

## **Team SAUCE: Systematic Approach to Up-Cycling for Employment**

Ying Yan Guan, Thien Nguyen, Jack Powers, Emily Rosenthal

### **Abstract**

The goal of this project is to develop an efficient, sustainable, and cost effective upcycling process for plastic bottles in El Sauce, Nicaragua. The proposed process will be used to turn bottles from the landfill into clean plastic chips. Once these chips are made, they will be melted down using technology developed by another Multidisciplinary Senior Design (MSD) team, after which the chips will be turned into a profitable product. Some crucial objectives are to create job opportunities for the locals, reduce the amount of plastic waste in the landfill, and clean up the environment. A few of the project's constraints include the size of the facility, the size and weight of the equipment, and the processing rate of 1kg of plastic per hour. In order to reduce the overall cost of our system, many of the tools used to prepare and wash the plastic are simple household items. The proposed process developed meets the processing rate, will hire six local employees, and fits a specified facility size. This paper will provide a detailed description of the proposed process, tools, Bill of Materials (BOM), and opportunities for further development.

### **Background**

All of the trash that is collected within El Sauce is thrown into a landfill, including items that could have been recycled. Due to this, the town has an excess of plastic bottles sitting around. While there is currently a local family that is responsible for sorting through the bottles and selling them, our project aims to create a system that will process the bottles further in order to increase their value. The proposed model will enable the people of El Sauce to collect, sort, clean, and shred the plastic bottles into plastic chips. From there, another team is working on a way to melt the plastic chips and turn them into a usable product that can be sold for a profit. On top of cleaning up the town, this endeavor would provide more employment opportunities for the citizens of El Sauce, which is something that is needed greatly throughout El Sauce.

The main stakeholders for this project are the citizens of El Sauce, since they will be directly impacted by changes made to their town. In addition, 4 Walls and the Enlace Project are two organizations that will likely be involved with developing the project further beyond the scope of MSD. For example, these organizations would help in the process of setting up a facility to run the proposed business. Finally, the local government is also an important stakeholder because they oversee what takes place within the town and make regulations that could impact the business.

There are many constraints that had to be taken into consideration throughout this project. Most importantly, the system needs to be able to process 1 kg of plastic every hour in order to run efficiently and support itself. Additionally, the business must have low startup costs and be easy to maintain so that it can be successful within the context of El Sauce. Another more technical requirement is that the chips cannot be contaminated, otherwise a whole batch could be ruined and it would decrease the overall profit. Lastly, the business needs to be able to operate with a maximum of 6 employees.

**Process Overview**

The bottle upcycling process was developed with the intentions of making it as simple as possible, in terms of tools, cost, and overall design. Maintenance needed to be minimized since the business will be in El Sauce, Nicaragua, where it will be more difficult to restock items and fix equipment. Also, due to the nature of designing a process for another hemisphere, it’s

important that the business and process are easy to set up without much technical knowledge. It was crucial that the process is as cost-effective as possible. Turning a profit wasn’t critical, but the process and business needs to be sustainable, meaning it needs to at least pay for itself. The process needs to be small scale, fit within a 55m<sup>2</sup> building and be able to run on tools that have a footprint smaller than 0.6m x 0.6m x 0.6m and a weight less than 22.7 kg.

**Figure 1** shows the overview of our team’s proposed bottle upcycling process. The wheel begins to turn with the plastic bottles being collected by local bottle collectors at the neighboring El Sauce dump. While collecting the bottles, the bottle collectors will do their best

Step	Description
1	Ensure bottles are PET using acceptance sampling
2	Weigh the plastic bottles
3	Pay the bottle collectors/citizens per kg of plastic
4	Unpack a plastic bottle from bag
5	Check to see if the plastic type is marked
6	Determine if bottle is PET
7	Place non-PET bottles in an opaque bin to be discarded
8	Place PET bottles in a clear bin to be used at the next step
9	Remove the neck of the bottle with a neck cutter
10	Empty out trash from inside the bottle
11	Heat up label with a heat gun and remove label
12	Wipe off remaining glue with WD-40 and a rag
13	Shred plastic
14	Collect plastic chips from the shredder
15	Load chips into mesh bag and place in salad spinner with water and soap
16	Put on lid and pump salad spinner
17	Pull out mesh bag with plastic chips
18	Run mesh bag under water in the sink to rinse out soap
19	Load chips into empty salad spinner with fine mesh covering the inner bowl
20	Put on lid and pump salad spinner
21	Pull up inner bowl to retrieve remaining chips
22	Load damp chips in dehydrator and run
23	Dump out dry chips into storage bin
24	Cover storage bin
25	Check and document weight of bin
26	Pick up bin
27	Stack bin on storage rack

**Figure 1: List of Process Steps**

to ensure that they are only collecting PET (polyethylene terephthalate) bottles to avoid contamination of the plastic chips that will be produced. Then, once they have collected plastic bottles, they will bring them over to the bottle upcycling facility and drop them off. The employees at the facility then take over by unpacking a few bottles from the collection bags. Using acceptance sampling, the bottles will be checked to ensure they are in fact PET. As long as the bottles that are checked are all PET, the entire bag will be accepted at this point in time. All of the bags that are deemed acceptable are then weighed on a scale, and based on the weight of the plastic bottles, the bottle collectors will be paid accordingly. Next, an employee will unpack the accepted bags to check the plastic type for every bottle. If a plastic bottle is marked as PET, it will be retained and moved on down the line in a clear bin. If a plastic bottle is not PET, or if it cannot be identified as PET, it will be thrown into an opaque bin and discarded.

The caps and circular bands around the necks of the plastic bottles are not PET plastic, so they need to be removed. Through the use of a purchased flexible tube cutter, each bottle neck will be cut off and thrown out. If there is any trash or waste located inside the plastic bottle, it will be quickly cleaned out before the plastic bottle is moved on down the line. The labels and glue on each of the bottles are usually not PET either, so those need to be removed as well. This proved to be tricky because just peeling the labels off by hand caused many labels to peel and remain stuck to the glue on the bottle's surface. Through the use of a heat gun, however, the glue will soften which allows the labels to be peeled off cleanly and easily. Then, while the glue is still warm, WD-40 will be put onto a rag that will be used to wipe off the remaining glue residue.

Once the bottles have been properly prepared, they will be dumped into a large hopper, which then feeds into a plastic shredder (purchased from an outside source). In order for the plastic chips to be acceptable for up-cycling, the plastic chips first need to be cleaned of all dirt, clay, waste, dried soda, debris, etc. To achieve this task, the plastic chips will be placed into a mesh bag and the bag will be loaded into a commercial salad spinner, which will be filled with soap and water. The lid will be placed on the salad spinner and then an employee will pump the salad spinner for 30 seconds. The mesh bag with the plastic chips will then be pulled out and rinsed under a faucet to remove any remaining dish soap. Next, the plastic chips will be dumped into a second salad spinner, lined with fine mesh, in order to dry the plastic chips. Again a lid is put onto the salad spinner, which is then pumped by an employee for two minutes. Next the chips are loaded into a food dehydrator to finish being dried. We modified the tray by using the fiberglass window screen that we bought previously as a mesh covering for the trays. This mesh prevented the chips from falling through the holes of the tray without blocking the airflow which could hinder the drying process. The dehydrator pushes hot air through the tray, helping to removing the remaining moisture from the chips. Then the dried plastic chips are pulled up via the tray and dumped into a plastic bin. The plastic bin is used for storage and it will be placed onto a rack by the door (the bin will be lifted by one or two employees depending on the weight to prevent injury) to keep until the plastic chips are shipped off to a buyer or to the other MSD team's design.

## Design Details

One of the critical operations that requires proper quality control is the removal of the bottles' necks. As previously mentioned, this section contains the cap and a tamper evident band, which are usually made of polypropylene (PP). This could lead to contamination in the final product, since different plastic types melt at different temperatures. In order to combat this, we tested several readily available tools such as utility knife and scissors to remove the neck of plastic bottles. Although these tools eventually removed the neck section, they were inefficient and posed major ergonomic problems. In the end, we decided to use a flexible tube cutter to perform our operation. This cutter is similar to scissors, but it has thinner blades and a spring attached to the handle. These blades are similar to the blades of a utility knife, cutting through the plastic with less strain on the operator. The attached spring allows the cutter to quickly return to its open position, which will allow the operator to close and open the cutter when needed, ultimately keeping them safe from an exposed blade.

At first, the flexible tube cutter worked on bottles with fairly small necks, but it needed modification in order to be used on a variety of bottles. We machined off the flanges of the cutter in order for bigger bottles to sit properly as the tool cut through the neck (see **Figure 2**). The modified cutter has improved both the amount of time taken to remove the neck as well as the amount of force required.



**Figure 2: Before and after picture of flexible tube cutter**

In addition to the cap, the label is also a potential source of contamination in our process. After the label is removed from the bottle, the glue used to attach the label will leave behind remnants. Since the glue is also contamination, we must remove it prior to the shredding operation. In order to address this, we decided to use WD-40 as a solvent to assist in the removal process.

One of the main objectives of designing the bottle upcycling process was to keep it as small scale and cost effective as we can. Therefore, instead of buying an industrial washer that is used by large-scale companies, which would be expensive and very hard to maintain and replace, we brainstormed cheaper “do-it-yourself” (DIY) washing ideas and settled on a salad spinner.

The size is small yet effective, and they are easily replaceable due to their large availability. In addition, salad spinners are relatively cheap and can be replaced without breaking the bank. Currently, the design for the washer is a standard salad spinner that has a pump at the top. We determined that a pump at the top is more ergonomically friendly than a hand crank, as it will save the employees from over exerting their hands, wrists, and arms every day. The pump at the top allows the employees either to push with their hands, or if they get tired, to pump just by pressing with their feet. The biggest issue with the unmodified salad spinner is that it has slits that are too wide, which allows for the plastic chips to fall out of the strainer and potentially cause wasted time scooping out those chips. In order to address this, we proposed buying a mesh bag that we can put the plastic chips into. This step will eliminate the chance of chips falling through the slits in the strainer, drastically reducing the time that it would take to scoop all of the chips out of the spinner after the washing period.



**Figure 3: Salad spinner utilized for washing and drying**

Since we want to keep our process simple, we decided to use the same salad spinner, with one adjustment, to dry the plastic chips. However, as mentioned previously, the unmodified salad spinner had slits that are too wide. To address this problem, we lined the inner bowl with a fiberglass window screen. This helped us to retain the chips without trapping the water inside the inner bowl like a mesh bag would. This fiberglass screen is also waterproof, which eliminates the need for regular maintenance and replacement. Overall, this solution allowed the chips to come out relatively dry, but the chips were not dry to the touch. After discussing with the team responsible for creating a device that will melt our chips, we realized that the current dryness of our chips was not sufficient to be used in the plastic melting device. In addition to the modified salad spinner, we also suggest that a food dehydrator is used to finish drying the chips. When tested, the food dehydrator was effective and efficient at removing the remaining moisture on the chips.

In addition to the tools we tested and proposed, we also recommend other tools to be used for the process. Although we are not testing these tools, we developed a BOM with the products, pricing, and location where the El Sauce citizens can get the tools. The links to the products can also provide the citizens with the specifications in case the recommended tool is not available in

El Sauce. A portion of our BOM, displaying what was actually purchased for our project, is shown below in **Figure 4**.

Part	Supplier	Quantity	Total Cost
Salad Spinner	Home Depot	2	\$59.99
Flexible Tube Cutter	Home Depot	1	\$14.98
Mesh Laundry Bag	Home Depot	1	\$7.14
Window Screen	Home Depot	1	\$5.14
Bingo Cage	Amazon	1	\$11.97
Clay	Home Depot	1	\$11.80
Dish Detergent	Home Depot	1	\$3.00
Food Dehydrator	Home Depot	1	\$54.38
			<b>\$168.40</b>

**Figure 4: Bill of Materials**

The first tool we recommend is a designated color plastic bin. Since contamination is crucial in our process, we need to separate the valuable materials such as PET bottles from non-PET plastics. Since the flow of bottles are relatively high, a color coded bin system will reduce the likelihood of cross contamination. In addition, we also recommend other tools that are more common for a facility setting. Some of the tools include cut resistant gloves, heat gloves, and safety glasses.

Since our final product is plastic chips, the plastic shredder plays a huge role in our process. We examined the shredder prototype from a previous MSD team and found that the prototype was not sufficient for our process. We then examined alternatives to a plastic shredder, such as manually cutting bottles into chips or utilizing a paper shredder. We found, however, that cutting the bottles manually takes a tremendous amount of time and the paper shredder consistently. Instead, we decided to research a commercial shredder from a vendor that we are recommending for use in the facility. Ultimately, we chose the “Mini Shredder” from Fila Maker. In addition to this shredder, we also are also recommending to use a motor that can be obtained from the local store or repair shops.

## Results

After many months of hard work, our team was able to produce a working process that was both simple and unique. Instead of using large, industrial machines, we’re proposing that the upcycling facility utilizes a salad spinner for washing, a salad spinner and food dehydrator for drying, a tube cutter for cutting the necks of the plastic bottles, a heat gun and WD-40 for removing the labels and its glue. We are also proposing a shredder for the facility to buy and utilize, due to the previous MSD team’s shredder not being ideal.

Through simulation and testing, we were able to estimate that the proposed process would have a cycle time of about 57 minutes per kilogram of plastic, which improves upon our customer's request of one hour. Our process meets many of the customer's requirements, including; input power, subassembly weight and dimensions, and number of employees. We are also proposing a facility in El Sauce with a floor plan and design which will meet footprint of processing plant requirement. There are also a few engineering requirements that we weren't able to test due to reasons such as not knowing the state of the other MSD team , not having a physical shredder to test on, or not having the actual facility set up yet.

The proposed process and facility layout (see **Figure 5**) are two successful products, but the result we are the proudest of is the potential to create six new jobs for citizens of El Sauce. In addition, by collecting and upcycling plastic bottles, we will simultaneously be cleaning up the environment!



**Figure 5: Proposed Facility Layout**

## **Conclusion**

Overall, the project was a very rewarding experience for us. Not only were we able to design a process from scratch, but we also created a way to help the town of El Sauce by providing them with an opportunity to turn plastic waste into valuable plastic chips. One of our biggest challenges was trying to keep the process as simple as possible, as this proved to be very limiting to our design options. Since our team focused heavily on simple tools and equipment, however, we were able to minimize our spending and concluded with an extra \$331 out of our initial budget of \$500. As we are now coming to completion with our part of the project, setting up the facility in El Sauce will be sure to pose new problems along the way, but we are confident in the process that we created. Hopefully, this project will be continued either by 4 Walls, the Enlace Project, or another MSD team that can work on setting up an actual facility in El Sauce.

## **References/acknowledgements**

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<https://edge.rit.edu/edge/P18434/public/Home>