# A Glass Recycling Business Plan for the Caño Martín Peña Communities


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# Abstract

Puerto Rican recycling infrastructure is insufficient, and glass is a neglected material. Our team partnered with ENLACE, a community-based organization, to develop a small-scale self-sustaining glass recycling program to mitigate glass pollution in the Martín Peña communities, a historically low-income and underserved region. By analyzing start-up and operational costs, collection methods, and clients, our team compiled a detailed business plan that ENLACE can adapt for grant applications. The business plan is based on a dual-income model that provides free glass recycling services for the Martín Peña communities and charging collection services for neighboring businesses and selling pulverized glass to cement manufacturers.

# Acknowledgments

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# Executive Summary

Solid waste management in Puerto Rico is an emerging crisis. The United States Environmental Protection Agency (EPA) estimated that all the landfills in Puerto Rico will exceed their capacities by 2023 (EPA, 2016). The lack of available land has led to landfills being placed near homes resulting in inhospitable conditions and an increase in the rate of disease due to exposure to harmful bacteria and mosquitos carrying illnesses like dengue (Sheffield, 2014; *Prevalence of Gastrointestinal Symptoms*, 2012). The Caño Martín Peña communities have been especially impacted by inadequate waste management. The Caño Martín Peña, the canal the communities surround, has been clogged with waste and has been shrinking steadily since the 1930s. Pollution leads to stagnant water that has elevated levels of E. coli and floods the communities during times of heavy rainfall, which is not uncommon due to Puerto Rico's climate and the prevalence of hurricanes. The bacteria in the water presents public health complications, with residents showing elevated incidence rates of respiratory conditions and gastrointestinal ailments (EPA, 2012). Many residents in the Martín Peña communities still live in unplanned housing, without proper sewage systems and improper drainage systems. In Puerto Rico there is virtually no governmental support for recycling initiatives, subsequently placing the burden of recycling on private organizations and non-profits.


*Figure 1: Caño Martín Peña special district, with communities labeled in the context of all of San Juan (Ponce, 2018).*

**Project Description and Objectives**

Our team worked with ENLACE, a community development organization established in 2004 and headquartered in San Juan, to address glass waste buildup by developing a business plan for a glass pulverizing center. Based on a discussion with Carmen Febres, the president of the only recycling initiative in the community, Martín Peña Recicla, our team learned that community members have attempted to recycle glass at their business. Martín Peña Recicla does not currently have the resources to collect glass waste, as they lack the ability to redistribute the waste to buyers. Glass is one of the few materials that is 100% recyclable and does not deteriorate after multiple uses. Furthermore, in a landfill, it could take over a million years for glass to decompose (Kellogg, 2019). Using glass sand in cement is a process that a few block cement companies in Puerto Rico have started and the uses for glass sand are expanding into areas such as sandblasting, landscaping, gardening, environmental restoration, and natural

disaster prevention. Therefore, our project developed an economically self-sustainable business plan for a glass pulverizing center in the Martín Peña communities. We achieved this by first determining an effective method of glass collection in the Martín Peña communities. We estimated the space, resources, personnel, and funding required to operate a glass pulverizing machine and center. Then, we compiled a list of potential clients and partners who may be interested in working with ENLACE to develop a self-sustainable glass pulverizing center in the Martín Peña communities. Finally, we compiled our findings into a business plan for ENLACE to use for grant applications.

**Methods**

We conducted a series of interviews with non-profit organizations, recycling companies, and other businesses to get a sense of their thoughts on glass recycling and what is currently in place to help us develop our business plan. Our project required the calculations of the costs for the first three years of operation and the initial costs to develop the facilities and purchase equipment. Then, we compiled a list of clients and partners for the business. Our team contacted multiple companies in hopes of interesting them in purchasing glass sand or providing funding. This process was challenging as it was difficult to acquire responses from most of the companies. In terms of potential partners, our team was able to successfully get in contact with Bacardi, Martín Peña Recicla, as well as Coconut Breeze Recycling[1]. Finally, we developed the business plan as a tool for ENLACE to understand the initial costs of operation and maintenance of a glass pulverizing center. Through interviews, our team also sought to determine whether the introduction of a self-sustainable glass recycling business would be feasible for the community.

**Findings**

The interview with the president of Martín Peña Recicla, Carmen Febres, allowed us to determine what materials they currently collect, the collection route, and the method of collection in the communities. Our team found that many residents are willing to recycle glass, but there are no current recycling systems that accept glass in the communities. A partnership with Martín Peña Recicla would allow our business to collect glass waste in the communities for free. Our team also investigated collecting glass from affluent communities as a secondary

[1] A glass recycling company who wishes to remain anonymous

collection method. This would result in collecting a greater volume of glass to pulverize, while simultaneously providing our business with a secondary flow of income to ensure profits. The business will charge a small fee for collection services, which will include a fixed rate and a variable rate for collection. Our team also found that we can charge increased rates depending on zone-based collection: the further away the company is from the collection center, the higher the cost of collection may be. Although our team was able to interview Bacardí, the information shared with us was not applicable to the business model.

The calculations of the costs for the first three years of operation and the initial costs provided us with an insight into the amount of money that ENLACE would need to receive in grants and partnerships to fund the initial costs of the business. The operational costs allowed our team to determine the required amounts of glass collection and processing the business will need to break even. This break-even point allows ENLACE to set goals on the amount of glass they will need to collect yearly, weekly, and daily to not only break-even but also begin to turn a profit. Our team provided ENLACE with the number of collection sites at external businesses they will need to theoretically partner with to offset the cost of collecting for free in the Martín Peña communities. In doing so, our team determined a fixed rate as well as a variable rate for glass collection that would give the business a competitive edge over other communities in San Juan.

The business plan includes the first all-in-one service in Puerto Rico that includes collecting, pulverizing, and delivering pulverized glass to our clients. After talking with a recycling company, we found that there are two distinct categories of clients for this business: clients who would pay for their glass to be collected by the company and businesses that would purchase glass sand from the recycling company. In addition, many companies and organizations are aware of the applications and importance of glass sand and that residents are willing to drop off the glass, but there is not a proper recycling system that allows glass recycling. This shows the potential of the business. In sum, the business plan would be an effective way to limit glass waste and provide a stream of pulverized glass to businesses looking for such a supply.

**Conclusions and Recommendations**

From our interviews, our team made several conclusions and recommendations for ENLACE to continue expanding the business plan. Our team concluded the following: glass sand

has many diverse potential uses; Puerto Rican residents are willing to recycle glass, but there is a lack of infrastructure; glass is 100% recyclable and reusable but is the most difficult material to recycle. Our team, recommends that ENLACE first secures collection contracts with businesses in San Juan, especially in Condado and on Borinquen Avenue due to the high volume of restaurants, bars, nightclubs, and liquor stores. Secondly, using the business plan will allow them to apply for grants and funding to further expand the business. Finally, our team recommends that future researchers pursue the implementation of a bottle bill in Puerto Rico.

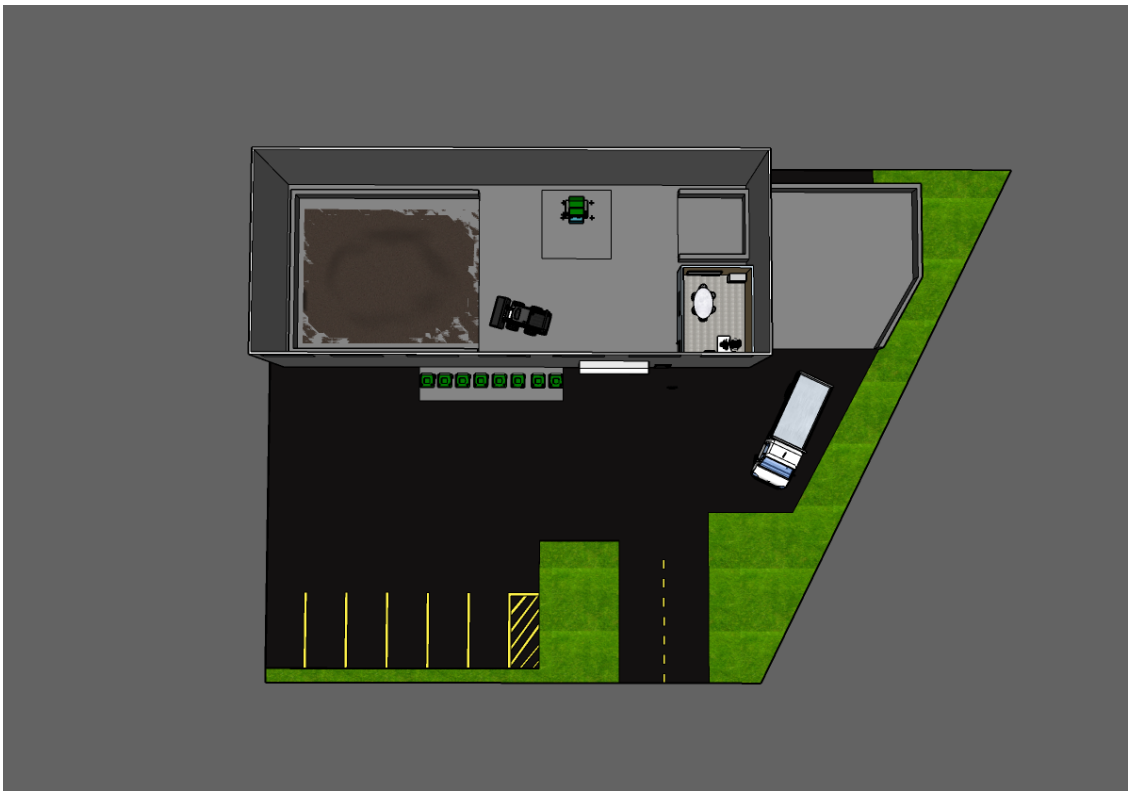

*Figure 2: 3D model of warehouse space.*

# CHAPTER 1: Introduction

A 2016 United States Environmental Protection Agency (EPA) report estimated that all landfills in Puerto Rico will exceed their capacities by 2023 (EPA, 2016). Overflowing landfills could be detrimental to Puerto Rico. Puerto Rico's limited land space means that landfills consume the land that would otherwise be able to cultivate rich ecosystems. Trash has begun to overflow into the surrounding oceans, causing mass pollution. Due to a lack of land, landfills are often located near people's homes leading to unsafe and even inhospitable living conditions. The need for strong recycling programs is now more urgent than ever, especially with an increase in the intensity and frequency of hurricanes because of climate change. These catastrophic events leave large quantities of waste and debris in their wake, which further exacerbates the problem of landfill capacity.

In communities where there are limited recycling programs, like those along the Caño Martín Peña (the Martín Peña channel) in San Juan, recyclable materials are either sent to landfills or disposed of in places such as parks and public waterways, which could otherwise be reused or recycled. Without the proper infrastructure in place to support environmentally sound practices, residents often resort to throwing their waste into the Martín Peña channel. What was once a steady-flowing waterway home to a thriving ecosystem is now clogged with waste and debris. The channel stands stagnant, prone to flooding, and blooming with bacteria and pathogens. Proyecto ENLACE del Caño Martín Peña (ENLACE) was founded in 2004 as a community development project with the main goal of dredging the channel, but preventative measures to avoid future pollution are not adequately covered. While recycling is present in Puerto Rico to some extent, with mandated recycling plans in certain areas, glass recycling is excluded from government-funded programs. With a lack of government recycling initiatives covering the full scope of recyclable materials, it is up to corporations like ENLACE to construct programs that effectively redirect glass waste streams away from landfills and public spaces into recycling centers.

Glass recycling has been a point of interest in Puerto Rico for several years. Life cycle assessments, infrastructure assessments, and different recycling strategies have been explored in Puerto Rico by multiple researchers and organizations (Baigés-Valentín & Franics-Cordereo, 2021; Monserrate-Cid & Rodriguez-Abudo, 2018). A critical issue is a lack of proper

infrastructure, such as labor, land space, required buildings, vehicles, machines, and enforced government legislature (De Sevilla, n.d.; Francis-Cordero, 2021). This lack of infrastructure is worsened in part by the prevalence of hurricanes on the island and the damage they cause (Glatsky, 2019). After a hurricane, chemically contaminated debris can sit in water for weeks until haulers and waste management groups have the chance to collect it (Maher, 2017). The mixture of different types of debris further hinders the ability to recycle, as all types of waste and debris are mixed and can be difficult to separate to ensure the waste gets to the correct collection centers (Maher, 2017). The whole island's recycling rate is estimated at 12-14%, but real figures vary by area (Glatsky, 2019). This is also true for Martín Peña, which is comprised of eight separate communities on either side of the channel. Based on survey data collected last year by a WPI research team, businesses in the Martín Peña communities do not recycle glass (Barthold et al., 2022).

There is little research on the creation of a privately funded glass recycling program, as most successful recycling models rely on government funding and regulations. The models used as examples are often within the mainland United States and Europe. Without government involvement, communities must rely on private companies and organizations to collect their waste which comes at a high cost to the community members. Furthermore, without government legislation or enforcement, communities will not be held accountable for recycling their recyclable goods.

Our project developed an economically self-sustainable business plan for a glass pulverizing center in the Martín Peña communities. Our team achieved this by first determining an effective method of glass collection in the Martín Peña communities. In addition, our team examined how glass is pulverized, the markets for pulverized glass, and its benefits to help improve glass recycling in the Martín Peña communities. Our team estimated the space, resources, personnel, and funding required to operate a glass pulverizing machine and center. Our team then compiled a list of potential clients and partnerships who may be interested in working with ENLACE to develop a self-sustainable glass pulverizing center in the Martín Peña communities. Finally, we compiled our above findings into a comprehensive business plan to be used for grant applications to financially support a glass recycling program.

# CHAPTER 2: Background

This chapter will provide necessary background information for this project. We first discussed the current waste management systems in Puerto Rico and the limitations of recycling infrastructure in the Martín Peña communities. Next, we examined different glass collection strategies. Our team then discusses different uses for recycled glass, specifically in pulverized form. Finally, we introduce the Caño Martín Peña communities, including their history and present-day challenges, and current community development efforts such as ENLACE.

## 2.1: Waste Management in Puerto Rico

Puerto Rico's recycling systems are inadequate. The Puerto Rico Recycling Partnership, created by the U.S. EPA and the Puerto Rican government, estimates that only 12-14% of waste generated by Puerto Rico is recycled (Glatsky, 2019). This is especially low considering the rate of recycling in the mainland United States is almost triple that, at 32% (EPA, 2022). Approximately four million tons of non-hazardous waste is dumped into Puerto Rico's landfills every year. Landfills are especially detrimental on islands, where land is limited and waste overflows. There are currently 29 landfills in Puerto Rico, most of which are over capacity and non-compliant and 12 are currently being closed by the U.S. EPA (Glatsky, 2019). Natural disasters, mostly hurricanes, bring high amounts of waste and debris and contribute to Puerto Rico's landfill problem. After Hurricanes Irma and Maria in 2017, 12 million cubic yards of debris were transferred to these landfills (Covington, 2019). Not only are landfills piling up rapidly, but the conditions of these landfills usually do not follow environmental regulations. For example, a landfill in Vieques lacks a liner. This in turn results in waste seeping into the ground and contaminating the local water sources (Closed Loop Partners, 2020). These leachates contain heavy metals, ammonia, and other toxins which can make their way into bodies of water and nearby communities. A lack of proper soil covers over landfills can lead to fires that harm the air quality in surrounding communities. Since Puerto Rico is a small island, there is limited space for landfills and they are often near communities, creating public health threats. Residents near the Vieques landfill report strong odors that are often so unbearable they feel the need to relocate (Dalmau, 2022). If waste could be allocated more effectively to recycling and composting streams, the landfills' growth rates would decrease significantly.

Recycling in Puerto Rico faces numerous challenges. One significant challenge is the lack of separation of recycled materials, which originates from collection. Specific guidelines

must be followed when recycling: recyclable goods must be washed, and the labels and tops must be removed to reduce cross-contamination with non-recyclable materials. Additionally, glass, plastic, and cardboard should be separated. These guidelines are often disregarded, which leads to cross-contamination and means that an entire cross-contaminated batch will be sent to landfills. Not only is it difficult to properly sort and discard recycled items, but it often appears cheaper to landfill. Puerto Rico charges a low rate for landfill tipping, at between $19 and $28 per ton, compared to the national average of $55 per ton. On many occasions, this means municipalities and companies will collect recycling only to send it directly to landfills (Glatsky, 2019).

The other reason for the lack of adequate recycling is the absence of sufficient legislation. Recycling practices are legislated through the Puerto Rico Solid Waste Reduction and Recycling Act of 1992 (PRSWRR). This act states that all municipalities, agencies, and private entities are required to formulate and implement a recycling plan. This plan must consist of established deposit centers, systems to deviate waste away from sanitary landfills, penalties for violations, and the prohibition of disposing of recyclables into landfills (Guillermo, 2019). In addition to recycling plans, municipalities must supply the Department of Natural and Environmental Resources with a quarterly report (Garofalo, 2019). Materials that are recycled are done so through around 103 entities and facilities in Puerto Rico, consisting of small operations handling specified streams of waste (Closed Loop Partners 2020).

The flaws of this act lie primarily in the lack of compliance. Zaidi Guzmàn of IFCO recycling, the main operator of recycling facilities, reports that although municipalities are required to recycle, there is a lack of enforcement. He estimates that only 48 out of 78 municipalities have some sort of recycling plan. Very few municipalities adhere to the requirements of the legislation, especially those in low-income areas. The municipalities in low-income areas do not have sufficient funds to finance operational costs of waste management infrastructures such as transportation, collection, and disposal. This becomes an even greater issue in urban areas where waste production is high. High waste production coupled with poor waste management infrastructures results in an increase in littering and improper waste disposal (Karak et al., 2012).

Despite the presence of plans in many communities, there is no enforcement of the policies. In this sense, there are discrepancies in what constitutes a good recycling plan, leading

municipalities to implement the bare minimum. The associated goal in the PRSWRR act was to recycle 35% of the generated waste but, as previously stated, Puerto Rico has only been able to recycle around 12-14% of its waste (Glatsky, 2019). Glass recycling is extremely sparse. The government does not provide any glass recycling programs; only paper, plastic, and metal, which means all glass recycling programs must be privately run. It is in the hands of non-profit organizations and environmental groups to provide glass recycling initiatives. These private recycling initiatives face many challenges, especially when it comes to generating a profit and gaining public participation.

## 2.2: Glass Collection

This section describes the differences between residential and commercial collection systems, the advantages and disadvantages of each, as well as ways to incentivize recycling behavior and increase awareness about glass recycling in the Martín Peña communities.

### 2.2.1 Collection Systems

In a simple commercial collection model, businesses would receive large recycling receptacles, like a trash dumpster, and the waste would be collected on a set schedule. If the businesses are working with buy-back facilities and companies, there could be a small profit earned each week just from recycling. This model would likely work best if there was little to no government funding and was instead run by a private recycling organization that collects and redistributes the waste. The most common model utilized in residential areas of the United States involves individual households, supplied with their own trash and recycling receptacles, with the waste company or municipality having a collection route they follow on a predetermined schedule.

With recycling comes costs. According to Cointreau-Levine (1994), in less industrialized countries approximately 95% of the costs associated with recycling are attributable to the collection and public cleaning, while in industrialized countries about 70% of the costs are attributable to the collection and public cleanings. Without government assistance, these costs fall onto private companies and organizations and can be difficult to manage. According to Harvey Black (1995), landfilling costs were only $28 per ton in 1995, compared to $147 per ton to recycle, with these numbers being from California and considering all their recycling waste streams. A commercial recycling program is easier to implement, as it begins with a smaller group recycling their waste but in larger quantities. It is cheaper to incentivize small groups as

opposed to all individuals in each community. Businesses would be able to make money off their waste and would be more likely to continue to recycle their waste if there was a buy-back incentive that generated a small profit (Lafferty, 2019). Collection, however, does rely on community involvement and willingness to participate.

### 2.2.2 Incentive Programs

Incentive programs have proven to be effective across the world in encouraging recycling behavior. Bottle bills are some of the most common incentive tools used, where a few cents are added on to the purchase of every bottle or can, and the container can be returned after use in exchange for those few cents back. Bottle bills, also known as "container deposit laws," are applied to plastic, glass, and aluminum containers (*Bottle Bill States and how they work,* 2021). Bottle bills have shown enormous success in countries such as Sweden and in some states in the United States such as Maryland (Swedish Recycling and Beyond, 2022).

Environmental and public health knowledge serve as non-monetary incentives. Educating the public on the benefits of recycling in their lives can motivate recycling behavior, but these are often more difficult to advertise and less motivating than monetary incentives (Aprile & Fiorillo, 2019). Using the idea of self-efficacy and change from within, providing the communities with the information required to be educated on the topic will hopefully encourage self-motivated change around their recycling behaviors (Strecher, 1986). People are much more likely to change their behavior if it comes from within their community or group rather than from a group of outsiders telling them their current practices are wrong (Juliana et al., 2021).

The state of Maine has the highest recycling rate according to TOMRA, the inventors of the reverse vending machine. In 2017 Maine's recycling rate was reported at 84%, and an estimated 91% of all beverage containers sold in the state were eligible for deposit refund (TOMRA, 2021). There is not an available breakdown of glass recycling rates but, when examining the states without bottle bills it was found they had significantly lower rates of recycling than states that did have bottle bills implemented. Looking at a state without a bottle bill, the worst state at recycling in the nation is West Virginia. Previous bottle bill proposals fell through and never passed. A 2021 study by Eunomia, commissioned by Ball Corp., reported that West Virginia had a recycling rate for glass, plastic, and aluminum of only 2% (Rose et al., 2021). Including cardboard in this rate brings this up to only 31%, making West Virginia 40$^{th}$ in the nation (Hodousek, 2022). While effective, incentive programs like bottle bills are difficult to

implement without some sort of public policy and government funding, making application in the Martín Peña communities a challenge.

## 2.3: Uses of Recycled Glass

Glass waste is one of the hardest materials to recycle due to its high weight, low value, and risk of cross-contamination (Schildgen, 2018). Even given the challenges of recycling glass waste, recycling methods have been developed to combat the growing rate of glass pollution in different areas around the world. Glass recycling takes on three forms: material recycling, product recycling, and feedstock recycling. Material recycling is when glass is used for its chemical properties. This form of glass recycling is used to create new glassware from the chemical compositions of old, recycled glassware. Product recycling is when the chemical and physical aspects of the glass are preserved, and the glass is cleaned and reused, such as for art. This process is also used to create other mediums such as concrete mixtures and water filtration when the glass is crushed into sand. The final process of glass recycling is feedstock recycling. This is when the physical and chemical properties of the glass material are reused and turned back into their original forms (Lebullenger, 2019).

Glass recycling takes the form of two larger systems: closed and open-loop recycling. Closed-loop glass recycling involves a process of melting the glass back down into its original contents and reusing the base materials in the creation of new glassware. The glass in this system needs to be sorted by color due to the chemical nature of each color of glass being slightly different. This process is important because the final product is the same as the original. It is considered “closed-loop” due to the nature of the processes being self-sustainable (Dyer, 2014). The secondary recycling system is open-loop recycling, in which the glass is melted but the contents of the glass are reused to make a new product. Both recycling systems are environmentally friendly, which is important for the well-being of the Caño Martín Peña communities.

One of the most common glass recycling options is pulverization. This process involves the physical destruction of glass into smaller particles which are then used in glass recycled products. There are two methods used to pulverize or “crush” glass waste. The first is abrasion crushing which uses the power of compression to break apart materials into smaller contents. This version of crushing also relies heavily on the force of friction (CWC, 1994). The second method of crushing is impact crushing, which relies on the collision of rocks or other strong

material to break apart the glass (CWC, 1994). The process of glass pulverization is efficient in opening new avenues for glass waste, such as concrete, water filtration, and other mediums.

Glass can be used in concrete mixtures to replace typical sand materials. The glass sand must be crushed and pulverized to be used in the cement-based mixture. Research performed by Edward Harrison and his team (2022) found the application of this glass-based cement mixture could replace sand-based mixtures. When glass accounts for around 20% of the glass mixture, the strength and rigidity of the cement are optimized (Harrison, 2022). When the glass was used in a mixture upwards of 30%, negative impacts on the cement began to be observed. The team compared properties of silica-based cement mixtures and glass waste cement mixtures, and both performed at similar levels. There was an overall improvement in the mechanical properties of the cement when the two mixtures were used in combination with one another (Aly, 2012). When the two mixtures are introduced to one another, the silica-based cement powder will increase the density of the glass mixture and increase the binding ability (Lu, 2018).

Typically, sand is mined from beaches, lakes, and riverbeds and is one of the most mined materials in the world (Hernandez, 2021). Environmentally, the replacement of sand with glass-based mixtures allows for the reduction of the demand for sand and introduces a sustainable source of material for concrete mixtures. The replacement of the sand mixture with glass-based mixtures has already been implemented in a company in Puerto Rico called Bloques Caribe and a business model like theirs will be beneficial for other concrete manufacturers in the area.

For example, glass is recycled in the US Virgin Islands (USVI) through the production of glass cullet, silica sand, or ground-glass pozzolan. Another example is St. Martín's glass recycling initiative, which involves using the cullet/silica sand for a multitude of different uses such as filtration, landscaping, and concrete substitutes (*Industrial Economics*, 2021). Finding a glass processing system that works for the Caño Martín Peña communities will be a crucial part of the waste management/glass recycling process. USVI's annual waste is handled through a system that processes twenty tons of glass per hour. In this system, there are a total of five glass crushers: two in St. Croix and three in St. Thomas (Cobb, 2021). The cost of the glass pulverizer should be considered, because to process "one-half ton of glass per hour, it costs $28,000 to purchase the machine and $8,400 to operate it annually" (*Industrial Economics*, 2021). For a larger system of twenty tons per hour, "it costs $350,000 for the machine and $16,900 to operate

it annually" (*Industrial Economics*, 2021). In addition, recycling glass is cost-effective within the USVI instead of having it shipped for disposal off-island (*Industrial Economics*, 2021).

*Figure 3: Glass Pozzolan (RED).*

*Figure 4: Glass cullets (Ksaibati 2007)*

*Figure 5: Glass sand (Rodriguez 2022).*

The usage of glass waste spans beyond concrete. Systems such as water filtration have been found to benefit from the implementation of glass waste. Implementing pulverized glass into water filtration mediums increases the lifespan of the filters and reduces the amount of maintenance energy required to upkeep the filtration mediums (Sioneer, 2018). Sioneer, a company focused on water filtration development, tested glass sand against silica sand and found it reduced the amount of clogging and increased the overall efficiency of the filtration process. The increase in the demand for recycled goods has led to studies about the usage of glass sand in the backfilling of landfills. The use of pulverized glass in landfills was found to yield satisfactory results for all parties involved: the buyer and the seller (Schmucker, 1995). The application of pulverized glass waste was found to have a widespread application like its traditional sand counterpart (Kazmi, 2021).

## 2.4: Caño Martín Peña

### 2.4.1: History

The communities built on the Martín Peña channel have endured a history of instability over the past century. The channel, spanning 3.75 miles, connects San Juan Bay to the Laguna San Jose (Urban Waters, 2022). The location of the channel and the surrounding communities can be seen in Figure 1. The 1920s and 1930s brought new hardships to Puerto Rico. Up until then, Puerto Rico had relied on a one crop economy: sugarcane. Two hurricanes destroyed nearly all the sugarcane plantations, leaving farmers with little source of income (Padilla, 1978). These catastrophes coupled with economic hardships from the Great Depression left

rural, impoverished Puerto Ricans with few options. The result was mass migrations in the 1920s and 1930s through the 1940s from inland farms to the capital city of San Juan. Many farmers came to San Juan in search of a place to live and work. Families faced difficulties finding opportunities to raise their families, and the land surrounding the Martín Peña Channel served as an opportunity for development in an already crowded city. New residents squatted on this public, government-owned land that was previously deemed unfit for residential or commercial use (Padilla, 1978). Homes were built on the once biodiverse banks of the channel using refuse and debris as a foundation. The result was the growth of overcrowded communities and crammed houses along the channel. The banks of the channel came to house around 80,000 people (Padilla, 1978). This area became known as the "slum belt" and consisted of eight neighborhoods: Lan Monjas, Israel-Bitumul, Barrio Obrero Marina, Buena Vista Hato Rey, Barrio Obrero San Ciprian, Buena Vista Santurce, Para 27, and Cantera. This area has been described as "the worst slum in the city." They have experienced more welfare cases, infant mortality, tuberculosis, pneumonia, and truancy than anywhere else in San Juan (Padilla, 1978).


*Figure 6: Caño Martín Peña special district, with communities labeled in the context of all of San Juan (Ponce 2018).*

### 2.4.2: ENLACE Project

Three entities were formed under Caño 3.7 in response to the deterioration of the canal and its surrounding communities: G8, ENLACE, and the Caño Martín Peña Community Land Trust. In 2002, G8 was formed as the first of the three organizations. G8, Grupo de las Ocho Comunidades Aledañas al Caño Martín Peña, serves as a community-based organization to bring together leadership from all eight communities. It serves as an organization to promote public engagement in decision-making for the advancement of the communities. Under law 489 in September 2004, Corporacion del Proyecto ENLACE del Caño Martín Peña (Caño Martín Peña ENLACE Project Corporation) was formed as a response to community efforts through G8 and in coalition with the Puerto Rican government. This is an extensive movement pushing for the betterment of the environmental, economic, and social integrity of the communities surrounding the channel (Brodine, 2019). The major plan of this project is to dredge the canal to bring its depth and width back to its' original state and relocate homes away from the banks. The Land

Trust was created to protect residents during this relocation process. In the process of dredging, residents are given new homes built under ENLACE with no extra costs. It also establishes residents' legal rights to their land along with necessary permits (World Habitat, 2016). This was not established before the trust due to the historic settlement on previously government owned land. Together with community participation from G8, ENLACE has grown into an internationally recognized project and has gained the support of the United States Environmental Protection Agency, who provided them with an Urban Waters Small Grant in 2011 and designated the Caño Martín Peña as an Urban Waters Federal Partnership location. This partnership recognizes the importance of waterways in urban communities and provides distressed communities with resources to reconnect them with their waterways (US EPA, 2022). The collaboration of community efforts, public corporations, and federal partnerships has resulted in a project that is sure to improve the conditions of the canal and its communities in the coming years.

### 2.4.3: Current state of Caño Martín Peña

*Figure 7: Aerial views of the Caño Martín Peña in 1936(top) and 2018(bottom) (Mazereeuw, et al. 2022).*

The Caño Martín Peña is in a state of deterioration and now provides unsafe living conditions for its citizens. The use of debris as a foundation paired with poor infrastructure and waste management has led to high levels of pollution in the channel. The channel has decreased significantly in size and depth in the past century from an original 200-400 feet in width to a maximum of barely 100 feet in 2018 because of development and pollution (River Rail, 2021). This shrinkage can be seen in aerial imagery in figure 6 above. Additionally, there is a lack of adequate stormwater and sewage drainage systems which also contributes to high levels of contamination (Sheffield, 2014). Beyond contamination, flooding is also a problem. The clogging of the channel has led to shallow, stagnant waters which flood easily into homes, yards, and streets. According to a Health Impact Assessment conducted in the communities, over half of the community experiences flooding in their homes. When these waters flood residential

areas, the people in the Martín Peña communities are exposed to harmful bacteria and disease. Water samples collected by students and faculty of the Public Health Program and Ponce School of Medicine and Health Sciences in December 2011 exceeded standards for fecal coliforms and enterococci. The flooded environments also provide ideal conditions for mosquitoes which can carry illnesses such as dengue and chikungunya. Exposure to these contaminants contributes to increased levels of gastrointestinal illnesses. These floods not only damage homes and expose residents to potentially dangerous contaminants, but they also lead to school closures and work disruptions. This can be especially detrimental in communities like Martín Peña that have a long history of poverty and instability and where education and work are critical for residents to build a future (Sheffield, 2014).

The root cause of the problems along the channel is pollution due to inadequate waste disposal. Glass, plastic, cardboard, and aluminum build up and clog the channel. Without proper waste management systems, the Caño Martín Peña communities continue to discard trash in informal ways (Padilla, 1978). Today, over 3,000 structures dump their sewage and waste into what remains of the channel (Urban Waters, 2022). With ENLACE's plan to dredge the channel, proper waste management systems must be put in place to prevent further destruction and prevent history from repeating itself.

# CHAPTER 3: Methodology

The goal of our project was to develop a business plan for a self-sustaining glass recycling company within the Martín Peña communities. The methodology is split into four objectives, which are discussed in depth in this chapter.

1. Determine an effective glass collection method for the Martín Peña communities.
2. Estimate the space, resources, personnel, and funding required to operate a glass pulverizing center.
3. Identify a list of potential clients and partnerships.
4. Compile all our findings into a business plan

This chapter describes our methodology to develop a glass bottle recycling business plan for ENLACE and the Caño Martín Peña communities.

## 3.1 Determine an effective method of glass collection for the Martín Peña communities.

We determined a collection method for the Martín Peña communities that maximized glass collection while minimizing operational costs to optimize profits. To do so, our team conducted semi-structured interviews with two recycling companies in San Juan, Puerto Rico. These recycling companies fell into two categories: (1) those with existing glass recycling programs, and (2) those that have not yet developed a glass recycling program. For example, Coconut Breeze Recycling has an existing glass recycling program, while Martín Peña Recicla does not, making both interviews integral to our team. We asked questions regarding:

- Why is glass difficult to recycle?
- Can glass recycling be profitable?
- What would the best way to collect a high volume of glass be?
- How do you receive your recycled material?
- What are some difficulties you have experienced in the collection process for recycled materials?

See appendix D for a complete list of the interview questions our team asked organizations with glass recycling processes already in place. Our interviews lasted around 30-45 minutes. The companies were given the option to conduct interviews in person or online based on their availability. Our team interviewed Martín Peña Recicla in person, and Coconut Breeze Recycling

online. The companies were given the option to conduct interviews in person or online based on their availability.

As outsiders in the Martín Peña communities, we did not have strong relationships with community members such as Carmen, the organizer of Martín Peña Recicla. To combat this, our team was able to partner with our sponsor José to garner more credibility. Within the same interviews we experienced a language barrier which was overcame with the presence of José who acted as a translator.

## 3.2 Estimate the start-up and operational costs of a glass recycling center.

Analyzing the start-up and operational costs, along with potential profits of all aspects of the business model allowed our team to determine the economic feasibility of a glass pulverizing business. We determined what costs needed to be included in start-up costs by looking into what was needed before operations could begin. These variables included the machinery, trucks, collection bins, warehouse construction, and the shipping costs associated with materials and machinery. We then determined the necessary costs to include in operational costs for the first year, which included insurance for workers and machinery, maintenance on machinery and vehicles, workers' wages, electricity, gas, and general warehouse maintenance.

After these costs were determined, we conducted internet searches, interviews with recycling companies, and inquiries with specific companies such as Andela Products to identify realistic estimates for each cost variable. The initial costs of the business were determined to provide ENLACE with an estimate of the funds required to begin the process. All the operational costs calculated were compared to the profits of the machines using an excel spreadsheet to determine the feasibility of operating the business. The use of the spreadsheet (see Appendix I) allowed our team to change variables such as wages and the amount of time working to determine the different possible scenarios associated with the operation of this business.

Our team ran into limitations regarding the generalization of numbers. Not all the numbers used in calculations are Puerto Rico specific or necessarily from this year or last year, meaning they don’t account for inflation. These generalizations can lead to minor inaccuracies in calculations such as gas costs for the first year. See appendix K for information on the research conducted to find each number in our business model.

## 3.3 Identify a list of potential clients and partnerships.

To ensure that ENLACE can be successful with their proposed pulverizing center, we created a list of potential clients and partners for the selling of the glass sand product. We determined if the potential clients were in an industry where glass sand could substitute a material they already use at a competitive price. The industries where glass sand can be used were determined through internet searches about the uses of glass sand. By providing ENLACE with a baseline number of potential clients and partnerships their pulverizing center business could have, our team ensured they had a good starting point of contacts to sell their product/service to, as well as companies and organizations who could potentially partner with them for business or financial support. See Appendix C for the full list of potential clients.

Potential partners were found in a similar way. Our team found some organizations and companies that collect and deliver glass for recycling, as well as businesses and organizations that pulverize glass and make products with the glass sand or cullet. With regards to potential financial partnerships, our team investigated Puerto Rican alcohol companies, such as Bacardí, Don Q, and Medalla, as they already have environmental sustainability efforts in place. Some of these companies have previously backed similar projects and have a higher vested interest in Puerto Rico's environmental efforts than a company based in the mainland United States or Europe.

When attempting to conduct interviews with potential clients for our business our team found there were very few companies willing to talk to us about becoming potential clients. Our team combatted this by conducting research on all cement companies in the San Juan area to compile a list for ENLACE to pursue within first year of operations and by attempting to send emails questions to the companies and their higher ups.

## 3.4 Compile all findings into a business plan

We developed a business plan to be used as a tool for ENLACE to acquire funding for the initial costs of operation. To complete the business plan, our team pulled information from all aspects of the results to determine the best possible approach for ENLACE when developing the glass recycling business. We researched the relevant information necessary for a business plan, which we found to include the following sections and more: factors for success, financial statements, and competition. We then pulled information from the previous objectives to create

the business plan. This business plan will give ENLACE all the information they need to follow through with the creation of a glass recycling business.

When compiling our business plan our team found that many businesses did not have an interest in talking to us and presenting themselves as potential clients. Without being an established business with services to offer, many companies were not interested in talking to us about becoming formal clients. Our team did, however, identify potential clients that could benefit from the business's services.

# CHAPTER 4: Findings

Our team developed a business plan for ENLACE which we expect to be used to guide the formation of a glass recycling center within the communities as well as to apply for funding. This business plan outlines the keys to success while also providing a comprehensive guide to the cost of operation. We have presented a compilation of the information found through interviews and research. We determined this business plan to be the most efficient method of displaying our findings and have attached it in the following section.

# BUSINESS PLAN

Reciclaje de Vidrio Caño Martín Peña


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## Executive Summary

Proyecto ENLACE del Caño Martín Peña has been committed to public development in the Martín Peña communities since 2004. Within the Caño Martín Peña communities, ENLACE aims to eradicate glass waste and simultaneously create job opportunities. By collecting glass waste from community members, pulverizing the glass, and then delivering the glass sand to clients, glass pollution can be reduced, helping prevent the clogging of the channel, and the economy can be stimulated. Glass sand has advantages over natural sand, as natural sand is a non-renewable resource with a steadily rising price due to lack of supply, and other sand substitutes such as silica sand have long term health risks such as silicosis and lung cancer. The impacts of collecting and recycling the glass include but are not limited to reducing the amount of glass pollution on the island by up to 430 tons a year, reducing the amount of limestone required to be imported, and saving space in landfills and by extension, saving the municipality money (EPA, 2018).

Throughout Puerto Rico, only a small percentage of glass is collected and recycled since it is more difficult to recycle than other waste streams. Through a novel business model, Reciclaje de Vidrio aims to provide glass recycling services free of charge to the Caño Martín Peña communities, which will be subsidized through a dual-income model. Income will be derived from the collection of glass waste outside of the communities in areas of high income and tourism, targeting businesses such as hotels and bars. The secondary stream of income will come from the selling of the pulverized glass to cement block companies and other companies in the realm of construction. ENLACE plans to steadily grow with the goal of being able to continue to employ more individuals from within the Martín Peña communities and eventually have the capacity to accept glass from individuals around San Juan.

While there are some companies that collect glass in San Juan, it is on a very small scale, they operate in a deficit, and only collect and deliver the glass. The largest glass collection company only caters towards affluent residents as they also charge $0.25 per pound of glass being dropped off. The current glass customers own pulverizers, but they do not receive glass in large quantities and must take on the costs associated with owning and operating a pulverizer.

With grant funding to cover the start-up and first year of operation costs, we project a profit of $14,509 in the first year with two full-time employees: a truck driver and a manager. During this first year, only collection will occur. After this point, three workers will be employed, a truck driver, a warehouse worker, and a manager for full operations of the pulverizing center. The truck driver and warehouse worker will be paid $15 per hour and the manager will be paid $23 per hour. The second year, we expect a gross profit of $29,059 through the collection and pulverization. We are seeking $324,474 in funds to finance the startup and first year operational costs.

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## Description of Business and Services

Reciclaje de Vidrio will tackle three phases of glass recycling in the Martín Peña communities. The first will be the collection of glass bottles and other glassware within the Martín Peña communities. This will be achieved through a partnership with Martín Peña Recicla, developing a collection route to allow for the collection of glass. The collection will also be completed through a collection site developed at the pulverizing center where community members and businesses can bring their glass waste and drop it off. Free collection in the communities will be subsidized through the collection of glass outside of the communities for a price. The second aspect of our business will pulverize collected glass waste. Reciclaje de Vidrio will obtain a pulverizing machine which will be used to crush the glass waste into sand and glass cullets. The final aspect of Reciclaje de Vidrio will be supplying pulverized glass and glass cullets to the market. Reciclaje de Vidrio will provide a steady stream of pulverized glass to cement manufacturers and other construction companies who are looking for a supply of pulverized glass.

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## Mission and Background

ENLACE has been dedicated to working with the Martín Peña communities since 2004 with the end goal of implementing the Comprehensive Development and Land Uses Plan for the Caño Martín Peña Special Planning District (CMP District Plan) through the dredging of the

canal. ENLACE has started many programs that promote community development such as their business incubator as well as public educations programs educating youth and adults alike. ENLACE's involvement in the community makes them valuable to community members. The relationship they have built with the communities has prompted community members to cooperate and participate regularly in ENLACE's programs.

One business that was created with the support of ENLACE and local government is Martín Peña Recicla. Martín Peña Recicla collects recyclable materials except for glass and the community participates highly in their collection program. Martín Peña Recicla will serve as a strategic partner as Reciclaje de Vidrio will follow their collection route and place bins along the route, so community members don't need to seek out new drop-off locations. When ENLACE was approached by a member of their own community about the issue of glass waste and the role it plays in the clogging of the canal, they knew it was an issue worth tackling. ENLACE wants to eliminate all glass waste from the community and create jobs and aims to achieve this by collecting glass bottles from the community members, pulverizing the glass, and selling it to companies. In Puerto Rico there is little glass recycling, as it is expensive and heavy and requires many resources. What ENLACE aims to do is pilot a program for glass recycling, starting first within the Martín Peña communities and then hopefully expanding across San Juan.

Extensive research has been done over the past two years by Worcester Polytechnic Institue (WPI) research teams regarding the collection, distribution, and uses for recycled glass, as well as into the Caño Martín Peña communities and glass recycling in other countries. This research culminated in the idea for this specific business model. Based on the history of community engagement from the Martín Peña community members and information gathered regarding successful recycling programs, the community is a good candidate for a community-led recycling collection process. Using a method of collection that involves the already established Martín Peña Recicla, ENLACE will be targeting a specific niche in the market with their pulverized glass sand.

## Factors for Success

The Martín Peña communities' residents have a history of engagement with each other as well as with their local businesses and ENLACE. This engagement will ensure that community members will support this effort and contribute their glass waste, ensuring a relatively steady quantity of glass to the pulverizing business. ENLACE will also be the first company providing an all-in-one collection-pulverization-delivery service in Puerto Rico and will then be able to market to a wide range of consumers, especially companies that do not own a glass pulverizer and are looking to use glass sand in their products. Unlike the competitor in the glass collection and delivery market, ENLACE will not charge for residents to drop off their glass, making it a more appealing company for individuals to drop off their glass waste to ENLACE/Martín Peña Recicla. To offset the cost of operating for free within the Martín Peña communities, a collection service was formulated for businesses outside of the communities, where hotels, bars and restaurants will be charged for the collection of their glass.

To ensure enough glass, during the first year of operation ENLACE will be focused solely on collection. By focusing on collection, ENLACE will be able to gauge the amount of glass that they are able to collect from the communities, allowing them to know how many external collection contracts are needed to supplement Reciclaje de Vidrio. During this year, a manager will also be employed to find clients both for collection and distribution. By doing this ENLACE will also be able to significantly cut down operational costs for the first year as the facility will not be used most of the time for anything besides storage, meaning electricity costs will be almost zero.

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## Statement of Finances

The tables below share information regarding the total costs for the operation of the facility as well as the initial costs for opening the center. The operational costs were then compared to the net yearly profit. This can be seen for year one, when only collection is to take place, and the following years, when collection and pulverization will take place.

*Table 1: Initial costs for the startup of the pulverizing center.*

| **Initial Costs** | |
|---|---|
| Powered dump dolly | $3,999.00 |
| Bobcat L23 | $38,200.00 |
| Pick-up Trucks | $45,000.00 |
| Pulverizer | $39,500.00 |
| Warehouse Construction | $90,000.00 |
| 95 gal recycling bins | $9,880.00 |
| Desktop computer combo | $284.00 |
| Chair | $150.00 |
| Desk | $300.00 |
| Wi-Fi installation | $350.00 |
| Concrete storage | $9,600.00 |
| Garage door | $5,000.00 |
| Total initial cost | $242,263.00 |

## YEAR 1:

*Table 2: Annual operational cost for the first year of collection-only.*

| Annual Operational Costs | |
|---|---|
| Gas | $(507.51) |
| Labor | $(79,040.00) |
| Worker's insurance | $(2,664.00) |
| Total operational costs | $(82,211.51) |

*Table 3: Annual profits for the first year of collection-only.*

| Annual Profits | |
|---|---|
| Collection fees | $96,720.00 |
| Operational costs | $(82,211.51) |
| Gross Profit | $14,508.49 |

## FOLLOWING YEARS

*Table 4: Annual operational costs of pulverization and collection after year one.*

| Annual Operational Costs | |
|---|---|
| Pulverizer electricity | $2,855.26 |
| Bobcat gas | $1,348.73 |
| Bobcat maintenance | $985.00 |
| Bobcat insurance | $1,200.00 |
| Truck gas | $507.51 |
| Pick-up truck maintenance/registration | $547.96 |
| Truck insurance | $2,126.00 |
| Labor costs | $108,400.00 |
| Workers' Insurance | $4,000.00 |
| Warehouse operations | $10,000.00 |
| Machine maintenance | $11,450.40 |
| Wifi | $120.00 |
| Total operational cost | $143,540.86 |

*Table 5: Annual profits of pulverization and collection after year one.*

| Annual Profits | |
|---|---|
| Collection fees | $93,600.00 |
| Product sales | $78,000.00 |
| Total profits | $171,600.00 |
| Operational costs | $(143,540.86) |
| Gross Profit | $28,059.14 |

## Clients

Our business will provide a collection service for areas outside of the Martín Peña communities. We are looking to partner with hotels, restaurants, and bars to provide them with a glass collection service. Hotels in tourist-heavy areas have a high volume of glass waste so they are an ideal candidate for a collection service. Hotels in the Condado area have expressed interest in Reciclaje de Vidrio's services and most hotels do not currently have a glass recycling system in place (some of them have no recycling system at all). These hotels would serve as Reciclaje de Vidrio's primary clients for collection outside the Martín Peña communities, as they produce the largest quantity of glass and can pay for a constant collection service. Reciclaje de Vidrio's secondary clients for collection will be restaurants and bars. Partnerships with these businesses will provide a secondary source of glass, however, their willingness to pay a collection fee may become an issue and could result in an inconsistent collection rate. Areas like La Placita and Condado would be perfect opportunities for glass waste collection due to the major buildup of glass beer bottles. With around 1000 restaurants, bars, and hotels in San Juan, there is no shortage of potential collection clients.

ENLACE plans to provide pulverized glass to the cement industry as a secondary stream of income, specifically companies who do not currently use pulverized glass in their cement manufacturing. As a part of the first year, the manager will provide information to cement block companies to become the main suppliers in a new and cost-effective business model. During the development of the business model, a list was compiled of all possible cement manufacturers to develop partnerships with. A secondary source of income will come from landscaping and seashore restoration companies, which the manager will contact in the first year of operation. Partnerships with these organizations would provide a smaller source of income, as they will not

be purchasing the pulverized glass at the same rate as the cement manufacturers. Rather, they will provide the business with a secondary source of income that will contribute to the stability and insurance of the company.

## Key Activities

The business will provide two key services: the collection of glass to reduce glass waste inside and outside of the communities, and pulverizing the glass waste that is collected.

For the first key service, glass collection will be carried out through two main methods. The first is a collection route in which the Martín Peña community members will fill bins with glass bottles and other glass waste, and then Reciclaje de Vidrio will collect all the glass waste from the bins. It is a low-effort method for the community and providing this service allows for a main steady stream of glass waste to be used in the pulverizing machine. The second method will be the creation of a collection center next to the pulverization center, where bins will be set up to collect glass waste. This will allow for the businesses and locals who do not have access to the bins in the collection route to recycle glass. It also provides the business with a second steady flow of glass. Reciclaje de Vidrio will provide a collection service for companies outside of the communities. Companies outside of the communities will be charged a rate for collection which will provide Reciclaje de Vidrio with a second flow of income.

The second key activity, the pulverizing of glass waste, will be completed using a pulverizing machine, where glass will be inserted and crushed into glass sand and cullets. The business will target specific markets that already use glass sand or can use glass sand in their products. The business will advertise the glass sand produced to appeal to potential clients and will offer a delivery service of the glass sand directly to clients. An option for clients to pick up glass sand at the pulverizing center will also be available, allowing customers to bypass the delivery fee and collect the product themselves. Clients will be able to either call for a delivery service or pick up from the center at a designated time or day to collect their product.

## Key Resources

Reciclaje de Vidrio will require a steady flow of glass waste to operate the pulverizing machine at full capacity. The machine will require around 24,000 bottles daily to operate at full capacity. This resource will be obtained through our multiple collection methods. Reciclaje de Vidrio will require at least one truck for the collection as well as the transportation of the glass before and after it is pulverized. Our business will also be reliant on the use of a front loader, a machine that is separate from the truck, to move and load large quantities of glass. This loader will transport the pulverized glass into storage areas within the center as well as load the trucks after the glass is pulverized. The final key resource in the operation of our business is the glass pulverizer machine. The glass pulverizer will be used to produce our product. Our business hinges on this key piece of equipment.

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## Key Partnerships

The main partnership for Reciclaje de Vidrio will be with Martín Peña Recicla. Martín Peña Recicla (MPR) is an organization developed with the goal of reducing the recycled waste disposed into landfills while simultaneously reducing the amount of waste that pollutes the 8 communities. In the time that they have been in operation, MPR has developed strong relationships with community members who drive the success of the organization. The organization has recently developed a home base located in the Martín Peña communities and uses the facility to store all necessary recycled waste. They have developed an efficient route which allows the organization to collect plastic, cardboard, and paper. One of the only recyclable goods not currently implemented into their business model is glass. Residents have shown interest in the idea of bringing glass to the collection site, as on multiple occasions community members have brought glass to the collection center. Partnerships with this community organization would provide sufficient collection methods and allow for a steady flow of glass waste from the communities.

Reciclaje de Vidrio also intends to partner with hotels, restaurants, and bars outside of the Martín Peña communities to provide a steady flow of glass waste as well as a second stream of income. These partnerships will expand our reach beyond the Martín Peña communities. In

doing so, they will provide these companies with the ability to promote themselves as green businesses and provide lower rates to recycle glass when compared to the municipalities. Reciclaje de Vidrio intends to constantly add businesses to this partnership as we expand to increase our profits and grow operations.

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## Competition

One possible competitor is Reciclaje del Norte (RDN), a recycling company in Padilla. They recycle multiple materials including newspapers, aluminum, plastic, and glass. Bloques Caribe and VICAL Costa Rica are currently their primary clients. At RDN, their clients pay to deliver recycled glass to them, while RDN then delivers the glass to Bloques Caribes for free. VICAL purchases their glass for $50 per ton and pays for export costs. RDN charges residents $0.25 per pound of glass they bring in. The purpose of this fee is to cover RDN's transportation and personnel costs. Their current model is not applicable to the Caño Martín Peña communities since they are generally a low-income area. RDN's services attract a higher income clientele. Their collection method is inconvenient for the demographic Reciclaje de Vidrio hopes to serve. Reciclaje de Vidrio will provide a service that the competitor does not: glass collection without a high charge and with convenient pick-ups.

In Reciclaje de Vidrio, ENLACE will take on the responsibility of collecting, pulverizing, and delivering the glass to our customers. This will eliminate the need for consumers to collect, sort, and pulverize the glass themselves. Furthermore, RDN mostly collects from residents and not from restaurants yet, but they plan on expanding their collection to restaurants in the future. ENLACE plans on collecting from restaurants and businesses outside of the Martín Peña communities, targeting wealthier areas in specific. This will allow Reciclaje de Vidrio to collect enough glass to run the pulverizing center as most glasses from restaurants and businesses local to the community goes in the waste.

Bloques Caribes and Bloques la Pino are both construction companies that produce cement blocks who have their own pulverizing machine and produce pulverized glass. These companies already have set suppliers for their glass waste, and they will provide cement block companies we intend to supply glass to with competition in the industry. These companies turn a profit using pulverized glass in their cement mixtures and it will be difficult for our potential

clients to enter this market. However, with a proper supply of the same amount, if not more pulverized glass,, our clients will have an easy time transitioning into the competitive market.

The final competitor will be the municipalities who collect waste from the areas outside of the Martín Peña communities. The organizations have fixed charge rates for their waste collection and for our business to function competitively with them, we will charge rates that are similar, if not cheaper, than the municipalities which charge around 400 dollars a month for pickup. Within the operations for Reciclaje de Vidrio, ENLACE will need to present hotels and other restaurants with reasons why their collection method is more efficient and overall better than that of the municipalities.

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**Marketing Strategy (Advertising Channels)**

The produced glass sand will be advertised in the construction and cement market as a cheaper and safer alternative to sand and limestone. When marketing to others, such as environmental organizations and artists, the product will be advertised as an eco-friendly and sustainable material that has diverse uses.

The main advertising channel will be through the local newspaper. This avenue was successful for Martín Peña Recicla to attract residents to sign up for collection services. Martín Peña Recicla currently also sets up signs and uses educational tools such as pamphlets to teach community members how to recycle. They currently teach the community the process for recycling every material besides glass, so partnering with them would allow for further education on the process and collection of recycling glass waste in particular. Information regarding glass recycling will be distributed along the collection route. The information provided in these pamphlets will not only promote glass recycling in the communities but will provide advertisement for Reciclaje de Vidrio. In doing so, this will attract community members to the collection areas, providing a steady flow of glass waste.

The secondary advertisement channel will be through restaurants and small businesses within the Martín Peña communities. Businesses that participate in the glass collection process will receive advertisement explaining that their business recycles glass with the pulverizing center. This will benefit the businesses by promoting their social responsibility as well as providing advertisements for the pulverizing center.

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## Products/Services and Pricing

The main product developed from this business is pulverized glass. This glass can be made in a multitude of sizes and has a variety of different uses. The main product will be glass sand. This glass will be pulverized down into a fine aggregate and used for applications such as concrete production, sandblasting, backfilling and coral restoration. Larger pulverized glass is a secondary product produced for applications such as landscaping and garden decoration. The product produced will be transported and delivered to the organizations who purchase it from our business. The pulverized glass will sell anywhere from 48 to 58 dollars per ton. Both products are easy to handle and do not require specialized labor outside of running machinery. The second service that Reciclaje de Vidrio will provide is a collection service inside and outside of the communities. A rate will be charged for businesses outside of the community but the residents and businesses inside of the community will receive this service for free. The rates for business collection will start at a base fee of $30 per bin and increase based on distance.


*Figure 8: Map of collection zones.*

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**Location**

The location of the pulverizing center will be within the Caño Martín Peña communities in San Juan, Puerto Rico. This center will be developed in the industrial area on a plot of land next to the new rotary. This plot of land is located at 18.43309° N, 66.04467° W. This will provide easy access to the center and provide opportunities for non-community members to be exposed to the collection site. This land is also located away from residential areas to avoid noise pollution in residents' homes. With the distance away from residential areas there is no risk to public health when pulverizing the glass into the sand aggregate. Below is an aerial view of the land that will be used for the construction of the pulverization center.

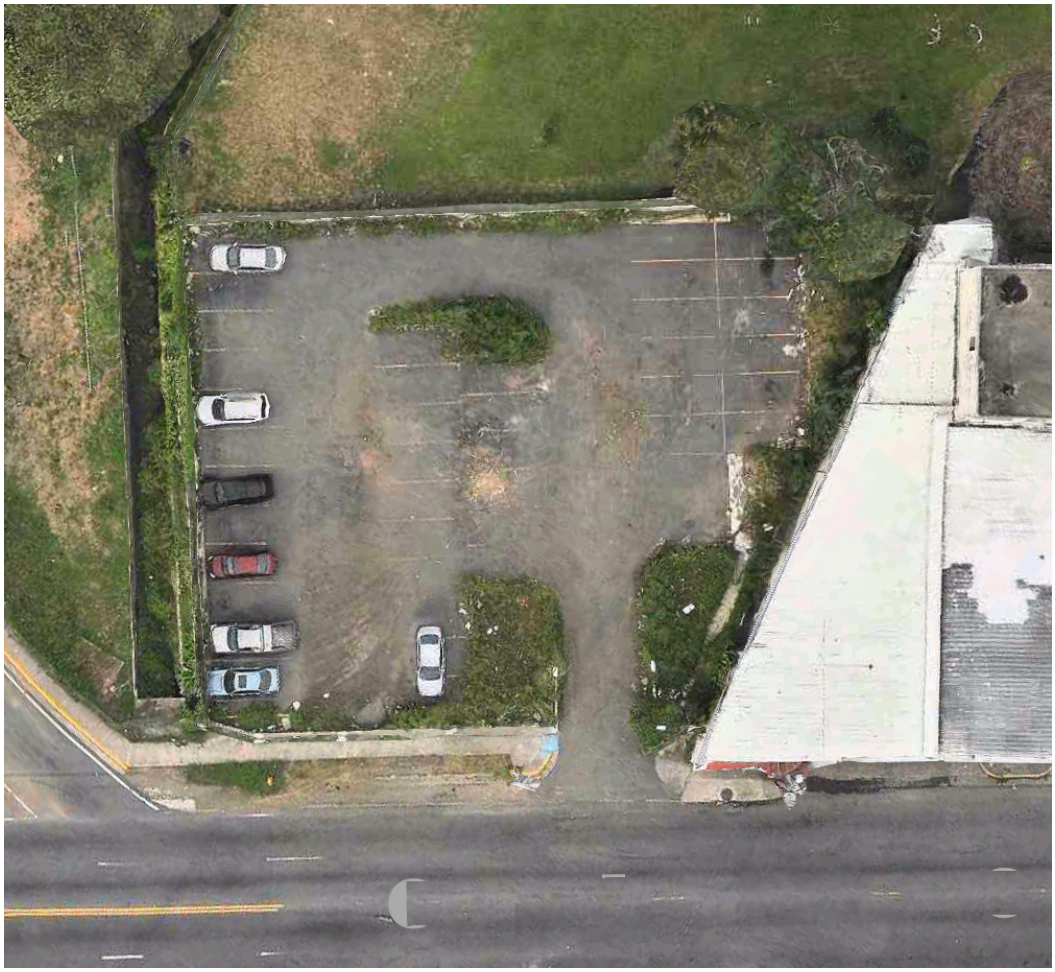

*Figure 9: Aerial image of space for warehouse.*

| Manual labor (dollar per hour) | Costs Yearly | Hours per year |
|---|---|---|
| 10 | 20800 | 5 days a week 8 hours 52 weeks |
| 11 | 22880 | 5 days a week 8 hours 52 weeks |
| 12 | 24960 | 5 days a week 8 hours 52 weeks |
| 13 | 27040 | 5 days a week 8 hours 52 weeks |
| 14 | 29120 | 5 days a week 8 hours 52 weeks |
| 15 | 31200 | 5 days a week 8 hours 52 weeks |

*Table 6: Manual labor calculations.*

## Human Resources and Capital

The hiring of individuals will depend on what wages the workers will be willing to work for, however, the average pay for a warehouse worker in the first year is estimated between 10-15 dollars an hour. ENLACE will ultimately have the final say in wages for workers when the business is first developed. Reciclaje de Vidrio has provided calculations of five different wages and their possible yearly salaries, as seen above in Table 6, to account for the different scenarios that could take place during the hiring process. In the center itself, it is estimated that there will be a need for only two workers and one manager. Reciclaje de Vidrio will require one worker to complete the collection route as well as transport the product to our clients. This worker will be responsible for the collection route on the required days as well as transporting the finished product to our clients when necessary. This worker will need to have an up-to-date driver's license as well as a certification to operate machinery. The second worker will operate the center as well as the glass pulverizer. They will operate the machinery in the center to move the glass around as well as operate the pulverizer. They will need to be trained in how to use the pulverizer as well as require certification for operating heavy machinery, in the likes of the front loader. Above is a cost breakdown for the hiring of one worker at different wage rates. The manager's position will ensure Reciclaje de Vidrio operates smoothly while also finding new business opportunities for collection and selling of pulverized glass. This position will pay more than the workers but will hold more responsibility. In the first year of operation, they will speak opportunities for collection in high tourist areas as well as areas around San Juan.  The projected employees, their wages, and annual salaries are summarized below, assuming 52 40-hour work weeks.

*Table 7: Summary of personnel and wages.*

| Labor costs | Warehouse Workers | Management | Truck drivers |
|---|---|---|---|
| Wage($/hr) | $15.00 | $23.00 | $15.00 |
| Number of workers | 1 | 1 | 1 |
| Annual pay | $31,200.00 | $46,000.00 | $31,200.00 |

## Organizational Chart

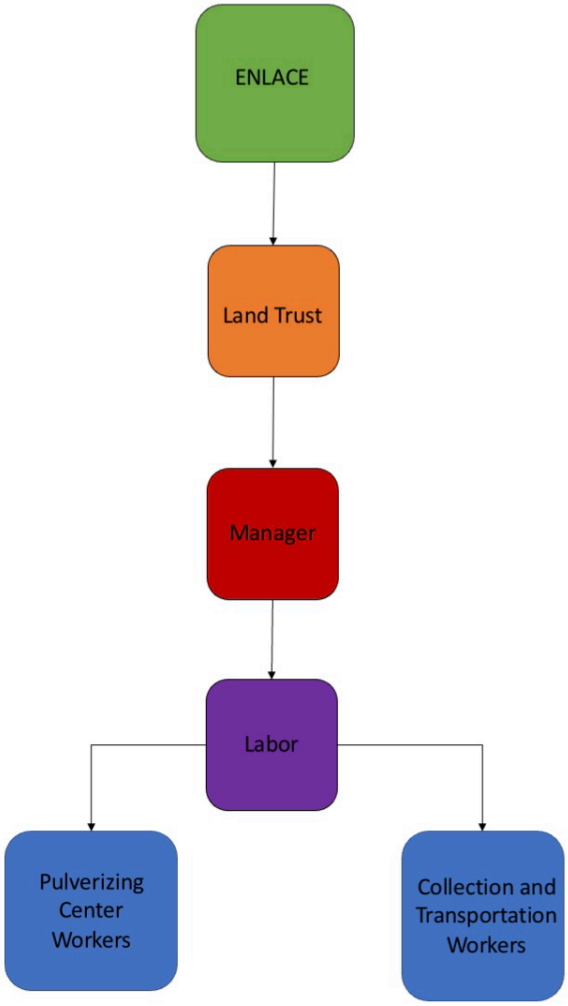


*Figure 10: Employee hierarchy chart of the business.*

Above is a diagram that outlines the operational hierarchy of our business. Once ENLACE's timeline is complete and the company is disbanded, the land trust will take over as the top of the organization.

**Business Process Flow Chart**

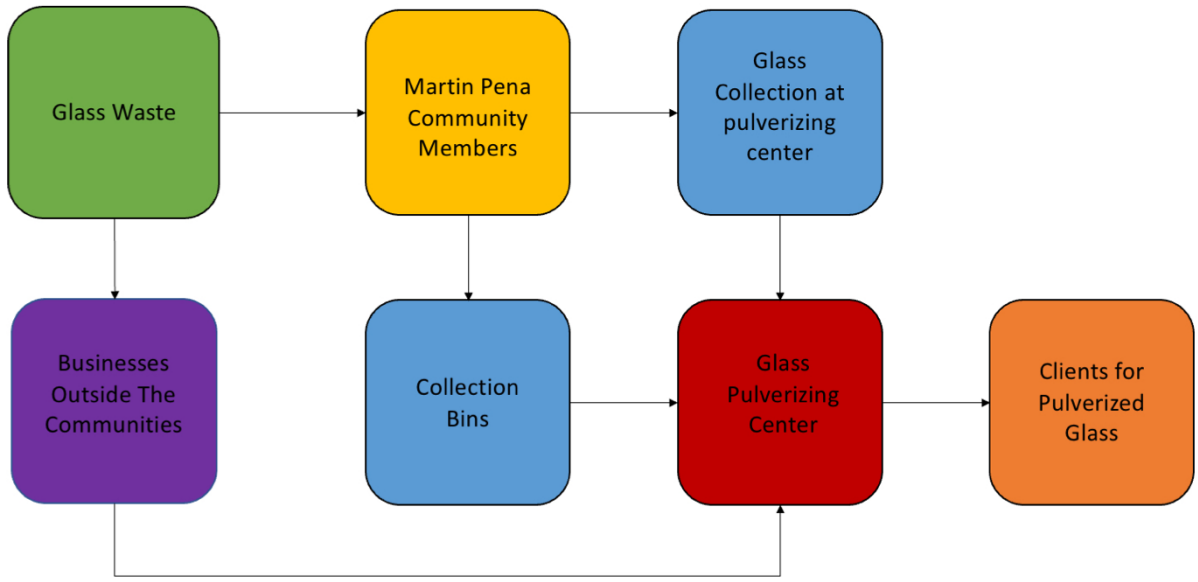


*Figure 11: Operational diagram of the business.*

Above is a diagram that describes the three main steps in our business and how the operation of our business flows from step to step.

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## Suppliers

Reciclaje de Vidrio will have three main suppliers of glass. The first supply will come from the collection route. Within this collection route, the community members will fill bins with their glass waste. Reciclaje de Vidrio, partnered with Martín Peña Recicla, will collect the waste from the bins and bring it to the pulverizing center. The community members will be the main suppliers for this form of collection, as they will fill the recycling bins with glass waste and our business will provide the collection service. The second supply will come from a collection area at the pulverizing center. The collection area is where businesses and community members can bring their glass waste and drop it off directly at the pulverizing center. Reciclaje de Vidrio will produce storage bins for businesses and community members to leave their glass waste at any hour of the day. Glass supply will rely on the community members, however, expansion in the future will focus on expanding collection methods. The third supplier will be businesses outside of the communities. Reciclaje de Vidrio will provide a collection service to businesses outside of

the communities for a set price which will allow for a secondary flow of income. Below is the list of supplies that will be required for the business to purchase before operations can commence. This list also includes where each item will be bought from.

- The pulverizing machine will be acquired from Andela, which designs and manufactures glass recycling equipment for turning glass waste into sand. The machine we will be using is the GP-Mini Glass Pulverizer as it has the same technology as Andela's larger pulverizer systems and is convenient for our location for the pulverizing center.
- The truck required will be acquired from a local San Juan dealership, if at the time of developing Reciclaje de Vidrio there is no 1-ton dump truck available at that moment in San Juan one will be imported to a Chevy or Ford dealership in the area.
- Heavy machinery will be acquired from Bobcat and will have to be imported if there isn't available machinery in Puerto Rico.
- The maintenance service on the machinery will be sourced from the Martín Peña Communities, local mechanics and machinists will be contracted first for maintenance
- Electricians from the Martín Peña communities.
- Construction companies will source workers from the communities and will have to present how they will do so in their proposals.
- All Labor will be sourced directly from the communities.

## Future Plans

Looking into the future of Reciclaje de Vidrio, ENLACE intends to expand to meet consumer demand. The expansion will be considered when there is a justified necessity to acquire more pulverizers and labor. ENLACE intends to acquire new methods of collection, expanding outside of the Martín Peña communities to provide a steady, high-volume flow of glass for our pulverizing machines. ENLACE intends to target areas of high tourist flow, such as Condado and Old San Juan, as they tend to yield a high volume of glass waste. Reciclaje de Vidrio intends to acquire new clients after a stable flow of income is generated to expand the profits and outreach of Reciclaje de Vidrio. Once ENLACE is disbanded, Reciclaje de Vidrio will be given to the Community Land Trust and provide opportunities for the community members to take over management.

## Operational Expenses

Below is a series of tables outlining the initial costs, operational costs, and profits of Reciclaje de Vidrio. One table provides information for the first year, where only collection will occur, and the second table provides information for the following years when the pulverization center will be run.

| **Initial Costs** | |
|---|---|
| Powered dump dolly | $3,999.00 |
| Bobcat L23 | $38,200.00 |
| Pick-up Truck | $45,000.00 |
| Pulverizer | $39,500.00 |
| Warehouse Construction | $90,000.00 |
| 95 gal recycling bins (76) | $9,880.00 |
| Desktop computer combo | $284.00 |
| Chair | $150.00 |
| Desk | $300.00 |
| Wi-Fi installation | $350.00 |
| Concrete storage | $9,600.00 |
| Garage door | $5,000.00 |
| Total initial cost | $242,263.00 |

YEAR 1:

| **Annual Operational Costs** | |
|---|---|
| Gas | $(507.51) |
| Labor | $(79,040.00) |
| Worker's insurance | $(2,664.00) |
| Total operational costs | $(82,211.51) |

| **Annual Profits** | |
|---|---|
| Collection fees | $96,720.00 |
| Operational costs | $(82,211.51) |
| Gross Profit | $14,508.49 |

FOLLOWING YEARS

| Annual Operational Costs | |
|---|---|
| Pulverizer electricity | $2,855.26 |
| Bobcat gas | $1,348.73 |
| Bobcat maintenance | $985.00 |
| Bobcat insurance | $1,200.00 |
| Truck gas | $507.51 |
| Pick-up truck maintenance/registration | $547.96 |
| Truck insurance | $2,126.00 |
| Labor costs | $108,400.00 |
| Workers' Insurance | $4,000.00 |
| Warehouse operations | $10,000.00 |
| Machine maintenance | $11,450.40 |
| Wifi | $120.00 |
| Total operational cost | $143,540.86 |

| Annual Profits | |
|---|---|
| Collection fees | $93,600.00 |
| Product sales | $78,000.00 |
| Total profits | $171,600.00 |
| Operational costs | $(143,540.86) |
| Gross Profit | $28,059.14 |

# CHAPTER 5: Conclusions

Waste management infrastructure, especially infrastructure supporting recycling, is highly inadequate in Puerto Rico. Recycling across Puerto Rico is supposed to be enforced by the Departmento de Recursos Naturales y Ambientales (Department of Natural and Environmental Resources), but enforcement rarely occurs due to limited government funding. Waste management in the Martín Peña communities in particular is a complex issue, given a long history of throwing waste into the canal and a general lack of education on recycling. The pollution issue in these communities must be immediately addressed as the dredging of the Caño Martín Peña recently began in February of 2023.

Glass has no value when it is left un-recycled and is typically incorporated with regular trash in almost all municipalities, including San Juan. Consequently, there is no incentive for residents to recycle their glass when it can be easily placed into the trash along with other waste. Glass has many uses when it is recycled and re-processed, making the creation of an economically self-sustainable pulverizing center within the Martín Peña communities a necessary and viable business to explore. Such a business would divert glass waste away from landfills and create jobs for residents.

For this project, our team created a business plan for a dual-income glass recycling model to provide free glass collection in the Martín Peña communities. The required funds for the business are acquired from selling the pulverized glass sand product and from getting external collection contracts with businesses outside of the Martín Peña communities. This model may also be applicable for low-income areas because if start-up costs can be secured, it does not rely on government funding nor on money from community residents. In the future, this model can hopefully be expanded to other low-income communities with similar settings.

In this section, our team presents and justifies our conclusions and recommendations after analyzing our findings. While our team created a business plan and evaluated the feasibility of creating a pulverizing center for ENLACE, this is only a start in helping mitigate the pollution problem in the Caño Martín Peña communities. Our team believes ENLACE will be able to utilize the following conclusions and recommendations as a framework for next steps and actions in creating this pulverizing center and business.

## 5.1: Key Conclusions

**Glass sand has many diverse potential uses.** Glass is a 100% recyclable material that can be repurposed and used in diverse markets. Glass can be recycled in multiple forms: whole, in large pieces, cullet, and glass sand. From there, the glass can be used as is or melted down for other purposes such as making fiberglass or art. Glass sand has the most uses as it can be used in cement, art, sandbags, landscaping, and gardening, environmental restoration, and disaster prevention and relief. Throughout our interviews our team spoke with companies that use recycled glass in coral replanting efforts, disaster relief, urban development, and block cement. These companies show the impressive ability for recycled glass to be reused and repurposed, specifically in the form of glass sand created by pulverizing whole glass bottles.

**Glass is 100% recyclable and reusable but is the most difficult material to recycle.** After speaking with Carmen Febres of Martín Peña Recicla, we discovered the biggest reasons for a lack of glass recycling. The potential for physical strain attempting to collect glass as well as its low value and high weight makes it an undesirable material to collect for many recycling companies. Supporting this, one of the most widely cited reasons that glass is difficult to recycle is that it is ten times heavier than other recyclable materials, like paper and plastic. It is therefore expensive to collect and recycle. Recycling glass requires more machinery, and it does not currently make sense for recycling companies to purchase additional machinery for recycling glass if they do not have a consistent customer and cannot ensure they will turn a profit. Non-recycled glass has no monetary value, so any glass that goes unsold means a loss for the business.

**Puerto Rican residents are willing to recycle glass, but there is a lack of infrastructure.** Without sufficient infrastructure, glass recycling is not possible. Speaking with Carmen Febres of Martín Peña Recicla, our team found that community members are willing to recycle glass and have attempted to do so multiple times, but as glass has little market value, there is nowhere to bring the glass after collection. The companies that do use recycled glass in their products rely on drop-offs by residents for small scale operations or rely on glass drop-offs from recycling companies like Reciclaje del Norte or from places like the Goyco community center. Companies using glass sand have all said the same thing: they don’t have enough space to store large quantities of glass. This lack of storage space means they can only accept small quantities of

glass at a time, making it impractical and cost ineffective for recycling companies to collect it. Many Puerto Ricans are unlikely to save glass for recycling as it can be easily taken out with the rest of their trash and regularly collected.

## 5.2: Recommendations

Based on the three key findings that emerged from our two months of fieldwork in San Juan, including site visits with our sponsor and interviews with multiple organizations and businesses, we present several recommendations for ENLACE that support our findings.

**Our team recommends that:**

1) **ENLACE obtain collection contracts with businesses in the San Juan area.** For the glass recycling business to be profitable, external contracts with businesses are necessary as ENLACE wants to keep recycling free of charge for community members. If $25-50 per pickup is charged to businesses, this stream of income could help offset the operational costs of the pulverizing center and collection from the Martín Peña communities. All throughout San Juan are many bars, restaurants, nightclubs, and hotels which each generate a lot of waste including a large amount of glass waste. Looking at places such as Condado where a concentrated number of tourists exist, businesses will likely be willing to pay for a collection service if they can promote themselves as socially responsible and eco-friendly. Another place where ENLACE may be able to secure collection contracts is Borinquen Avenue. Borinquen Avenue has many restaurants and bars that are likely to produce a lot of glass waste all within a 1.4-mile stretch. Collection would be simple if collection contracts could be obtained with the businesses along the street. Along with these two areas other potential areas to explore are Old San Juan and places with a high density of bars such as La Placita de Santurce.
2) **ENLACE use our business plan to apply for grants and funding.** Grants and funding are what will allow the business to start up and for the center to be built. Our business plan can be used in grant applications to show potential funders the complete vision for the business as well as the many benefits the community and government will reap. There are several environmentally focused grants for which ENLACE qualifies that should be pursued.

3) **Future researchers pursue the implementation of a bottle bill in areas of Puerto Rico.** One of the main struggles our team encountered during this project was how to incentivize individuals to recycle their glass. Our team instead targeted pre-determined routes and businesses to compensate for a lack of individual glass recycling motivation. One solution our team found that has worked in other places is the implementation of bottle bills and buyback programs. Using a bottle bill, the community members pay a few extra cents for their bottles at the time of purchase. After they are done with the bottles, they can return them to stations to receive that initial deposit back. Bottle bills have shown great success all over the world, and specifically in the United States where states with bottle bills have significantly higher glass recycling rates. In some regards the system is self-sustaining, however it has been rejected multiple times in Puerto Rico. While the reason behind bottle bills failing to pass is not completely certain, recycling island wide is supposed to be enforced by municipalities, but many are strapped for cash and are unable to enforce the recycling laws. Due to the lack of government funds, implementing a bill where the municipality would become responsible for collecting more waste from new locations is at the bottom of many policy makers' priority lists. Our team recommends future researchers investigate how to independently fund and create a bottle bill, as being able to start-up an incentivized return program without government funds is likely the only current possibility. Our team recommends that future research is conducted on developing a branch of the business that focuses on the advocacy of glass recycling. Our team recommends that this branch of the company focus on the promotion of glass recycling within the communities first then branch out to the entirety of Puerto Rico. This branch would advocate for bottle bills throughout the entirety of Puerto Rico, pushing for real change for glass recycling across the entire island. The implementation of one of these systems would allow for a whole new aspect of the collection that could be implemented into the expansion of the business model our team developed for ENLACE.

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# Appendix A: Informed Consent Agreement

## Informed Consent Agreement for Participation in a Research Study

**Investigators**: Douglas Cain, Claire Matthews, Priyankha Sunil, Leah Harnisch-Weidauer

**Contact Information:** gr-pr23cano@wpi.edu

**Title of Research Study:** Development of an economically self-sustaining business plan for the Martín Peña communities.

**Sponsor:** ENLACE

**Introduction:** You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

**Purpose of the study:** Our team will develop an economically self-sustaining business plan for a glass pulverizing center in the Martín Peña Communities.

**Procedures to be followed:** Our team will conduct semi-structured interviews. These interviews will be around 30 minutes to an hour depending on conversation content.

**Risks to study participants:** No risks.

**Benefits to research participants and others:** Impact on community recycling procedures.

**Record keeping and confidentiality:** If participants consent, interviews will be recorded. If not, records will be kept through note-taking. Residents will be kept confidential but businesses will not, unless otherwise requested. Records of your participation in this study will be held confidential so far as permitted by law. However, the study investigators, the sponsor or it's designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or presentation of the data will not identify you.

**For more information about this research or about the rights of research participants, or in case of research-related injury, contact:**

The team can be contacted through the email provided at the top of this form.

Manager (Ruth McKeogh, Tel. 508 831- 6699, Email: irb@wpi.edu

Gabriel Johnson, Tel. 508-831-4989, Email: gjohnson@wpi.edu

Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit.

By signing below, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing.

_____ Date: _____

Study Participant Signature

_____

Study Participant Name (Please print)

_____ Date: _____

Signature of Person who explained this study

By signing below, you acknowledge that you've been informed about and consent to be a participant in the study described above. But you wish to keep your shared personal information confidential. You are entitled to retain a copy of this consent agreement.

_____ Date: _____

Study Participant Signature

_____

Study Participant Name (Please print)

_____ Date: _____

Signature of Person who explained this study

# Appendix B: Interviewee Details

| Company | Type of Company | Did they respond | When did Our team interview them | In-Person/Zoom |
|---|---|---|---|---|
| Oceanline[2] | Organization | Yes | 1/17/2023 | Zoom |
| Coconut Breeze Recycling[3] | Recycling | Yes | 1/19/2023 | Zoom |
| USVI | Organization | Yes | 1/19/2023 | Zoom |
| Martín Peña Recicla | Recycling | Yes | 1/20/2023 | In-Person |
| Olin Labs | Organization | Yes | 1/25/2023 | Zoom |
| Bacardí | Organization | Yes | 1/31/2023 | Zoom |
| Bloques Caribe | Cement | No | | |
| Barreto Best Blocks | Cement | Yes | 1/25/2023 - but couldn't interview | Didn't show up |
| Glass Half Full | Organization | Yes | Didn't secure an interview as they were too busy | N/A |
| Bloques La Pino | Cement | No | | |
| IFCO | Recycling | No | | |
| Conwaste | Waste Management | No | | |
| La Goyco | Organization | No | | |
| Cervecera de Puerto Rico | Organization | No | | |
| Sioneer | Recycling | No | | |

[2] a company who wishes to remain anonymous
[3] A recycling company who wishes to remain anonymous

| | | | | |
|---|---|---|---|---|
| PR Dustless Blasting | Sandblasting | No | | |
| Basura Cero PR | Organization | No | | |
| DonQ | Organization | No | | |
| Landtech | Landscape | No | | |
| Lambs Lawn | Landscape | No | | |
| Duarte Waste | Waste Management | No | | |
| CEMEX PR | Cement | No | | |

# Appendix C: Potential Clients and Partners Contacted

| Company | Type of Company | Did they respond | When did Our team interview them | In-Person/Zoom |
|---|---|---|---|---|
| Coconut Breeze Recycling[4] | Recycling | Yes | 1/19/2023 | Zoom |
| Martín Peña Recicla | Recycling | Yes | 1/20/2023 | In-Person |
| Bacardí | Organization | Yes | 1/31/2023 | Zoom |
| Bloques Caribe | Cement | No | | |
| Barreto Best Blocks | Cement | Yes | 1/25/2023 - but couldn't interview | Didn't show up |
| Bloques La Pino | Cement | No | | |
| IFCO | Recycling | No | | |
| Conwaste | Waste Management | No | | |
| La Goyco | Organization | No | | |
| Cervecera de Puerto Rico | Organization | No | | |
| PR Dustless Blasting | Sandblasting | No | | |
| Basura Cero PR | Organization | No | | |
| DonQ | Organization | No | | |
| Landtech | Landscape | No | | |
| Lambs Lawn | Landscape | No | | |
| Duarte Waste | Waste Management | No | | |
| CEMEX PR | Cement | No | | |

[4] A recycling company who wishes to remain anonymous

# Appendix D: Interview Questions for Recycling Companies with Glass Recycling

1. Can you tell us about your process for the collection and recycling of glass?
2. How are people incentivized to bring glasses to you and pay you to do so?
3. What do you do with the glass that is collected?
4. How do you deal with contaminated glass?
5. Who are your main suppliers?
    a. Small businesses, or residential?
6. Who do you give the glass to after it is collected?
    a. Who are the buyers?
    b. Do they buy it or is it given for free?
7. Where do you store the glass when it is given to you?
8. How much glass do you receive per year?
9. How do people find out about your organization?
    a. Is it through advertisements or word of mouth?
10. How is the glass transported? What are the costs associated with this?
11. Did you ever pulverize your own glass? What was the reason you stopped pulverizing glass?
    a. How much did the machine cost? Operational cost? Maintenance?
12. Do you receive any funding from the government?

# Appendix E: Interview Questions for Recycling Companies without Glass Recycling

1. What is your current partnership with the municipalities?
2. How do you receive your recycled materials?
3. Are your collection methods effective and what is something you would want to improve on in the future?
4. What are difficulties you have experienced in the collection process for recycled materials
5. How would the collection of glass alter your current methods of collection?
6. Do you believe it would be feasible to add the collection of glass to the recycling route?
7. How do you think the community would respond to the addition of glass to the recycled materials
8. Would glass be the most difficult material for you to recycle if it were introduced?
9. Jose mentioned that you have bins in people's homes that their neighbors and themselves use as a collection site. Is it feasible to add another bin to this process that would be for the collection of glass?

# Appendix F: Interview Questions for Cement Companies

## Bloques Caribe

1. How much money on average do you save per year?
2. When did your glass cement model begin and why did the company begin or shift to this model?
3. Has there been any complications in the process or areas where you guys have had to go back to the drawing board and rework some of your process?
4. Are you aware of the use of silica sand in cement production?
5. What are some of the limitations you have found with using glass instead of silica sand?
6. Is your inflow of recycled glass enough? Do you have too much or too little?
7. Have your profits improved since switching to a glass cement approach?
8. Do you find yourself competitive in the market with this current model?
9. Would you be willing to share information about your profits or losses?
    a. Follow up: Would you consent to us using this information to help convince other companies to adopt eco-friendly productions of cement?
10. What is your relationship with RDN?
    a. How long have you been acquiring glass from them?
11. Are you receiving glass from them for free and if so how is this mutually beneficial?
    a. Follow up: How would your business model shift if you were not receiving glass for free?
12. How much space is required for the operations?

## Barretto Best Blocks

1. How long have you been involved in the recycled cement mixture industry?
2. How much glass do you pulverize monthly and or yearly?
3. Does this vary with consumer demand?
4. How much space does your pulverizing center require?
5. How much consumer demand is there for cement blocks, specifically ones made from glass waste?
    a. Do you find that there is a lack of trust in glass mixtures cement blocks by consumers?
6. How much do you pay in all aspects of your pulverizing system?

a. Insurance
b. Operational costs
c. Employees
d. Maintenance
e. Savings

7. Where do you acquire your glass from and is it free? How long have you been in business with this supplier of glass?
8. Is there a reason why you still have a department that is focused on the production of cement not using glass
9. Do you save any money using the glass recycling model and if so how much?
10. Do you see yourself switching to only producing glass cement in the near future?
    a. Are there any factors that prevent you from switching at the current moment?
11. Do mainly construction companies purchase your blocks or are your consumers more individual?
12. Do you use only glass in the production of your cement blocks or are you still using sand?
13. Is contamination a concern
14. Is there a specific type of glass required for cement production? What are your processes for separating glass?
15. How much does it cost to make one cement block?
16. How much space is required?

## Bloques la Pino

1. How long have you been involved in the recycled cement mixture industry?
2. How much glass do you pulverize monthly and or yearly?
3. Does this vary with consumer demand?
4. How much pulverized glass is used for each of the sizes of blocks
5. Do the different colors of blocks come from the use of different glass colors?
6. How much consumer demand is there for cement blocks, specifically ones made from glass waste?
7. Do you find that there is a lack of trust in glass mixtures cement blocks by consumers?
8. How much do you pay in all aspects of your pulverizing system?

9. Insurance
10. Operational costs
11. Employees
12. Maintenance
13. Where do you acquire your glass from and is it free? How long have you been in business with this supplier of glass?
14. Do you save any money using the glass recycling model and if so, how much?
15. Would you be open to acquiring your pulverized glass from an external source to lower your operational costs?
16. How much glass would you require yearly?

# Appendix G: Interview Questions for Glass Recycling Organizations

## Oceanline

1. If applied to other projects or locations, is there any area where multiple types of bottles could be used?
2. How are you sourcing the glass? Is Medalla collecting used bottles from consumers?
    a. While Our team understand that the scale you pulverized bottles on is small, how much glass have you pulverized? Is it reliant on individuals or companies
3. On your website Our team read about the success of the 400 corals planted, what challenges did you run into that were specifically caused by including glass into the cement mixture?
    a. During your trials, did you experiment with what percentage of the mix was composed of glass? If so, what was the maximum amount of glass in the mix that you found to not affect the integrity and strength of the hardened material?
4. The last project update is from May 2022. Within the past 7 months have you noticed any issues or changes with the cement? Does the cement affect the corals in any way?
5. Over the course of more than just two years will anything additional need to be done to ensure the corals remain secured, or has fusion to the cement allowed the corals to be secure for the foreseeable future?
6. How do you receive the funding?
7. Will these techniques be applicable to other coral species?
8. How is it applicable on a larger scale?
9. What factored into choosing the glass pulverizer you have?

## USVI Glass Crusher Project

1. Could you explain the idea/concept behind the Glass Crusher Project? When did it start?
2. What inspired you to get a grant and buy these glass crushers? How do you get funded?
3. Are you working with other people on this project?
4. Do you get money from other organizations and companies now? Do you have any partnerships currently?
5. How are you collecting the glass necessary for this project?

6. How do you bring the collected glass to your pulverizing center? Is it through a truck? If so, what kind/model?
7. What challenges do you face in the collection process?
8. How do you deal with any cross contamination?
9. How much glass is being collected weekly, monthly, and annually?
10. How many glass crushers do you currently have and where are they located?
    a. What type of machine do you use?
    b. How much did it cost to buy these glass pulverizers?
    c. How long is the pulverizing process?
    d. How much does it cost to operate/maintain the machine?
    e. What is required for the operations of the pulverizer (personnel, maintenance, insurance etc.)? How many people are currently working for you?
    f. Is there insurance?
11. Do the glass cullets come in different sizes or are they all uniformly sized for the sand? If so, what size?
12. How much glass is being pulverized daily, monthly, and annually?
13. How much pulverized glass is used to make one sandbag? How much does one sandbag weigh? What's the ratio of sand to glass?
14. Do you sell these sandbags? How many sandbags do you sell monthly/annually? Who do you mostly sell it to?
15. Who are the main consumers/customers? How do they get in contact with you?
16. What are the sandbags used for?
17. Have you seen an improvement in the amount of glass waste in the community since you started this project?
18. How is your current relationship with the local government?
19. Have you guys thought about expanding this project from just making sandbags to possibly partnering with companies/organizations from different places to sell them (Puerto Rico)?
20. Have you thought about using pulverized glass sand mixture for the rain gardens?

## Olin Labs

1. Can you tell us about what soilless soil is?

2. How are you currently sourcing/collecting glass?
3. How much glass do you collect and pulverize each year if you have that data?
4. You mentioned to the team last year that you are planning on opening a pilot factory this year for larger scale glass pulverizing, are you willing to share estimated startup costs such as insurance, required land space, personnel, cost of machinery, etc.?
5. Is there a purpose to pulverizing glass into more than one size? What are the potential uses for different sizes?
6. Our team read an article that mentioned the pH of crushed glass is higher than that of sand and that ferrous sulfate is needed to fix the levels. If one were to make cement blocks using pulverized glass as fine aggregate, replacing sand or limestone, would the higher pH of the glass be an issue in the short or long term?
7. How is glass sand being used in urban development in Philadelphia?
8. Has the city of Philadelphia been able to save money using pulverized glass sand in their urban development/are they projected to save money in the future?
9. Where is the funding coming from?
10. Can you tell us about rain gardens and any efforts they're being used in?

## Glass Half Full

1. How did you build the program from the ground up? Were there any obstacles you had to overcome in the early stages of the project? If so, what were they and how did you go about overcoming them?
2. Who are your main consumers and customers? How to get into contact with them and what is the kind of work they do?
3. Has the government contacted you about acquiring Sand for disaster relief?
    a. Has the government shown any interest in this project?
4. How does giving out free sand provide value to your business model?
5. At what point did you start receiving donations from sponsors?
6. Where do all your profits come from? Did you have a hard time in the beginning turning a profit? Was there a point in time where you were negative?
7. Where did you get the pulverizing machine and how long did it take for you to pay it off?
8. How do the machines produce different sizes of glass material?

    a. Are there different settings or does it run through the machine more than once?
9. Have you seen any substantial effects in the local community?
    a. Are you seeing any reduction in the amount of glass waste around on the streets?
    b. How was the overall initial response in the beginning by the community?
    c. Where did you receive most of your glass, was it from small businesses?
10. What challenges did you face in the collection process?
    a. What have you found to work best for collection and is there a set model that you guys follow that allows for successful collection rates?
    b. Is the community involved in helping the collection process?
11. How much glass do you sell as a result of your online website?
12. How much glass do you receive? How is it measured? Is there a certain amount?
13. How much glass do you pulverize daily, monthly, annually?

## Bacardí

1. Can you tell us when your environmental sustainability initiatives started and the driving force behind starting those initiatives?
2. What are the current initiatives you're involved in? I know you don't bottle here in Puerto Rico, but do you know of any glass-centered sustainability initiatives?
    a. How did the biodegradable bottle idea come about? Our team saw the aim is to support your plastic free by 2030 goal, will these bottles as well as the paper bottle largely replace glass bottles and the plastic components, or are these more of a "limited" item that will not largely replace materials currently being utilized?
3. Are there any initiatives on the horizon that you're not directly working towards yet but will be in the future
4. How do you choose what environmental sustainability efforts you're involved in?
5. Would you ever consider partnering with organizations or other companies for recycling and sustainability initiatives, like the way Medalla partnered with Isla Mar for reef restoration?
6. Are you able to put us in contact with someone who works at the bottling facilities so Our team could potentially learn more about that process?
7. Do you happen to have any contact information about the packaging team

# Appendix H: Start-up and Year 1 Costs and Operations

## Start-up

| Initial Costs | |
|---|---|
| Powered dump dolly | $3,999.00 |
| Bobcat L23 | $38,200.00 |
| Pick up Trucks | $45,000.00 |
| Pulverizer | $39,500.00 |
| Warehouse Construction | $90,000.00 |
| 95 gal recycling bins | $9,880.00 |
| Desktop computer combo | $284.00 |
| Chair | $150.00 |
| Desk | $300.00 |
| Wi-Fi installation | $350.00 |
| Concrete storage | $9,600.00 |
| Garage door | $5,000.00 |
| Total initial cost | $242,263.00 |

## Year 1

| Annual Operational Costs | |
|---|---|
| Gas | $(507.51) |
| Labor | $(79,040.00) |
| Worker's insurance | $(2,664.00) |
| Total operational costs | $(82,211.51) |

| Annual Profits | |
|---|---|
| Collection fees | $96,720.00 |
| Operational costs | $(82,211.51) |
| Gross Profit | $14,508.49 |

| Fixed Numbers: | |
|---|---|
| **Collection bins** | |
| Bin size(gal) | 95 |
| lbs/gallon | 1.88143 |
| lbs in 60 gal bin | 112.8858 |
| lbs in 95 gal bin | 178.73585 |
| Truck capacity(tons) | 4 |
| Truck capacity(lbs) | 8000 |
| 95 gal bins per truck | 44.7587879 |
| 60 gal bin per truck | 70.86808084 |
| **Gas** | |
| mpg | 10 |
| gas price($/gal) | 4.539 |
| $/mile | 0.4539 |
| | |
| **Collection fees(gains)** | |
| fee($/collection) | 30 |
| 1 collection=1 95 lb bin | |
| # collections/wk | 62 |
| # trips/week | 1.385202838 |
| # collections/yr | 3224 |
| Annual collection fe | 96720 |

95 gallon bins

| Business Route | |
|---|---|
| Distance roundtrip | 10 |
| Cost/trip | 4.539 |
| Trips/week | 1.385202838 |
| Trips/yr | 72.03054755 |
| Cost/week | 6.287435679 |
| Cost/yr | 326.9466553 |

60 gallon bins:

| Martin Pena Route | |
|---|---|
| Distance roundtrip(n | 7.65 |
| Collections/wk | 45 |
| cost/trip | 3.472335 |
| Trips/week | 1 |
| Trips/yr | 52 |
| cost/yr | 180.56142 |

| Collection quantities(lbs) | | | | |
|---|---|---|---|---|
| | Business Route: | MP route: | Total | Total(tons) |
| daily | 2,216.32 | 1,015.97 | 3,232.30 | 1.62 |
| weekly | 11,081.62 | 5,079.86 | 16,161.48 | 8.08 |
| annually | 576,244.38 | 264,152.77 | 840,397.15 | 420.20 |

| Labor costs | | | |
|---|---|---|---|
| **Truck Drivers** | 1 | **Manager** | 1 |
| Wage($/hr) | 15 | Wage($/hr | 23 |
| hr/wk | 40 | hr/wk | 40 |
| hr/yr | 2080 | hr/yr | 2080 |
| $/yr | 31200 | $/yr | 47840 |
| Insurance | 1332 | insurance | 1332 |

# Appendix I: Yearly Operational Costs

| Annual Operational Costs | |
|---|---|
| Pulverizer electricity | $2,855.26 |
| Bobcat gas | $1,348.73 |
| Bobcat maintenance | $985.00 |
| Bobcat insurance | $1,200.00 |
| Truck gas | $507.51 |
| Pick-up truck maintenance/registration | $547.96 |
| Truck insurance | $2,126.00 |
| Labor costs | $108,400.00 |
| Workers' Insurance | $4,000.00 |
| Warehouse operations | $10,000.00 |
| Machine maintenance | $11,450.40 |
| Wi-Fi | $120.00 |
| Total operational cost | $143,540.86 |

| Annual Profits | |
|---|---|
| Collection fees | $93,600.00 |
| Product sales | $78,000.00 |
| Total profits | $171,600.00 |
| Operational costs | $(143,540.86) |
| Gross Profit | $28,059.14 |

| Fixed Rates | Min | Max | Avg |
|---|---|---|---|
| Commercial Electricity($/kwh) | 0.3347 | | |
| Diesel($/gal) | 4.539 | | |
| Warehouse cost($/sq ft) | 2 | 3 | 2.5 |
| Administrative costs($/hr) | 30 | 40 | |
| Warehouse constr.($/sq ft) | 20 | | |
| Gas for trucks($/mile) | 0.1567 | | |
| Warehouse size(sq ft) | 4000 | | |

| Machine run time | |
|---|---|
| hrs/day | 8 |
| Days/wk | 5 |
| Total hrs/wk | 40 |
| hrs/year | 2080 |

| | | | | Glass required based on machine run time | | | | Electricity Rates | | | | Electricity cost | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pulverizers | Price($) | Efficiency(lb/hr) | Maintenance($/ton) | Lb/day | lb/week | lb/year | tons/yr | Horsepower | kw | Kwh/week | Kwh/yr | weekly | annually | Annual Maintenance |
| GP-Mini | 39,500 | 1500 | 7.34 | 12000 | 60000 | 3120000 | 1560 | 5.5 | 4.10135 | 164.054 | 8530.808 | 54.9088738 | 2855.261438 | 11450.4 |
| GP-Mega Mini | 67,100 | 2000 | 5.8 | 16000 | 80000 | 4160000 | 2080 | 7 | 5.2199 | 208.796 | 10857.392 | 69.8840212 | 3633.969102 | 12064 |

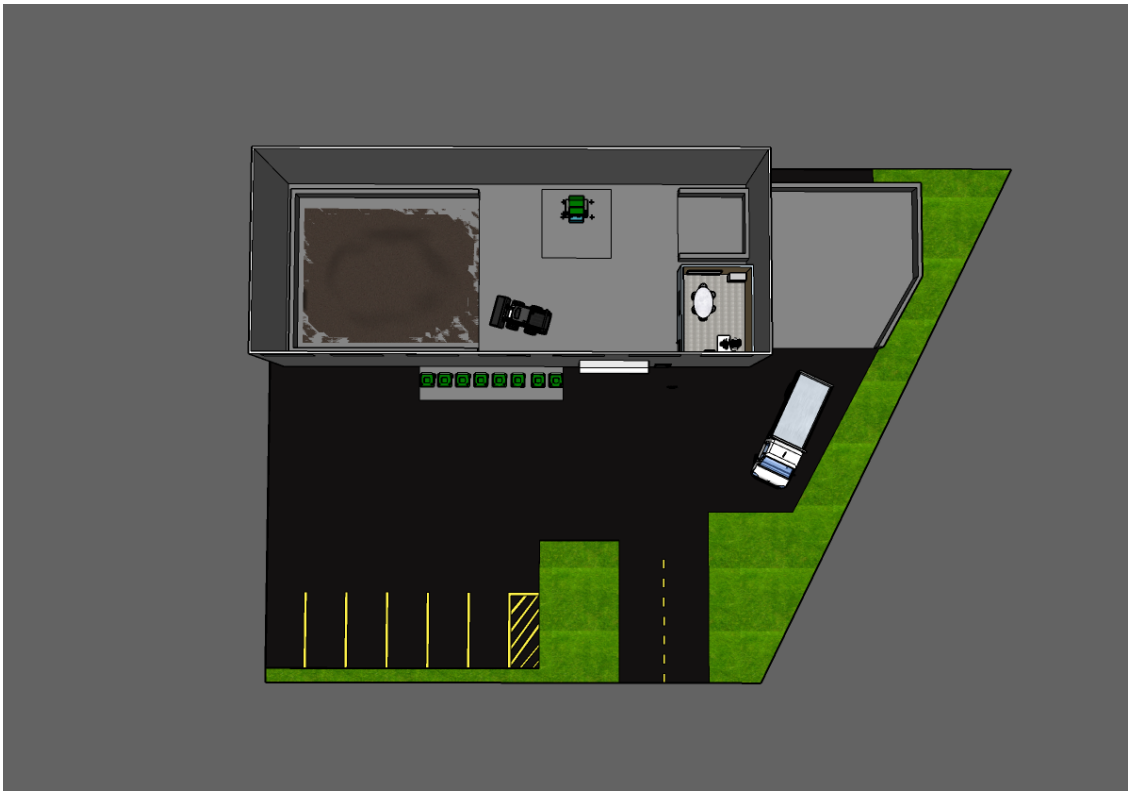
| Bobcat operations | |
|---|---|
| Fuel economy(hr/tank) | 7 |
| Diesel price($/tank) | 4.539 |
| Annual refuels | 297.1428571 |
| Annual cost of fuel | 1348.731429 |

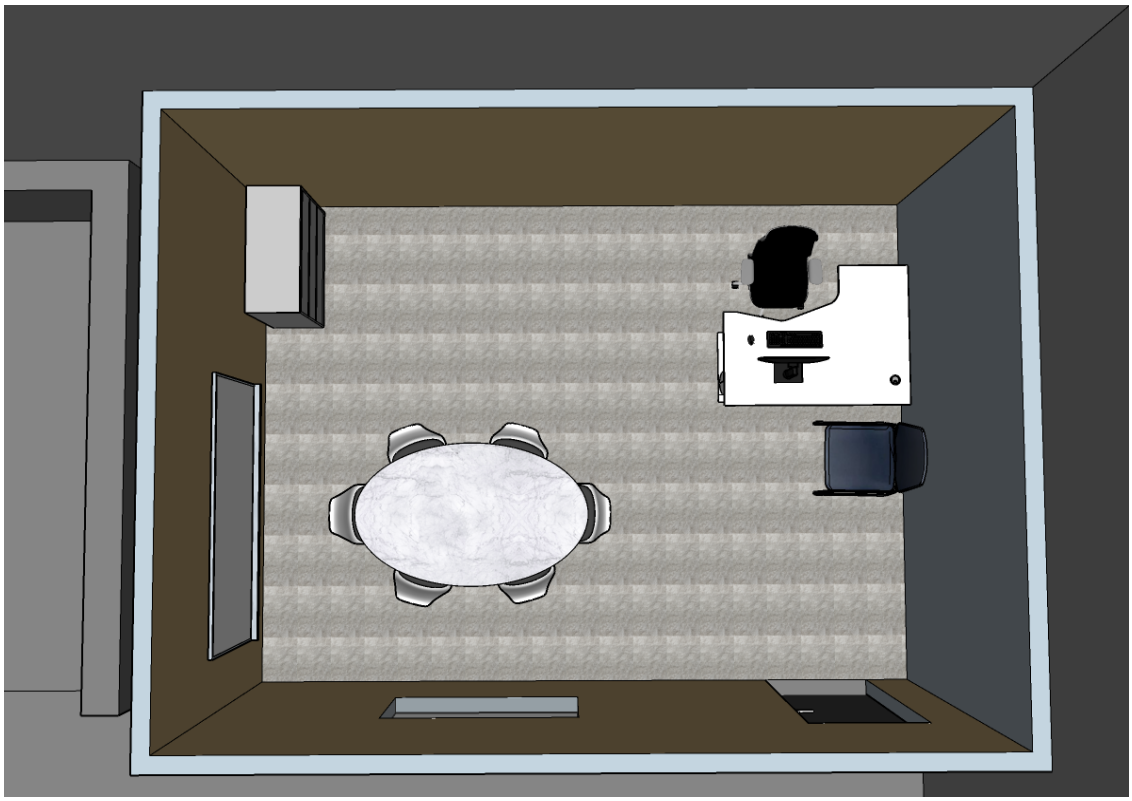
| Labor costs | Warehouse Workers | Management | Truck drivers |
|---|---|---|---|
| Wage($/hr) | $ 15.00 | $ 23.00 | $ 15.00 |
| Number of workers | 1 | 1 | 1 |
| Annual pay | $ 31,200.00 | $ 46,000.00 | $ 31,200.00 |

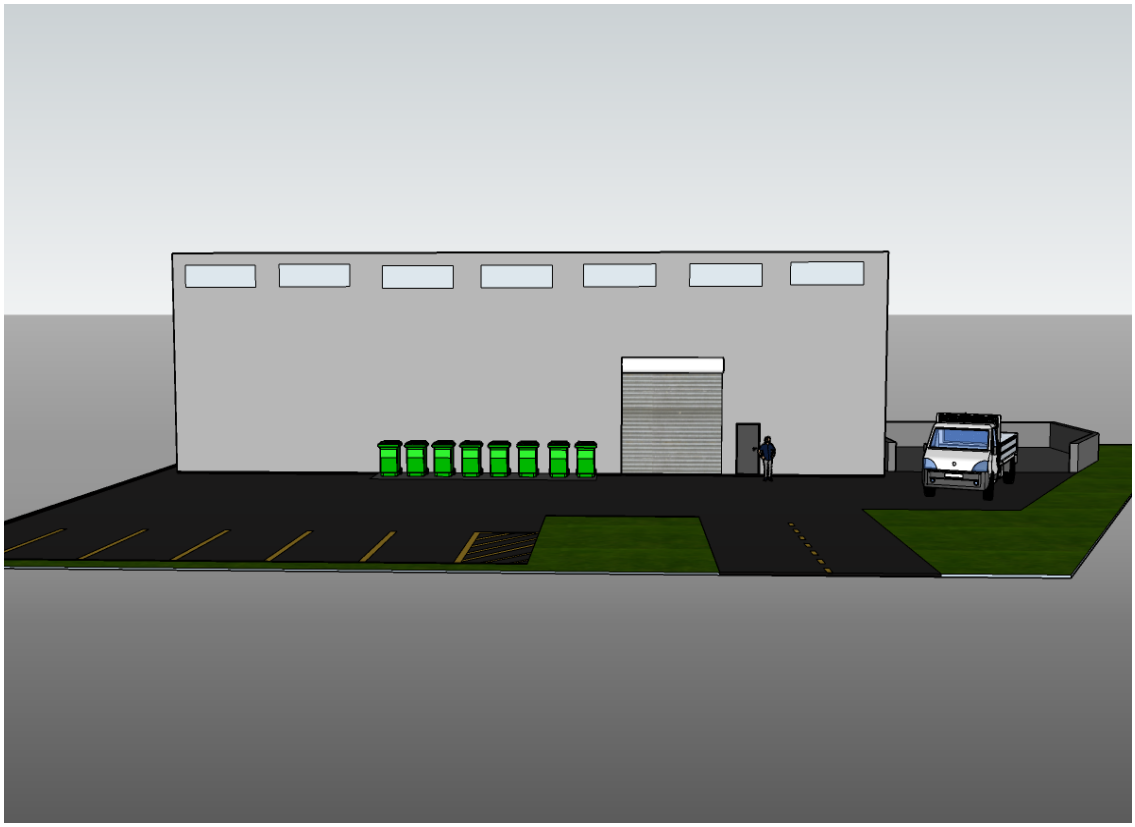
| All operations($/yr) | GP-Mini |
|---|---|
| Pulverizer electricity | 2855.261438 |
| Bobcat gas | 1348.731429 |
| Bobcat maintenance | 985 |
| Bobcat insurance | 1200 |
| Truck gas | 507.5080753 |
| Pick up truck maintenance/regist | 547.96 |
| Truck insurance | 2126 |
| Labor costs | 108400 |
| Workers' Insurance | 4000 |
| Warehouse operations | 10000 |
| Machine maintenance | 11450.4 |
| Wifi | 120 |
| Total operational cost | 143540.8609 |
| Profits from collection | 93600 |
| Profits from selling glass | 78000 |
| Net gains | 28059.13906 |

| Cost of pulverized glass | GP-mini |
|---|---|
| $/ton | 50 |
| $/lb | 0.025 |
| $/yr | 78000 |

# Appendix J: 3D Model of Facility







# Appendix K: Documentation of Numbers

### Documentation of Numbers:

Below is a documentation of all the numbers we calculated in our business plan. This list contains information on where each of the number's were derived from as well as areas of uncertainty within our calculations. Uncertainties within our calculations stemmed from a lack of information through interviews or information available in our research.

- **Pulverizer:**
  - All numbers for glass pulverizers we received from the Andela company directly. They provided our team with all the information about the machine's costs and the maintenance costs of the machine. Direct contact with them ensured exact and accurate pricing.
- **Electricity:**
  - The electrical costs were found using it the commercial electricity costs for Puerto Rico(https://www.eia.gov/state/print.php?sid=RQ) and applying it to the motor used in the Andela machines. The series of calculations was sourced from the previous IQP group's work with the Andela machines.
- **Recycling rate:**
  - The calculations for the rate of recycling yearly were found by taking the maximum efficiency rate and multiplying it by the hours, days and weeks operated.
- **Tons per year:**
  - Calculated using in the pounds per year and dividing by 2000 pounds per ton.
- **The maximum gross profit:**
  - Determined using the market price for pulverized glass which is around $50 per ton and multiplying it by tons per year. The number for market price of pulverized glass was obtained through research and also an interview with RDN.
- **The cost of labor:**
  - Determined using the dollars per hour and multiplying it by the amount of hours, days and weeks working.
- **The daily glass required to maximize the pulverizer machines efficiency**
  - Calculated using the total glass needed in pounds pr year and using the 1 pound is equal to 2 bottles model obtained through interviews with Isla Mar we were able to obtain bottles per day.

- **Warehouse construction costs:**
    - Found through research from this website. (https://apxconstructiongroup.com /warehouse-construction-cost/#:~:text=A%20small%20warehouse%20building% 20ranging,a%20cost%20calculator%2C%20click%20here!)
    - Using their numbers for a 1200 sq foot warehouse we were able to determine the ratio for dollar per sq foot and use that value to obtain an estimate for our warehouse size and costs
- **Bobcat operation numbers:**
    - We obtained them by reading multiple forums and customer reports on the fuel efficiency of their machines. Complaining that data allowed our team to estimate the cost of operation of our bobcat machine. Our team compared this data to a landscaping company's (who wishes to remain unnamed) numbers for the operation of their machinery.
- **The Powered dump dolly:**
    - They had the price for purchase on their website. We used that number in our initial cost calculations.
- **Operational costs of the warehouse:**
    - Estimated through research online suggesting that the average cost per square foot to operate a warehouse yearly was around 2-3 dollars per year. Our team used this website as a guide for warehouse calculations: https://www.prologis.com/what-we-do/resources/best-ways-to-reduce-warehouse-costs#:~:text=Administrative %20and %20management%20expenses%20for,square%20foot%20of%20storage%20space.
- **Office equipment:**
    - Estimated numbers from amazon and other potential sellers.
- **Fuel efficiency of the truck:**
    - Determined by accumulating data from all over the internet from sellers to buyers to determine an accurate fuel economy. Then using the miles we will travel on average daily, our team was able to estimate the fueling costs daily and yearly.
- **The cost of the truck:**
    - Determined using research into local dealerships to accurately predict the cost of acquiring a truck with a Dump bed that would allow for collection and transportation.
- **Truck Insurance:**

- Acquired using information found through research at this website: https://www.dumptruckinsurancehq.com/insurance-tips/the-average-cost-of-dump-truck-insurance/

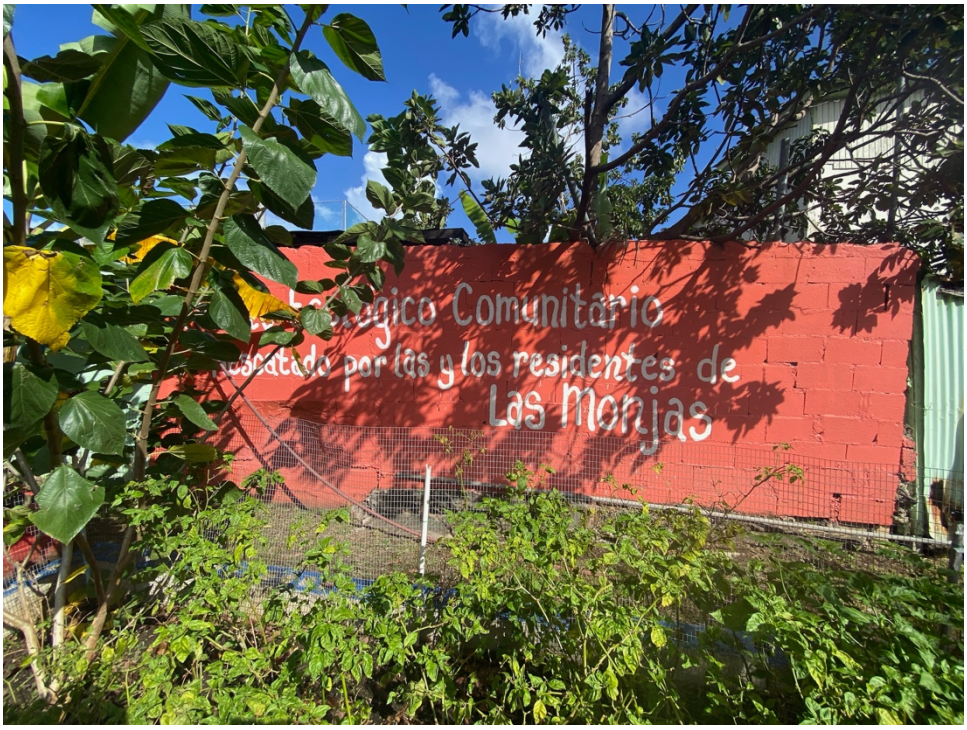
- **Worker's Insurance:**
  - Our team obtained a price off of Progressive website for commercial workers. We used the average rate found on their website per worker, per year. https://www.progressivecommercial.com/business-insurance/workers-compensation-insurance/workers-compensation-insurance-cost/#:~:text=In%202021%2C%20the%20median%20monthly,than%20what%20most%20policyholders%20paid.

# Appendix L: ENLACE Machine List

List of Equipment and Materials Presented to ENLACE

- Truck: Chevy or Ford 3500 dump bed
    - 1 ton dump truck
- Front loader: Bobcat L23 compact loader
- Trash Bins: 95 gallon trash bins with wheels
- Trash bin lifter: Powered Dump Dolly EZ-Latch garbage can hand truck lift – 94" tall
- Pulverizer: GP-Mini from Andela
    - Contact information: smower@andelaproducts.com

# Appendix M: Pictures of Bike Tour of the Martín Peña Communities




WPI


Esta comunidad no es invisible