira, if residents of the Caño Martín Peña area were to understand the reasonings behind recycling and have simple steps to follow, they would be more willing to recycle their waste (Naveira, 2022). Our team sees these same principles applying to businesses in the Caño Martín Peña area, based on our survey results and interviews.

Recycling in Puerto Rico relies primarily on non-profit organizations and/or environmental groups because there is a lack of support from the local government. Without assistance and resources from the government, implementing glass recycling is a difficult task. Speaking with Miguel Naveira from Martín Peña Recicla and José Mercado Quintana from Bloques Caribe Inc., one thing is clear: the government is aware of many of the environmental efforts occurring across the island of Puerto Rico but chooses not to support them. José Mercado Quintana has engaged in many meetings with the Guaynabo and San Juan municipalities about his efforts in recycling glass bottles for cement blocks but has never been financially supported for his efforts. José Bauza informed our team that he has attempted to contact Miguel A. Romero Lugo, the mayor of San Juan, several times about his ideas for glass recycling projects for the Caño Martín Peña area and has yet to receive a response. There is a clear drive from community members to start recycling, the next step is to gain government support to fund the recycling processes.

Glass recycling is arduous to implement since, unlike plastics and metals, unrecycled glass has no monetary value. Businesses like Reciclaje del Norte have a difficult time making a profit from recycling glass, since they have yet to find a buyer for the glass waste material. To make a profit, businesses need to convert the glass into a finished product for sale, such as the concrete blocks from Bloques Caribe Inc.. These products often yield high initial start-up costs that we believe small businesses may be hesitant to invest. Our group believes that although the initial costs may be high, the environmental and economic benefits outweigh the upfront costs. For

example, Bloques Caribe Inc. saved approximately half a million dollars last year, see Appendix G, using glass aggregate in their limestone concrete mix. This shows that although there is a lack of options to recycle glass in San Juan, it has the potential to be a successful area of business for the Caño Martín Peña area.

5.2: Recommendations for Future Initiatives

We recommend that ENLACE encourages businesses in the Caño Martín Peña area to recycle their glass bottles through an incentive program. Based on the data collected from our team's survey, found in Appendix D, we concluded that business promotion and money were the top incentives for recycling glass waste for businesses in the Caño Martín Peña area. José Bauza informed our team of a community website, created by ENLACE, that displays local businesses and surveys in the Caño Martín Peña area (more information located in Appendix A). Our suggestion to ENLACE to help promote businesses is to create online flyers for them on the website Hecho en el Caño website (link: http://hechoenelcano.org/) This could potentially bring more customers (inside and outside of the Caño neighborhoods) to their businesses. For a monetary incentive, our team suggests running a program similar to the volunteer program ran by the G-8. This program rewards community members by rewarding their volunteer hours with "coupons." These "coupons" can be used to shop for clothes, cleaning supplies, and other necessities, all of which are donated by community members and local businesses. This program could be implemented for the business owners in the Caño Martín Peña area; if they recycle a certain weight of glass bottles, then they could get a "coupon" to use for restaurant/market supplies. This recommendation is to help start the process of glass recycling in the Caño Martín Peña area and could be worked on by future IQP teams.

We recommend that ENLACE and Bloques Caribe Inc. come to an agreement to recycle glass from the Caño Martín Peña area. Bloques Caribe Inc. receives glass waste (for free) from several communities around the Guaynabo area and pulverizes them into aggregate, which then is used in their cement block mixture. These communities have verbal contracts with Bloques Caribe Inc. to ensure that the company has a constant supply of glass for their production. If Bloques Caribe Inc. agrees to work with ENLACE, ENLACE could collect glass waste from businesses around the canal and transport them to Bloques Caribe Inc., for recycling. Thus, creating a business relationship that benefits both ENLACE and Bloques Caribe Inc. There are two options that our group discovered when investigating a recycling plan with Bloques Caribe Inc.. The first is to rent a semitruck to transport the glass waste to Bloques Caribe Inc. in Guaynabo. Our team recommends this option because it is the most direct. The first step in investigating this option would be to determine how much renting a semitruck would be for cost, and then determining how the glass waste could be collected from our surveyed businesses. The second option is to transport the glass to Reciclaje del Norte, which charges for glass bottle waste and sends it to cement block companies like Bloques Caribe Inc.. Reciclaje del Norte charges 25 cents per pound (about 550 dollars per ton) for glass to be dropped off at their facility, which is an added cost that can be avoided when working directly with Bloques Caribe Inc.; however, if transportation costs are high, this is a viable option to recycle glass for the same result of cement block material.

We recommend that ENLACE collects glass waste from businesses around the canal and starts a micro-business operating a glass pulverizer to produce glass cullets. Uses for the glass cullets should be explored further. Given glass is a heavy material, pulverizing glass on-site should be a focus as it eases transportation and reduces transportation costs to other entities outside the Martín Peña. The Andela GP-Mini is easy to operate, and takes 4.1 kW to run the machine, or 32 cents to run the pulverizer for an hour (calculations can be found in Appendix G). The Andela brand appears to be a well-known in the glass pulverizing industry considering OLIN and Bloques Caribe Inc. both own Andela machines. It would be simple to find the space and install the GP-Mini, but with a product and delivery cost of $38,450 per unit, the upfront costs would be high. However, the raw glass aggregate material can then be used to create valuable materials for the Caño Martin Peña Community. From our interview with Rebecca Popowsky, our team learned that starting a soil-blending business can easily be scaled down to operate on-site in the Martín Peña. Glass, sand, compost, and natural soil are the required materials to create the soil-less soil. The soil can be used in the construction for the Paseos, and may also be applicable to road construction. Additional research for the applications of glass aggregate is needed, but glass cullets, when crushed to the ASTM C33 concrete sand size distribution (shown in Table 1), have promising results for future applications. If an entrepreneur is willing to front a large startup cost, we believe that this microbusiness could be beneficial for environmental and economic aspects within the Caño Martín Peña area.

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APPENDIX A: PERSONAL REFLECTIONS FROM OUR TEAM'S FIRST MEETINGS WITH ENLACE

Our team wrote down personal reflections from our first couple of meetings with different employees at the ENLACE office. These reflections show our individual opinions which lead to our project decision.

Julia's Reflection:

I would like to thank Francisco De La Cruz, Estrella Santiago, José Bauza, Carlos Muniz, Estelí Capote, Nicole Rodriguez for meeting with us on Thursday, March 17th, Monday, March 21st, and Sunday, April 10th to share the details of the history and current projects within their specific divisions and/or provide our team with tours of the area. I look forward to working with you all in the future of our time here and hope to make an impact within the ENLACE Corporation!

Estrella's Environmental Division Presentation: Estrella's presentation provided me with a great overview of the history of the Caño Martín Peña as well as the surrounding communities from the nineteenth century to present day, and how these conditions impact the health of residents. Some great details were provided, such as the width of the canal being 200 meters at one point, that the government built and abandoned 260 homes in the northwest of the Caño Martín Peña communities, and that regular rainfall has resulted in 26 inches of flooding in recent years; these were details that our team was unable to find online, so it was great to get more of an inside look on the history of the canal and surrounding community. However, there was a lot of overlap in knowledge from the high content of Zika-carrying mosquitoes as well as the Health Impact Assessment completed in 2014. It was comforting to me that our research from miles away is relevant to information that ENLACE uses currently. I really appreciated the discussion of the National Ecosystem Restoration Plan which plans to increase the canal width and depth to 100 meters by 10 meters, respectively. This plan will hopefully reduce the flooding previously mentioned, which would reduce the negative health impacts such as gastrointestinal disease, asthma, and skin allergies. Estrella discussed that the relocation committee (which assists families that need to be relocated) is made up of families that were previously relocated to provide first-hand comfort to individuals experiencing this difficult moving process. At the end of the presentation, Estrella asked how our individualized skills would be beneficial to the ENLACE projects and vice versa, which I thought was a great question to better understand the purpose of our trip to San Juan. Thank you, Estrella, for sharing your time and knowledge with our team!

José's Economic Division Presentation: José's presentation provided me with a great understanding of the purpose and current projects within the economic division of ENLACE. The business incubator program was discussed in detail, including the ideation and workshop steps to the process and the several businesses that have grown throughout the program. Some of these companies are Bici-Caño, Martín Peña Recicla, Inc., and Jewel Pretty and Study Craft. These companies and several others are shown on http://hechoenelcano.org/, which is a wonderful way to highlight the businesses in the area. We also discussed the market which occurs on the second Sunday of each month and includes many shops, workshops, and

community activities. This market was originally an abandoned building that ENLACE worked to clean up. Then, José discussed some of the current and future projects involved with his organization, including the improvement of businesses within the abandoned Santiago Iglesias Pantín School, now functioning as a community center. Finally, José brought up the idea of researching glass recycling with the Marina neighborhood because of the waste from glass bottles in the area. There are many different applications that this glass could be used for, such as crushing into glass pulverizes for art, filling land with glass, and covering the well of pollution after the canal is dredged. This glass recycling project would include investigating how much glass that businesses produce, what the community would want the recycling process to be, how much this process would cost, etc. to provide recommendations to ENLACE on how to recycle glass in the Marina neighborhood. I think this would be a fantastic way to reduce pollution but would like to hear Carlos's proposal on Monday before making a final decision with the team. Thank you, José, for sharing your time and knowledge with our team!

Carlos's Infrastructure and Development Presentation: Carlos's presentation on the infrastructure development process provided me with a deeper understanding of the comprehensive development plan that Francisco had discussed in our previous meeting. Carlos described the theme that lack of resources produces lack of resilience, not the other way around, which was helpful to my understanding of the area. Carlos then went into depth about both the current state and planning for infrastructure placements in the communities surrounding the canal. Some details of the relocation process were mentioned, including how the infrastructure needs to be occupied by ENLACE for the urbanism and infrastructure team to be able to tear down the building and plan for redesigning the area. Carlos also provided our team with some of the plans for housing redevelopment, which seemed incredibly thoughtful and productive to the relocation process. These plans are also in a OneDrive file that our team will access in the coming weeks as preliminary research. Carlos's presentation highlighted the importance of keeping the canal clean because after the relocation occurs, it is important to stay vigilant about avoiding pollution, so all this urban design work does not go to waste. This presentation allowed me to understand the canal's neighborhoods more thoroughly. Thank you, Carlos, for sharing your time and knowledge with our team!

Bus Tour with Estelí and Francisco: Estelí provided our team with a bus tour of the northern Caño Martín Peña area. During this tour, our team was able to see different infrastructure present, pollution levels, and key areas for community involvement. The infrastructure varied from house-to-house, but it was clear which houses were remodelled or rebuilt for relocation purposes, and those that had been abandoned because the previous residents had relocated. It was also important for our team to see the types of waste left behind on the streets, which included lots of appliances and plastic. There were mostly large piles of trash in specific areas, but some locations (like the stables) had trash scattered throughout. This waste is like what I have seen back home in Worcester, but Worcester has smaller trash throughout the community while the Caño Martín Peña area has larger pieces of trash that seem abandoned. I look forward to investigating the community activities and businesses sooner, such as the recycling plant, market, schools, etc. to develop a greater understanding of the community to determine what project would benefit them. I also noticed that Estelí and Francisco have great connections with their community members, which is great to see! I am starting to understand this area more each meeting, which is making me even more excited to start working on an impactful project for this

community. Thank you, Estelí and Francisco, for sharing your time and knowledge with our team!

Bike Tour with Nicole and Francisco: Nicole and Francisco took our team on a Caño Martín Peña bike tour with the BiciCaño small business on April 10, 2022. As this bike tour occurred a few weeks into our research, this tour was a wonderful opportunity to reflect on our initial findings and remember the purpose of our project: to help improve the environmental conditions of the canal and surrounding areas. However, throughout this bike tour, I noticed some of the beauty within the area that was less apparent in some of our group's other trips to the area. This canal could easily be a tourist attraction after the dredging occurs if they can manage waste appropriately. Some of the areas even reminded me of trips to the lakes in New Hampshire from when I was younger. I thoroughly enjoyed the community garden in the southern region of the canal, which had several different plants I had heard of and several more that I had not. This was a reminder to me that although there are many things that I know about the Caño Martín Peña area from research before and during our project time, there is so much more I can learn. At the end of the bike tour, our team visited the artisan market where we saw community members exchanging food and hand-made goods. Thank you, Nicole and Francisco, for sharing your time and knowledge with our team!

Tatyana's Reflection:

Estrella works with the health and environmental impact of the community. Her department shows how the neglect of the environment has had a major impact on the health of the communities surrounding the Caño Martín Peña. She also described the history of the communities surrounding the canal and how that affected the present state. One project that her department works on is to inform the community on the health conditions that are prevalent in the area, like asthma and the Zika virus. Another project was working with the students as a program to better understand the environment. However, due to COVID-19 it has been difficult to start up this program with the students, many of the schools in the area have closed and it has been hard to stay connected to see how the students are doing.

José works with the economic department of ENLACE. His role is to help local businesses in the area in many ways, whether that is through helping obtain a loan, finding a place for the business to start up, there are multiple ways he helps the business in the community flourish. One process José talked about was micro incubation of businesses. A passion project that José talked about was the recycling programs and how we could help the recycling of glass in the area. In the neighborhoods there are many places where people will go and drink out of glass bottles, the issue is that little to no business recycle these glass bottles producing waste. Figuring out what places use the most glass waste, determining what places are willing to recycle glass, and the cost for the complete process of recycling glass. There are a lot of factors to consider in this project, but the end goal is to make businesses start recycling more. The big idea is that once the canal is dredged, we want to keep it clean, this is just one small process that can help eventually. Carlos works in urban development plans and urban design for ENLACE. His presentation to us was a brief history of the neighborhood and explaining why they are in the current conditions. He also explained a lot about the urban development master plan. This is a comprehensive plan describing what the plan is for the future of the neighborhood surrounding the canal. A big take

away from his presentation was that there are many projects focusing on the same goal and they plan to take a long time. What stood out to me was the idea of community empowerment and how it is a key element for change in urban development. I was extremely interested in seeing the slides about the future and the vision for the community. Some facts that stood out to me were that 1)85% of the district of communities surrounding the canal are in the flood zone, 2) the community has one of the highest working rates but is a community with higher poverty rates.

The bus tour was very eye opening for me. I have been writing about this area for so long but to see it in its entirety was a pleasant experience. My initial thoughts were about how much trash and waste were around the areas and neighborhoods. Lots of the trash was not new, it has been there for a while. It was also amazing to see how many abandoned buildings and houses there were in this neighborhood, however it also correlated to the fact that ENLACE was able to relocate the families living near the canal so that is why some of the houses were abandoned. It amazed me to see how many families were able to relocate because I know that is not an easy task. I also was surprised to see how easy it is to get glass waste, if you looked in any convenience store you could see a wall of glass bottles so now, I understand why glass waste is an issue.

Bike tour Nicole and Francisco: I think the bike tour was one of my favorite activities to do while working with ENLACE. The bike tour allowed for me to see the canal in a positive manner. So much of our report is focused on the Caño Martín Peña's in a negative light, describing what is wrong with it, why is hurting the communities, etc. While on the bike tour we got to see it for its beauty. It was great to see the animals, like the turtles, swimming in the water. At one of our stops, we saw a man feeding the turtles bread and just watching them water, it was very wholesome. The bike tour also allowed for our group to have fun with one another, it gave us a nice break on the weekend to go and explore together.

Newton's Reflection:

Our first experience with the sponsor of Caño3.7 gave us a clear understanding of Caño Martín Peña's background, current projects, and the goal of the organization. The background reflected our research well, except there was a larger involvement of the mangroves in the health of the canal than we expected. Within the organization, there are many stakeholders. We learned that the comprehensive development plan was not only created by ENLACE but by the local communities within Caño Martín Peña also. We got to learn how much involvement the community had in the construction efforts which created a bottom-up structure in the Caño Martín Peña organization rather than a typical top-down organization you would expect to see from a government organization. There are many projects that ENLACE is working on and many suggestions they presented. Estrella presented the work on the canal and why the dredging of the canal was particularly important to the Caño Martín Peña and San Juan. José, the economic developer, presented his idea of a glass recycling program that would recycle glass into construction materials. Francisco presented the Triangulo Artisan Market that ENLACE wishes to develop into a food truck plaza. Many ideas were presented and as a team, we are planning to scale down our project scope to a more concentrated area; however, the methodology of our project will still be relevant. We are still unsure what to concentrate on, but we are sure we want to provide a deliverable for the community and ENLACE.

Our team had the opportunity to meet with Carlos, the Urbanism and Infrastructure manager for ENLACE. Carlos presented the infrastructure goals of the Caño Martín Peña along with the projects that are under construction or are completed which help accomplish those infrastructure goals. There appear to be two different plans for Caño: the OLIN plan and the Master Plan; however, I am unsure if this is a misunderstanding. Carlos explained to us the significance of the Caño to the community and the city of San Juan, and he explained how restoring the Caño would bring three dollars for every one dollar invested according to FEMA. The infrastructure that ENLACE builds is expected to have a 50-year lifespan. Since the infrastructure plans were created 10-20 years ago, many of them have become outdated for their expected life span. With current issues such as the rising sea levels from climate change, ENLACE must redesign their infrastructure plans from the older Master Plan created in 2004 with the newer OLIN plan. Carlos presented many useful maps that our team plans to analyze for our own project such as flooding maps, zoning maps, Community Land Trust maps, and demographic maps. Carlos also reiterated local community enterprises that José had touched upon such as the recycling program in the Marina neighborhood. These new pieces of information really helped our group understand the information Caño3.7 has collected and how our group can continue developing the master plan through a recycling assistance project proposal our group created.

Afterward, we had a bus tour with Francisco and Estelí that helped our team understand the conditions of the Caño. We got to view many of the project sites that were under construction that Carlos and Francisco had discussed. We also got to see many of the problems that ENLACE are trying to solve, such as the abundance of dead-end streets which make it difficult for emergency vehicles to navigate. We also saw lots of garbage on the streets which include broken appliances, vehicles with flat tires, and fences with trash piled on them. We also understood the lengthy process it takes to begin construction or demolition on the empty lots and buildings in the neighborhoods due to the amount of paperwork needed to acquire the land. There were many areas that needed to be worked on by ENLACE but imagining the amount of time it would take for the paperwork to be completed was overwhelming. At the end of the tour, we gave our condolences and now we have a promising idea of what our team can do.

Eduardo's Reflection:

In our first meeting with Enlace our team got to meet in person with Francisco, José, and Estrella. All of them are coordinators of different areas of Enlace. This meeting served as an introduction between ENLACE and us and as an overview of the current projects that ENLACE is working on. We proceeded with showing them our own project proposal regarding Urban development and Infrastructure. After all the presentations were done, it was clear that there are many options on the table for us to work on. We could adopt one of their ideas, such as a recycling project, or we could stick with our urban development proposal. However, if we were to stick with our development proposal it is clear to us that some changes need to be made since it can be too broad and extensive for the limited time we have in San Juan. Our project could be narrowed down to a smaller area instead of the whole neighborhood, or it could take a new focus entirely. I believe that in the following days our team should look to gain more clarity on what we want to do. As I see it, this is a question of whether we want to change our project proposal or simply reshape it.

Carlos is a coordinator in the Urbanism and Infrastructure division of ENLACE. This division, like many others in ENLACE, is complex and is tasked with many preparations for the future dredging of the canal. Carlos began with a detailed presentation regarding the Urbanism and Infrastructure development master plan. He went over the masterplan origins and how the need for government intervention in the Caño Martín Peña gave birth to law 489-2004 and consequently to organizations like ENLACE and the Community Land Trust. Through Carlos' presentation, our team got to experience a more in-depth explanation and vision for the future of the community. Thanks to Carlos, we can say we clearly understand the direction ENLACE's urbanization and infrastructure division wants to take for the future of the neighborhoods. In addition, it is important to mention a common theme among all presentations we have heard so far. That is the importance of community involvement. Carlos, Estrella, José, and Francisco have all made it clear how this project aligns with the community's vision for the future, and it is made to ensure the long-lasting presence of the community.

After Carlos' presentation, our team got to show Carlos and Estrella our own project proposal. This meeting, like the previous meeting, concluded that while our ideas and methodology were on the right track, a lot of the work had already been done by ENLACE themselves. Therefore, following their recommendations, we are now exploring a new direction for our project, but at the same time keeping the essence of the previous proposal, which was community empowerment.

A special thanks to both Francisco and Estelí for organizing this bus tour along the different communities of Caño Martín Peña. The tour began at the ENLACE office where we were joined by Francisco, Estelí, and our advisors. Estelí took us along the streets of Caño Martín Peña, more specifically Marina, Obrero Oeste, San Ciprian, Las Monjas, Parada 27, and Peninsula de Cantera. It is possible we went through other communities but given that there are not clear division lines it is hard to confirm. During our tour we saw many of the projects Francisco is currently working on. For example, the construction of the roundabout and the movement of the waterline running below the canal are two big infrastructure projects he is tasked with overseeing. For our team, this tour was very eye-opening since we got to see the community that we have researched so much about for the first time. It was remarkably interesting to see the many abandoned structures and houses along the streets and how these lots are ideally going to be converted to beautiful structures like the ones Carlos showed us in his presentation.

APPENDIX B: INFORMED CONSENT SCRIPT

The following informed consent script was read to participants of our interviews and surveys to ensure that they are fully willing to participate in our optional studies.

Informed Consent Script for Restaurants/Business Owners/Mangers/Employees:

Hi, my name is ___ and this is ___, ___, and ___. We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are inviting you to participate in a research study regarding glass recycling in the Marina neighborhood in Puerto Rico. We strongly believe this kind of research will enhance recycling procedures in place, as well as improve community understanding of recycling. This research will be published as a requirement for our graduation. This survey will take around fifteen minutes. We would prefer to use names and short descriptions such as "Manager of _ restaurant" in our report, but this is not necessary if you would like to remain anonymous. No addresses will be used in our report. Please remember that your answers will remain Anonymous if you please, so no identifying information would appear in any of the project reports or publications. Your participation in this interview is completely voluntary and you may withdraw at any time. This is a collaborative project between Caño 3.7 and Worcester Polytechnic Institute, and your participation is appreciated. You can contact us with any questions you may have by emailing gr-cano_pr_d22@wpi.edu. At this point, do you have any questions for us before we begin?

APPENDIX C: RESTAURANT AND LOCAL BUSINESSES SURVEY

Marina Neighborhood - Restaurant and Local Business Survey

This survey aims to understand how local business and restaurants contribute to glass waste in the Marina Neighborhood via glass bottles.

Informed Consent Script for restaurant and business owners/mangers/workers:

Hi, my name is ___ and this is ___, ___, and ___. We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are inviting you to participate in a research study regarding glass recycling in the Marina neighborhood in Puerto Rico. We strongly believe this kind of research will ultimately enhance recycling procedures in place, as well as improve community understanding of recycling. This research will be published as a requirement for our graduation. This survey will likely take around fifteen minutes. We would prefer to use names and short descriptions such as "Manager of local restaurant" in our report, but this is not necessary if you would like to remain anonymous. No addresses will be used in our report. Please remember that your answers will remain Anonymous if you please, so no identifying information would appear in any of the project reports or publications. Your participation in this interview is completely voluntary and you may withdraw at any time. This is a collaborative project between Caño 3.7 and Worcester Polytechnic Institute, and your participation is greatly appreciated. You can contact us with any questions you may have by emailing gr-cano_pr_d22@wpi.edu. At this point, do you have any questions for us before we begin?

Name *

Short answer text

Name of establishment *

Short answer text

Job title *

Short answer text

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Informed Consent Script for restaurant and business owners/mangers/workers:

Hi, my name is ___ and this is ___, ___, and ___. We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are inviting you to participate in a research study regarding glass recycling in the Marina neighborhood in Puerto Rico. We strongly believe this kind of research will ultimately enhance recycling procedures in place, as well as improve community understanding of recycling. This research will be published as a requirement for our graduation. This survey will likely take around fifteen minutes. We would prefer to use names and short descriptions such as "Manager of local restaurant" in our report, but this is not necessary if you would like to remain anonymous. No addresses will be used in our report. Please remember that your answers will remain Anonymous if you please, so no identifying information would appear in any of the project reports or publications. Your participation in this interview is completely voluntary and you may withdraw at any time. This is a collaborative project between Caño 3.7 and Worcester Polytechnic Institute, and your participation is greatly appreciated. You can contact us with any questions you may have by emailing gr-cano_pr_d22@wpi.edu. At this point, do you have any questions for us before we begin?

Name *

Short answer text

Name of establishment *

Short answer text

Job title *

Short answer text

On average, how many glass bottles do you sell in you establishment per week? *

- 0-25
- 25-50
- 50-75
- 75-100
- 100-125
- 125-150
- 150-175
- 175-200
- 200+

Do you participate in recycling? *

- Yes
- No

Would you be willing to participate if there was some incentive (ex: a reward system, business promotion, money)? *

- Yes
- No

Which incentive would best appeal to you? *

- Reward system
- Promotion
- Money

Would you be willing to name who your supplier for glass bottles (like beer and soda) is? *

Short answer text

Would you be willing to put a poster in your establishment about recycling? *

- ◯ Yes
- ◯ No

APPENDIX D: SURVEY RESULTS

Name

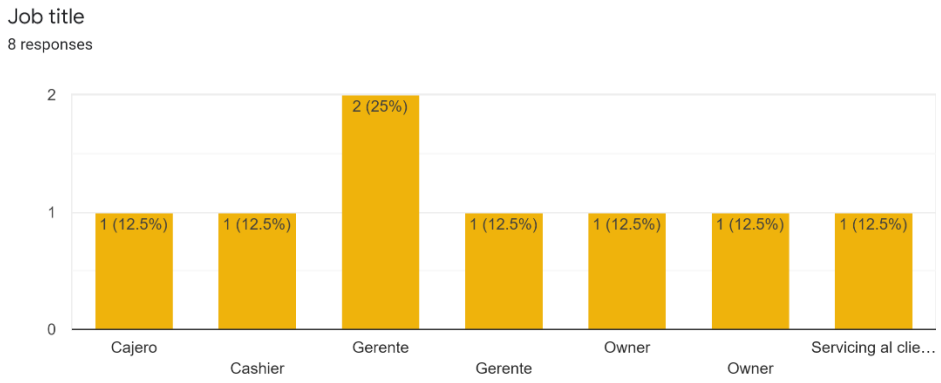
8 responses

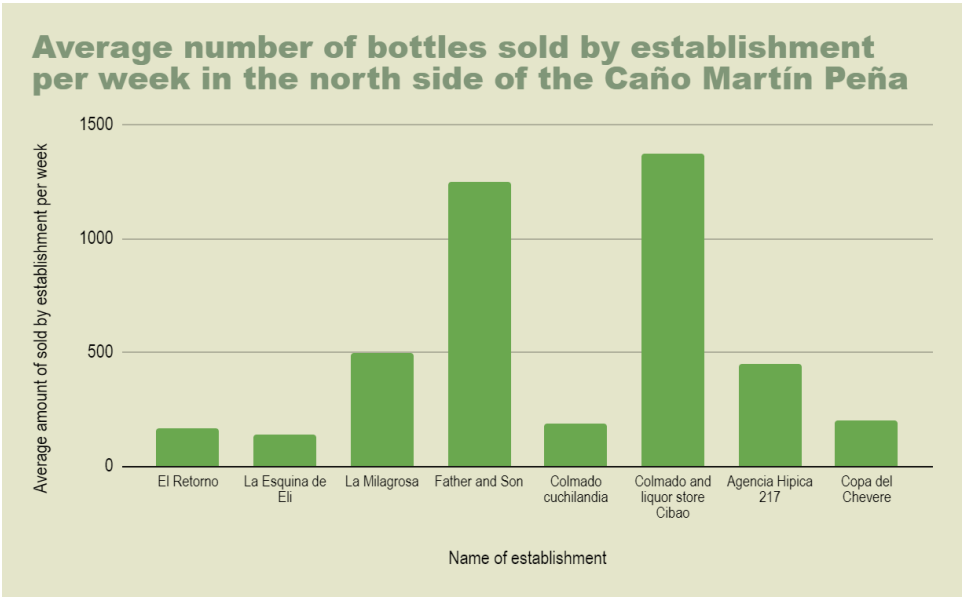
- Jesus
- Randy Santana Castillo
- Wanda
- Jorge
- Cira
- Aurora
- Neftali Hernandez
- Josue Diaz

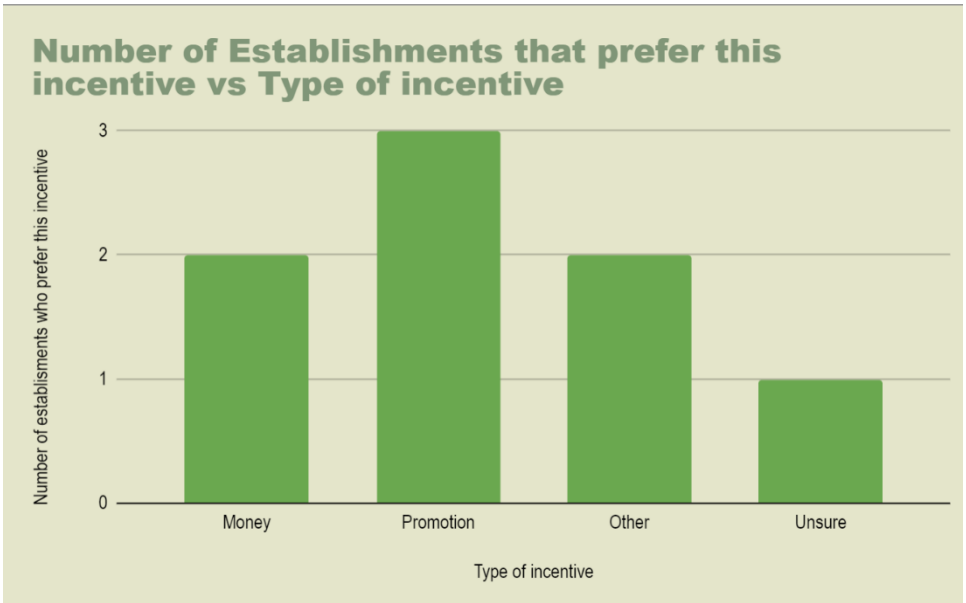
Name of establishment

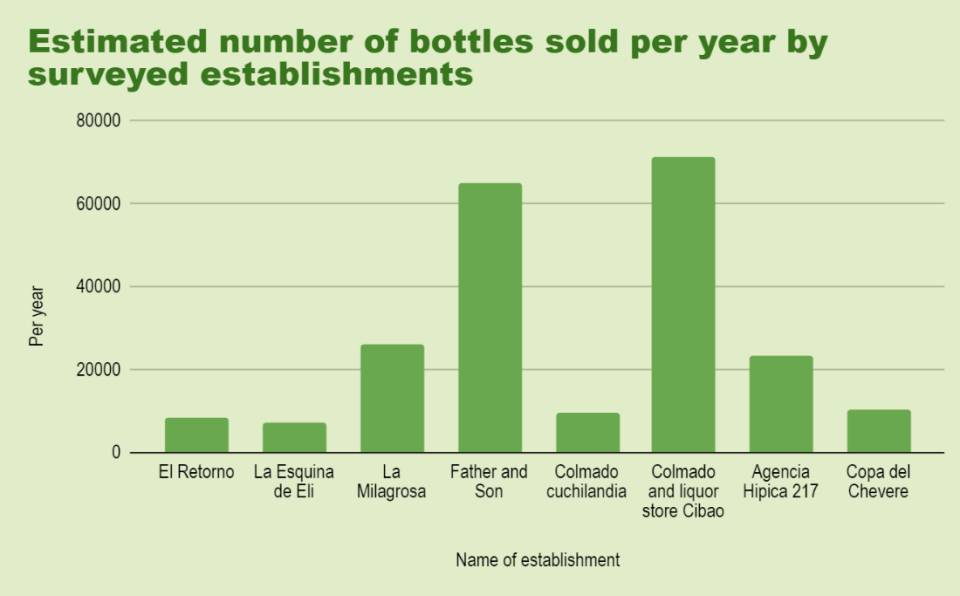
8 responses

- El Retorno
- Colmado and liquor store Cibao
- Colmado cuchilandia
- Agencia Hipica 217
- La Esquina de Eli
- Father and Son
- La Copa del Chevere
- La Milagrosa


Job title
8 responses
2
1
0
1 (12.5%)
1 (12.5%)
2 (25%)
1 (12.5%)
1 (12.5%)
1 (12.5%)
1 (12.5%)
Cajero
Cashier
Gerente
Gerente
Owner
Owner
Servicing al clie…

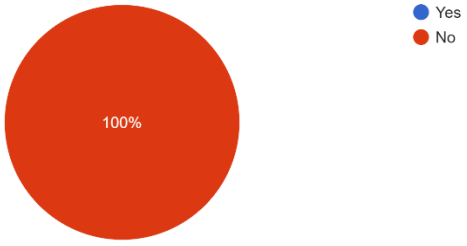

Average number of bottles sold by establishment per week in the north side of the Caño Martín Peña
Average amount of sold by establishment per week
1500
1000
500
0
El Retorno
La Esquina de Eli
La Milagrosa
Father and Son
Colmado cuchilandia
Colmado and liquor store Cibao
Agencia Hipica 217
Copa del Chevere
Name of establishment


Number of Establishments that prefer this incentive vs Type of incentive
Number of establismments who prefer this incentive
3
2
1
0
Money
Promotion
Other
Unsure
Type of incentive



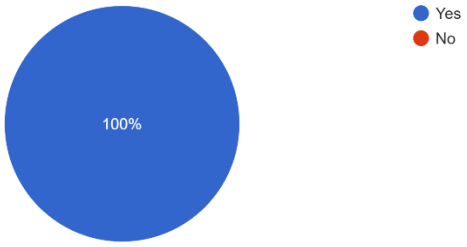
Do you participate in recycling?

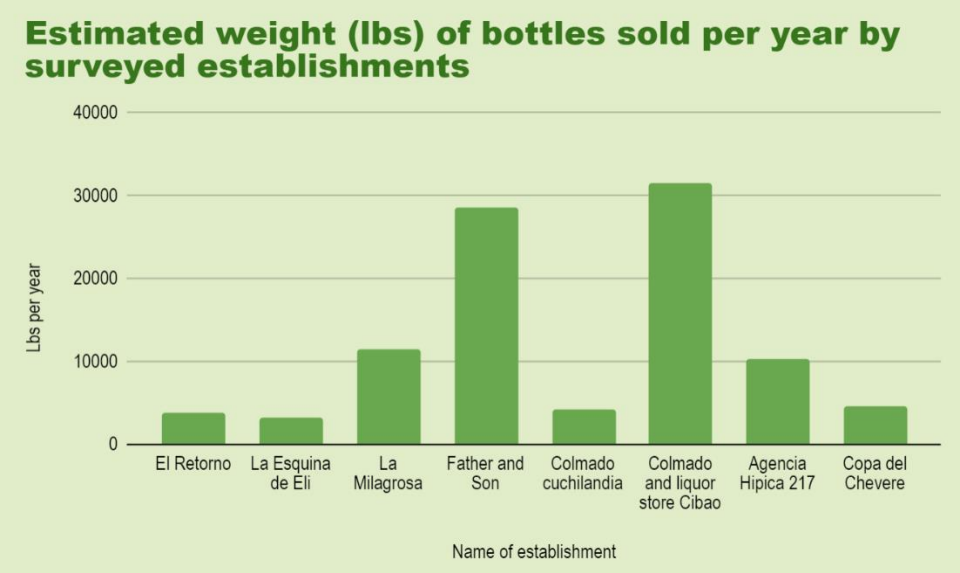
8 responses

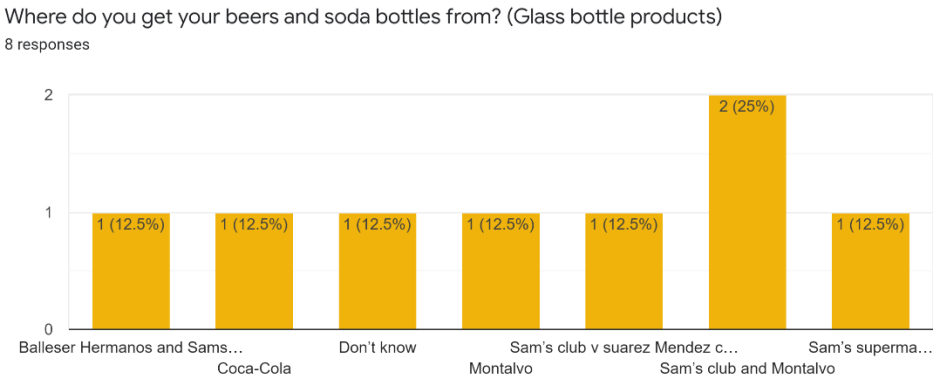


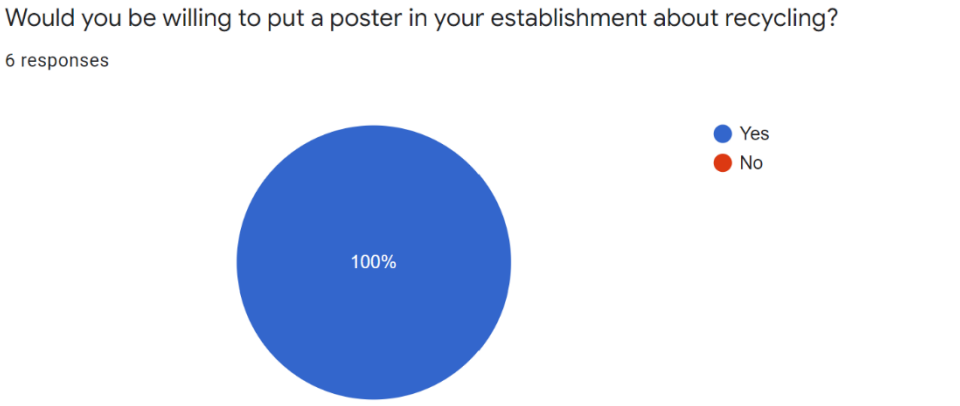
Would you be willing to participate if there was some incentive (ex: business promotion, money, other)?

8 responses




Estimated weight (lbs) of bottles sold per year by surveyed establishments
40000
30000
20000
10000
0
Lbs per year
El Retorno
La Esquina de Eli
La Milagrosa
Father and Son
Colmado cuchilandia
Colmado and liquor store Cibao
Agencia Hipica 217
Copa del Chevere
Name of establishment


Where do you get your beers and soda bottles from? (Glass bottle products)
8 responses
2
1
0
1 (12.5%)
1 (12.5%)
1 (12.5%)
1 (12.5%)
1 (12.5%)
2 (25%)
1 (12.5%)
Balleser Hermanos and Sams…
Coca-Cola
Don't know
Sam's club v suarez Mendez c…
Montalvo
Sam's superma…
Sam's club and Montalvo


Would you be willing to put a poster in your establishment about recycling?
6 responses
100%
Yes
No

APPENDIX E: ABOUT THE MARINA NEIGHBORHOOD

Within the Caño Martín Peña community is the Marina neighborhood, which is an area of about 0.18 square miles, located on the west end of Caño Martín Peña, shown in Figure 4 (Corporation of the ENLACE Project of the Martín Peña Channel, 2016). The median household income in the Marina neighborhood is $18,143, which is $5,000 less than the median annual income of $23,000 in San Juan (Data USA, 2019). The Marina neighborhood has assets that include a train station, artisan markets, the ENLACE office, and a municipal gym. As of early 2022, the Marina neighborhood is in the process of delegating potential sites to create an area for new housing for the residents currently living in flood-prone areas of the canal. There are about 1000 families that the ENLACE organization, a government entity responsible for the construction of Caño Martín Peña and the dredging of the canal, is planning to relocate. To begin the process of relocation, the Caño 3.7 corporation, through ENLACE, is working on the urban development of the Marina area which includes the planning, design, and construction of homes. (De La Cruz, 2022).

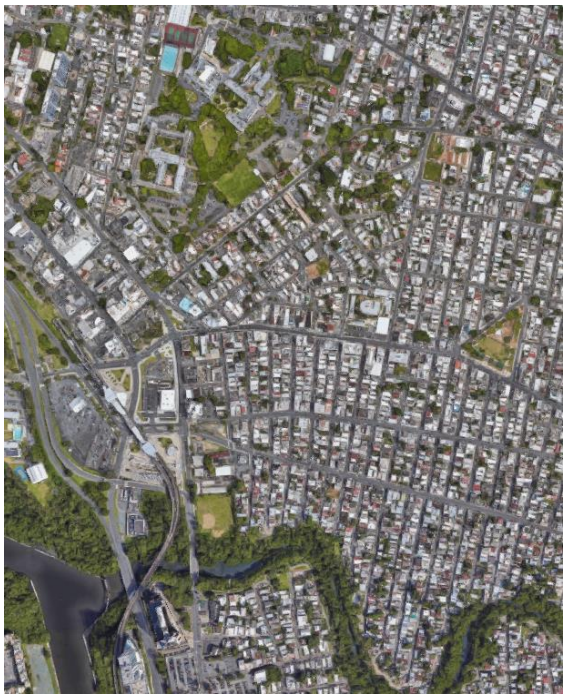


Figure 10: A satellite view of the Marina neighborhood (Google Maps, 2022).

The geography of the Marina neighborhood (shown in Figure 10) includes the Caño Martín Peña to its south, a major road that stretches from the train station to the Laguna Los Corozos on its north, a major highway (Highway 1) on the west, and the rest of the Caño Martín Peña to its east (Google Maps, 2022). The train station is located on the west side of the area along with another major road that stretches from south to north with many businesses and shops. This makes the Marina neighborhood a gateway into the Caño Martín Peña because of its connections to major transportation hubs like the highway and the train station unlike the other neighborhoods in the Caño Martín Peña. There is also Sagrado Corazón University that is in the northern vicinity of

the Marina (Google Maps, 2022). With an understanding of the pieces of infrastructure inside the Marina, we can begin analyzing the process of recycling glass waste.

APPENDIX F: IMAGES TAKEN BY OUR PROJECT TEAM IN PUERTO RICO

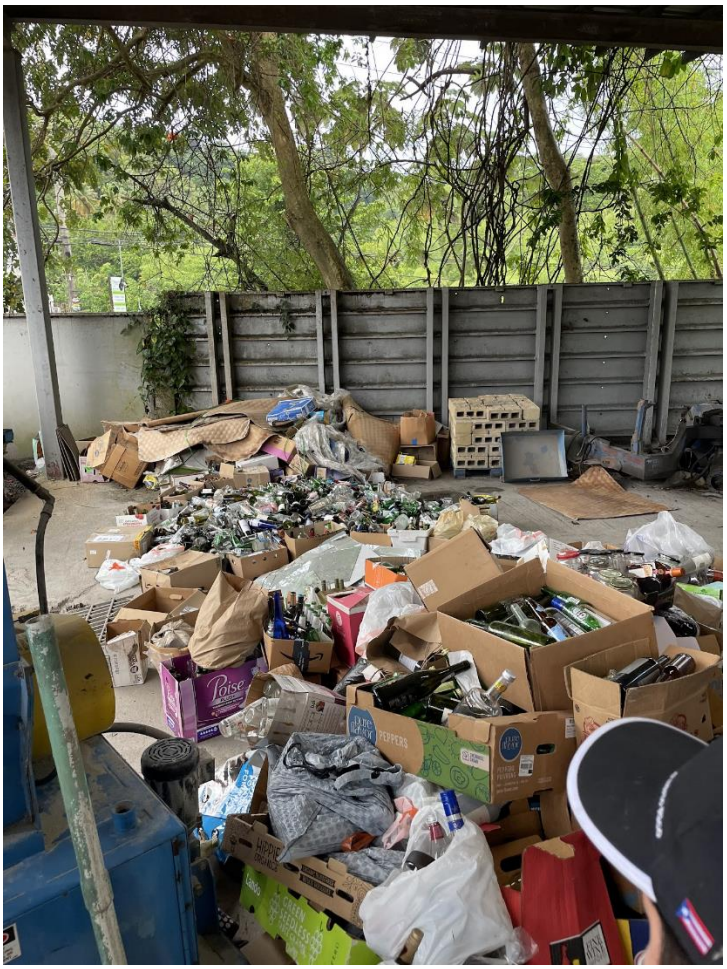
Volunteer Work with G-8 Images

Group Surveying and Observation Images

Bike Tour with BiciCaño Images


PARE

Interview with Bloques Caribe Inc. Images



Interview with Reciclaje del Norte Images


RDN
20 AÑOS
PUBLICO L-V
7:00 AM A 2:30 PM
SERVICIO A TODA LA ISLA
787-262-0305
OPERACIONES
6:00 AM A 6:00 PM
L-V
www.reciclajedelnorte.com
PROPIEDAD PRIVADA
24 HORAS
AVISO


RDN
SERVICIO A TODA LA ISLA
787-262-0305
www.reciclajedelnorte.com
RÉNTAME
TRITURACIÓN DE DOCUMENTOS
25 AÑOS

APPENDIX G: WPI GLASS RECYCLING DATA SHEET

This data was calculated by the Worcester Polytechnic Insititute's D Term 2022 IQP Team on April 26, 2022, for ENLACE's use in glass recycling for the Caño Martín Peña area.

Raw data calculations are located on the left. Charts and data images are located to the right.

Calculation Source Data

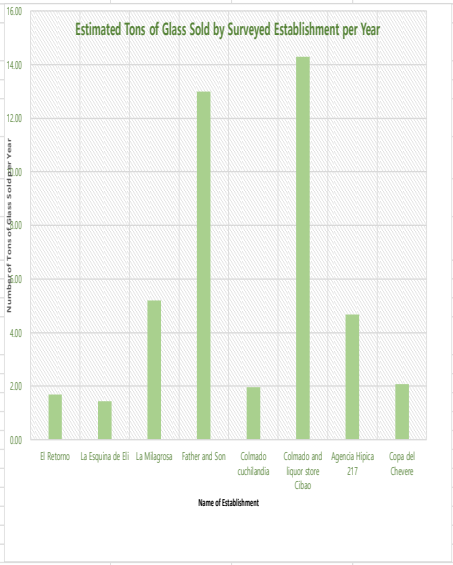
*Weight of an Empty Glass Bottle (12 oz) in grams**	200
Grams per metric ton	1000000
Kilowatt per horsepower	0.7457
Hours per week that GP Mini runs for at Bloques Caribe Inc.	20
Cost of landfill dump in USD per ton (San Juan Landfill)	42
Estimated cost of limestone per ton in USD ($30-38)	35
Commercial electricity cost per Kilowatt-hour in San Juan in USD as of	0.24
Recovery rate (approximation)	30%

***The price is found here: https://www.eia.gov/state/print.p**

Surveyed Businesses Data

Name of establishment	*Bottle sales per week (from survey)*	*Bottle sales per year*	*Weight in tons per year*
El Retorno	163	8476	1.70
La Esquina de Eli	138	7176	1.44
La Milagrosa	500	26000	5.20
Father and Son	1250	65000	13.00
Colmado cuchilandia	188	9776	1.96
Colmado and liquor store Cibao	1375	71500	14.30
Agencia Hipica 217	450	23400	4.68
Copa del Chevere	200	10400	2.08
Total	**4264**	**221728**	**44.35**
Estimated Recycled Glass Potential**			**13.30**

****Dependent on the recovery rate of glass**



Bloques Caribe Glass Pulverizer Data **Andela GP Mini Machine**

Cost of machine delivery and purchase in USD	*Horsepower of machine*	*Kilowatts of machine*	*Kilowatt-hours used per week***	*Kilowatt-hours used per year***	*CO2 emissions in tons per year** see more to right*	*Cost to run machine for one week in USD***	*Cost to run machine for one year in USD***
38450	5.50	4.10	82.03	4265.40	**1.80**	**19.69**	**1023.70**

****If run for 20 hour per week**

Cement Block Data at Bloques Caribe

Weight of 8"x8"x16" Cement Block in grams	*Glass % in weight*	*Glass weight in grams, per 8"x8"x16" block*	*Glass weight in tons, per 8"x8"x16" block*	*Cost savings of glass in cement blocks per block*	*Cost savings from using glass for last year's cement blocks sold*
13600	0.11	1496	0.0015	0.05	**507892**

Cement Block Costs in Dollars

Number of cement blocks sold by Bloques Caribe per year	*8"x8"x16" Cement Block - Bloques Caribe Inc.*	*8"x8"x16" Cement Block - Home Depot*	*8"x8"x16" Cement Block - Lowes*	*Cost Difference from Bloques Caribe Inc. to Lowes*
9700000	0.98	2.07	1.78	**0.80**

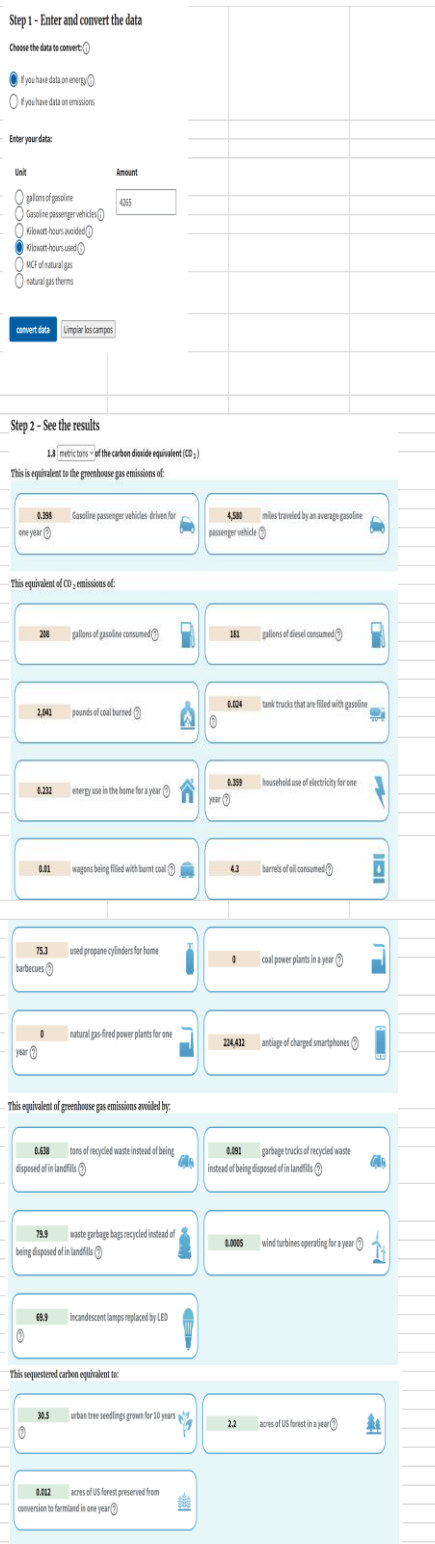
Landfill Dump Costs

Tons per year of glass waste from surveyed businesses	*Total cost in USD of glass waste in dumped in landfill per year from surveyed businesses*
44	**1863**

Cano-wide Glass Generation Estimate

*Formal sales**	*Informal sales**	*Projected bottle weight in tons per year*	*Total potential recycled glass weight in tons per year*
400%	200%	266	80

***Formal and informal sales are an estimate of the total number of businesses in Caño Martín Peña compared to the study area**



APPENDIX H: ANDELA GP-MINI SPEC SHEET

Andela

www.andelaproducts.com

ANDELA GLASS PULVERIZER SYSTEM
MODEL GPM
Hand Fed Miniature Pulverizer
1000-1500 lbs. /hr.

MACHINE SPECIFICATIONS

Dimensions
- Overall Length ..... 75"
- Overall Width ..... 52"
- Overall Height ..... 70"
- Approx. Shipping Weight ..... 2000 lbs.

Pulverizer
- Machine Input Opening ..... Infeed up to 8" Dia. Bottles or Glass
- Barrel Diameter and Length ..... 16" x 34"
- Barrel Liner ..... CC Abrasion Resistant Steel
- Motor Size ..... 5 hp
- Solid Steel Shaft Diameter ..... 2"
- Number of Hammers 28
- Hammer Type ..... Flailing Arm/Hardened Steel
- Bearing Size ..... 2" Heavy Duty
- Seal Protection ..... 2 Seals at Each Shaft Bearing

Trommel
- Screen Barrel Diameter and Length ..... 14" OD x 2' long
- Screen Type ..... Stainless Steel Woven Wire
- Motor Size ..... 1/2 hp

Pulverized Glass Bin ..... 29" x 22" x 10"
Waste Bin ..... 9" x 22" x 10"

Safety Features
- E-Stop
- Protective Guards ..... Cover Input Hopper, Drive Unit and Bearings

Electrical – Control Panel Included Pre-wired to Motors
- Motor Voltage ..... 230/460V, 60 Hz 3 Phase (Single Phase Option)
- Controls ..... Push Button Start/Stop

The manufacturer reserves the right to change designs and specifications without notice.

493 State Route 28, Richfield Springs, NY 13439 315-858-0055

APPENDIX I: GUIDEBOOK DELIVERABLE

Glass Recycling in Caño Martín Peña

Authors: Julia Afthim, Tatyana Barthold, Eduardo Carrillo, and Newton Le

caño 3.7
g-8 • enlace • fideicomiso

WORCESTER POLYTECHNIC INSTITUTE 1865 LEHR UND KUNST

WPI

Table of Contents

The Authors

This guidebook is a deliverable provided to the ENLACE Cooperation from a team of students researching at Worcester Polytechnic Institute, located in Worcester, Massachusetts to complete the Interactive Qualifying Project (IQP). The team worked with ENLACE on this project for 7 week in Worcester Massachusetts (January 12-March 4, 2022) as well as 7 week in San Juan, Puerto Rico (March 14-May 3, 2022).

Julia Afthim

Chemical Engineering Major at Worcester Polytechnic Institute

Class of 2023

Contact: jmafthim@wpi.edu

Tatyana Barthold

Biomedical Engineering Major at Worcester Polytechnic Institute

Class of 2023

Contact: tabarthold@wpi.edu

Eduardo Carrillo

Chemical Engineering Major at Worcester Polytechnic Institute

Class of 2023

Contact: eacarrillo@wpi.edu

Newton Le

Aerospace Engineering Major at Worcester Polytechnic Institute

Class of 2023

Contact: nnle@wpi.edu

Acknowledgements

Our team would like to acknowledge the contributions of the following individuals for their role in helping us complete our project. First, we would like to give a huge thank you to Francisco De La Cruz for his continual support and guidance. We are grateful to Francisco for connecting us with individuals and organizations that gave us valuable information for our project.

We are thankful for Professors Brigitte Servatius and Alex Sphar, our advisors, for pushing us to work harder. They helped shape our project and set a writing standard that continued until its completion. We would also like to acknowledge Scott Jiusto and John-Michael Davis for their contribution to the initial stages of our project.

ENLACE provided input and assistance along the way including but not limited to: Carlos Muñiz Pérez who worked with Francisco to shape our project; José Bauza for assisting us in our research on the glass circular economy; Estelí Capote, Miguel Naveira, Kimberly Perez, and Estrella Santiago who all provided input to our project proposal; and José Caraballo for assisting us during our surveys around the Caño.

OLIN Labs was very open to sharing their research with our team. We would like to thank Rebecca Popowsky for sharing her work on innovating projects such as soil-less soil with our team.

We would like to thank José Mercado Quintana, a manager of Bloques Caribe, and Rubén González Abreu, an owner of Reciclaje Del Norte, for taking time out of their schedules to share their initiatives for glass recycling.

Finally, we would like to thank the businesses around the Caño that provided us enlightening and detailed survey responses.

Intent and Summary

This guidebook's intended purpose is to provide information to Caño 3.7 on the feasibility of glass recycling in the Caño Martín Peña area. In this guidebook, we will recount the problem identification, background information, research, and analysis that led our team to the final recommendations and conclusions about implementing glass-waste recycling in the Caño Martín Peña area.

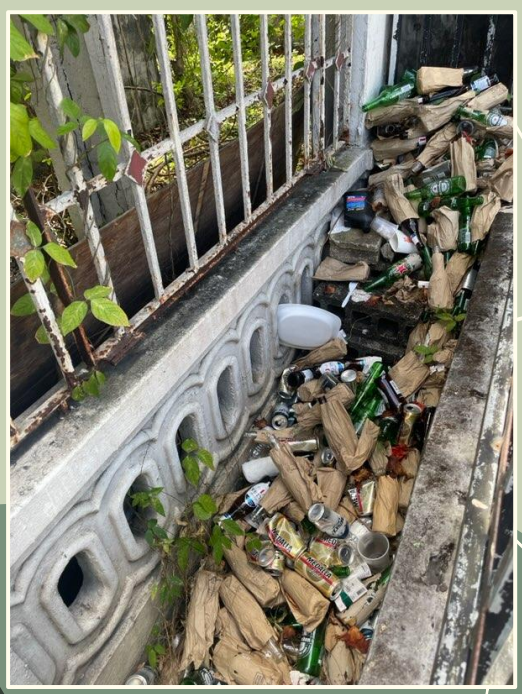
Identifying the Problem

POLLUTION IN THE CANAL:

Since the 1930s, residents in and outside of the Caño Martín Peña area have been dumping their waste into the canal. The pollution in the canal has built up to the point where the canal no longer flows from the two large bodies of water it connects (World Habitat, 2016).

GLASS WASTE:

After walking around the community, our team observed multiple businesses selling glass beer bottles that were then left in trash cans or throughout the streets. These glass materials could be used for several of the current projects at ENLACE, including landfill cover material, construction materials, or even art materials for local micro-businesses.



Interviews

Why conduct interviews?

1. To accurately communicate the ideas being presented to ENLACE and the participant.
2. Questions are developed to the interview liking, have the interview go in a certain direction.

How to conduct an interview properly?

1. Before going in, determine how the interview should be structured (formally, loosely), this depends on the results you are looking for.
2. Understand who you are interviewing and adjust accordingly.

How to come up with interviews questions?

1. Questions are the foundation to an interview, be sure any question asked are related to your topic of the interview.
2. Ask question in a way that will motivate the interview is answer, stay respectful and polite.

https://ctb.ku.edu/en/table-of-contents/assessment/assessing-community-needs-and-resources/conduct-interviews/main#:~:text=show%20you%20how.-,Why%20should%20you%20conduct%20interviews%3F,the%20questions%20will%20be%20answered

Interviews

Interview with Miguel Naveira: Coordinator at Martín Peña Recicla, INC.

Interview conducted on March 25th, 2022 at ENLACE, followed by a tour of MPR's facility.

The purpose for this interview was to gain an understanding what the recycling conditions are in the communities surrounding the Caño Martín Peña.

According to Miguel, the community is engaged with the efforts for recycling, however the challenge lies in educating them on how to recycle since often the trash set aside for recycling can be contaminated with other substances. To address this issue, Martín Peña Recicla has provided the community with detailed instructions on how to set aside trash for recycling, for example plastic containers must be clean and cardboard must be dry. In the future, Martín Peña Recicla seeks to educate children on environmental consciousness, collect and recycle materials that would instead go to landfills, create jobs, and most importantly increase the environmental value for the community surrounding the canal.

Background on Miguel Naveira:
Graduate student studying Environmental Science.
Before working at Martín Peña Recicla, he worked in Urban and infrastructure at ENLACE as a developer in green infrastructure and housing development.

Overview on Martín Peña Recicla INC.:

Martín Peña Recicla, INC. was established in 2011.
Recycle plastic types 1 and 2, paper, cardboard, and aluminum.
Martín Peña Recicla, INC. has only two employees, which receive $4,000 a month in funding from the San Juan municipality.
From 2011 to 2020, MPR has collected and recycled **90,000 pounds** of the above materials!

Interviews

Interview with Jose Mercado Quintana from Bloques Caribe Inc.

Interview conducted on April 22th, 2022 at Bloques Caribe Guaynabo, followed by a tour of the facilities.

The purpose for this interview was to learn about the cement blocks manufacturing process using glass aggregate. The glass used in this process is provided by environmental groups that have verbal agreements with Bloques Caribe Inc.

Each glass bottle collected is shredded by a glass pulverizer, the shredded glass is added with limestone grains to produce a concrete mixture. After this mixture is created, it is then formed into block-like shapes and dried for 24 hours.

Background on Jose Mercado Quintana: Jose is the administrator for Bloques Caribe Inc. In our interview, Jose informed our group that his dad was in the same business and that's why he currently in the construction business. Now he takes a more environmental approach; since 2000, Jose has been working on incorporating glass with cement block and construction.

BLOQUES CARIBE INC.

Overview on Bloques Caribe Inc.:

- Bloques Caribe Inc., is a construction company that produces concrete blocks, specifically made from limestone and shredded glass.
- In the past year, they sold approximately **9.7 million cement blocks** across the island of Puerto Rico.

Interviews

Interview with Rubén González Abreu from Reciclaje del Norte.

Interview conducted on April 22th, 2022 at Reciclaje del Norte, followed by a tour of their facility.

The purpose for this interview was to learn about the the recycling process in the Caño Martín Peña area. Our team also want to understand why RDN stopped recycling glass and if they would considering starting it again.
According to Rubén, there is no market for glass. To reduce losses, RDN charges $0.25 per pound of glass to people who recycle glass to their distribution centers. RDN also charges a custom fee to private companies that hired RDN to collect recycling from the businesses.

Background on Rubén González Abreu from Reciclaje del Norte: Rubén is a manager for RDN. He is also one of the 32 owners of RDN.

Overview on Reciclaje del Norte:

- RDN recycling centers has been operating since 1996 in Puerto Rico.
- RDN collects recyclable material from businesses and homes.
- They then prepare these materials to either be exported to them off the island or sell them domestically to clients.

Interviews

Interview with Rebecca Popowsky from OLIN Labs.

Interview was conducted on April 26th, 2022 over Google Meetings

The purpose for this interview was to learn about OLIN Lab to gain more information about their current research on the soil-less soil project. Our team also inquired about other OLIN projects that could utilize pulverized glass.

They work with glass sizes similar to the composition of ASTM C33 concrete sand.

Background on Rebecca: She is the OLIN Labs external research coordinator. Her main focus currently to provide project management for the soil-less soil project

OLIN

Background on OLIN Labs:

- Conducting research on the soil-less soil for four years.
- Beginning research on using pulverized glass for dredge material in Baltimore, Maryland.

Survey

Why conduct Surveys?

1. Collect a variety of information (behavior, opinions, statistics, etc.)
2. Measure the ideas of a community issue and how that relates to the topic you're interested in

When should surveys be conducted?

1. When you need to collect information quickly
2. Collecting larger samples of data

Advantages to a Survey:

1. Cost efficient
2. Wide range of participants
3. Recorded data
4. Can reach a larger audience

https://ctb.ku.edu/en/table-of-contents/assessment/assessing-community-needs-and-resources/conduct-interviews/main#:~:text=show%20you%20how.-,Why%20should%20you%20conduct%20interviews%3F,the%20questions%20will%20be%20answered.

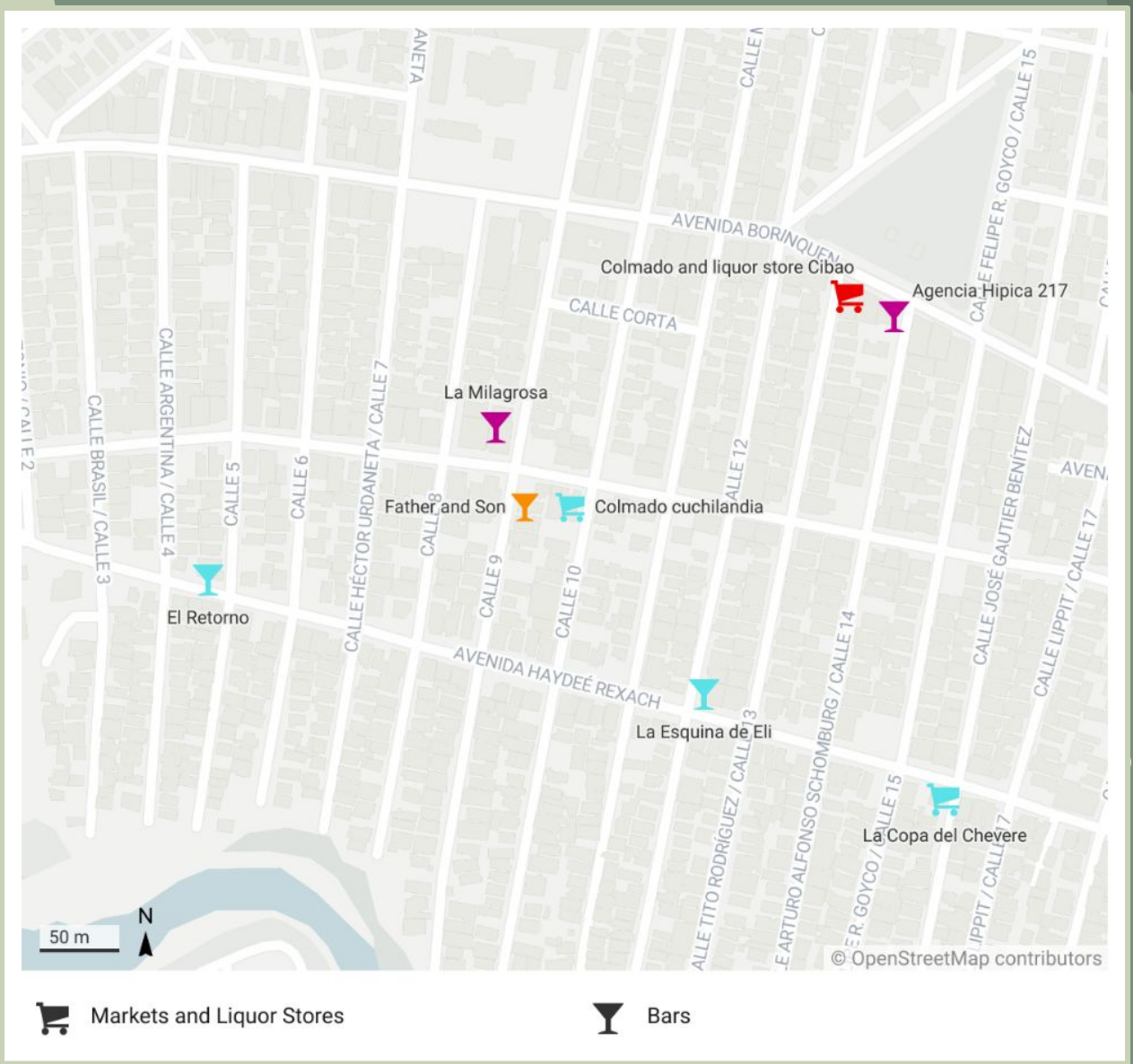
Survey

Survey Questions:

Questions on survey:

- Name of Participant
- Name of Establishment
- Job Title
- On average, how many bottles do you sell in your establishment per week?
  - 0-25
  - 25-50
  - 75-100
  - 125-150
  - 150-175
  - 175-200
  - 200+
- Do you participate in recycling?
  - Yes
  - No
- Would you be willing to participate (in recycling) if there was some incentive (ex. business promotion, money, other)?
  - Yes
  - No
- Which incentive would best appeal to you?
  - Promotion
  - Money
  - Other
- Where do you get your beers and soda (glass) bottles from?
- Would you be willing to put a poster in your establishment about recycling?

Map of Surveyed Businesses



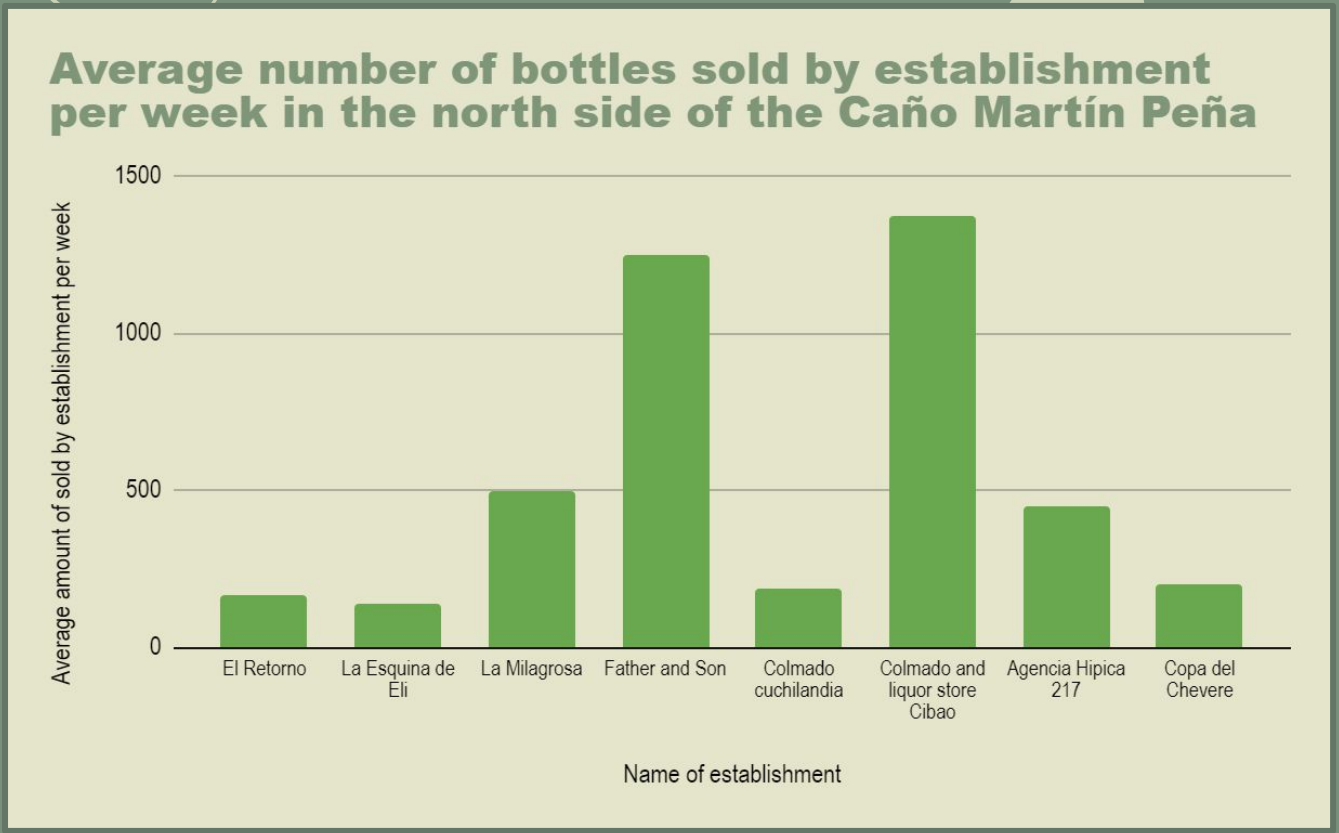
MAP KEY

Number of glass bottles sold per week

- 100-250
- 250-500
- 1000-1250
- 1250+

Data

Through our efforts, we were able to conduct 8 surveys.

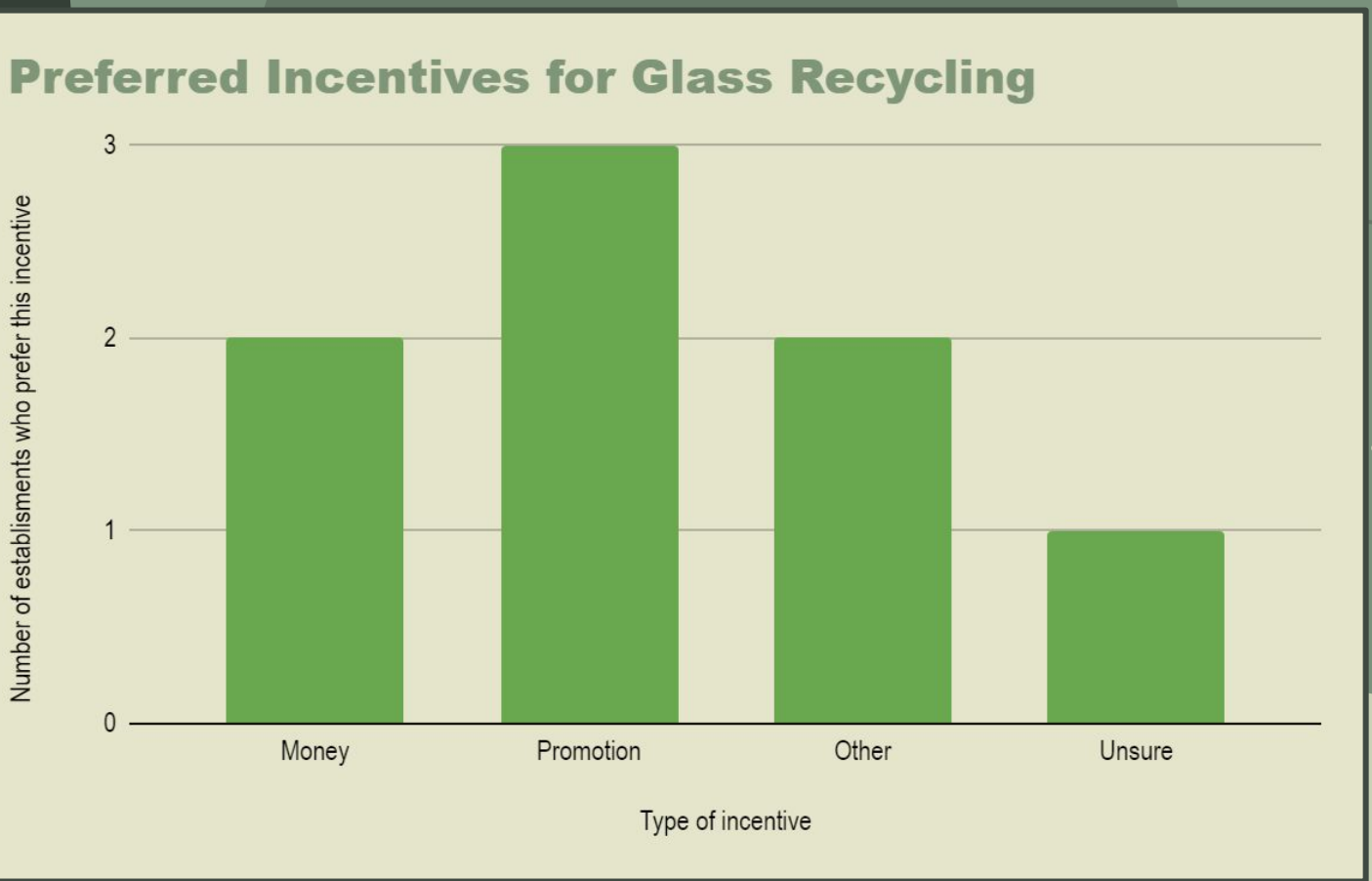


Name of establishment	Average number of bottles sold by establishment per week
El Retorno	163
La Esquina de Eli	138
La Milagrosa	500
Father and Son	1,250
Colmado cuchilandia	188
Colmado and liquor store Cibao	1,375
Agencia Hipica 217	450
Copa del Chevere	200

Data

We asked the surveyed businesses what incentives they would prefer. Here are the results from that survey question:

Image of team walking through Caño Martín Peña with community leader Jose Caraballo



Data

100% of establishments who participated in this survey said they do not currently participate in any form of recycling.

100% of establishments who participated in this survey said they would participate in recycling if there was an incentive involved.

6 out of 8 (75%) of establishment who participated in this survey were open to the idea of hanging an informational poster about recycling in their business.

Images taken outside a bar on April 13th, 2022 by our team while surveying.

Data

From our survey, the team analyzed the weekly bottle sales to calculate the annual number of bottles sold.

Name of establishment	Bottles sold per year
El Retorno	8,476
La Esquina de Eli	7,176
La Milagrosa	26,000
Father and Son	65,000
Colmado cuchilandia	9,776
Colmado and liquor store Cibao	71,500
Agencia Hipica 217	23,400
Copa del Chevere	10,400
Total	**221,728**

Data

We estimated the weight of each glass bottle to be 200 grams and multiplied it by the yearly number of bottles sold. The resulting value was then converted to metric tons using the conversion: 1000000 grams is equal to 1 metric ton.

Sample calculations for El Retorno
(8476 * 200) / 1000000
= 1.70 metric tons

Name of establishment	Metric tons of glass sold per year
El Retorno	1.70
La Esquina de Eli	1.44
La Milagrosa	5.20
Father and Son	13.00
Colmado cuchilandia	1.96
Colmado and liquor store Cibao	14.30
Agencia Hipica 217	4.68
Copa del Chevere	2.08
Total	**44.35**

Data

Bloques Caribe manufactures 8"x8"x16" cement blocks. We calculated how much money Bloques Caribe saves from substituting limestone grains with glass aggregate.

8"x8"x16" Cement block weighs 13600 grams. 11% of the weight is made with glass.

Glass weight in grams, per 8"x8"x16" block	1496
Glass weight in tons, per 8"x8"x16" block	0.0015

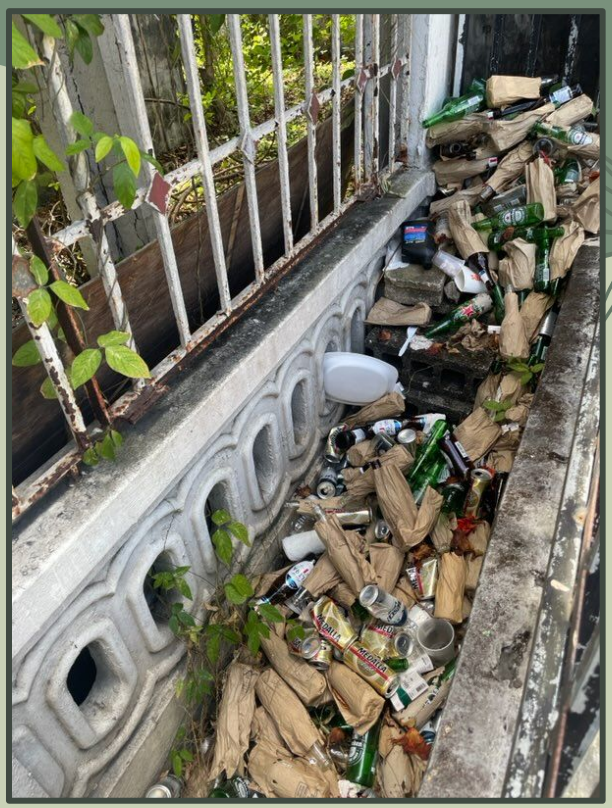
The cost to purchase 1 ton of limestone is $35

Cost savings of glass in cement blocks per block	0.05
Cost savings from using glass for last year's cement blocks sold	$507892

Data

The cost to send a ton of material to the San Juan landfill is $42

If we were to send the bottles from the survey area to the landfill:



Total cost in USD of glass waste in dumped in landfill per year from surveyed businesses	$1863

Uses of Glass Bottle Recycling

Cement Blocks

Following Bloques Caribe Inc Manufacturing Process

Glass aggregate added to cement blocks:

- Reduces 11% in manufacturing costs per block
- Easy to train workers on Andela GP-Mini

For example:
Bloques Caribe saves

$507,892

In estimated annual limestone material savings

Uses of Glass Bottle Recycling

Soil-Less Soil

Following OLIN Lab Research

Advantages:

- Machinery in San Juan already exists to pulverize the glass to the size ASTM C33 concrete sand.
- Applications in farming, stormwater infiltration, and construction.

Photo by You Wu, 2019 for OLIN Lab Soil-Less soil project

Made out of a 60/20/20 ratio of: 60% sand, 20% compost, 20% natural soil.
Possible to add pulverized glass to the sand mixture. OLIN is testing different ratios of glass-to-sand mixtures.

Conclusions

- **Businesses around the Caño Martín Peña are willing to recycle if they understand the purpose behind it and the process is feasible.** If businesses of the Caño Martín Peña area were to understand the reasonings behind recycling and have simple steps to follow, they would be more willing to recycle their waste. Our team sees these same principles applying to businesses in the Caño Martín Peña area, based on our survey results and interviews.

- **Recycling in Puerto Rico relies primarily on non-profit organizations and/or environmental groups because there is a lack of support from the local government.** Without assistance and resources from the government, implementing glass recycling is a difficult task. The government is aware of many of the environmental efforts occurring across the island of Puerto Rico but chooses not to support them.

- **Glass recycling is arduous to implement since, unlike plastics and metals, unrecycled glass has no monetary value.** To make a profit, businesses need to convert the glass into a finished product for sale, such as the concrete blocks from Bloques Caribe Inc.. These products often yield high initial start-up costs that we believe small businesses may be hesitant to invest.

Recommendations

ENLACE encourages businesses in the Caño Martín Peña area to recycle their glass bottles through an incentive program.

Business Promotion Incentive

- José Bauza informed our team of a community website, created by ENLACE, that displays local businesses and surveys in the Caño Martín Peña area
- Our suggestion to ENLACE to help promote businesses is to create online flyers for them on the website Hecho en el Caño website (link: http://hechoenelcano.org/) This could potentially bring more customers (inside and outside of the Caño neighborhoods) to their businesses.

Monetary Incentive

- For a monetary incentive, our team suggests running a program similar to the volunteer program ran by the G-8. T
- his program rewards community members by rewarding their volunteer hours with "coupons."
- These "coupons" can be used to shop for clothes, cleaning supplies, and other necessities, all of which are donated by community members and local businesses. This program could be implemented for the business owners in the Caño Martín Peña area; if they recycle a certain weight of glass bottles, then they could get a "coupon" to use for restaurant/market supplies.

Recommendations

Collecting the glass and sending them to places, like Bloques Caribe, to be recycled.

The Caño Martín Peña would benefit if the glass waste being produced in the area was brought somewhere out to be recycled

This would primarily benefit the community

- Keep the canal clean
- keep the street clean
- Reduce the amount of glass in trash and landfill

For ENLACE

- Potentially create a an agreement with Bloques Caribe

Once the canal is clean up from the dredge, it should stay clean. For the animals and community that live in the Caño Martín Peña area.

There are two options that our group discovered when investigating a recycling plan with Bloques Caribe Inc.. The first is to rent a semi truck to transport the glass waste to Bloques Caribe Inc. in Guaynabo. Our team recommends this option because it is the most direct. The first step in investigating this option would be to determine how much renting a semi truck would be for cost, and then determining how the glass waste could be collected from the surveyed businesses. The second option is to transport the glass to Reciclaje del Norte, which charges for glass bottle waste and sends it to cement block companies like Bloques Caribe Inc.. Reciclaje del Norte charges 25 cents per pound (about 550 dollars per ton) for glass to be dropped off at their facility.

Recommendations

ENLACE collects glass waste from businesses around the canal to start a potential micro-business. This business would involve using a glass pulverizer and exploring the potential uses for glass cullets.

To begin pulverizing glass:

Andela GP-Mini

- **Compact machinery**
- **$38,450 to buy and deliver**
- **Easy to operate**

Specifications:

- **4.1 kW**
- **1 ton/hour**

Why?

1. **Eliminate the costs of transporting glass outside of the Caño Martín Peña.**
2. **Glass, sand, compost, and natural soil are materials to create OLIN's soil-less soil. The soil can be used in the construction for the paseos, and may also be applicable to road construction, given further research.**

Reciclaje de Vidrio en Caño Martín Peña

Autores: Julia Afthim, Tatyana Barthold, Eduardo Carrillo, y Newton Le

caño 3.7
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Tabla de Contenido

Los Autores

Esta guía fue proporcionada a la Cooperación ENLACE por un equipo de estudiantes del Instituto Politécnico de Worcester, ubicado en Worcester, Massachusetts, para completar el Proyecto Calificador Interactivo (IQP). El equipo trabajó con ENLACE en este proyecto durante 7 semanas en Worcester Massachusetts (del 12 de enero al 4 de marzo de 2022), así como 7 semanas en San Juan, Puerto Rico (del 14 de marzo al 3 de mayo de 2022).

Julia Afthim

Ingeniería Química en Worcester Polytechnic Institute

Clase del 2023

Contacto: jmafthim@wpi.edu

Tatyana Barthold

Ingeniería Biomédica en Worcester Polytechnic Institute

Clase del 2023

Contacto: tabarthold@wpi.edu

Eduardo Carrillo

Ingenieria Química en Worcester Polytechnic Institute

Clase del 2023

Contacto: eacarrillo@wpi.edu

Newton Le

Ingeniería Aeroespacial en Worcester Polytechnic Institute

Clase del 2023

Contacto: nnle@wpi.edu

Reconocimientos

Nuestro equipo desea reconocer las contribuciones de los siguientes individuos por su papel en ayudarnos a completar nuestro proyecto. En primer lugar, nos gustaría dar un enorme agradecimiento a Francisco De La Cruz por su apoyo y orientación continuos. Estamos agradecidos a Francisco por conectarnos con individuos y organizaciones que nos dieron información valiosa para nuestro proyecto.

Estamos agradecidos por los profesores Brigitte Servatius y Alex Sphar, nuestros asesores, por empujarnos a trabajar más duro. Ellos ayudaron a dar forma a nuestro proyecto y establecer un estándar de escritura que continuó hasta su finalización. También nos gustaría reconocer a Scott Jiusto y John-Michael Davis por su contribución a las etapas iniciales de nuestro proyecto.

ENLACE proporcionó asistencia en el camino incluyendo pero no limitado a: Carlos Muñiz Pérez quien trabajó con Francisco para dar forma a nuestro proyecto; José Bauza para ayudarnos en nuestra investigación sobre la economía circular del vidrio; Estelí Capote, Miguel Naveira, Kimberly Pérez y Estrella Santiago, quienes nos dieron información sobre nuestra propuesta de proyecto; y José Caraballo por ayudarnos durante nuestras encuestas alrededor del Caño.

OLIN Labs estuvo muy abierto a compartir su investigación con nuestro equipo. Nos gustaría agradecer a Rebecca Popowsky por compartir su trabajo en proyectos innovadores como el soil-less soil con nuestro equipo.

Queremos agradecer a José Mercado Quintana, gerente de Bloques Caribe Inc., y a Rubén González Abreu, uno de los dueño de Reciclaje Del Norte, por haber tomado tiempo de sus horarios para compartir sus iniciativas para el reciclaje de vidrio.

Finalmente, nos gustaría agradecer a las empresas alrededor del Caño que nos proporcionaron respuestas detalladas en la encuesta.

Intención y Resumen

El objetivo de esta guía es proporcionar información a Caño 3.7 sobre la viabilidad del reciclaje de vidrio en el área de Caño Martín Peña. En esta guía, vamos a relatar la identificación de problemas, la información del problema, la investigación y el análisis que llevaron a nuestro equipo a las recomendaciones y conclusiones finales sobre la implementación del reciclaje de residuos de vidrio en el área de Caño Martín Peña.

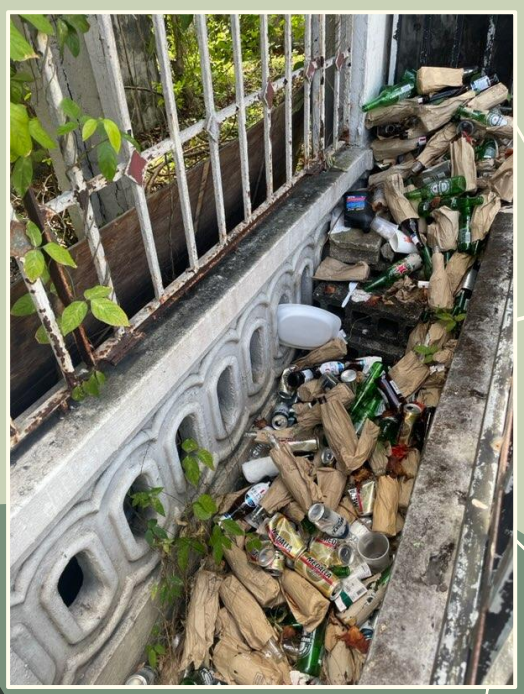
Identificando el Problema

Contaminación en el Canal

Desde los 1930s, los residentes dentro y fuera del área del Caño Martín Peña han estado arrojando sus desechos al canal. La contaminación en el canal se ha acumulado hasta el punto en el que el canal ya no fluye de los dos grandes cuerpos de agua que conecta (World Habitat, 2016).

Desechos de Vidrio

Después de caminar por la comunidad, nuestro equipo observó varios negocios que vendían botellas de cerveza en envases de vidrio que luego se dejaban en botes de basura o por las calles. Estos materiales de vidrio podrían ser utilizados para varios de los proyectos en ENLACE, incluyendo materiales de cubierta de vertedero, materiales de construcción, o incluso materiales de arte para micro-negocios locales.



Entrevistas

¿Por qué realizar entrevistas?

1. Para comunicar con precisión las ideas que se presentan a ENLACE y a el participante.
2. Las preguntas se desarrollan a gusto de la entrevista, que la entrevista vaya en una dirección determinada.

¿Cómo realizar una entrevista correctamente?

1. Antes de entrevistar, determinar cómo debe estructurarse la entrevista (formalmente, vagamente), esto depende de los resultados que esté buscando.
2. Entienda a quién está entrevistando y ajuste en consecuencia.

¿Cómo determinar las preguntas de las entrevistas?

1. Las preguntas son la base de una entrevista, asegúrese de que cualquier pregunta que se haga esté relacionada con su tema de la entrevista.
2. Haga la pregunta de una manera que motive una respuesta, manténgase respetuoso y educado.

https://ctb.ku.edu/en/table-of-contents/assessment/assessing-community-needs-and-resources/conduct-interviews/main#:~:text=show%20you%20how.-,Why%20should%20you%20conduct%20interviews%3F,the%20questions%20will%2

Entrevistas

Entrevista a Miguel Naveira: Coordinador en Martín Peña Recicla, INC.

Entrevista realizada el 25 de marzo de 2022 en ENLACE, seguida de un recorrido por las instalaciones de MPR.

El propósito de esta entrevista fue comprender cuáles son las condiciones de reciclaje en las comunidades aledañas al Caño Martín Peña.

Según Miguel, la comunidad está comprometida con los esfuerzos de reciclaje. Sin embargo, el reto reside en saber cómo reciclar, ya que a menudo la basura que se aparta para reciclar puede estar contaminada con otras sustancias. Para abordar este problema, Martín Peña Recicla ha proporcionado a la comunidad instrucciones detalladas sobre cómo dejar a un lado la basura para su reciclaje. Por ejemplo, los contenedores de plástico deben estar limpios y el cartón debe estar seco. En el futuro, Martín Peña Recicla busca educar a los niños sobre la conciencia ambiental, recolectar y reciclar materiales que en su lugar irían a vertederos, crear empleos y, lo más importante, aumentar el valor ambiental para la comunidad que rodea el canal.

Informacion sobre Miguel Naveira: Estudiante de posgrado en Ciencias Ambientales. Antes de trabajar en Martín Peña Recicla, Miguel trabajó en Urbanismo e Infraestructura en ENLACE como desarrollador en infraestructura verde y desarrollo de viviendas.

Visión general de Martín Peña Recicla INC.:

- Martín Peña Recicla, INC. Fue fundada en 2011. Recicla los tipos de plástico 1 y 2, papel, cartón y aluminio.
- Martín Peña Recicla, INC. tiene dos empleados, que reciben $4.000 al mes en financiamiento del municipio de San Juan para seguir operando.
- De 2011 a 2020, MPR ha recogido y reciclado 90.000 libras de los materiales anteriormente mencionados.

Entrevistas

Entrevista a José Mercado Quintana de Bloques Caribe Inc.

Entrevista realizada el 22 de abril de 2022 en Bloques Caribe Guaynabo, seguida de un recorrido por las instalaciones.

El propósito de esta entrevista fue aprender sobre el proceso de fabricación de bloques de cemento usando agregado de vidrio. El vidrio usado en este proceso es provisto por grupos ambientales que tienen acuerdos verbales con bloques Caribe Inc.

Cada botella de vidrio recogida es triturada por un pulverizador de vidrio, el vidrio triturado se añade con granos de piedra caliza para producir una mezcla de concreto. Después de que esta mezcla se crea, se forma un bloque y se seca por 24 horas.

Información sobre José Mercado Quintana:
José es el administrador de Bloques Caribe Inc. En nuestra entrevista José informó a nuestro grupo que su padre estaba en el mismo negocio y por eso es que el actualmente está en el negocio de la construcción. Ahora, él toma un acercamiento más ambiental. Desde el año 2000, José ha estado trabajando en incorporar el vidrio con el bloque de cemento y la construcción.

BLOQUES CARIBE INC.

Descripción general de Bloques Caribe Inc.:

- Bloques Caribe Inc., es una empresa de construcción que produce bloques de cemento, específicamente hechos de piedra caliza y vidrio triturado.
- El año pasado, vendieron aproximadamente 9.7 millones de bloques de cemento en toda la isla de Puerto Rico.

Entrevistas

Entrevista a Rubén González Abreu de Reciclaje del Norte.

Entrevista realizada el 22 de abril de 2022 en Reciclaje del Norte, seguida de un recorrido por sus instalaciones.

El propósito de esta entrevista fue conocer el proceso de reciclaje en el área de Caño Martín Peña. Nuestro equipo también quiere entender por qué RDN dejó de reciclar el vidrio y si consideran iniciarlo de nuevo.

Según Rubén, no hay mercado para el vidrio. Para reducir las pérdidas, RDN cobra $0.25 por libra de vidrio a las personas que reciclan vidrio a sus centros de distribución. RDN también cobra una cuota personalizada a las empresas privadas que contrataron RDN para recoger el reciclaje de los negocios.

Información sobre Rubén González Abreu de Reciclaje del Norte: Rubén es uno de los 32 propietarios de RDN.

Descripción general sobre reciclaje del Norte:

- Los centros de reciclaje RDN han estado operando desde 1996 en Puerto Rico. RDN recoge material reciclable de empresas y hogares.
- A continuación, preparan estos materiales para exportarlos fuera de la isla o venderlos internamente a los clientes.

Entrevistas

Entrevista con Rebecca Popowsky de OLIN Labs

La entrevista se realizó el 26 de abril de 2022 a través de Google Meetings

El propósito de esta entrevista fue aprender acerca de OLIN Labs para obtener más información sobre su investigación actual sobre el proyecto de soil-less soil. Nuestro equipo también preguntó acerca de otros proyectos de OLIN que podrían utilizar vidrio pulverizado.

Trabajan con tamaños de vidrio similares a la composición de la arena de hormigón ASTM C33.

Información sobre Rebecca:
Es la coordinadora de investigación externa de OLIN Labs. Su enfoque principal actualmente es proporcionar gestión de proyectos para el proyecto de suelo sin suelo.

OLIN

Información sobre OLIN Labs:

- Han realizado investigaciones sobre soil-less soil durante cuatro años.
- Investigación sobre el uso de vidrio pulverizado para material de dragado en Baltimore

La Encuesta

¿Por qué realizar encuestas?

1. Recopilar una variedad de información (comportamiento, opiniones, estadísticas, etc.)
2. Mide las ideas alrededor de un problema de la comunidad y cómo se relaciona con el tema de interes.

¿Cuándo se deben realizar las encuestas?

1. Cuando se necesita recopilar información rápidamente
2. Recopilación de muestras de datos más grandes

Ventajas de una encuesta:

1. Costo efectivo
2. Amplio rango de participantes
3. Datos grabados
4. Puede llegar a un público más amplio

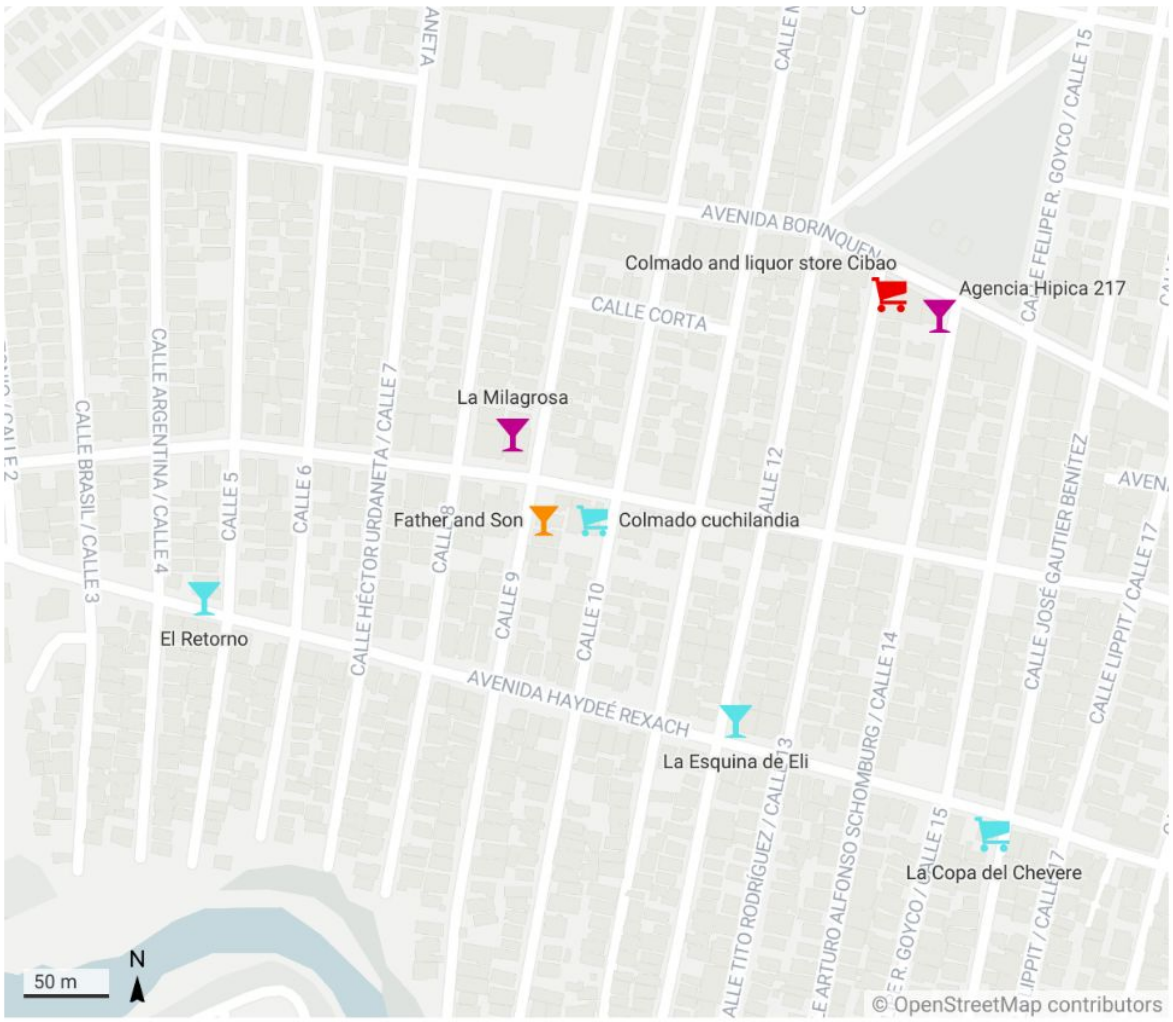
https://ctb.ku.edu/en/table-of-contents/assessment/assessing-community-needs-and-resources/conduct-interviews/main#:~:text=show%20you%20how.-,Why%20should%20you%20conduct%20interviews%3F,the%20questions%20will%20be%20answered

La Encuesta

Preguntas en la Encuesta:

- Nombre del Participante
- Nombre del Establecimiento
- Posición en el trabajo
- En promedio, ¿cuántas botellas venden en su establecimiento por semana?
    - 0-25
    - 25-50
    - 75-100
    - 125-150
    - 150-175
    - 175-200
    - 200+
- ¿Participas en el reciclaje?
    - Sí
    - No
- ¿Estarías dispuesto a participar (en el reciclaje) si hubiera algún incentivo (por ejemplo, promoción comercial, dinero, otros)?
    - Si
    - No
- ¿Qué incentivo le atraería mejor?
    - Promoción
    - Dinero
    - Otro
- ¿De dónde sacas tus cervezas y botellas de refrescos (vidrio)?
- ¿Estarías dispuesto a poner un cartel en tu establecimiento sobre el reciclaje?

Mapa de Empresas encuestadas



Markets and Liquor Stores

Mercados y licorerías

Bars

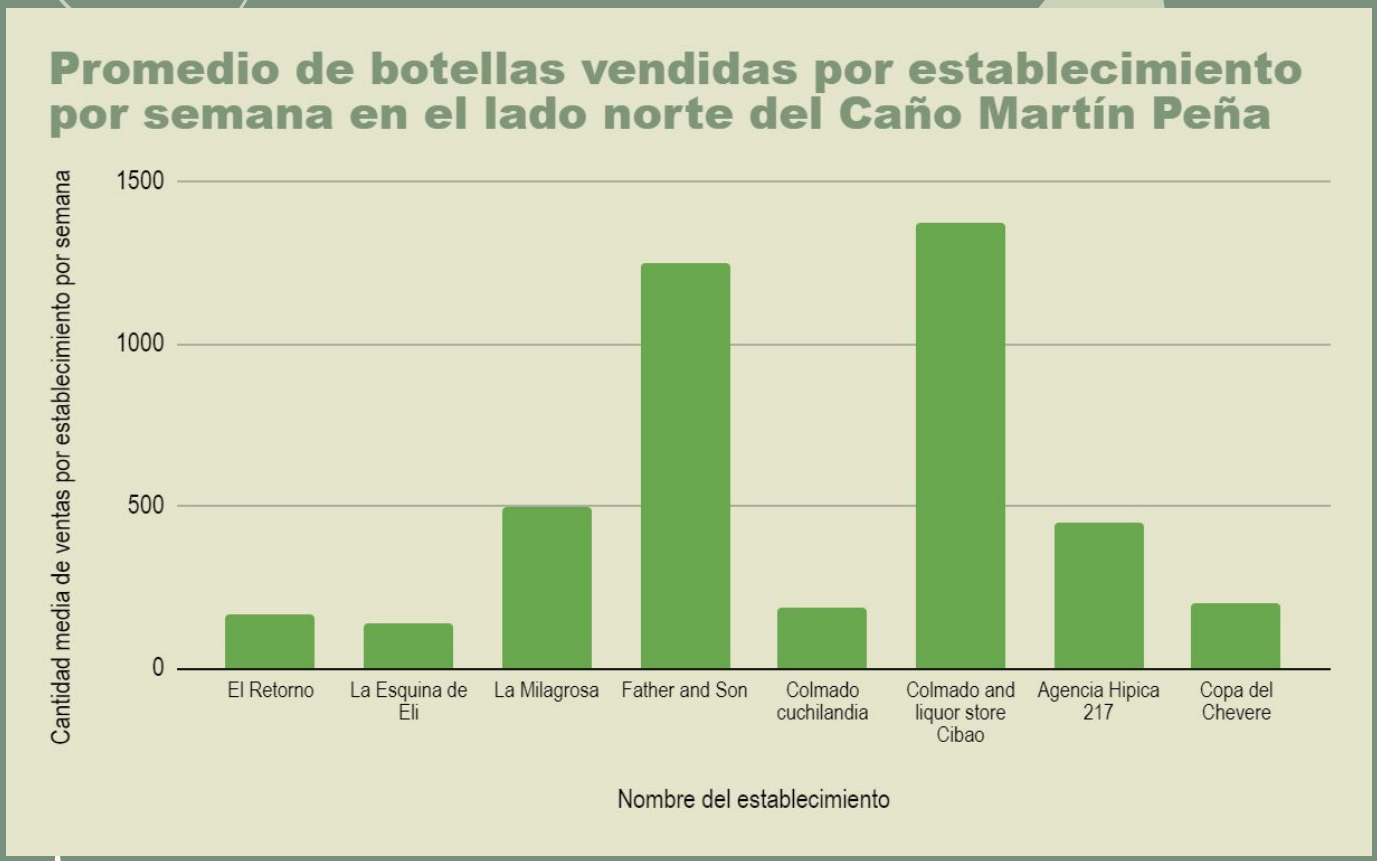
Simbología del mapa

Número de botellas de vidrio vendidas por semana

- 100-250
- 250-500
- 1000-1250
- 1250+

Datos

A través de nuestros esfuerzos pudimos realizar 8 encuestas.



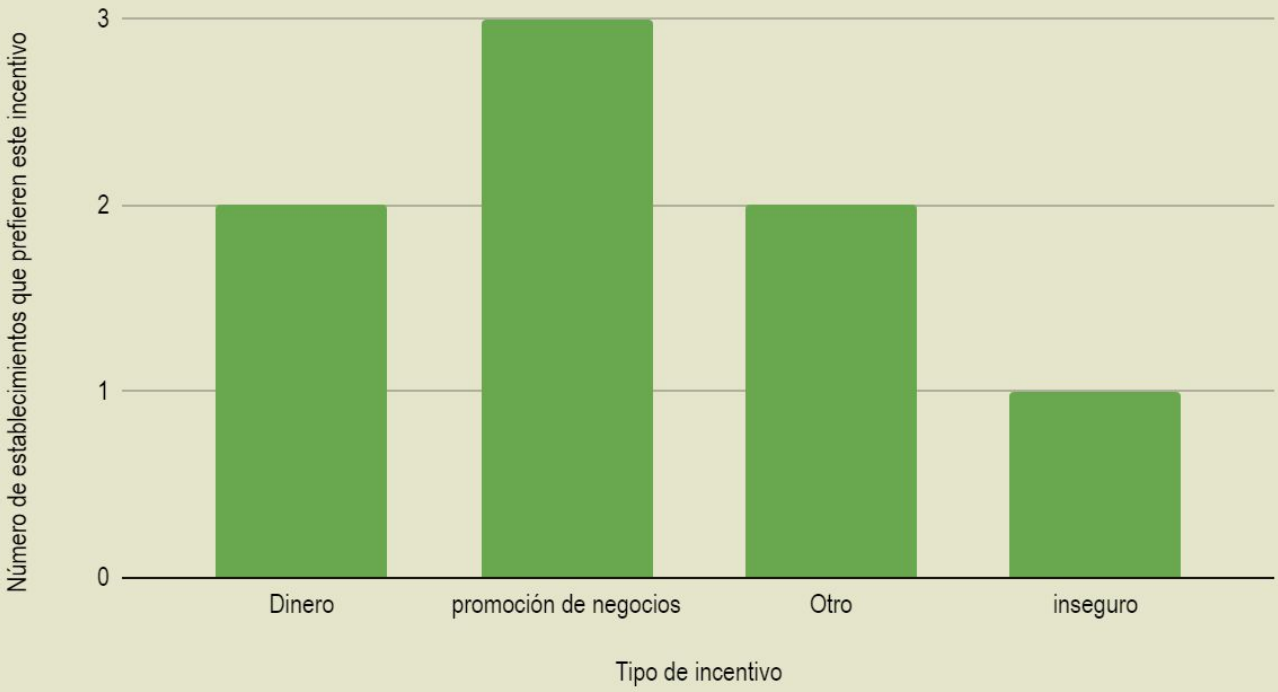
Nombre del Establecimiento	Promedio de botellas vendidas por establecimiento por semana
El Retorno	163
La Esquina de Eli	138
La Milagrosa	500
Father and Son	1,250
Colmado cuchilandia	188
Colmado and liquor store Cibao	1,375
Agencia Hipica 217	450
Copa del Chevere	200

Datos

Le preguntamos a las empresas qué incentivos preferirían. Aquí están los resultados de esa pregunta:

Imagen del equipo caminando por Caño Martín Peña con el líder comunitario José Caraballo

Incentivos preferidos para el reciclaje de vidrio



Datos

El 100% de los establecimientos que participaron en esta encuesta dijeron que actualmente no participan en ninguna forma de reciclaje.

El 100% de los establecimientos que participaron en esta encuesta dijeron que podrían participar en el reciclaje si hubiera un incentivo involucrado.

6 de cada 8 (75%) de los establecimientos que participaron en esta encuesta estaban abiertos a la idea de colgar un cartel informativo sobre reciclaje en su negocio.

Datos

El equipo analizó las ventas semanales de botellas para calcular el número anual de botellas vendidas.

Nombre del Establecimiento	Número anual de botellas vendidas
El Retorno	8,476
La Esquina de Eli	7,176
La Milagrosa	26,000
Father and Son	65,000
Colmado cuchilandia	9,776
Colmado and liquor store Cibao	71,500
Agencia Hipica 217	23,400
Copa del Chevere	10,400
Total	**221,728**

Datos

Calculamos que el peso de cada botella de vidrio es de 200 gramos y lo multiplicamos por el número anual de botellas vendidas. El valor resultante se convirtió entonces en toneladas métricas usando la conversión: 1000000 gramos es igual a 1 toneladas métricas.

Cálculos de muestra para El Retorno: (8476 * 200) / 1000000 = 1.70 toneladas métricas

Nombre del Establecimiento	Toneladas métricas de vidrio vendidas anualmente
El Retorno	1.70
La Esquina de Eli	1.44
La Milagrosa	5.20
Father and Son	13.00
Colmado cuchilandia	1.96
Colmado and liquor store Cibao	14.30
Agencia Hipica 217	4.68
Copa del Chevere	2.08
Total	**44.35**

Datos

Bloques Caribe fabrica bloques de cemento con las dimensiones de 8"x8"x16". Calculamos cuánto dinero ahorra Bloques Caribe al sustituir granos de piedra caliza con agregado de vidrio.

El bloque de cemento de 8"x8"x16" pesa 13600 gramos. El 11% del peso está compuesto por vidrio.

Peso del vidrio en gramos, por bloque de 8"x8"x16"	1496
Peso del vidrio en toneladas, por bloque de 8"x8"x16"	0.0015

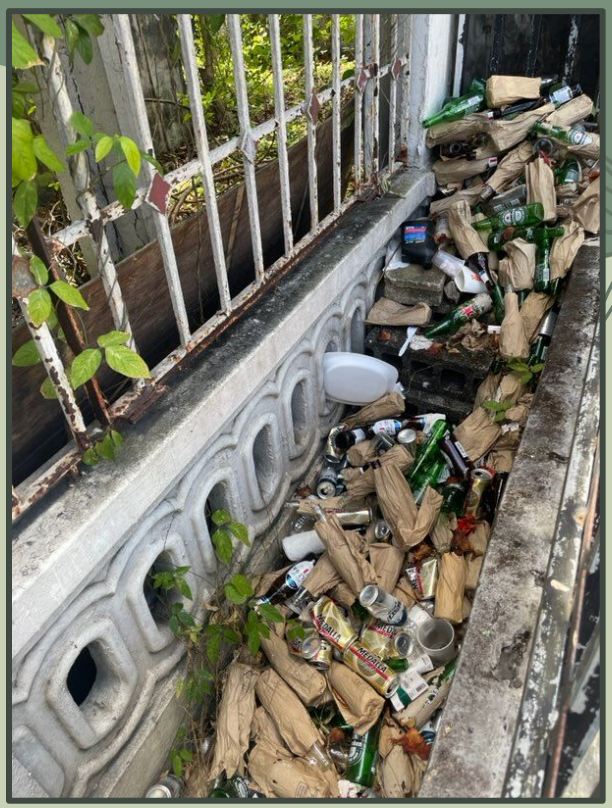
El costo de 1 tonelada de piedra caliza es $ 35

Ahorro de costos al usar vidrio en bloques de cemento por bloque	0.05
Ahorro de costos por el uso de vidrio para los bloques de cemento vendidos el año pasado	$507892

Datos

El costo de enviar una tonelada de material al vertedero de San Juan es de $42

Si fueramos a enviar las botellas desde el área de estudio al vertedero:



Costo total en USD de los residuos de vidrio vertidos en vertederos por año de las empresas encuestadas	$1863

Usos del reciclaje de botellas de vidrio

Bloques de cemento

Siguiendo el proceso de fabricación de Bloques Caribe Inc

Vidrio agregado a bloques de cemento:

- Reduce un 11% los costos de fabricación
- Andela GP-Mini es facil de usar

Por ejemplo:
Bloques Caribe ahorra un estimado de

$507,892

anuales en material de piedra caliza

Usos del reciclaje de botellas de vidrio

Soil-less Soil

Siguiendo la investigación de OLIN Lab

Ventajas:

- Ya existe maquinaria en San Juan para pulverizar el vidrio al tamaño de arena de concreto ASTM C33.
- Aplicaciones en agricultura, infiltración de aguas pluviales y construcción

Photo by You Wu, 2019 for OLIN Lab Soil-Less soil project

Hecho de una proporción 60/20/20 de:
60% arena y vidrio, 20% abono, 20% tierra natural.
OLIN está probando diferentes proporciones de mezclas de vidrio a arena.

Conclusiones

- **Los negocios alrededor de la Caño Martín Peña están dispuestos a reciclar si entienden el propósito detrás del reciclaje y si el proceso es factible.** Si los negocios del área de Caño Martín Peña entendieran los razonamientos detrás del reciclaje y tuvieran pasos simples a seguir, estarían más dispuestos a reciclar sus desechos. Nuestro equipo considera que estos mismos principios se aplican a las empresas del área del Caño Martín Peña.

- **El reciclaje en Puerto Rico depende principalmente de organizaciones sin fines de lucro y/o grupos ambientales ya que hay una falta de apoyo del gobierno local.** Sin la ayuda y los recursos del gobierno, implementar el reciclaje de vidrio es una tarea difícil. El gobierno es consciente de muchos de los esfuerzos ambientales que ocurren en toda la isla de Puerto Rico, pero decide no apoyarlos.

- **El reciclaje de vidrio es difícil de implementar ya que, a diferencia de los plásticos y metales, el vidrio no reciclado no tiene valor monetario.** Para obtener ganancias, las empresas necesitan convertir el vidrio en un producto terminado para la venta, como los bloques de hormigón de Bloques Caribe Inc.. Estos productos suelen producir altos costos iniciales que, en nuestra opinión, los micro-negocios pueden dudar a la hora de invertir.

Recomendaciones

ENLACE motiva a las empresas de la zona de Caño Martín Peña a reciclar sus botellas de vidrio a través de un programa de incentivos.

Incentivo de Promoción Empresarial

- José Bauza informó a nuestro equipo de un sitio web comunitario, creado por ENLACE, que muestra negocios locales y encuestas en el área de Caño Martín Peña.
- Nuestra sugerencia a ENLACE para ayudar a promover negocios es crear volantes en línea para ellos en el sitio web hecho en el caño (enlace: http://hechoenelcano.org/). Esto podría atraer a más clientes (dentro y fuera de los barrios de Caño) a sus negocios.

Incentivo Monetario

- Para un incentivo monetario, nuestro equipo sugiere ejecutar un programa similar al programa de voluntariado dirigido por el G-8.
- Este programa recompensa a los miembros de la comunidad canjeando sus horas de voluntariado con "cupones".
- Estos "cupones" se pueden usar para comprar ropa, artículos de limpieza y otras necesidades, todos los cuales son donados por miembros de la comunidad y empresas locales. Este programa podría ser implementado para los propietarios de negocios en la zona de Caño Martín Peña; si reciclan un cierto peso de botellas de vidrio, entonces podrían obtener un "cupón" para usar para suministros de restaurantes/mercados.

Recomendaciones

Recoger el vidrio y enviarlo a lugares, como Bloques Caribe Inc., para ser reciclado.

El Caño Martín Peña se beneficiaría si los residuos de vidrio que se producen en la zona fueran sacados a algún lugar para ser reciclados.

Esto beneficiaría principalmente a la comunidad al:

- Mantener el canal limpio
- Mantener la calle limpia
- Reducir la cantidad de vidrio en la basura y el vertedero

Para ENLACE

- Potencialmente crear un acuerdo con Bloques Caribe

Una vez que el canal se limpia de la draga, debe permanecer limpio. Para los animales y la comunidad que viven en la zona de Caño Martín Peña.

Hay dos opciones que nuestro grupo descubrió al investigar un plan de reciclaje con bloques Caribe Inc. El primero es alquilar un camión para transportar los residuos de vidrio a Bloques Caribe Inc. en Guaynabo. Nuestro equipo recomienda esta opción porque es la más directa. El primer paso en la investigación de esta opción sería determinar el costo para alquilar un camión, y después determinar cómo los residuos de vidrio podrían ser recogidos de las empresas encuestadas. La segunda opción es transportar el vidrio a Reciclaje del Norte, que cobra por los residuos de botellas de vidrio y lo envía a empresas de bloques de cemento como bloques Caribe Inc. Reciclaje del Norte cobra 25 centavos por libra (alrededor de 550 dólares por tonelada) por el vidrio que será dejado en sus instalaciones.

Recomendaciones

ENLACE recoge los residuos de vidrio de los negocios alrededor del canal para iniciar un potencial micro-negocio. Este negocio implicaría el uso de un pulverizador de vidrio y la exploración de los usos potenciales para el vidrio triturado.

Para comenzar a pulverizar el vidrio:

Andela GP-Mini

- **Máquina compacta**
- **$38,450 para comprar y entregar**
- **Fácil funcionar**

Las especificaciones:

- **4.1 kW**
- **1 tonelada/hora**

Por que es conveniente?

1. **Eliminar los costos de transporte de vidrio fuera del Caño Martín Peña.**
2. **El vidrio, la arena, el abono y el suelo natural son materiales para crear el suelo sin suelo del OLIN. El suelo puede ser utilizado en la construcción para El Paseo, y también puede ser aplicable a la construcción de carreteras, dada investigación adicional.**