City of Helena Transfer Station Glass Recycling Process Improvement

Montana State University

Project Client:
City of Helena

Project Contact:
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Management Summary

The City of Helena Transfer Station has been experiencing additional transportation costs for glass recycling caused by plastic flow regulator contamination. These plastic flow regulators are present in glass bottles that customers often recycle, and they cannot be handled locally in Ash Grove Cement's glass cement processing. Instead, glass must be shipped to Salt Lake City, the nearest location where glass recycling with plastic contamination can be processed. On a 10 year horizon, this transportation will cost the City of Helena roughly $266,000 in today's dollars.

This project was focused on developing solutions to mitigate the costs and carbon emissions associated with transporting glass recycling contaminated by plastic flow regulators. The scope of the project included conducting industry research on applicable methods and developing one or more solutions that are tailored to the City of Helena's unique challenge. Additionally, the project scope included an implementation plan that the City of Helena can follow. Creating and installing the physical solution(s) was outside the scope of the project. The objective of the project was to provide a recommendation that significantly reduces the costs and carbon emissions associated with this problem for the City of Helena, while contributing positively to the safety and accessibility of recycling at the City of Helena Transfer Station.

To achieve this goal, our team met with the City of Helena Transfer Station leaders to best understand their problem. We then developed an exhaustive list of potential methods to solve the challenge. After reviewing those solutions with the client, we identified three solutions worthy of pursuing at a more detailed level, producing current and proposed future state process maps. The three solutions are listed below in order of highest to lowest recommendation:

1. **"Maildrop" Spike Device with Additional Bulk Permit**

This solution involves two separate process improvements; first, individuals must obtain a permit to use the bulk glass recycling, promising to remove all plastic flow regulators before recycling glass. Second, a device will be installed in the residential bin that only enables glass bottles to enter the bin if there is not a plastic flow regulator present. This solution would reduce the 10-year horizon cost from $266,000 to $3,200, and would reduce carbon emissions by 98%.

2. **Metal Grate Filter**

This solution would install a canopy structure at the City of Helena Transfer Station, with a metal grate filter ceiling. Glass transport trucks would enter under the canopy, and crushed glass would be poured through the top, removing all plastic flow regulators through the filtration. This solution would reduce the 10-year horizon cost from $266,000 to $22,000 and would reduce carbon emissions by 98%.

3. **Industrial Sorting Solution**

This solution involves contracting a customized device to remove plastic flow regulators in tandem with the construction of a new recycling facility. This solution is the most costly, but has potential for long term utility. This solution would increase the 10-year horizon cost from $266,000 to $1.3M - $6M and would reduce carbon emissions by 40%.

We recommend adoption of the "Maildrop" spike device with additional bulk permit for its low cost, high impact potential. To implement this solution, we recommend employing a mechanical engineering and mechanical engineering technology capstone team at Montana State University to prototype, build, and install the device.

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Project Description

The goal of this project was to provide several alternative process improvement solutions to help The City of Helena reduce the adverse impact of plastic flow regulators in glass bottles. The project focus included reducing costs and environmental impacts of operations. Success was measured by how well the proposed solutions helped to optimize the economic impact of the operation with respect to also reducing the overall carbon footprint of the recycling operation. The solutions had to be realistic to be completed under the City's budget and be convenient and intuitive for the citizens of Helena. The current process has glass bottles shipped all the way to Salt Lake City which is a huge cost to the City of Helena and to the environment. Desirable solutions needed to include process improvements to reduce the adverse impact of the presence of plastic flow regulators in glass bottles, which was the main criteria for success, in addition to exploring overall process flow improvement of the recycling system. Many potential solutions to accomplish this were ideated and then analyzed to eventually narrow to several optimal solutions to improve the processing.

Metrics that were useful to evaluate solutions to the problem included the frequencies of the different types of glass bottles that tend to be recycled, the percentage of bottles that contain plastic flow regulators on average, and the total cost of the current process. To obtain this data we asked the client to conduct a random sample test of 100 glass bottles with 20 bottles tested each day to further randomize the test. This gave a +/- 10% range for the proportion of bottles including plastic flow regulators at a 95% confidence level. The cost of the current operation was recorded and shared for analysis. These metrics helped better understand the current problem and put the team on the right path to finding viable solutions.

The main client need within the proposed project scope was figuring out solutions to ameliorate the adverse consequences of flow restrictors in glass recyclables; this was the primary focus of the project. The process was constrained to not be able to use water for removal. There was also flexibility for finding other reuse/recycling methods for the glass bottles which would have been outside of our initial project scope but were explored superficially. Detailed mechanical design and building of any solution was also beyond the scope of this project.

An important component of the project was identifying solutions that would be effectively integrated into current recycling processes. The implementation of any designed solution needed to fit well with the current recycling processes for glass and other materials.

In summary, the project explored the following objectives:

1. Thoroughly map the current process.
2. Identify the issues in the current process and document process limitations.
3. Define desired feasible solutions.
4. Selecting the best solutions from available options.

Project Background

The City of Helena's recycling program encompasses the recycling for the City of Helena and Lewis and Clark County residents. The recycling program is funded through the solid waste assessment paid by city and county property owners in their property taxes. This allows property owners full access to Helena's Transfer Station. For renters to have access to recycling at the Transfer Station they must purchase a permit for $6; this permit enables residents to recycle up to 200 lbs of recyclables every trip. In 2021, the City passed a resolution with a goal to increase solid waste diversion from the landfill by 50% by 2040.

Initially, glass bottles were crushed into sand that was then used to sand roads in the winter. This use was quickly met by backlash from the citizens of Helena due to a lack of understanding of the process and out of fear that the crushed glass on the streets might cause issues for bike tires and walking dogs on the street. After backlash was received the city went on to search for other techniques of recycling the crushed glass and was able to come to an agreement with a local cement company (Ashgrove Cement) that could use the glass for their concrete process. Up until recently, the process of taking the recycled glass to the cement company was running smoothly, but plastic flow restrictors that were left in some of the bottles were affecting the concrete manufacturing process. These plastic flow restrictors were clogging the kiln used to manufacture the concrete and the excess plastic was also affecting the overall structural stability of the concrete. The concrete company was therefore forced to stop accepting the glass from the recycling center until they could guarantee that plastic flow regulators were removed beforehand.

Crushed glass recycling is currently being sent to a facility for use in fiberglass manufacturing (Momentum Recycling) in Salt Lake City, Utah where trace plastic is not an issue in their manufacturing process. Although this method means the glass is being recycled and not thrown into the landfill, the increased carbon footprint and increased cost of shipping the glass to Salt Lake City are major concerns. The need of removing these plastic flow regulators from the recycling stream is considerable and would greatly reduce the cost to the City and reduce the overall environmental impact of the process. The current process at the Transfer Station is diagrammed in Figure 1 below.

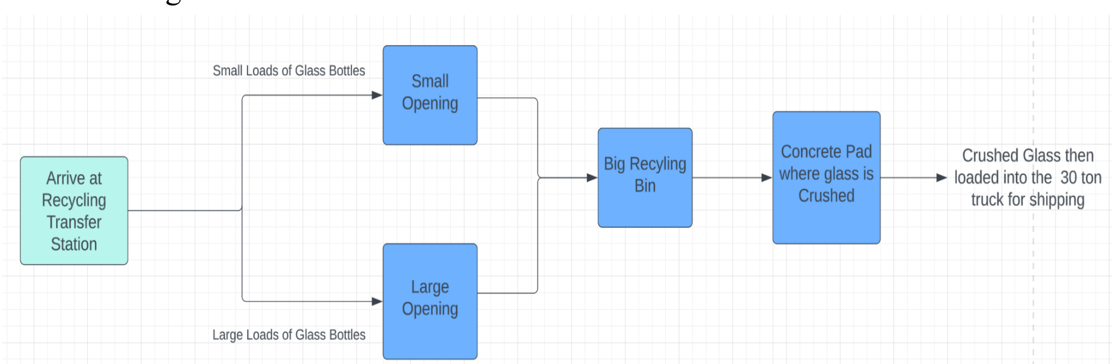

Figure 1. Current Glass Recycling Process

Stakeholder Needs Assessment

Process for Identifying Stakeholders:

To identify stakeholders, the team met with the initially known stakeholders: Miranda Griffis, Leea Anderson, and Kevin Cook. From these meetings, more light was shed on the project objectives and the problems to be addressed. Having gathered further information, stakeholders were split into groups from the City of Helena staff, City of Helena recycling customers, MSU M&IE department, and any others that were relevant. Stakeholders from each of these categories are engaged in the issue and project from different angles, and therefore hold differing needs and concerns, as identified through our meetings and documented below. Further brainstorming and research is filled in below with additional details about our stakeholders.

City of Helena

- **Miranda Griffis**: Sustainability and Recycling Coordinator
    - Miranda has been our primary point of contact with the City of Helena as we worked on this project. We have communicated with Miranda every sprint to touch base on progress, deliverables, and feasibility of generated solutions. Her primary need has been a feasible, cost-effective solution to mitigate challenges associated with plastic flow regulators in glass bottles that are dropped off for recycling or to find an alternative use for the glass.
- **Leea Anderson**: Environmental Regulation Pretreatment Manager
    - Leea manages Miranda's position and shares the same needs and concerns. Her approval has been necessary throughout the development of solutions.

Recycling Customers in Helena

- **Residential Customers**
    - Residential recycling customers are those who regularly drop off their household's glass bottles at the transfer station. These individuals often drop bottles off in the single-bottle drop window. Their primary need and concern is a simple, straightforward, and intuitive process to interface with at the transfer station. The less cumbersome the better.
- **Commercial Customers**

    - Commercial recycling customers are businesses who drop off larger quantities of glass bottles at the transfer station. These customers generally drop full bins of glass into the receptacles, bypassing the single-bottle drop window. Similar to residential customers, commercial customers seek a low-hassle experience in dropping off their recyclables.

Montana State University M&IE Department

- **Dr. Sage Kittelman**
    - Dr. Kittelman has been our capstone professor and has been a point person from the university providing guidance and support throughout the project, as well as holding us accountable to our project deliverables. We have checked in with Dr. Kittelman throughout the project. Her primary needs and concerns have been that we are working effectively with our client and producing results.
- **Kevin Cook**
    - Professor Cook has been our capstone project advisor and has been our other point person from the university to provide guidance and support throughout the project, as well as holding us accountable to our project deliverables. We have checked in with Professor Cook every other week. His primary needs and concerns have also been that we are working effectively with our client and producing results.

Other

- **Ash Grove Cement** **(**Ash Grove A CRH Company, 2023)
    - This is the cement company that previously accepted glass from the City of Helena. A successful project outcome would result in Ash Grove Cement being able to once again accept glass bottles from the city, which we are confident the proposed solutions will enable. The company's primary concern is that the shape and size of plastic flow regulators clog up their kiln, and if there is more than ~1% plastic contamination in the concrete then crushed plastic would still be enough to melt and clog the kiln.
- **Momentum Recycling** **(**Utah Glass Recycling, 2023)

- The recycling center in Salt Lake is the current destination for glass recycling from Helena. They have no need/concern in this project, but it is very costly to transport glass this distance.

- **City of Helena Taxpayers**
  - The City of Helena Taxpayers bear the burden of funding glass recycling (through the city's residential fund). It is in their best interest to have the most affordable recycling solution for glass bottles. Additionally, these citizens have historically expressed concerns about interacting with crushed glass in their environments (as part of road sanding), and crushed glass can, therefore, not be used in applications that are directly in contact with the citizenry.

Data Collection Methods

Much of the data collection needs for this project were qualitative, gathered via email and face-to-face communications with the client. These communications were ongoing, but were mostly contained within several key asks. At the onset of the project, a list of questions was compiled to ask in the first virtual meeting with our client. Having collected preliminary data through these questions, the Data Needs and Collection Plan (Table 1) served to retroactively document some of the previous data collection, while simultaneously filling in gaps. The team compiled another list of questions for the client following the site visit in Helena. Another list of questions was compiled following our presentation of brainstormed solutions. As the project progressed, emails were used to clarify further questions as they arose.

Questions for First Meeting with Client

- What will be most important to see in person?
  - How many site visits should we plan for?
- What kind of data is available?
  - Processing data.
    - Volume of glass processed.
  - Financial data (input, revenue, opportunity costs).
    - Cost to ship glass to Salt Lake (and emissions)?
- Are you currently accepting glass recycling?
- Describe the process a customer goes through to recycle at your plant.
- What did the local cement company pay for glass?
  - How did they use the glass?
- What methods to remove plastic have you already tried or considered, what were the results?
- What types of glass contain plastic? Visuals?
- What portion of recycled glass contains restrictors?
- What concentration of plastic contaminates the glass recycling?
- What is the relationship with the local cement company? What is their demand for glass recyclables? How would the demand affect the potential need for other alternative glass recycling/reuse solutions?
- Creating SOW, what is the range of acceptable outcomes you are looking for (exploration of options; implementation of solution)?

Data Needs and Collection Plan

Table 1. Data Needs and Collection Plan

Data	Date Collected By	Responsible Party	Purpose	Method of Collection	Data Type	Notes
Shipment weight by date	January 2rd	Helena Recycling	To understand the frequency and size of shipments	N/A	Quantitative Time Series	
Budget and expenditures	January 2nd	Helena Recycling	Analysis of the operational costs associated with glass recycling and shipping	Automated Index reporting	Quantitative	
Frequency of plastic flow regulators	February 7th	Helena Recycling	to identify the prevalence of plastic flow regulators	random sampling by hand	Binary variable	Sample size = 100, collected over 5 days
Current process flow	February 7th	Student Design Team	To understand and illustrate the current process flow	Site visit and photo documentati on	Visual Figure	The document will be created during Sprint 2

Proportion of Glass with Flow Regulators Data:

Prior to the site visit, we had our client sample 20 glass bottles for 5 consecutive days to get a statistical analysis of the proportion of glass with flow regulators in the recycling stream (14-34% at a ~95% confidence level). Here's the data:

1. 4/20
2. 6/20
3. 4/20
4. 6/20
5. 4/20

Data Request Following Transfer Station Site Visit

Following our site visit, the client was asked for the following information -- responses in red:

- Map of the transfer station.

Figure 2. Map of Transfer Station

- Clarification from Ash Grove Cement on how much plastic is too much plastic in their process — some quantification would be helpful if possible. Is there a plastic percentage threshold at which they can no longer accept recycling?
    - I called Ashgrove but have not been able to get any more information. If they do get back to me and I can let you know.

- Data on the total volume of glass recycling broken down by single-drop glass vs. commercial-drop (number of times each bin is emptied multiplied by the volume of each dump)
    - For FY22, the bins were emptied 4 times, and the truck holds 40 tons max.

- Data on the number of recycling customer vehicles visiting the Transfer Station.

    - I attached that document “Daily Data” The column titled “Rec” is recycling, however we don’t break it down by commodity.

- Cost per hour of the wage of an employee to remove plastic flow regulators
    - Current scale operators are paid $15.75

Data Request Following Solution Brainstorm Presentation

Following our presentation of brainstormed solutions to the City of Helena, we had a few additional pieces of data we hoped to obtain, including a more detailed map of the Transfer Station labeling the different collection areas. Miranda Griffis kindly provided that information which is documented below:

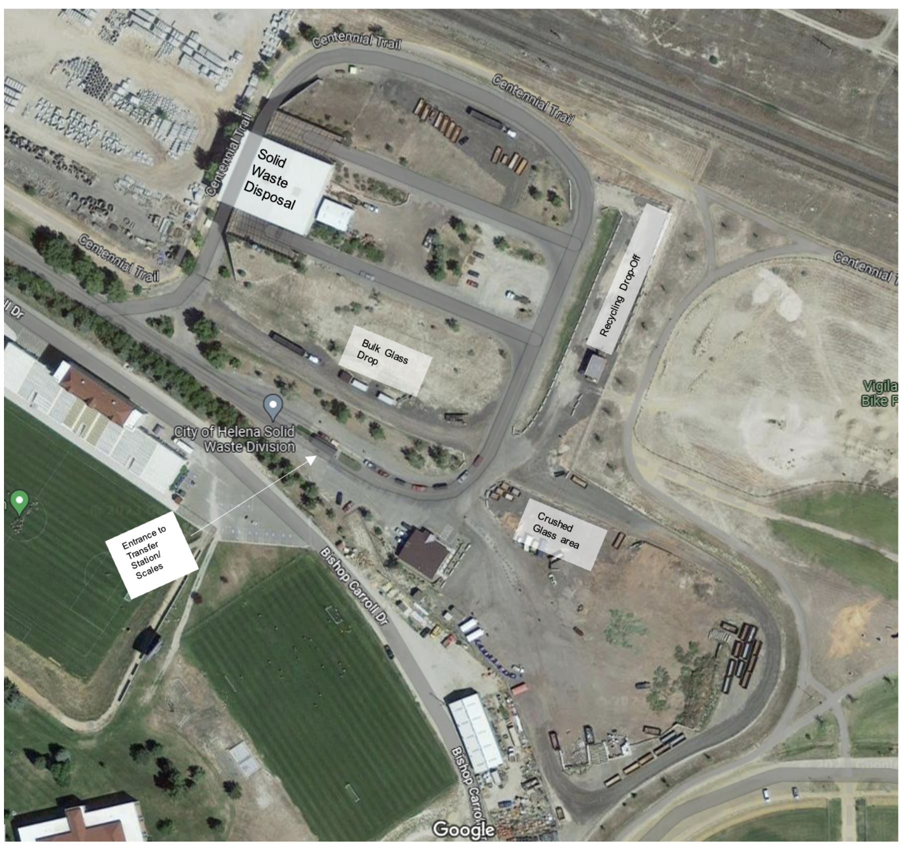

Figure 3. Updated Map of Transfer Station

Follow Up Communication Answering our Questions (Answers in red):

- What is the breakdown between residential and commercial drop-off glass volume?:
    - I chatted with our Solid Waste Supervisor Pete this morning, and he couldn’t give me a solid answer on commercial bulk vs. residential drop. However, he did say

that the bulk drop gets emptied about 6x a year, whereas the residential bins get emptied at least once a week.

- How full bins usually are when they are emptied:
  - Usually they are as close to capacity as they can be so typically around 85-100%

- Detailed pay data:
  - For 2023, New seasonal Solid Waste Employees start out at $15.76, and FTE start out at $18.30. The City has a step program, so if an employee works here a certain amount of time, (usually a year) they move up a step, which is a 5% pay increase. I'm not sure how that works for Seasonal employees, but I attached the pay matrix for both seasonal and FTEs below.
    - When I spoke with Pete, he stated that seasonal employees do not get benefits, however for employees who do get benefits, he budgets 30% for fringe benefits.
    - A FTE is 2080 hours in a year, and a seasonal number can vary depending on when they are hired. We recently submitted a grant to hire a few employees, and this was what I calculated for 3 years of 3 seasonal employes:

Table 2. Annual Employee Compensation Expenses

Hours	Year 1	Year 2	Year 3	Total
1040	$16,390.40	$17,212.00	$18,075.20	$51,677.60
1040	$16,390.40	$17,212.00	$18,075.20	$51,677.60
1040	$16,390.40	$17,212.00	$18,075.20	$51,677.60
	$49,171.20	$51,636.00	$54,225.60	**$155,032.80**

Table 3. Seasonal Employee Matrix

Building Maintenance Tech	503	$ 15.76	$ 16.55	$ 17.38
Shop/Fleet Laborer	503	$ 15.76	$ 16.55	$ 17.38
Solid Waste Laborer/Tipping Floor Operator	503	$ 15.76	$ 16.55	$ 17.38
Streets/Traffic Laborer	503	$ 15.76	$ 16.55	$ 17.38
Civic Center Laborer*	503	$ 15.76	$ 16.55	$ 17.38

Table 4. Full Time Employee Matrix

Solid Waste Tipping/Scale Operator	130	18.3039	19.2191	20.1800	21.1890	22.2485
Utility Maintenance Worker-Trainee	130	18.3039	19.2191	20.1800	21.1890	22.2485
Wastewater Plant Operator - Trainee	130	18.3039	19.2191	20.1800	21.1890	22.2485

Further Data Collection from Client

Email communication from Miranda Griffis, City of Helena point person providing data from our request (questions in black text, responses in red):

- What is the size of the tractor that crushes the glass? How much space does it need during the glass crushing process? (approximate width, length, height)
  - The loader weighs about 28,000 lbs. During the glass crushing process it needs about 40 x 40 feet of space.
    - Here is a more detailed link on the specs of the Loader (this may not be the exact model or year, but pretty close)
    - (Small Wheel Loaders 926m, 2020)

- What is the size of the truck that comes to pick up the crushed glass that would be sent to Ashgrove? (approximate width, length, height)
  - Empty, this truck weighs about 34,000 lbs. and is 34 ft. long.

- What are the dimensions of the drop off window at the residential recycling area?
  - 10 X 10 inches.

Problem Exploration

Overview

From the beginning of this project, we knew that a successful outcome from this capstone design project would result in presenting the City of Helena with an environmentally and economically viable glass recycling solution to replace their current expensive and high-emissions process of shipping glass to Salt Lake City, Utah for recycling. Currently, the pervasive presence of plastic flow regulators is preventing the city from sending glass to Ash Grove Cement where it used to be accepted. A large part of our solution space has considered different options for eliminating these plastic pieces from the recycling stream, though some outside-the-box solutions were also explored. Throughout the project, we have communicated with the client, the City of Helena Transfer Station, to ensure that our proposed solutions are in line with their expectations.

We began by conducting an early ideation process in which we identified many potential solutions to explore further. We presented these findings to the City of Helena after this initial ideation phase. These solutions included process improvements for sorting out plastic flow regulators after the glass has been crushed (machine vision, vibration, sifting, etc), sorting out bottles with flow regulators before glass has been crushed (machine vision, separate drop-off locations, sorting by bottle dimensions, shearing neck of all bottles, etc), forcing recycling customers to remove the flow regulators themselves (drop-box mechanism that only accepts bottles with an open top, signage, and education, etc), and other solutions that bypass the removal of plastic flow regulators all together. These solutions were all explored at a high level for viability and economic justification, before narrowing down to several feasible solutions to dive into further. In this digging deeper phase, we further investigated the feasibility of the most promising solutions, conducting extensive economic analyses on the foreseen costs and savings of the solution, and high-level environmental impact assessments, reviewing the predicted greenhouse gas emissions and overall environmental implications of the given solutions.

Having ideated substantially and narrowed down to several feasible solutions, the final findings have been presented to the City of Helena in a written report and presentation. Instead of presenting a single, fully built-out solution, we have presented the plans and designs for three solutions, laying out the pros and cons of each. The two most promising recommended solutions involve future MSU Mechanical Engineering or Mechanical Engineering Technology capstone projects to build and install the proposed physical solutions. The City of Helena is now able to select the option from our proposed solutions that best accommodates their environmental, economic, and timeframe needs.

February 7th, 2023 Site Visit Documentation

On Tuesday, February 7th we met with our project client from the City of Helena for an in-person site visit at the Transfer Station. At this meeting, we were able to take photos and notes documenting the glass recycling process at the Transfer Station and gain further clarification on the extent to which plastic flow regulators are present in the recycling stream. Notes and an updated process map from this visit are included below.

Notes from visit:

- Customers can dump up to 3000 lbs per year of garbage; if individuals are only recycling, it does not count towards the 3000 lbs.
- Bulk glass dump has significantly less plastic flow regulators than the residential dump spot.
- Metal bar is used at the residential station to prevent users from putting in entire bags of recycling (must take out of bag).
- Plastic rings are still not ideal, but are not as detrimental, and outside the scope of the project.
- Currently, all glass is combined into one flow… limited space is cited as the reason why
- Glass is crushed with a giant tractor.
- There is a 2-week lead time between requesting a pickup from salt lake and arrival of trucks.
- A total of $38k is spent per year to send recycling shipments to Salt Lake.
- It is difficult to tell how many customers use the residential recycling, because some may use it and the waste dump, and not state which they are using.
- The total glass from bulk and residential can be discerned by calculating the total number of times each is emptied.
- There may be some space available on the back side of the covered waste dump area.

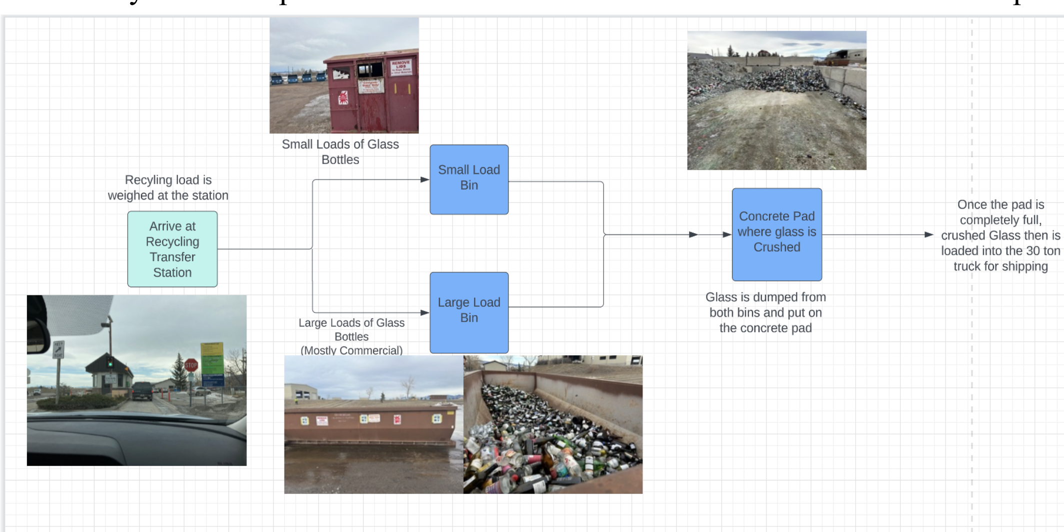

Figure 4. Current Glass Recycling Process with Visuals

Solution Development

Having explored the underlying causes of the plastic flow regulator problem and gained further insight through a site visit, we began developing our solutions. This process began with a structured brainstorm to generate as many solutions as possible. Having listed these solutions, we developed brief descriptions for each and presented them to our client. We took feedback from our client to select our three primary solutions to pursue further.

Solution Brainstorm List

Following the site visit, we generated a list of potential solutions, generating a high-level view of their functionality. The results of this exercise are documented below.

Chopping the neck off of bottles:

- Gravity fed funnel slotting bottles from the small bin.
- Machine that slices off tops, which are discarded. Remaining glass is plastic free and good for recycling at Ash Grove.

Separate flows of bulk and residential flow

- Need to find an additional space to facilitate two flows.
- Could inspect to ensure no plastic.
- Inspector just throws away glass.

Further separation of flows inside residential

- Have customers put beer and wine (maybe others) in a different area from other glass.
- Need to handle increased flow paths with spacial redesign.

Melt out the plastic flow regulators

- Impacts on glass and transportation?
- Cost?
- Space?

Rotating Spike Device

- Customers must place glass on a spike, preventing bottles with flow restrictors from entering.

Grate Filter

- Sifts crushed glass through a fine filter, catching all plastic pieces before distribution.
    - Have a filter as the layer upon which the glass is crushed.
    - OR scoop crushed glass onto a filter at different location.

Vibration Sorting

- Vibrating platform separates crushed glass from plastic based on weight/density.

Machine Vision

- Automatically sort out plastic from crushed glass with machine vision and search algorithm, with robots grabbing out plastic bits.
- Automatically find and sort bottles with plastic flow regulators before crushing using machine vision and robot grabber.

Signage and Education
- Educational resources on how to remove bottles at home.
- "Loud" signage at dropoff locations about flow regulators.
- Provide tools (securely attached to wires) that work effectively for removing regulators.

Alternative Glass Recycling Solutions
- Machinex: Eco Enterprises Quebec Innovative Glass Works.
    - Up to 99.9% glass purity.
    - Developed by Machinex and industry partners, the MX Glass Solutions remove the contaminants in glass, such as paper, metals and organics to ensure you produce marketable glass products.
    - (MX Glass Solutions, 2017)

Rapid Inspection Process
- Inspector either throws away or cuts off top of all bottles with flow restrictors.

Have people drop glass right where it is crushed and other general layout considerations
- Need to protect people from being exposed to glass shards.

Brainstormed Solutions with Written Client Feedback (In Red)

Having generated a solution brainstorm list, we wrote out a general description for each proposed solution. This list of solutions was presented to the client, who provided feedback on each solution. Our summary of each solution, along with the City of Helena's feedback is documented below. The solution brainstorm presentation slidedeck can be found in Appendix D: Ideation Presentation.

Chopping the neck off of bottles:

Ensure flow restrictors are gone by chopping off the neck of the bottle. This solution can be scaled with varying degrees of automation from a sweeping chop off of every bottle's neck to a machine-vision-incorporated solution that specifically identifies bottles with the flow restrictor. The solution would require a conveyor belt or gravity-fed funnel moving each bottle past a specified neck-shear location. The tops of bottles are discarded to the landfill in this scenario, accepting a small amount of waste for the overall glass recycling solution in which the majority of material can be recycled being now guaranteed plastic-free and ready to go for Ash Grove cement. Shearing is completed either with a machine or by hand of an inspector.

Great Idea! We could even send the contaminated sections/ tops of bottles to Momentum instead of the landfill. Instead of sending twice a year, maybe this would allow us to send once every 2-3 years and send the uncontaminated bottles to Ash Grove. One concern was, would an employee have to handle these by hand after they have been disposed of in the bins?

Separate flows of bulk and residential flow

In this process, the bulk and residential flows would be kept separate, since the bulk recycling has significantly less (almost none) plastic flow regulators. Using this strategy, the bulk recycling could be sent to the local Ashgrove for concrete use, reducing the total volume of glass that would be sent to Salt Lake City. There would be two ways to accomplish this:

1. Create a separate crushing station for bulk recycling, enabling each recycling flow to have a completely separate facility.
2. Expand the storage capability of both residential and bulk recycling, enabling the glass crushing area to be alternated between each flow type, without any cross contamination.

Overall this would significantly decrease the volume of glass needed to be sent to Salt Lake.

I think this would still allow for a possibility of flow regulators to contaminate the bulk section.

Further separation of flows inside residential

Have a separate dumping site for beer and wine bottles which don't have flow restrictors to separate the flow to ensure that there are at least no flow restrictors within the separated bin to make it easier to implement a device or technique on the other glass bottles that are more likely to have flow restrictors. To implement this we would need to implement informative signs that are visible that direct customers to the correct bin and make sure that there is space for an extra bin. We could also separate the current residential bin into two halves and incorporate another window for beer and wine.

Too much human error. The public already creates contamination with the signage that is there, I don't think we can rely on them to further separate.

Melt out the plastic flow regulators

Digging further into the material melting/burning characteristics of glass and plastics, this solution would heat all crushed glass (requiring a non-negligible amount of energy) to a point where any present plastic would melt or burn off, but not hot enough for the glass to melt. Issues may arise with handling/separation of plastic residue from glass itself. To be explored in this solution would be the impact this would have on the crushed glass itself and how those impacts might affect the ability to transport the material. Primary considerations would be cost, energy demands (and environmental implications), and space requirements for a machine of those capabilities.

I think this could be a cool idea, would need more information on how It would exactly be done.

Rotating Spike Device

This solution would implement a row of rotating spikes that users can place their glass recycling bottle on. The users could only place a glass bottle on to the tool if there was no plastic flow regulator present, removing all plastic flow regulators from the process. The spike would accept glass from users and drop it into the glass recycling bin. This solutions would ensure a 100% success rate of removing plastic flow regulators, but would be difficult and potentially frustrating to use.

This is my favorite! Paired with some kind of device that attaches to the side of the bin, that would allow people to pull out the flow regulators if needed. . Leea also mentioned that we could potentially combine this idea with the 1st one: Bottles are loaded upside down into a chute that is slightly tilted to one side with a trough in the middle that the neck of the bottle goes through. When the door is closed, a spring-loaded metal bar runs across the underside of the trough and sheers the necks off. The bottles then fall to one side and the necks fall to the other. The spring could be tied to the door, so it is released and rests every time the door is opened and closed.

Grate Filter

Have some sort of metal grate that filtered the crushed glass through and stopped any flow restrictors from going through. The grate would need to sit on top of the current concrete pad with enough clearance to gather all of the glass. The grate would also need to be strong enough to support the crusher vehicle which weighs a lot. This solution would ensure that no flow restrictors are within the crushed glass.

Also love this idea! We could even pour the crushed glass over the grate as well. I wonder if some kind of rubber grate would work best, so it doesn't get bent? Also, maybe even looking into a bin that has a build in grate/crusher, so we could crush the glass in the bin, and use the grate, all at once, so we would never have to transport it to the crushing location. Our plastics bin, has a compactor built into it, I wonder if we could find something like that? (Just a thought)

Vibration Sorting

Crushed glass would either be on a surface that can vibrate or be moved to a vibrating platform that utilizes the different resonance frequencies of glass and plastic (based on weight/density of material) to mechanically sort the crushed glass from the plastic flow regulators. This would require the tunable vibrating table and further research into how the plastic would actually be separated via vibration.

Pair this with the previous idea?

Machine Vision

This solution would implement machine vision technology to identify where plastic flow regulators were present. This could either be used as a tool before glass crushing (identifying bottles) or after glass crushing (identifying individual plastic flow regulators. This machine vision technology would be integrated with a tool that could either remove the plastic flow regulator, or slice the end off of the bottle containing the flow regulator.

This would be a possibility in the future if we had a recycling facility with warm storage.

Signage and Education

A different approach to solving the plastic flow regulator problem, this solution relies completely on the competence of recycling customers to remove their plastic flow regulators prior to dropping glass off for recycling. To ensure this, a combination of educational resources/campaigns and signage would be used to persuade recycling customers to remove all of their plastic flow regulators. Resources would be distributed to all recycling customers on at-home solutions to removing these plastic flow regulators, then "loud" signage on-site would catch the stragglers who have failed to remove the regulators beforehand, providing adequate tooling onsite (securely attached to wires) enabling customers to effectively remove the plastic flow regulators. These tools would also be available for purchase.

Has to be paired with another idea.

Machinex Alternative Glass Recycling Solutions

This is a commercial solution to glass recycling sorting. Machinex is a company that builds industrial glass sorting machinery that can create a recycling stream of up to 99.9% purity. Upon cursory exploration, the efficacy of this machinery to remove plastic flow regulators is unclear as the primary sorting mentioned is metals and papers. However, pursuing this option further may reveal that this company would be a valuable partner to design and build an effective glass recycling solution at the Transfer Station. Currently implemented at a number of locations, particularly Eco Enterprises Quebec Innovative Glass Works. "Developed by Machinex and industry partners, the MX Glass Solutions remove the contaminants in glass, such as paper, metals and organics to ensure you produce marketable glass products." Further exploration of this solution would prove beneficial. (MX Glass Solutions, 2017)

This would be a possibility in the future if we had a recycling facility with warm storage.

Rapid Inspection Process

An inspector either throws away or cuts off top of all bottles with flow restrictors. While it has been identified that it is too expensive to hire an employee to remove the flow restrictors, it would be much faster and cheaper if the employee only had to throw the bottle away, or use a fast-acting tool to remove the top of the bottle.

Would take additional funds to hire employees. And factor in their safety of handling glass.

Have people drop glass right where it is crushed and other general layout considerations

Infrastructure would need to be implemented at the current glass crushing site to have one side of the crushing pad dedicated to commercial dumping and the other side be residential dumping. The commercial side could be open like the current commercial dumping site where large loads can be dumped easily and then the residential side would need to be built up to limit residents from dumping multiple glass bottles at a time.

- Need to protect people from being exposed to glass shards.

Notes from Brainstorm Presentation

Following our presentation, we recorded our own notes including insights gained from our questions to the client during the presentation. These notes helped inform our follow up questions to the client after the presentation. The notes from our presentation are documented below.

General

- Our site visit was during low volume winter season.
- Client feedback to combine spike solution and neck chop solution to have customers place bottles in trough and close mechanism to chop necks, dropping bottle into recycling and neck (with flow restrictors) into trash.

Further Questions/Areas of Inquiry

- What are options for PPE in glass inspection?
- What is the best tool for removing flow regulators? Is this easily available for use at the transfer station?
- More information from Ash Grove cement would still be useful but the City of Helena still has not heard anything.
- Their GIS system they used in committee may break down areas within transfer station, otherwise labeled aerial view will suffice.
- Can we get more detailed volume data -- Which is more: residential or commercial: number of pounds from bulk vs. residential.
    - Data not available at this time.

Feedback on Solutions

- Separation of flow -- bulk vs. residential recycling
    - Contamination in bulk recycling is infrequent, but *large volume* when it does occur.
- Separate wine and beer from the rest of recycling flow
    - Face resistance from customers for more sorting.
    - Will be less diversion than originally hoped.
- Melt out plastic

    - "Cool and innovative"
- Conveyor spikes
    - force lid off, remove liquids.
    - Device to pop off flow regulators.
    - Row of spikes, close door and flip over (mail deposit).
- Grate Filter
    - Gravel separation at gravel pit -- grate stands at angle, fine moves through, bulky slides down for further processing.
- Vibration
    - Combine with grate.
    - Future implementation indoors.
- Machine Vision
    - Hard to implement outside -- exposed to the elements.
- Signage & Education
    - Always an education component in any solution.
    - Can't do anything without, cannot rely solely on education.
- Machinex
    - Future potential for implementation indoors.
- Rapid inspection
    - Broken glass in bins (employee safety).
    - Most handling with machines, not by hand.
    - Hire additional staff part-time -- a challenge (hazard pay?).
        - ~$30,000 savings from Salt Lake may not cover it.

Identified Solutions to Pursue Further

Once we had solid feedback from the City of Helena Transfer station on our initial solutions, and had important additional data, we identified three solutions that were promising enough to warrant additional examination. These solutions were selected to pursue further, and each solutions overview along with the estimated path forward are documented below.

1) **Mail Drop Row of Spikes + Extra Permit to Use Bulk Recycling**

    a) **Description from Brainstorm:**

This solution would implement a row of rotating spikes that users can place their glass recycling bottle on. The users could only place a glass bottle on to the tool if there was no plastic flow regulator present, removing all plastic flow regulators from the process. The spike would accept glass from users and drop it into the glass recycling bin. This solution would ensure nearly a 100% success rate of removing plastic flow regulators.

b) Our Solution to Explore Further:

This option would incorporate a row of spikes where each bottle would be placed in a manner where there would be no room to place bottles in between the spikes so each bottle would need to have the flow restrictor removed beforehand. The door to the recycling bin would close like a mail drop box, rotating the row of spikes to dump the bottles when the door closes. There will be a device for customers to remove flow restrictors from the bottles so that they can remove them on site. This is our most hopeful all-encompassing solution to eliminating glass flow regulators and seems very promising for successful implementation.

c) Extra Permit:

The solution above will not work if there is any flow restrictor contamination within the commercial recycling bin since the solution is to only be incorporated in the residential recycling bin. To guarantee that there is no contamination within the commercial bin, every business or person that applies to dump glass recyclables in bulk will need to also apply for a permit that is an agreement that there will be no plastic flow restrictors within their dump or else they will not be able to dump at the transfer station in the future.

2) Metal Grate Filter

a) Description from Brainstorm:

Have some sort of metal grate that filtered the crushed glass through and stopped any flow restrictors from going through. The grate would need to sit on top of the current concrete pad with enough clearance to gather all of the glass. The grate would also need to be strong enough to support the crusher vehicle which weighs a lot. This solution would ensure that no flow restrictors are within the crushed glass.

b) Our Solution to Explore Further:

Mimic method for gravel separation at gravel pit. Filter grate stands at fixed angle, crushed glass is poured over, with finely crushed glass passing through, while bigger chunks and plastic flow regulators slide to the bottom for an additional round of crushing then sifting. Final sorted plastic will be landfilled. This is a stretch solution to eliminating glass flow regulators and still has quite a few unknowns and questions that may prove it infeasible as we dig deeper.

3) Machinex Quote

i) Disclaimer

One of the original solutions we identified to pursue further was a quote from the company Machinex which manufactures machines for industrial recycling sorting. However, this solution evolved as we explored it, since we soon learned that Machinex's solutions are meant for macro sorting of aggregate single-stream recycling collection. For our purposes, we need micro-level sorting of contaminants within a crushed glass stream. Throughout our solution development, this third solution became "Industrial Sorting Solution" as we explored other companies' industrial sorting solutions.

a) Description from Brainstorm

This is a commercial solution to glass recycling sorting. Machinex is a company that builds industrial glass sorting machinery that can create a recycling stream of up to 99.9% purity. Upon cursory exploration, the efficacy of this machinery to remove plastic flow regulators is unclear as the primary sorting mentioned is metals and papers. However, pursuing this option further may reveal that this company would be a valuable partner to design and build an effective glass recycling solution at the Transfer Station. Currently implemented at a number of locations, particularly Eco Enterprises Quebec Innovative Glass Works. "Developed by Machinex and industry partners, the MX Glass Solutions remove the contaminants in glass, such as paper, metals and organics to ensure you produce marketable glass products." Further exploration of this solution would prove beneficial.

b) Our Solution to Explore Further:

This option would be explored superficially as a potential solution down the road if the City of Helena builds a dedicated, indoor recycling center. We will seek out a rough quote from the company and ascertain whether their technology is able to sort out plastic. No further exploration will be conducted. This is the biggest reach out of the three solutions we are exploring further.

General Considerations For Further Solution Development:

- How to implement high-level inspection for assurance to Ash Grove that their maximum contamination threshold is not exceeded.
- Education and signage on-site and in the community.
- Use of space at the Transfer Station.

Project Interim Presentation

Following the identification of the solutions to pursue further, we conducted more rigorous analysis of each solution, bringing a finalized version of each concept together in an interim project presentation. This presentation was delivered during a EIND 499R Capstone course period, with Miranda Griffis form City of Helena Transfer Station viewing the presentation remotely. This presentation provided an opportunity to illustrate a summary of our findings, along with the process taken to reach those results and next steps. The slide deck from this presentation is available in the Appendix E: Project Interim Presentation.

Analysis Methods & Results

A primary analysis tool used was process mapping of current and proposed processes via process flow maps. Depicting the current process flow enabled us to understand its strengths and weaknesses and identify bottleneck points to isolate and address the problem of plastic flow regulators. Using these process flow maps, we identified a few critical challenges. First, the point at which the problem was occurring was the drop off at both the residential and the bulk recycling. At this stage, plastic flow regulators were entering the material flow. We needed to introduce a fail-proof filter into the process at some point to remove flow regulators from the final material flow. Additionally, we needed to create a solution that would preserve or improve the overall efficiency of the current process to maintain effective use of time and resources. Understanding where the problem stemmed from in the process flow, we curated our final solutions to address these challenges, building associated process flow maps. The current state and future state of each solution process flow maps are shown below.

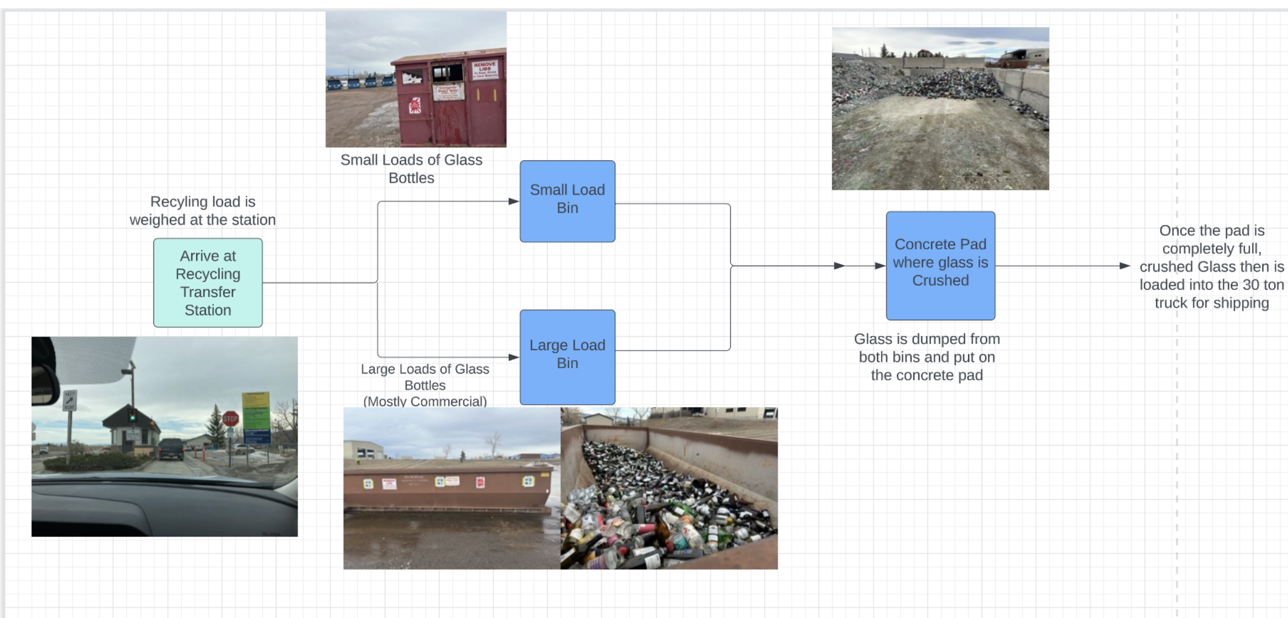

Figure 5. Current Glass Recycling Process with Visuals

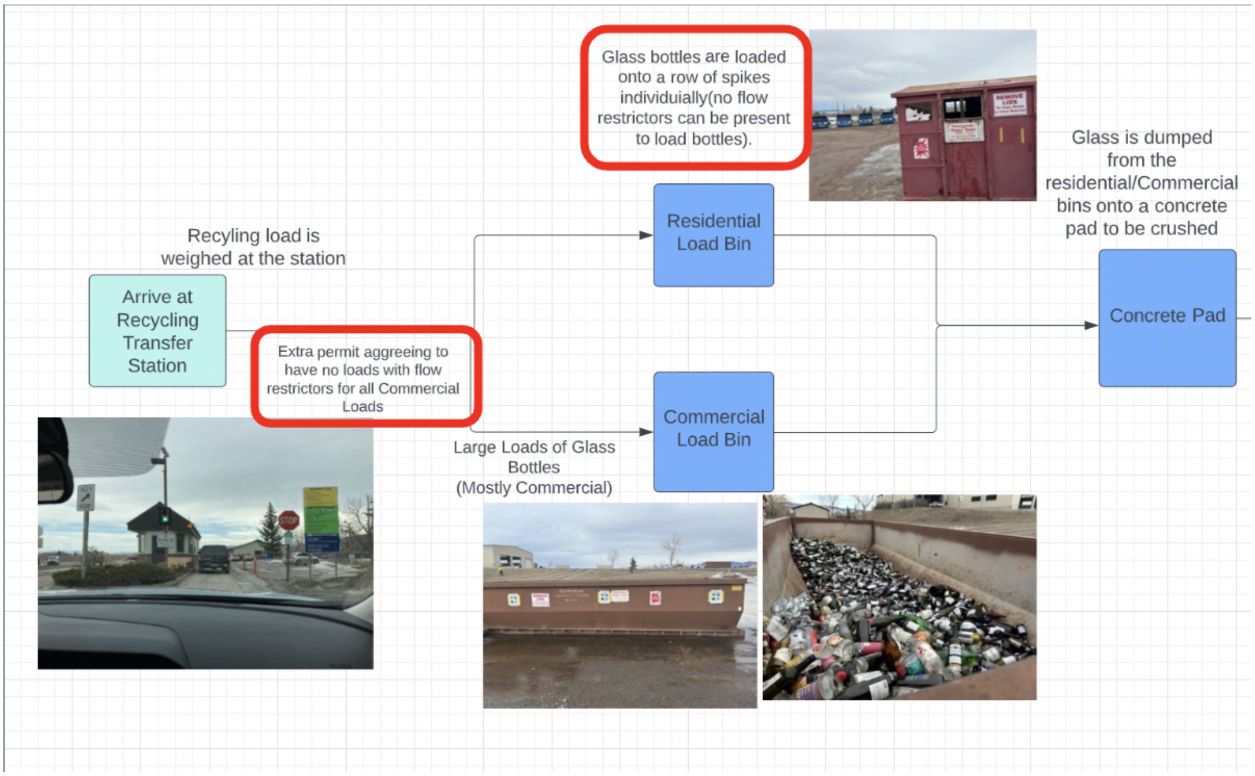

Figure 6. Glass Recycling Process with "Maildrop" Spike Solution

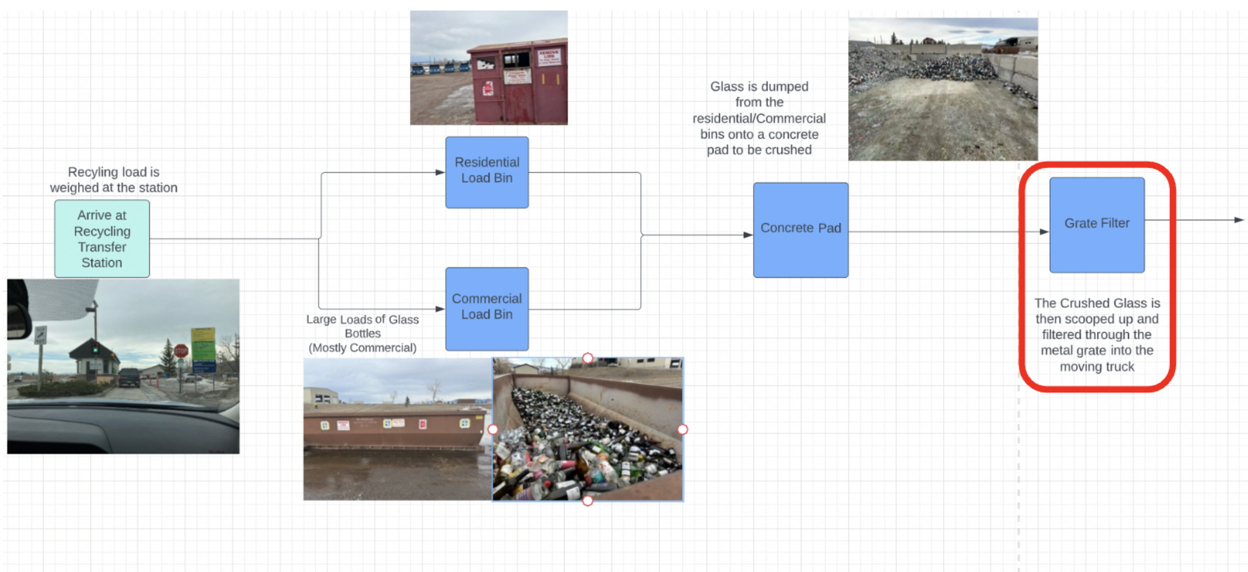

Figure 7. Glas Recycling Process with Metal Grate Filter Solution

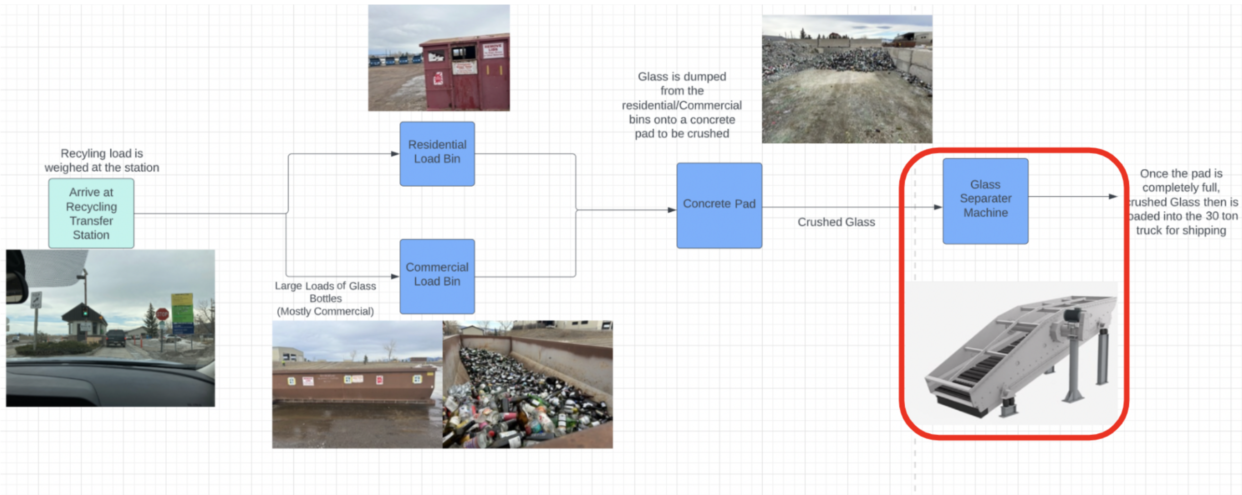

Figure 8. Glass Recycling Process with Industrial Sorting Solution

Impact & Efficacy of Solutions

The core component of the impact and efficacy of our project is examining the environmental impact of each proposed solution. Each solution that we have provided yields a significant improvement to the current environmental impact of the operations at the City of Helena Transfer Station. The detailed results of each of the environmental analyses are shown below.

Environmental Impacts Assessment 1: “Maildrop Spikes Solution

Table 5. Comparison of Spike Mail Drop and “Do Nothing” Solutions

Outcome	Greenhouse Gas Emissions Per Year (lb CO2)	Greenhouse Gas Emissions Per Year (Tons CO2)
Spike Mail Drop	300	0.15
“Do Nothing” Solution	14511	7.26

*For reference, MSU’s annual emissions are ~50,000 metric tons CO2 equivalent

Assumptions:

- We assume that the carbon emissions associated with building this solution are negligible in comparison to the emissions associated with transporting materials.
- We assume the truck drives empty to the Transfer Station before picking up crushed glass, both in the “do nothing” and metal grate solution.

Environmental Impact After Spike Mail Drop Solution

- Total Mileage of transport required:
    - 10 Miles (Distance from City of Helena Transfer Station to Ashgrove) * 2 (driving to Ashgrove and Back) * 4 (trips per year) = **80 miles of travel required per year.**

- Assuming 6 miles per gallon for Peterbilt 389X moving truck, 80/6 = **13.33 Gallons of Diesel Fuel required.**

- Using estimation of 22.44lbs of CO2 emissions per gallon of diesel fuel, 22.44*13.33 = **<u>300 lbs of CO2 per year.</u>**

“Do Nothing” Environmental Impact of Shipping to Salt Lake

- Total Mileage of transport required:
  - 485 Miles (Distance from City of Helena Transfer Station to Ashgrove) * 2 (driving to Salt Lake and Back) * 4 (trips per year) = **3880 miles of travel required per year.**

- Assuming 6 miles per gallon for Peterbilt 389X moving truck, 3880/6 = **647 Gallons of Diesel Fuel required.**

- Using estimation of 22.44lbs of CO2 emissions per gallon of diesel fuel, 22.44*647 = **<u>14511.2 lbs of CO2 per year.</u>**
  - (“What Is the Carbon Footprint of Diesel Fuel?, 2023)

Environmental Impacts Assessment 2: Metal Grate Filter Solution

Table 6. Comparison of Metal Grate Filter and “Do Nothing” Solutions

Outcome	Greenhouse Gas Emissions Per Year (lb CO2)	Greenhouse Gas Emissions Per Year (Tons CO2)
Metal Grate Filter	300	.15
“Do Nothing” Solution	14511	7.26

*For reference, MSU’s annual emissions are ~50,000 metric tons CO2 equivalent

Assumptions:

- We assume that the carbon emissions associated with building this solution are negligible in comparison to the emissions associated with transporting materials.
- We assume the truck drives empty to the Transfer Station before picking up crushed glass, both in the “do nothing” and metal grate solution.

Environmental Impact After Metal Grate Filter Solution

- Total Mileage of transport required:
  - 10 Miles (Distance from City of Helena Transfer Station to Ashgrove) * 2 (driving to Ashgrove and Back) * 4 (trips per year) = **80 miles of travel required per year.**

- Assuming 6 miles per gallon for Peterbilt 389 X moving truck, 80/6 = **13.33 Gallons of Diesel Fuel required.**

- Using estimation of 22.44lbs of CO_2 emissions per gallon of diesel fuel, 22.44*13.33 = **<u>300 lbs of CO_2 per year.</u>**

"Do Nothing" Environmental Impact of Shipping to Salt Lake

- Total Mileage of transport required:
    - 485 Miles (Distance from City of Helena Transfer Station to Ashgrove) * 2 (driving to Salt Lake and Back) * 4 (trips per year) = **3880 miles of travel required per year.**

- Assuming 6 miles per gallon for Peterbilt 389X moving truck, 3880/6 = **647 Gallons of Diesel Fuel required.**

- Using estimation of 22.44lbs of CO_2 emissions per gallon of diesel fuel, 22.44*647 = **<u>14511.2 lbs of CO_2 per year.</u>**
    - ("What Is the Carbon Footprint of Diesel Fuel?, 2021)

Environmental Impacts Assessment 3: Industrial Sorting Solution

Table 7. Comparison of Industrial Sorting and "Do Nothing" Solutions

Outcome	Greenhouse Gas Emissions (lb CO_2)	Greenhouse Gas Emissions (tons CO_2)
Industrial Sorting Solution	8,816	4.41
"Do Nothing" Solution	14,511	7.26

*For reference, MSU's annual emissions are ~50,000 metric tons CO_2 equivalent

Assumptions:

- We assume that the carbon emissions associated with this solution are primarily associated with the yearly operation of the facility, namely from energy consumption.
    - Greenhouse gas emissions from building the facility are considered negligible for the sake of this analysis.

- Colstrip Energy Limited Partners (CELP), Yellowstone Energy Limited Partners (YELP) (from NorthWestern Generation portfolio) are treated as coal emissions for electricity emissions calculations.
    - Facility operation emissions are combined with emissions to transfer glass to Ash Grove Cement for total emissions value.
- For the current state analysis, we assume the truck drives empty to the Transfer Station from Salt Lake City before picking up the crushed glass to bring back to Salt Lake City.

Greenhouse Gas Emissions for Proposed Industrial Sorting Solution

- **Estimated Energy Consumption for New Recycling Center Facility**
    - "Electricity use ranged from 4.7 to 7.8kWh per Mg [metric ton] of waste input. In a single-stream MRF, equipment required for glass separation consumes 28% of total facility electricity consumption, while all other pieces of material recovery equipment consume less than 10% of total electricity."
        - (Analysis of Material Recovery Facilities for Use in Life-Cycle Assessment, 2015)
    - City of Helena 2019 waste volume → Helena Disposal (Landfill): 19,962 tons.
    - City of Helena 2019 recycling volume → Total Diversion (Recycle & Compost) attributed to City of Helena: 5,672 tons.
        - (*Helena Strategic Plan for Wastewater Reduction*. June 2022)
    - 5,672 tons/year * 6.25 kWh/ton (average from above) * 0.28 (glass percentage) = **9926 kWh/year for glass processing.**

- **Montana Electricity Generation Portfolio**

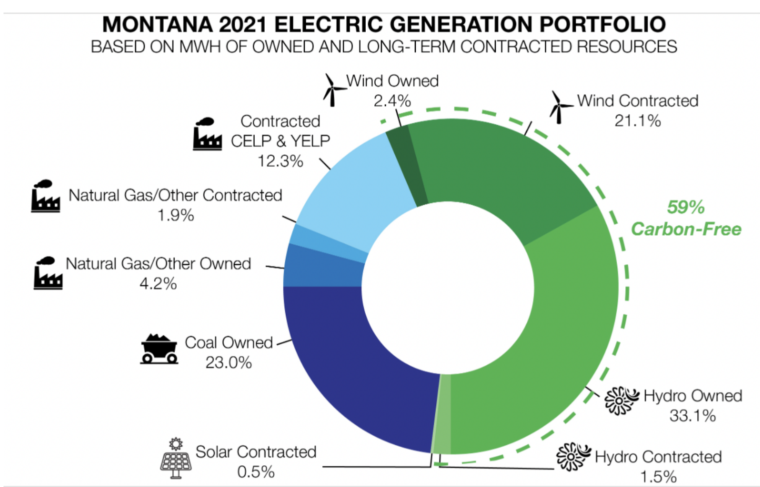

Figure 9. NorthWestern Energy Montana 2021 Electric Generation Portfolio

- 6.2% natural gas, 23% coal, 12.3% Colstrip Energy Limited Partners (CELP), Yellowstone Energy Limited Partners (YELP) -- treated as coal here for total 35.3% coal electricity.
    - (“Where Does Your Energy Come from?”, 2022)
- Coal: 0.353 * 9926 kWh/year = **3504 kwH/year from coal electricity.**
- Gas: 0.062 * 9926 kWh/year = **615 kWh/year from natural gas electricity.**

- **Emissions from Electricity**
    - Coal: 2.26 lb CO2/kWh.
    - Natural Gas: 0.97 lb CO2/kWh.
        - (U.S. Energy Information Administration, 2022)

- **Total CO2 Emissions for Energy at Industrial Recycling Facility**
    - Coal: 3504 kwH/year * 2.26 lb CO2/kWh = **7919.04 lb CO2.**
    - Natural Gas: 615 kWh/year * 0.97 lb CO2/kWh = **596.55 lb CO2.**
    - **Total: 8515.59 lb CO2.**

- **Emissions from Transporting to Ash Grove Cement**
    - Total Mileage of transport required:
        - 10 Miles (Distance from City of Helena Transfer Station to Ashgrove) * 2 (driving to Ashgrove and Back) * 4 (trips per year) = **80 miles of travel required per year.**
    - Assuming 6 miles per gallon for Peterbilt 389X moving truck, 80/6 = **13.33 Gallons of Diesel Fuel required.**
    - Using estimation of 22.44lbs of CO2 emissions per gallon of diesel fuel, 22.44*13.33 = **300 lbs of CO2/year.**
        - (What Is the Carbon Footprint of Diesel Fuel, 2023)

- **Total Emissions for Industrial Sorting Solution**
    - 8515.59 lb CO2/year for Energy at Recycling Facility.
    - 300 lbs of CO2/year for transportation to Ash Grove Cement.
    - **8,816 total lb CO2/year = 4.41 tons.**

“Do Nothing” Environmental Impact of Shipping to Salt Lake

- Total Mileage of transport required:
    - 485 Miles (Distance from City of Helena Transfer Station to Ashgrove) * 2 (driving to Salt Lake and Back) * 4 (trips per year) = **3880 miles of travel required per year.**

- Assuming 6 miles per gallon for Peterbilt 389X moving truck, 3880/6 = **647 Gallons of Diesel Fuel required.**

- Using estimation of 22.44lbs of CO_2 emissions per gallon of diesel fuel, 22.44*647 = **<u>14511.2 lbs of CO_2 per year.</u>**
    - (What Is the Carbon Footprint of Diesel Fuel, 2023)

Economic Justification

A main component when evaluating if a solution is viable or not is the overall cost of implementation and the cost over time of maintenance that the solution would accumulate. Since a successful solution would eliminate a large cost of transport, we constructed economic analyses for each solution and compared those values to the "Do Nothing" cost of the current situation.

Economic Analysis 1: "Maildrop" Spikes Solution

Table 8. Comparison of "Maildrop" Spikes and "Do Nothing" Solutions

Outcome	**Net Present Value of Costs Based on 10-year Horizon, 7% ROI**
"Do Nothing" Solution	$266,896.04
"Maildrop" Spikes Solution	$3,197.74

Materials (Final Solution):

- Metal pegs x8 (x4 1/4 in. x 36 in. Plain Steel Hot Rolled Square Rod)
    - $8.07 each x 4 = $32.28
    - (Metal Peg Product, 2023)
- Sheet metal 9 square feet (for wedge)
    - $89.93 (9 square feet each)
    - (M-D Building Products 3 Ft. X 3 Ft, 2023)
- Sheet metal 29 square feet (for filler)
    - $89.93 x 3 = $269.79 (9 square feet each)
    - (Building Products 3 Ft. X 3 Ft. Diamond Tread, 2023)
- 30" Piano Hinge (To be cut down)
    - $67.00
    - (Steel, 30 in Door Leaf Ht, Continuous Hinge, 2023)
- Magnet fastener
    - $4.99 for pack of 4
      (Cabinet Magnetic Catch Jiayi 4 Pack Ultra Thin Cabinet Door Magnetic, 2023)
- Screwdriver for removing flow regulators
    - $6.59
    - (Craftsman 1/4 in. X 4 in. L Slotted Screwdriver, 2023)

Table 9. "Maildrop" Spike Solution Expenses By Line Item

Category	Line Item	Cost
Design	ME/MET Capstone Team	**$0**
Materials	Metal Pegs	$32.28
	Sheet Metal for Wedge	$89.93
	Sheet Metal for Filler	$269.79
	Hinge	$67.00
	Magnetic Fastener	$4.99
	Subtotal	$463.99
	Total for Prototype and 2 Final (Subtotal x 3)	**$1,391.97**
	Screwdriver	**$6.59**
Construction	ME/MET Capstone Team	**$0**
Installation	ME/MET Capstone Team	**$0**
Administration	Bulk Drop-Off Permitting Process (1 hr/month at $15.75/hr)	**$189/year**
Maintenance	Replace after ~10 years	**$927.98**

Cost of Implementing “Maildrop” Spike Solution

NPV Analysis (Based on 10-year horizon, 7% ROI):

(P/A, 7%, 10) = 7.02358
(P/F, 7%, 10) = 0.50835
NPV = 7.02358 * -$189.00 + 0.50835 * -$927.98 - $1,398.54 = **-$3,197.74**

“Do Nothing” Cost of Transporting Glass to Salt Lake

-$38,000 per year to transport crushed glass to Salt Lake City

NPV Analysis (Based on 10-year horizon, 7% ROI):

(P/A, 7%, 10) = 7.02358
NPV = 7.02358 * $38,000 = **-$266,896.04**

Economic Analysis 2: Metal Grate Filter Solution

Table 10. Comparison of Metal Grate Filter and “Do Nothing” Solutions

Outcome	**Net Present Value (NPV) of Costs Based on 10-year Horizon, 7% ROI**
“Do Nothing” Solution	$266,896.04
Metal Grate Filter	$22,164

Dimensions, Materials, and Costs

Dimensions of grate filter:

- Has to be at least 11 Ft tall to let the truck be able to back in.
- The truck is 34 ft long that picks up the glass so the length of the grate will have to most likely be close to as long as the bed of the truck.

Figure 10. Demonstration of Loading Crushed Glass into Transportation Truck

- The angle of the grate will need to be set at a 20 degree angle for maximum efficiency of sifting.
    - Most gravel sifters have a 20 Degree angle.

Material (Final Solution):

- Metal Grate x 4 (48" X 120" - (4 X 10 ft.))
    - $428.63 each x 4 = $1714.52
    - (“0.75’ Hole X #18, 2023)
- Steal Beams x 4 (W 8 x 28 lb (8.06" x .285" x 6.54") (Legs of the structure)
    - $1008 Each x 4 = $4032
    - (Products: Steel Beams, 2023)
- Steal Beams x 7 (8.06" x .285" x 6.54") (Top frames of the structure)
    - $700 each x 7= $4900
    - (Products: Steel Beams, 2023)

Table 11. Metal Grate Filter Expenses By Line Item

Category	**Line Item**	**Cost**
Design	ME/MET Capstone Team	**$0**
Materials	Metal Grate	$1,714.52
	Steel Beams x 4 (8.06" x .285" x 6.54")	$4,032
	Steal Beams x 7 (8.06" x .285" x 6.54")	$4,900

	Subtotal	$10,646.52
	Total for Prototype and Final (Subtotal x 2)	**$21,293.04**
Construction	ME/MET/CE Capstone Team	**$0**
Installation	ME/MET/CE Capstone Team	**$0**
Maintenance	Replace grate after ~10 years	**$1,714.52**

Cost of Implementing Metal Grate Filter

NPV Analysis (Based on 10-year horizon, 7% ROI):

(P/F, 7%, 10) = 0.50835
NPV = 0.50835 * -$1714.52 - $21,293.04 = **-$22,164**

"Do Nothing" Cost of Transporting Glass to Salt Lake

-$38,000 per year to transport crushed glass to Salt Lake City

NPV Analysis (Based on 10-year horizon, 7% ROI):
(P/A, 7%, 10) = 7.02358
NPV = 7.02358 * $38,000 = -**$266,896.04**

Economic Analysis 3: Industrial Sorting Solution

Table 12. Comparison of Industrial Sorting and "Do Nothing" Solutions

Outcome	**Net Present Value of Costs Based on 10-year Horizon, 7% ROI**
"Do Nothing" Solution	$266,896.04
Industrial Sorting Solution (Low Estimate)	$1,363,301.20
Industrial Sorting Solution (High Estimate)	$6,039196.20

The Solutions

Several companies in the recycling industry have been explored for their sorting machinery to be implemented in the glass process after the glass has been crushed. Companies with potentially viable sorting solutions are listed below.

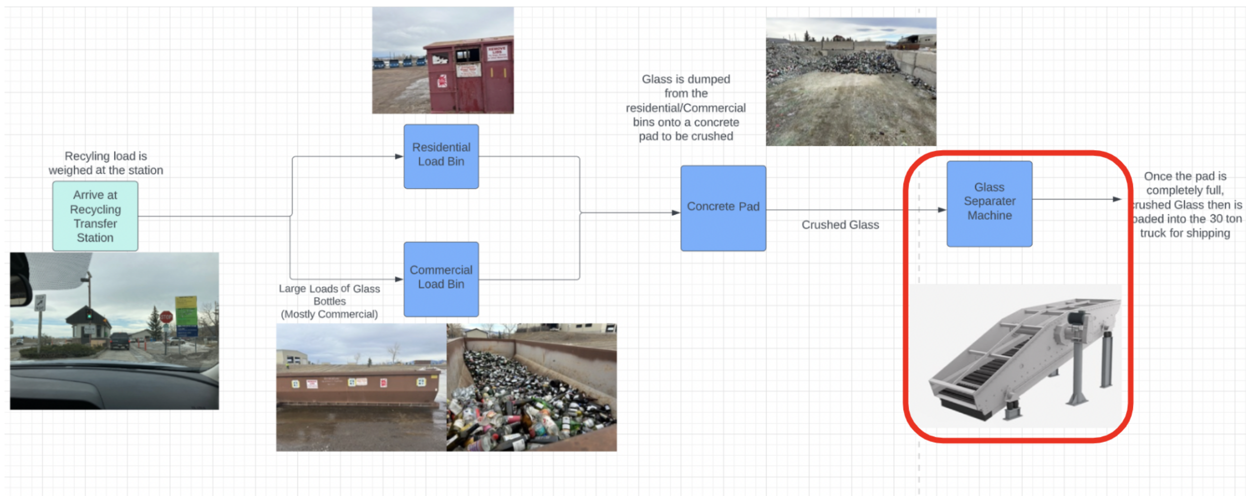

Figure 11. Location of Industrial Sorting Solution Machine in Glass Recycling Process

- Sesotec Glass Sorting:
    - (Recycling Sorting Systems with Chute, 2023)

Figure 12. Sesotec Glass Sorting Machine

- Glass Aggregate Solutions
    - (Glass Aggregate Systems)

Figure 13. Glass Aggregate Solutions Sorting Machine

- Binder+Co
    - (Recycling Screening Machine: Efficient Waste Screening, 2023)

Figure 14. Binder+Co Sorting Machine

Expenses of Implementation:

All three companies above were contacted for quotes, but none got back to us. Accounting for the general severity of weather in Helena, Montana, any intricate sorting machine solution must be implemented as part of a dedicated recycling facility in helena. With that in mind, the rough cost estimate for an industrial sorting solution is drawn from the costs of building a fully equipped recycling center.

(How Much Does It Cost to Build / Open a Recycling Plant in 2023, 2023)

Table 13. Industrial Sorting Solution Low Estimate Costs

Category	Line Item	Cost
Land Requirement	Based on size and demand of land.	**$120,000**
Utilities	Cost of establishing utilities in initial build	**$90,000**
Machines	All recycling machines	**$170,000**
Technician and Labor	Annual cost or technician(s) and labor in the facility	**$140,000/year**

Table 14. Industrial Sorting Solution High Estimate Costs

Category	Line Item	Cost
Land Requirement	Based on size and demand of land.	**$1,000,000**
Utilities	Cost of establishing utilities in initial build	**$300,000**
Machines	All recycling machines	**$2,000,000**
Technician and Labor	Annual cost or technician(s) and labor in the facility	**$390,000/year**

Cost of Implementing Industrial Sorting Solution (Low Estimate)

NPV Analysis (Based on 10-year horizon, 7% ROI):

(P/A, 7%, 10) = 7.02358
NPV = -$120,000 - $90,000 - $170,000 + 7.02358 * -$140,000 = **-$1,363,301.20**

Cost of Implementing Industrial Sorting Solution (High Estimate)

NPV Analysis (Based on 10-year horizon, 7% ROI):

(P/A, 7%, 10) = 7.02358
NPV = -$1,000,000 - $300,000 - $2,000,000 + 7.02358 * -$390,000 = -**$6,039196.20**

“Do Nothing” Cost of Transporting Glass to Salt Lake

-$38,000 per year to transport crushed glass to Salt Lake City

NPV Analysis (Based on 10-year horizon, 7% ROI):

(P/A, 7%, 10) = 7.02358
NPV = 7.02358 * $38,000 = -**$266,896.04**

Final Deliverables & Recommendations

Statement of Work Proposed End-Of-Project Deliverables

At the beginning of this project, we worked with the City of Helena Transfer Station and capstone advisors to develop the following list of deliverables for the project:

1. A powerpoint presentation documenting early-stage potential solutions' outlines.
2. Value-stream (process flow) maps illustrating flow before and after the proposed solution(s).
3. Economic justifications for the proposed solution(s).
4. Projected implications of proposed solution(s).
5. A final report, documenting all previous deliverables, and containing an implementation plan.

Below are the three final detailed solutions for each respective proposed solution. These detailed solutions describe the summary, development process, technical feasibility, and strengths and weaknesses of each potential solution.

Detailed Solution 1: Mail Drop Row of Spikes + Extra Permit to Use Bulk Recycling

Executive Summary

This solution implements a device at the residential recycling area that only allows users to recycle glass if the bottle does not contain a plastic flow regulator. This is accomplished using a row of spikes on which users place bottles, preventing bottles with flow regulators from entering. A tool is provided to remove flow regulators on site. Second, this solution incorporates a simple and expedited training and agreement for any person using the bulk glass recycling area. This will require an explicit agreement from users that they will not submit bottles with plastic flow regulators.

Next Steps

The implementation of the mail drop spike solution would take much more engineering design work and overall testing to validate the solution. To figure out the right material and dimensions for the design, prototyping and testing must be done to successfully implement the solution. Unfortunately this is outside the scope of our project and we do not have the knowledge to pursue this step in an efficient manner. To successfully implement this solution at the facility we recommend the admission of a Mechanical Engineering capstone team to help implement this solution successfully.

Brainstorm and Solution Description

a) Brainstorm:

This solution would implement a row of rotating spikes that users can place their glass recycling bottle on. The users could only place a glass bottle on to the tool if there was no plastic flow regulator present, removing all plastic flow regulators from the process. The spike would accept glass from users and drop it into the glass recycling bin. This solutions would ensure nearly a 100% success rate of removing plastic flow regulators.

b) Our Solution to Explore Further:

This option would incorporate a row of spikes where each bottle would be placed in a manner where there would be no room to place bottles in between the spikes so each bottle would need to have the flow restrictor removed beforehand. The door to the recycling bin would close like a mail drop box, rotating the row of spikes to dump the bottles when the door closes. There will be a device for customers to remove flow restrictors from the bottles so that they can remove them on site. This is our most hopeful all-encompassing solution to eliminating glass flow regulators and seems very promising for successful implementation.

c) Extra Permit:

The solution above will not work if there is any flow restrictor contamination within the commercial recycling bin since the solution is to only be incorporated in the residential recycling bin. To guarantee that there is no contamination within the commercial bin, every business or person that applies to dump glass recyclables in bulk will need to also apply for a permit that is an agreement that there will be no plastic flow restrictors within their dump or else they will not be able to dump at the transfer station in the future.

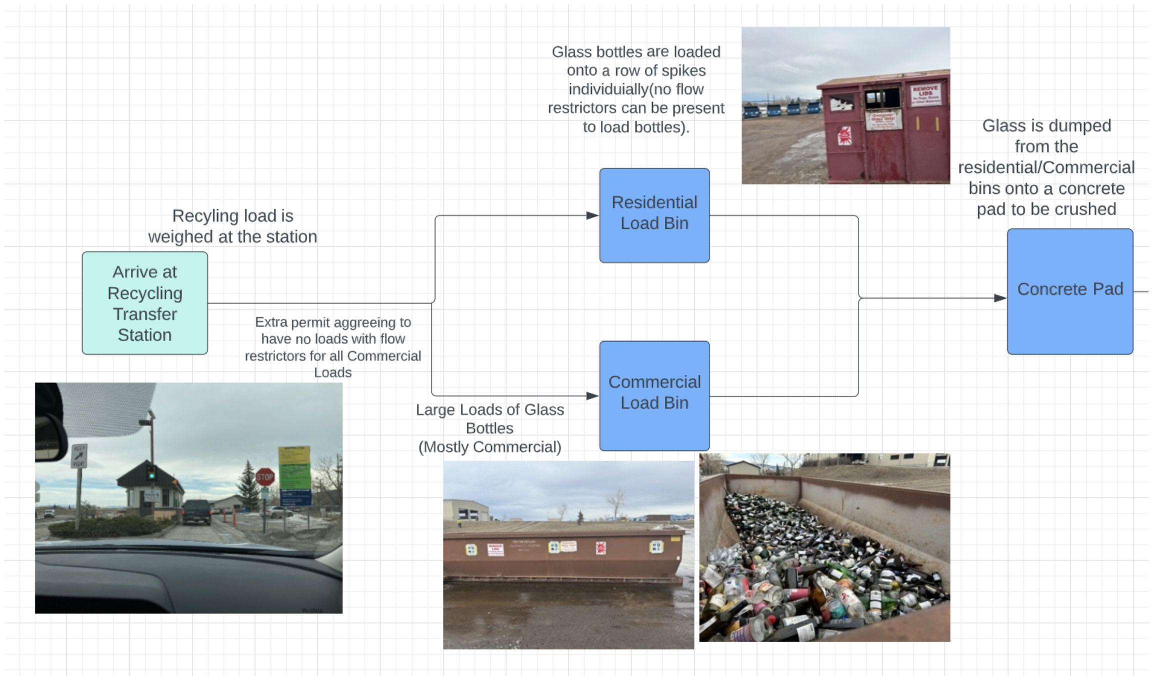

Figure 15. Proposed Process Flow Under "Maildrop" Spike Solution

Technical Feasibility

- Have two rows of four spikes evenly spaced in which the largest and smallest glass bottles will fit and not interfere with each other. The diameter of each opening is 5 inches where the bottle sits with the spikes coming out of each hole.
- This solution would have the spikes rotate out of the opening of the recycling bin by a lever or handle where the person can then place each bottle individually on the spikes. Once full the spike platform would rotate back into the opening via a spring loaded mechanism disposing of the bottles.

Strengths:

- Would be pretty easy to implement and it would not need any large scale infrastructure changes.
- Would completely solve the problem for the residential dump where the majority of the contamination is, narrowing down the source of any additional flow restrictor contamination which would be coming from the commercial dump.

Weaknesses:

- Might still have a little contamination within the commercial dump even with the permit.
- Helena Transfer Station would need to hire another mechanical capstone team or a mechanical engineering firm to design the product.
- The citizens of Helena may not like the design that much since it requires them to individually place each bottle.

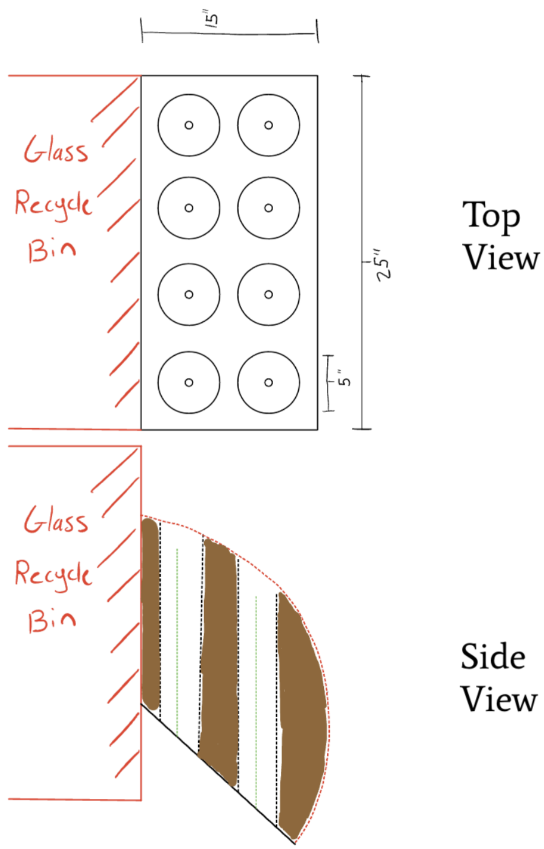

Figure 16. Sketch of "Maildrop" Spike Solution

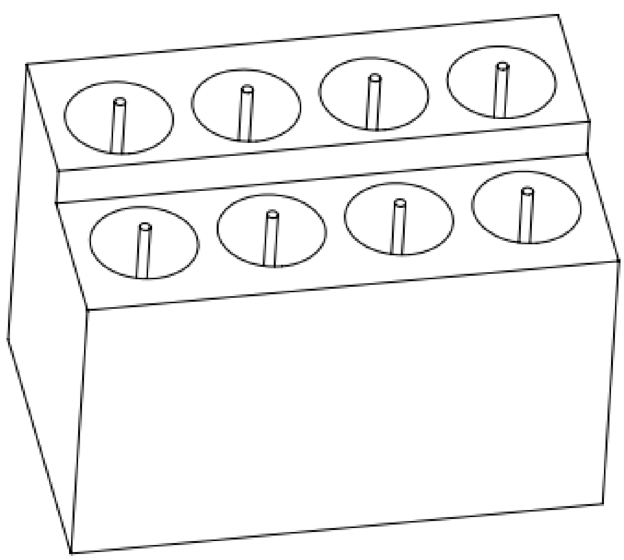

Figure 17. Solidworks Drawing of "Maildrop" Spike Solution (All views in Appendix B)

Detailed Solution 2: Metal Grate Filter

Executive Summary

The metal grate filter solution centers around the creation of a canopy with a grate filter ceiling. A moving truck drives under the canopy, after which, the crushed glass is poured on top of the filter. The finely crushed glass passes through the filter, while the plastic flow regulators do not. This leaves plastic free glass inside the moving truck ready for transport.

Next Steps

The implementation of the metal grate filter solution would require additional infrastructure and much more engineering work. To garner the right material, structural calculations, and specific dimensions prototyping and additional testing must be done to validate the solution and its success. Unfortunately this is outside of the scope of our project and we do not have the knowledge to pursue this step. Ultimetally we recommend the admission of a Civil Engineering capstone team to tackle the implementation of this solution idea.

Brainstorm and Solution Description

a) Brainstorm:

Have some sort of metal grate that filtered the crushed glass through and stopped any flow restrictors from going through. The grate would need to sit on top of the current concrete pad with enough clearance to gather all of the glass. The grate would also need to be strong enough to support the crusher vehicle which weighs a lot. This solution would ensure that no flow restrictors are within the crushed glass.

b) Our Solution to Explore Further:

Mimic method for gravel separation at gravel pit. Filter grate stands at fixed angle, crushed glass is poured over, with finely crushed glass passing through, while bigger chunks and plastic flow regulators slide to the bottom for an additional round of crushing then sifting. Final sorted plastic will be landfilled. This is a stretch solution to eliminating glass flow regulators and still has quite a few unknowns and questions that may prove it infeasible as we dig deeper.

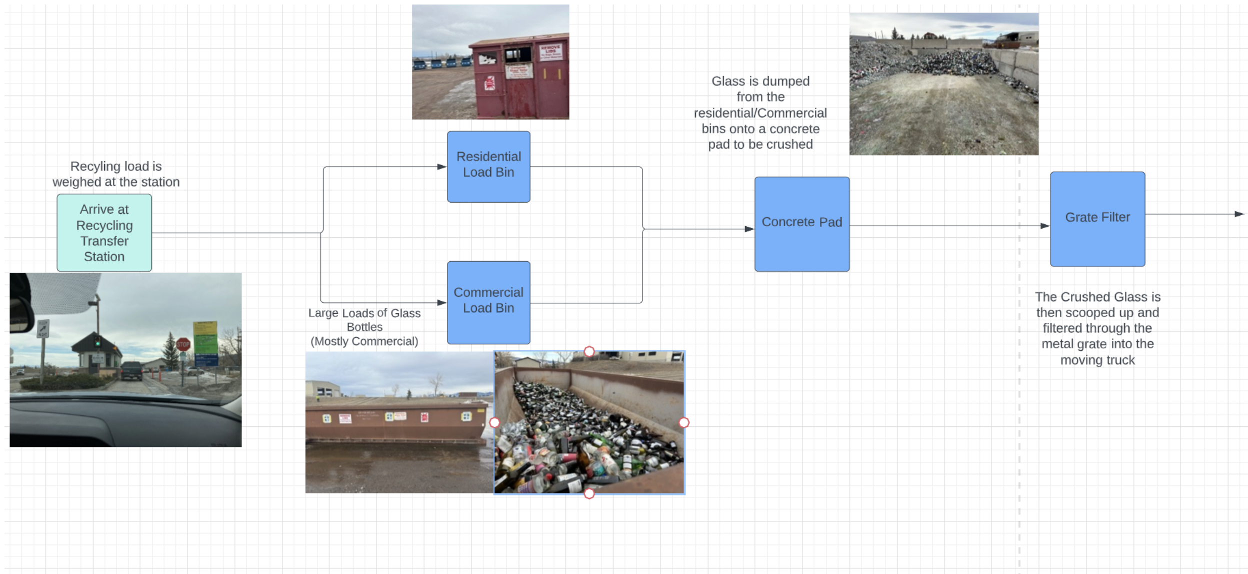

Figure 18. Proposed Process Flow Under Metal Grate Filter Solution

Technical Feasibility

- We would need to implement the grate at an angle to help prevent build up and encourage a more efficient sifting process.
- We would need the contraption high enough off of the ground so that the truck can fit underneath and still have it be reachable for the loader to dump the glass over it.
- The truck will need to have enough space in general to back into and out of the concrete pad area.

Strengths:

- If successful this solution would take care of glass from both residential and commercial flows.
- It is an efficient solution, requiring little, if any, additional steps for processing glass once implemented.
- It would likely eliminate all plastic flow regulators from the final glass pile, yielding a perfect batch.

Weaknesses:

- This solution would sacrifice some glass as not all of the glass would make it through the holes since we are assuming that the glass pieces most likely will deviate in size quite a bit.
- We don't know exactly what the flow regulators look like after the glass is initially crushed so more work must be done to understand the particle size of both crushed glass and plastic flow regulators to design an effective filter.

- This solution would take a bit of infrastructure in building the contraption on top of the concrete pad.
- Gravity alone may not be enough to bring the glass through the filter. Some vibration components may need to be integrated into the design to make the filter effective.
- Helena Transfer Station would need to hire another mechanical capstone team or a mechanical engineering firm to design the product.

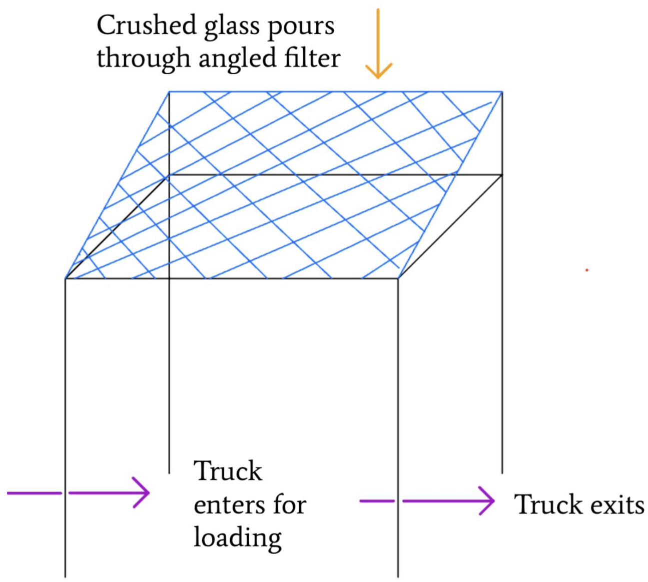

Figure 19. Sketch of Metal Grate Filter Solution

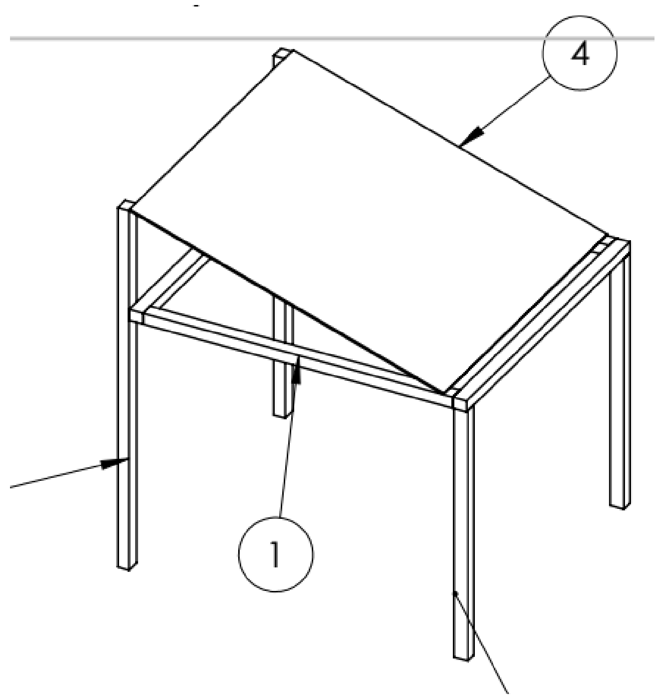

Figure 20. Solidworks Drawing of Metal Grate Filter Solution (All views in Appendix B)

Detailed Solution 3: Machinex/Industrial Sorting Machine Solution

Executive Summary

This solution adds a processing step after the glass has been crushed to mechanically sort plastic flow regulators from the glass stream. Industry leaders in glass recycling sorting such as Machinex, Glass Aggregate Systems, and Binder+Co provide unique solutions, utilizing size screening, optical color sorting, density sorting with pressurized air, or other methods to sort crushed glass in a beneficiation process. This is a stretch solution in that it would be challenging to implement outdoors, and would therefore be more suitable if the City of Helena ever builds a dedicated, indoor recycling station in the future. This is also the most costly solution.

Next Steps

This solution would require a full scale facility for the City of Helena Transfer Station. We do not recommend this as an immediate solution, but it could be considered down the road.

Brainstorm and Solution Description

a) Brainstorm

This is a commercial solution to glass recycling sorting. Machinex is a company that builds industrial glass sorting machinery that can create a recycling stream of up to 99.9% purity. Upon cursory exploration, the efficacy of this machinery to remove plastic flow regulators is unclear as the primary sorting mentioned is metals and papers. However, pursuing this option further may reveal that this company would be a valuable partner to design and build an effective glass recycling solution at the Transfer Station. Currently implemented at a number of locations, particularly Eco Enterprises Quebec Innovative Glass Works. "Developed by Machinex and industry partners, the MX Glass Solutions remove the contaminants in glass, such as paper, metals and organics to ensure you produce marketable glass products." Further exploration of this solution would prove beneficial.

b) Our Solution to Explore Further:

This option would be explored superficially as a potential solution down the road if the City of Helena builds a dedicated, indoor recycling center. We will seek out a rough quote from the company and ascertain whether their technology is able to sort out plastic. No further exploration will be conducted. This is the biggest reach out of the three solutions we are exploring further.

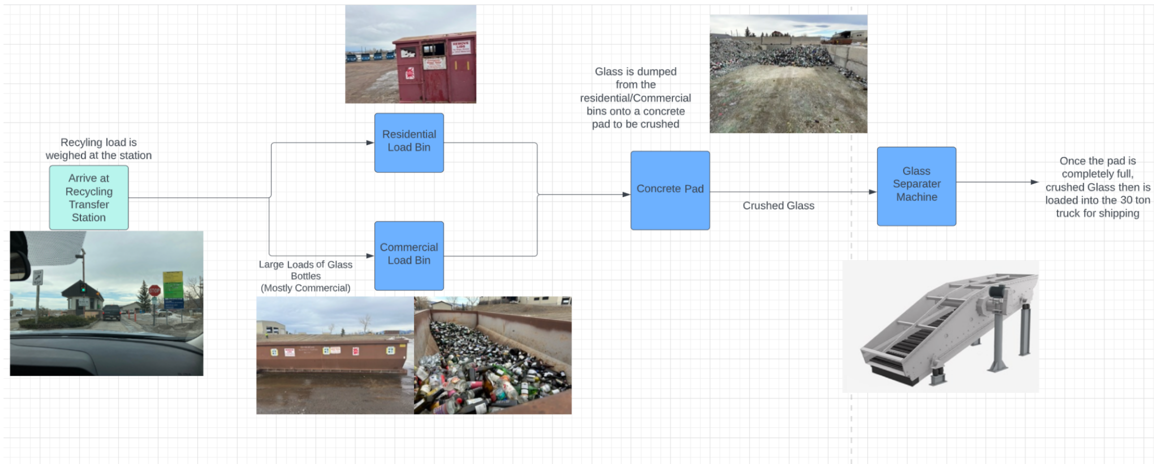

Figure 21. Proposed Process Flow Under Industrial Sorting Solution

Technical Feasibility

- Machinex provides glass recycling solutions to sort glass from single-stream recycling collection at a macro level.
- More granular sorting takes place in a process called beneficiation, where contaminants are separated from the crushed glass recycling stream via optical color sorting, size screening, density sorting using pressurized air, or other methods.
- Machinex does not do beneficiation, other industrial sorting companies would need to be pursued.
    - Glass Aggregate Systems (Glass Aggregate Systems)
    - Binder+Co (Recycling Screening Machine: Efficient Waste Screening, 2023)
- Have reached out to Glass Aggregate Systems as well as Binder+Co for quotes, but have not heard back.
- This may be worth looking into further if the City of Helena ever builds a dedicated, indoor recycling facility down the road.

Strengths:
- Industry-proven solutions from experienced companies.
- Work with the company as a valued partner to deliver a high-quality solution to guarantee plastic is separated fully.

Weaknesses:
- Costly solution.
- Must add an additional processing step once the glass has been crushed.
- Sorting mechanism must be able to withstand Helena weather.
    - A more viable solution for an indoor facility, perhaps down the road.
- Many unknowns.

Figure 22. Sesotec Glass Sorting Machine

Figure 23. Glass Aggregate Solutions Sorting Machine

Figure 24. Binder+Co Sorting Machine

Project Performance

Project Management Plan

Meeting Schedule

Throughout the project, we developed and executed consistent meetings with necessary stakeholders to ensure proactive communication.

- **Advisor Meetings**
  - Every other Tuesday 3-4pm
- **Group Meetings**
  - Monday, Wednesday, Friday 8am - 9am
  - Additional meetings coordinated as needed
- **Client Meetings**
  - Weekly email updates
  - Virtual check-ins as needed

Group Leader Schedule (Alphabetical by last name, rotating)

Group leaders coordinated communications with client, faculty advisor, and between students, and ensured that all submissions were made by set deadlines. The leader also spearheaded the division of tasks in each sprint. Regardless of who was the leader, the volume of work was evenly distributed among all team members each sprint.

- Sprint 1: Norris
- Sprint 2: Nick
- Sprint 3: Sven
- Sprint 4: Norris
- Sprint 5: Nick
- Sprint 6: Sven
- Sprint 7: Norris

Team Norms

At the beginning of the project, we developed a set of team norms to create a shared understanding of the expectations within the team. This team norms document was revisited at the beginning of each sprint to ensure that it was still reflective of the norms that the team desired to exhibit. The following document is the original team norms document that remained intact over the duration of the project.

- We will always use time efficiently and effectively -- three people’s worth of work.

- We will complete quality work.
- Whenever possible, we will work Monday through Thursday, not working on the weekends whenever possible.
- We will cycle through “project managers” alphabetically in each spirit. However, we will all take initiative throughout the project, and the “project manager will not have more work than the other team members.
- We will complete as much work as possible during the class period.
- Team meetings will generally be in person.
- We will communicate at the start of each week who is working on what each week.
- We will communicate class absences at least one class period in advance.
- We will submit all class deliverables by set deadlines.
- We will always attack problems, not people.
- No hidden agendas.
- We will show up prepared for meetings.
- We will communicate via our text group chat for timely updates as needed.
- We will use a shared google drive folder for all documents in this project.

Major Project Milestones:

Our major project milestones acted as checkpoints to ensure that we remained on track to deliver quality results for our client. Each major deliverable was crafted around the sprint schedule, usually with deliverables at the end of respective sprints.

1. Final Statement of Work completed (Sprint 1 Deliverable) **Friday, February 3rd**
2. Site visit in Helena -- already confirmed (Start of Sprint 2) **Tuesday, February 7th**
3. First round of solution ideation completed (Sprint 2 Deliverable) **Friday, February 17th**
4. Presentation to Helena Recycling (Halfway through Sprint 3) **Friday, February 24th**
5. Solutions to pursue further selected (Sprint 3 Deliverable) **Friday, March 3rd**
6. Selected solutions fully detailed & explored (Sprint 4 Deliverable) **Friday, March 24th**
7. Economic analyses for proposed solutions (Sprint 5 Deliverable) **Friday, April 7th**

8. Environmental impact assessments completed (Sprint 6 Deliverable) **Friday, April 21st**

9. Final report and presentation delivered to Helena Recycling (Sprint 7) **Friday, April 28th**

10. Design Fair Poster Sessions **Thursday, May 4th**

The Baseline Project Plan:

1. Work Breakdown Structure

The work breakdown structure provided an overview of the work required for the entire project. The work was divided into the sprint that it took place in. We were successful in completing work as scheduled.

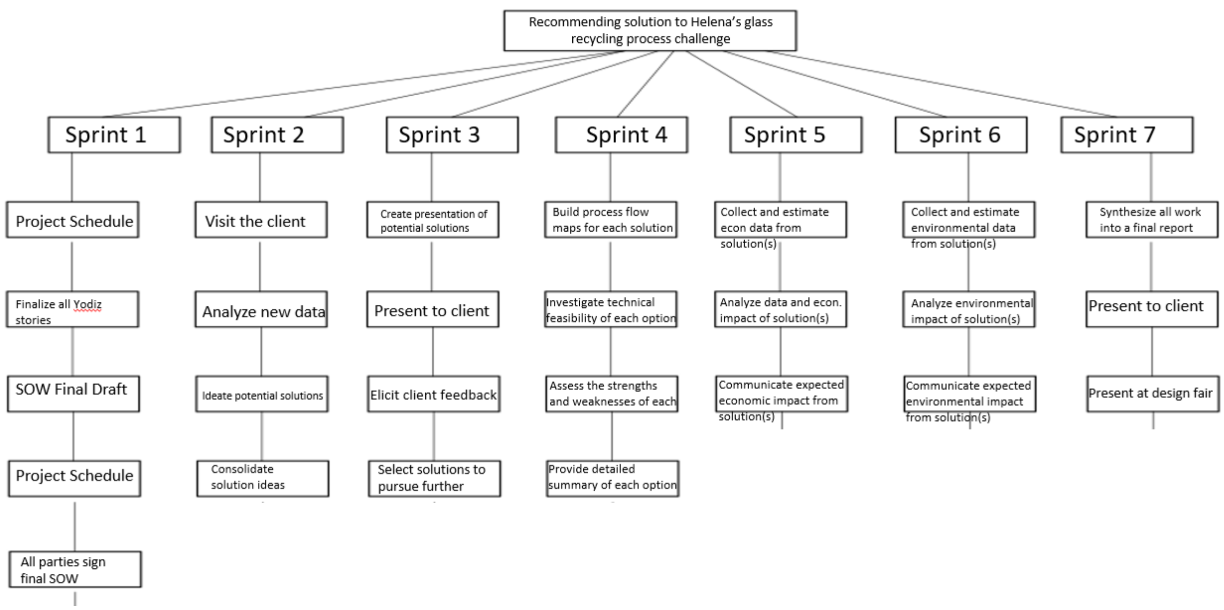

Figure 25. Project Work Breakdown Structure

2. Project Schedule in Smartsheets:

We utilized Smartsheets to plan the work breakdown at the beginning of each sprint. This tool was helpful to break down work into a hierarchy, assign individuals responsible for work, and set dates for starting and completing work. The Smartsheet was updated at the beginning and end of each sprint, and kept track of tasks throughout the sprint. This Smartsheet was calibrated to the schedule of sprints from the course schedule as well as our determined milestones, which kept the project team on track against the overall schedule. The Smartsheet project management plan for this entire project can be viewed in Appendix G.

3. Project Management System Using Yodiz.com:

Yodiz project management software was used in tandem with Smartsheets to plan and keep track of progress throughout this project. This was reviewed and updated at the start and end of each sprint and was updated throughout the sprints. The finalized Yodiz project management plan for this project can be viewed in Appendix H.

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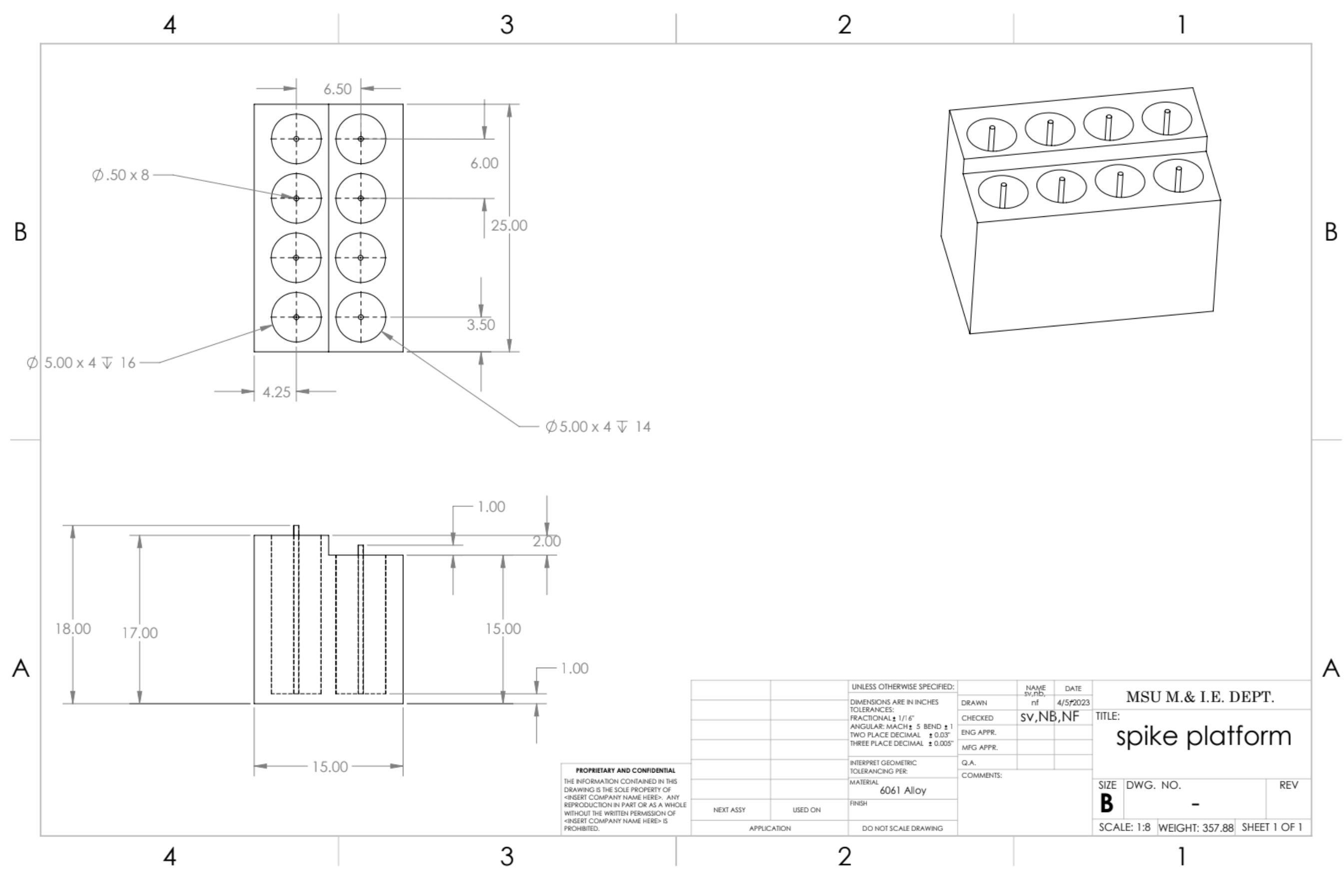
Appendices

Appendix A: Courses Drawn on for this Project

Courses	Tools/Concepts
EMEC 103	Solidworks/part dimensioning
ECHM 205 CS (Sustainability Cognate)	Environmental impact assessment greenhouse gas calculations.
EIND 300	Ethical considerations weighing the implications on overall waste diversion vs. monetary savings for client.
EGEN 310R	Engineering group project teamwork and task allocation. How to ideate and refine engineering solutions
EGEN 325	Net Present Value analysis
EIND 354	Statistical analysis of population samples to make informed estimates on overall contamination rate in the population.
EIND 410	Interaction design to isolate and address the human factors in recycling contamination
EIND 413	Consideration of ergonomics in user's interaction with recycling process, particularly "Maildrop" spike solution.
EIND 434	Use of Gantt Charts and task allocation among team members
EIND 442	Process mapping within the context of facility layout
EIND 477	Process mapping/Root cause analysis cause and effect diagrams
Online Research	Industry-proven glass recycling solution alternatives

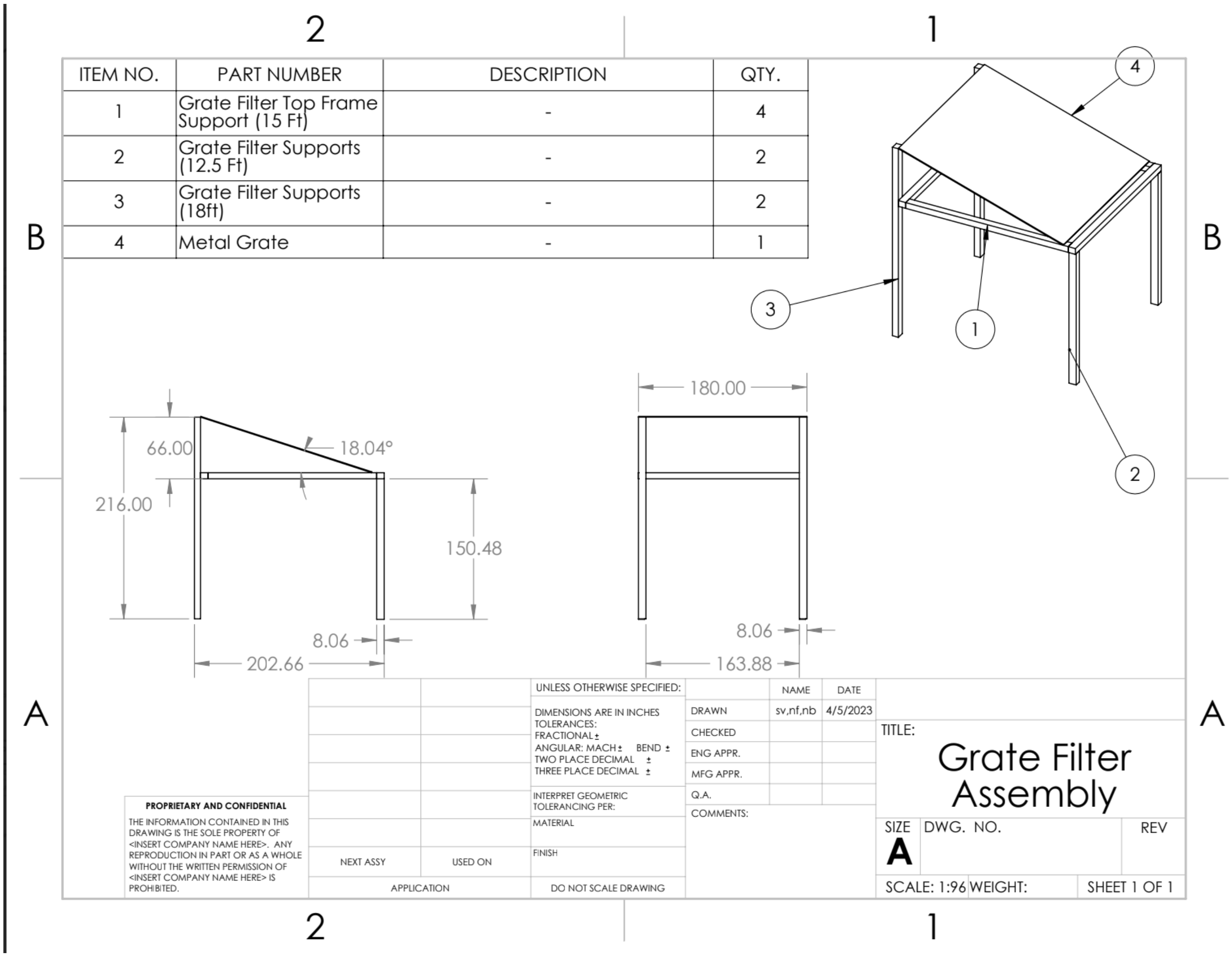
Appendix B: Solid Works Drawings

"Maildrop" Spike Solution



Metal Grate Filter Solution

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Grate Filter Top Frame Support (15 Ft)	-	4
2	Grate Filter Supports (12.5 Ft)	-	2
3	Grate Filter Supports (18ft)	-	2
4	Metal Grate	-	1



Appendix C: Data Collection

Statistical Analysis on Population Sample: Percent of Glass with Flow Regulators

Day	Total Bottles	Number with Flow Regulators		14%-34% of glass has flow restrictors at a 95% Confidence Level
1	20	4		
2	20	6		
3	20	4		
4	20	6		
5	20	4		
Total:	**100**	**24**		
			Norris:	We are also curious to know the frequency of plastic regulators in recycling (i.e. what percentage of glass bottles contain regulators). Unless you already collect this data, we would love to conduct a statistical sample test to get a rough idea of the frequency of plastic regulators. To conduct this test, we would like to randomly sample roughly 100 bottles, tracking how many contain flow regulators. Given that it may be difficult to get a truly random sample from pulling 100 bottles in one moment (since it would potentially be extracted from one or two batches), we would like to sample 20 bottles a day for 5 days. Would it be possible for someone on your team to randomly select 20 bottles for 5 days, recording the number that contain regulators?
			Miranda	Here is that information you were needing for the random sample. From my perspective alone, I think a majority of the glass coming in looked to be wine bottles, beer bottles and kombucha bottles. Aside from flow regulators, a large portion of contamination is the plastic rings around the bottles, lids, and plastic wrapping around the neck of wine bottles.

Total Annual Tonage and Expenditures Transporting Glass to Salt Lake City

Glass (Tons)				**Expenditures**
JULY	26.2			$13,291.83
AUG	19.4			$7,341.87
SEPT	22.0			
OCT	21.1		**Total**	**$10,316.85**
NOV	18.0			
DEC	18.2			
JAN	23.0			
FEB	12.7			
MAR	17.3			
APR	21.1			
MAY	22.2			
JUNE	16.9			
Total	**238.0**			

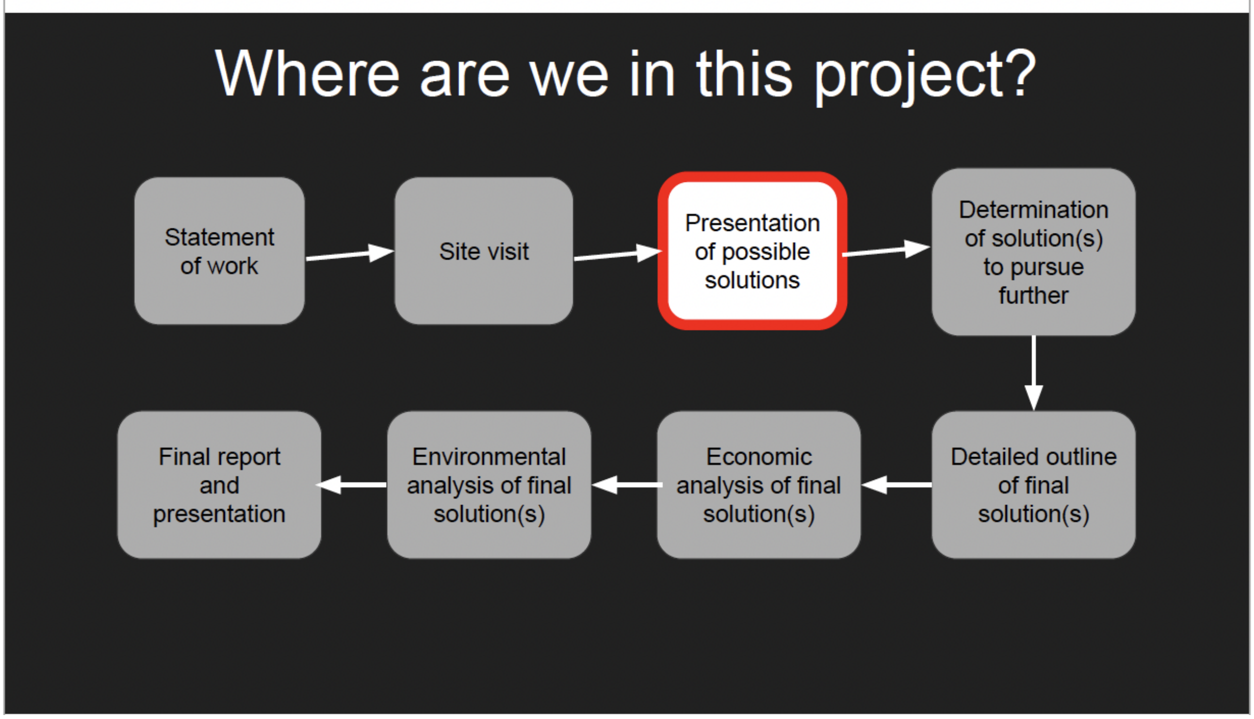
Fiscal Year 2022 Glass Recycling Expenditures

```
GM200I13                    City of Helena                         1/23/23
Fiscal Year 2022         Account Balance Inquiry                  12:01:12
  Account number . . . . : 547-3151-438.30-94
  Fund . . . . . . . . . : 547  Recycling
  Division . . . . . . . :  31  Public Works
  Department . . . . . . :  51  Recycling
  Activity basic . . . . :  43  Public Works
  Sub activity . . . . . :   8  Solid Waste Utilities
  Element  . . . . . . . :  30  Purchased Services
  Object . . . . . . . . :  94  Glass Recycle

  Original budget  . . . . . . . . . :           5,950
  Revised budget . . . . . . . . . . :          12,800   06/30/2022
  Actual expenditures - current  . . :             .00
  Actual expenditures - ytd  . . . . :       13,291.83
  Unposted expenditures  . . . . . . :             .00
  Encumbered amount  . . . . . . . . :             .00
  Unposted encumbrances  . . . . . . :             .00
  Pre-encumbrance amount . . . . . . :             .00
  Total expenditures & encumbrances:         13,291.83    103.8  %
  Unencumbered balance . . . . . . . :          491.83-     3.8- %
F5=Encumbrances    F7=Project data         F8=Misc inquiry
F10=Detail trans   F11=Acct activity list  F12=Cancel         F24=More keys
```

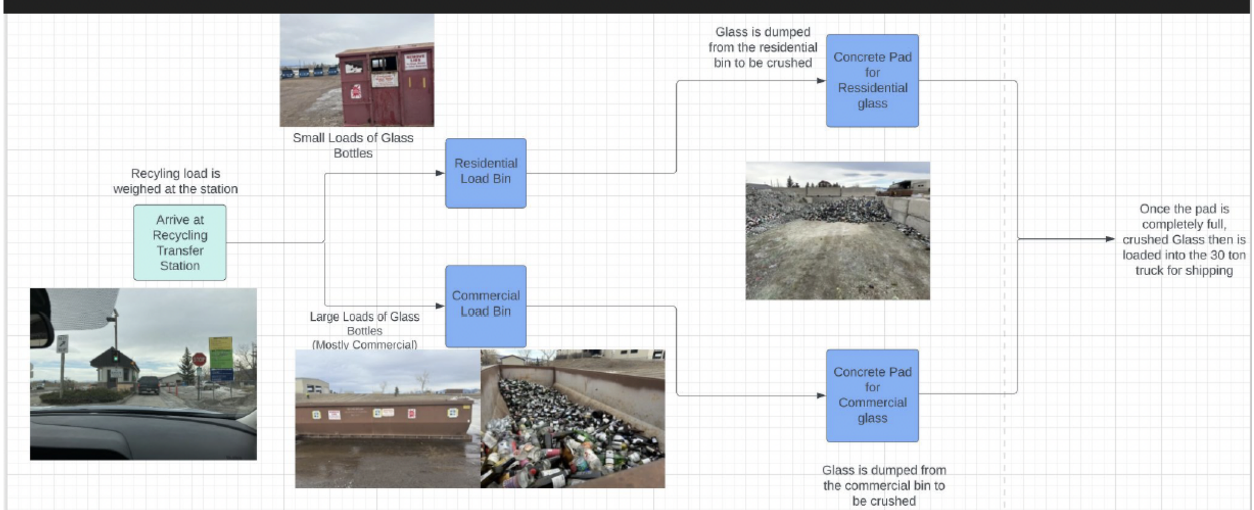
13,291.83
- 5949.96 pull charges (Haul)
7,341.87
-7341.87 glass-Actual to Momentum
0

Appendix D: Ideation Presentation



Chopping of the neck of the bottles

Separate Flows of Bulk and Residential Recycling



Continued: Separate Flows of Bulk and Residential Recycling

- Create a separate crushing station for bulk recycling, enabling each recycling flow to have completely separate facility
- Expand the storage capability of both residential and bulk recycling, enabling the glass crushing area to be alternated between each flow type, without any cross contamination.

Bulk

Residential

Separate Beer & Wine Within Residential Drop

- Separate beer and wine bottles from other glass in residential drop
- Focus on flow regulators in “other” stream

Beer & Wine

Liquor, etc

Melt Plastic out of Glass Bottles

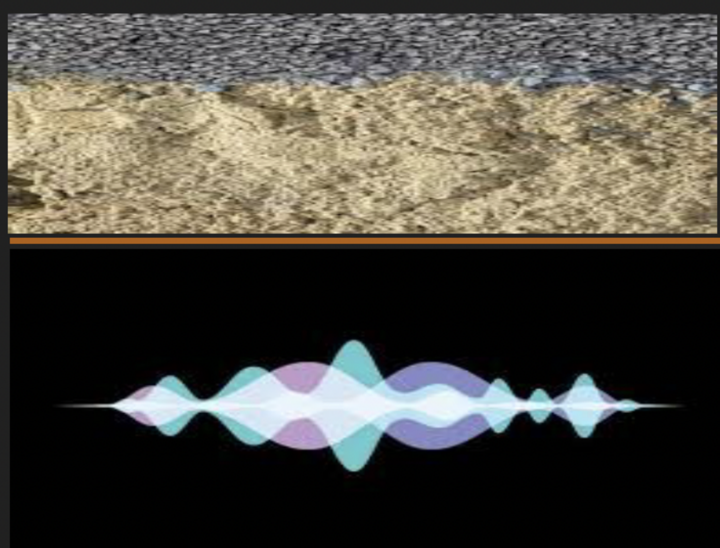
Considerations:

- Impact on glass properties
- How to handle melted plastic
- Cost / method of melting
- Space requirements

Implement device that only accepts bottles without flow regulators

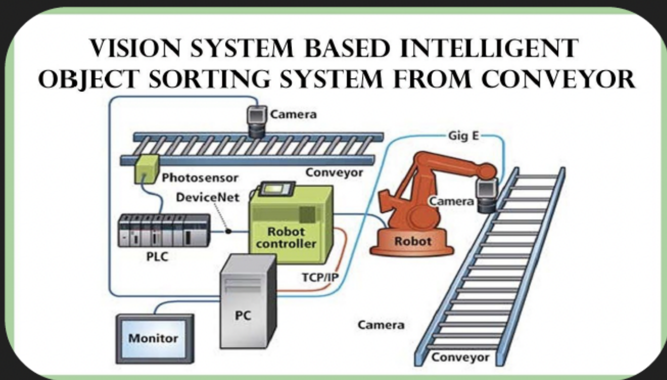
Use a Grate Filter after glass crushing to remove all plastic pieces

Vibration Sorting of Plastic in Crushed Glass



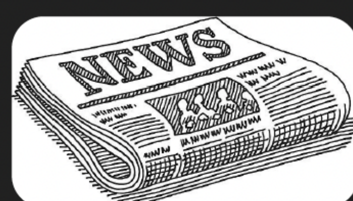
Machine Vision Solution

- Before or after crushing
- Select and sort bottles/plastic for removal



Signage and Education

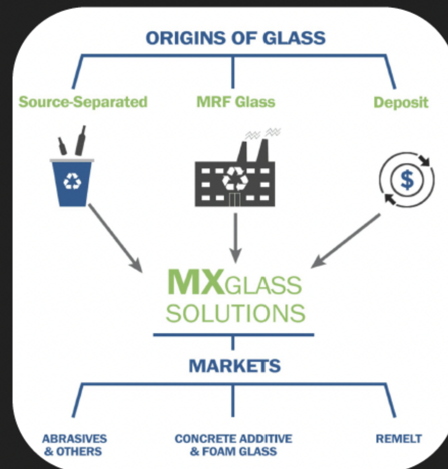
- Encourage home removal, tools on-site
- Resources and “loud” signage



Commissioned Machinex Sorting Machine

- Commissioned glass sorting solutions for up to 99.9% glass purity
- Likely spendy
- Can it remove plastic?

MACHINEX
Experience Results



Rapid Inspection Process

OR

Opportunities for General Layout Considerations Throughout

- Any of these proposed solutions might incorporate a consideration of layout redesign at the Transfer Station site

Thank You!

We appreciate your feedback.

Appendix E: Project Interim Presentation

City of Helena Transfer Station: Glass Recycling Process Improvement

•••

Nicholas Fitzmaurice, Norris Blossom, and Sven Tate

March 27th, 2023

Overview

- **Problem**

Plastic flow regulators prevent local cement processing

  - Causing $38k/year in transport costs to Salt Lake

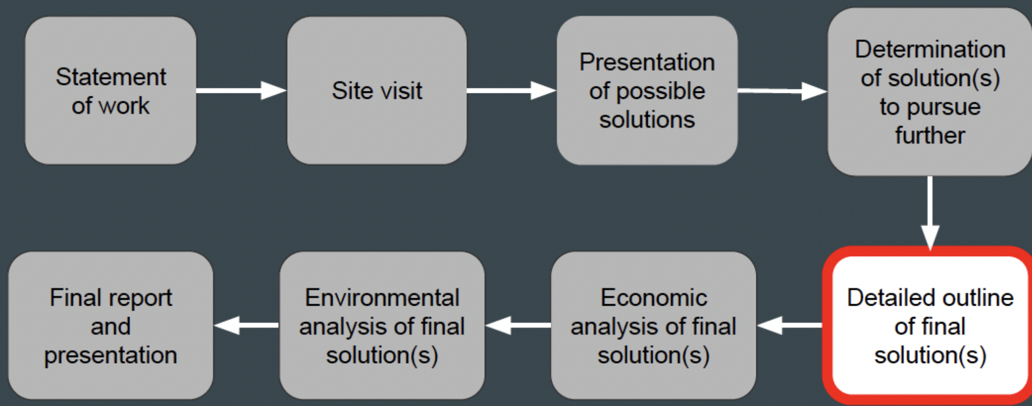
- **Desired Solution**

Develop a systematic way to remove flow restrictors

- **Outcomes**

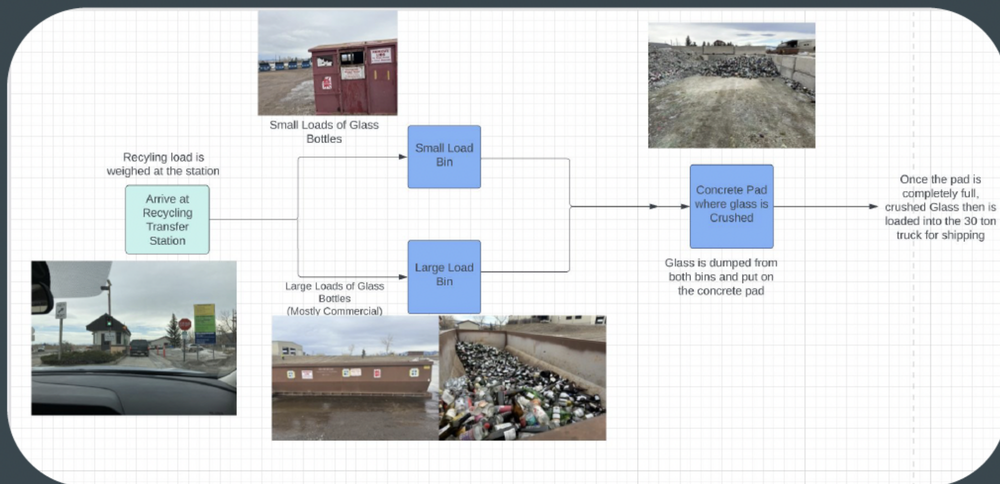
Save money, reduce carbon emissions

Current Project Status

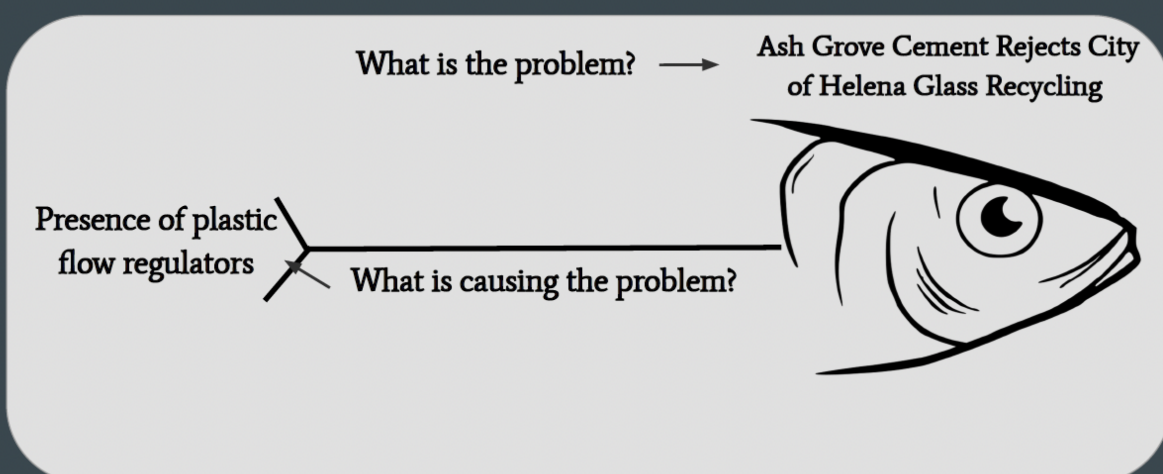


Transfer Station Facility Layout

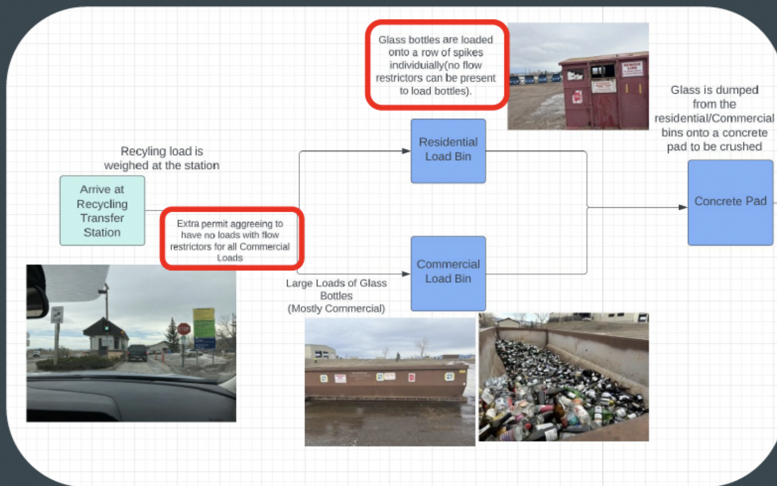
Current Process Flow Map



Root Cause Analysis

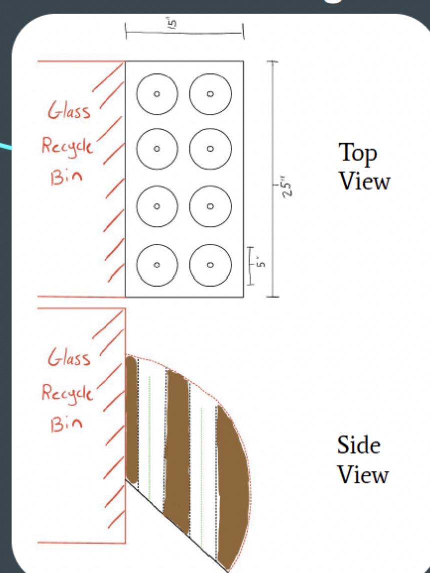


Solution 1: "Mail Drop" Spikes & Additional Bulk Permitting



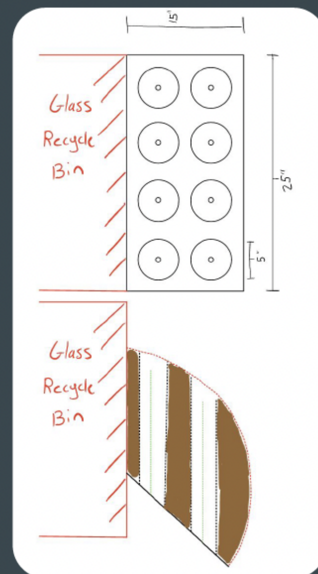
Proposed Process Map

Solution 1: "Mail Drop" Spikes & Additional Bulk Permitting

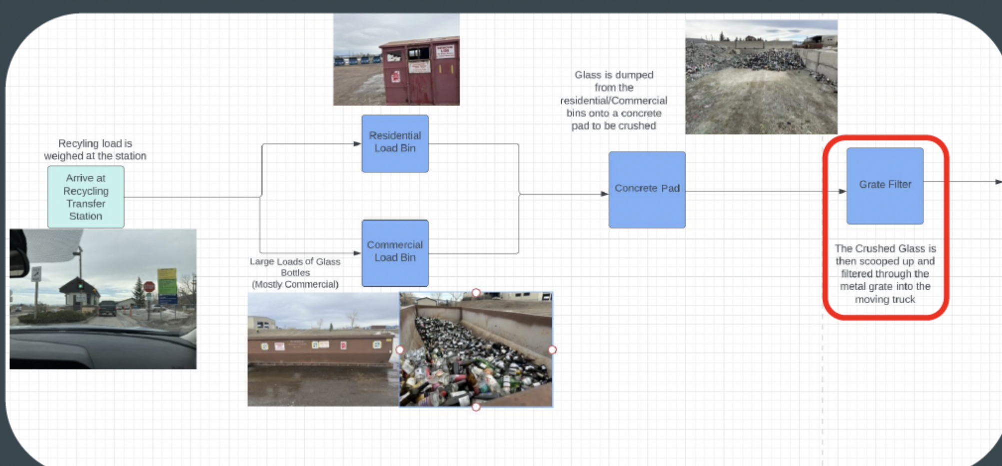


Solution 1: "Mail Drop" Spikes & Additional Bulk Permitting

- Force recycling customers to remove plastic flow regulators before dumping
  - Tool on-hand to remove and discard regulators
- Increase screening for bulk drop-off to eliminate contamination in that stream
- Glass stream will be free of plastic flow regulator contamination before crushing

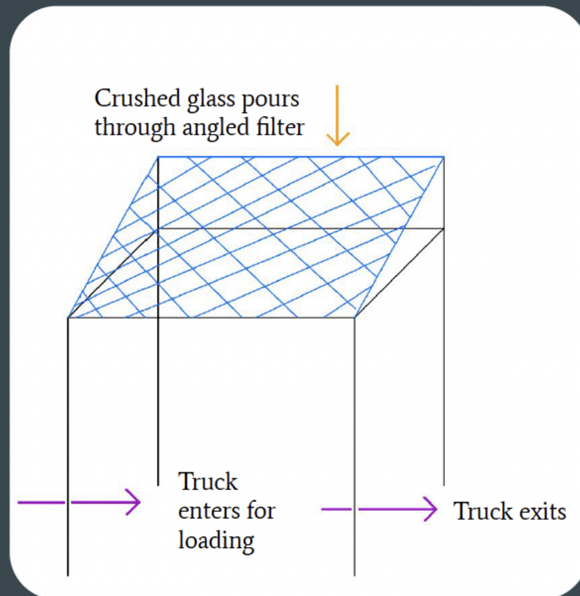


Solution 2: Metal Grate Filter



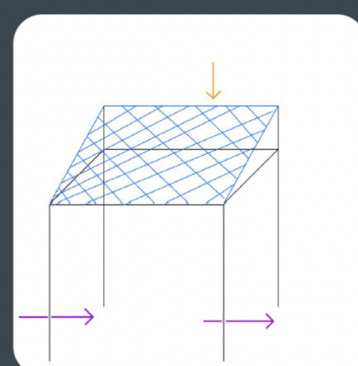
Proposed Process Map

Solution 2: Metal Grate Filter

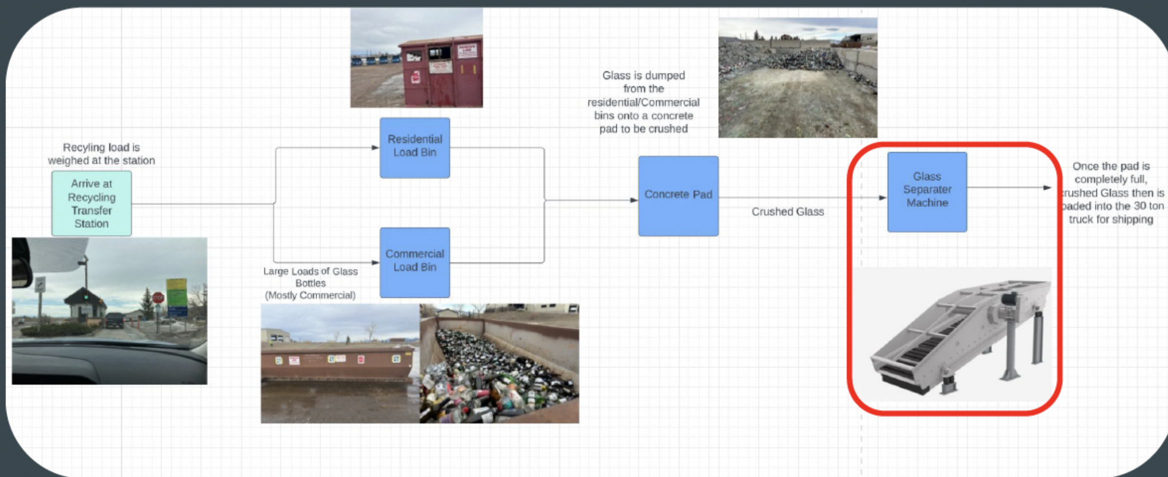


Solution 2: Metal Grate Filter

- Creation of a canopy with a grate filter ceiling.
- A moving truck drives under the canopy, after which, the crushed glass is poured on top of the filter.
- The finely crushed glass passes through the filter, while the plastic flow regulators do not.
    - Leaves glass without contamination inside the truck



Solution 3: Machinex — Industrial Sorting Solution



Proposed Process Map

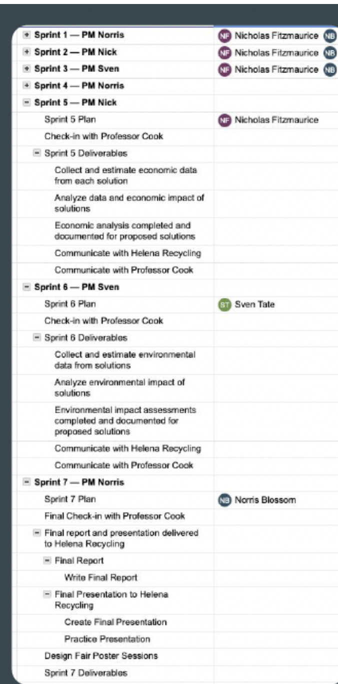
Solution 3: Machinex -Industrial Sorting Solution

- Machinex sorts single-stream recycling collection
- Beneficiation for granular sorting
  - Contaminants sorted via optical color sorting, size screening, density sorting with pressurized air, etc
  - Beyond the scope of Machinex solutions
- Glass Aggregate Solutions
- Binder+Co
- Possible down-the-road solution

Plan Going Forward

Remaining SOW Deliverables:

- Economic Analyses (Sprint 5)
  - Friday, April 7th
- Environmental Impact Assessments (Sprint 6)
  - Friday, April 21st
- Final Report and Presentation to City of Helena (Sprint 7)
  - Friday, April 28th
- Design Fair Poster Sessions
  - Thursday, May 4th
- Continue utilizing Yodiz in conjunction with Smartsheets



Sprint 1 — PM Norris	NF Nicholas Fitzmaurice NB
Sprint 2 — PM Nick	NF Nicholas Fitzmaurice NB
Sprint 3 — PM Sven	NF Nicholas Fitzmaurice NB
Sprint 4 — PM Norris	
Sprint 5 — PM Nick	
Sprint 5 Plan	NF Nicholas Fitzmaurice
Check-in with Professor Cook	
Sprint 5 Deliverables	
Collect and estimate economic data from each solution	
Analyze data and economic impact of solutions	
Economic analysis completed and documented for proposed solutions	
Communicate with Helena Recycling	
Communicate with Professor Cook	
Sprint 6 — PM Sven	
Sprint 6 Plan	ST Sven Tate
Check-in with Professor Cook	
Sprint 6 Deliverables	
Collect and estimate environmental data from solutions	
Analyze environmental impact of solutions	
Environmental impact assessments completed and documented for proposed solutions	
Communicate with Helena Recycling	
Communicate with Professor Cook	
Sprint 7 — PM Norris	
Sprint 7 Plan	NB Norris Blossom
Final Check-in with Professor Cook	
Final report and presentation delivered to Helena Recycling	
Final Report	
Write Final Report	
Final Presentation to Helena Recycling	
Create Final Presentation	
Practice Presentation	
Design Fair Poster Sessions	
Sprint 7 Deliverables	

Risk Assessment and Contingency Planning

Potential Risk	Mitigation Strategy
Project Hand-Off	Clear Implementation Plan
Technical Design Feasibility	Hire MSU ME Capstone Team
Cost of Implementation	Tiered Solutions Available
Unforeseen Implementation Challenges	Detailed Analysis of Proposed Solutions
Persistent Contamination	Close Collaboration With Client

Thank You!

Questions?

Appendix F: Final Project Presentation to City of Helena

City of Helena Transfer Station: Glass Recycling Process Improvement

Nicholas Fitzmaurice, Norris Blossom, and Sven Tate

April 26th, 2023

Overview

- **Problem**

Plastic flow regulators prevent local cement processing

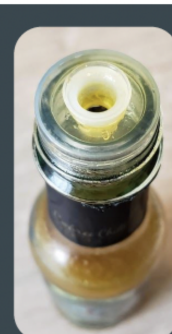
  - Causing $38k/year in transport costs to Salt Lake

- **Desired Solution**

Develop a systematic way to remove flow restrictors

- **Outcomes**

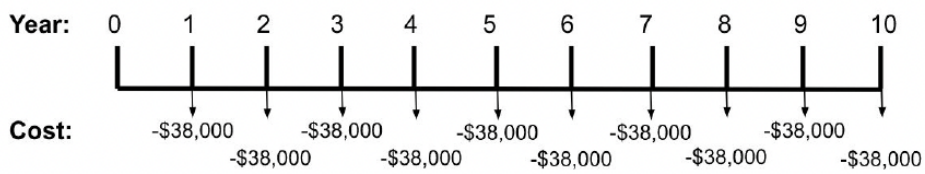
Save money, reduce carbon emissions



Current Cost of Transporting Glass to Salt Lake

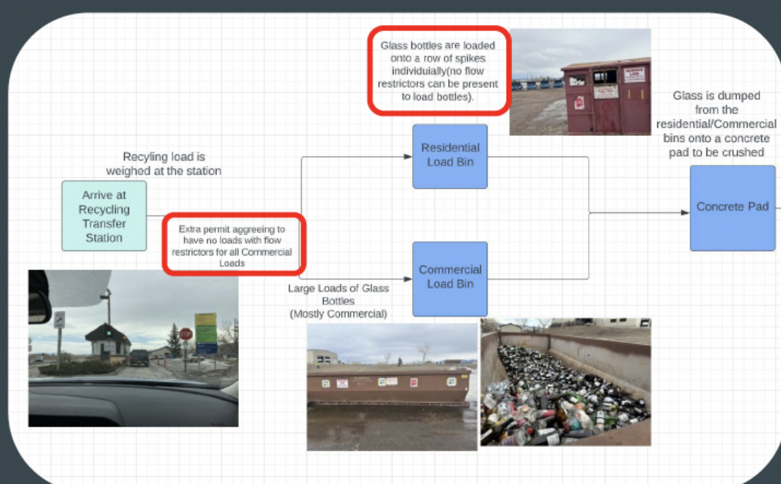
"Do Nothing" Cost of Transporting Glass to Salt Lake

-$38,000 per year to transport crushed glass to Salt Lake City



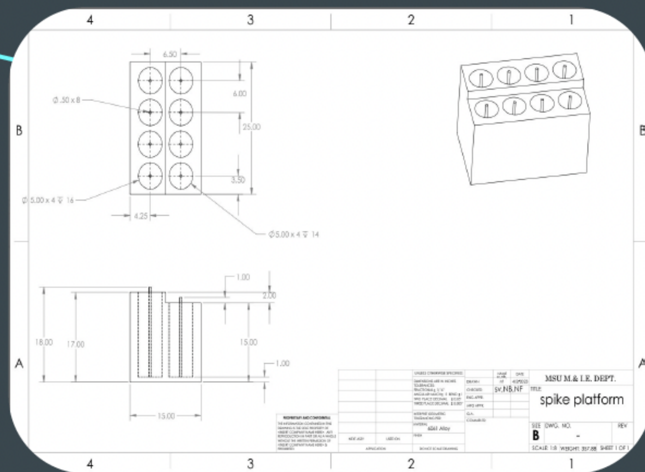
- **NPV Analysis (Based on 10-year horizon, 7% ROI):**
- (P/A, 7%, 10) = 7.02358
- NPV = 7.02358 * $38,000 = -**$266,896.04**

Solution 1: "Mail Drop" Spikes & Additional Bulk Permitting



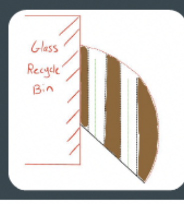
Proposed Process Map

Solution 1: "Mail Drop" Spikes & Additional Bulk Permitting

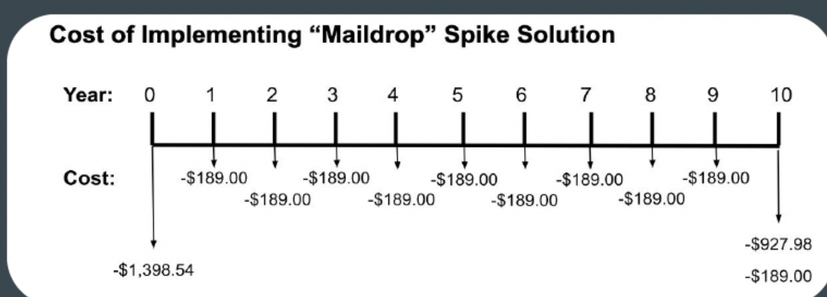


→ Bulk Permitting

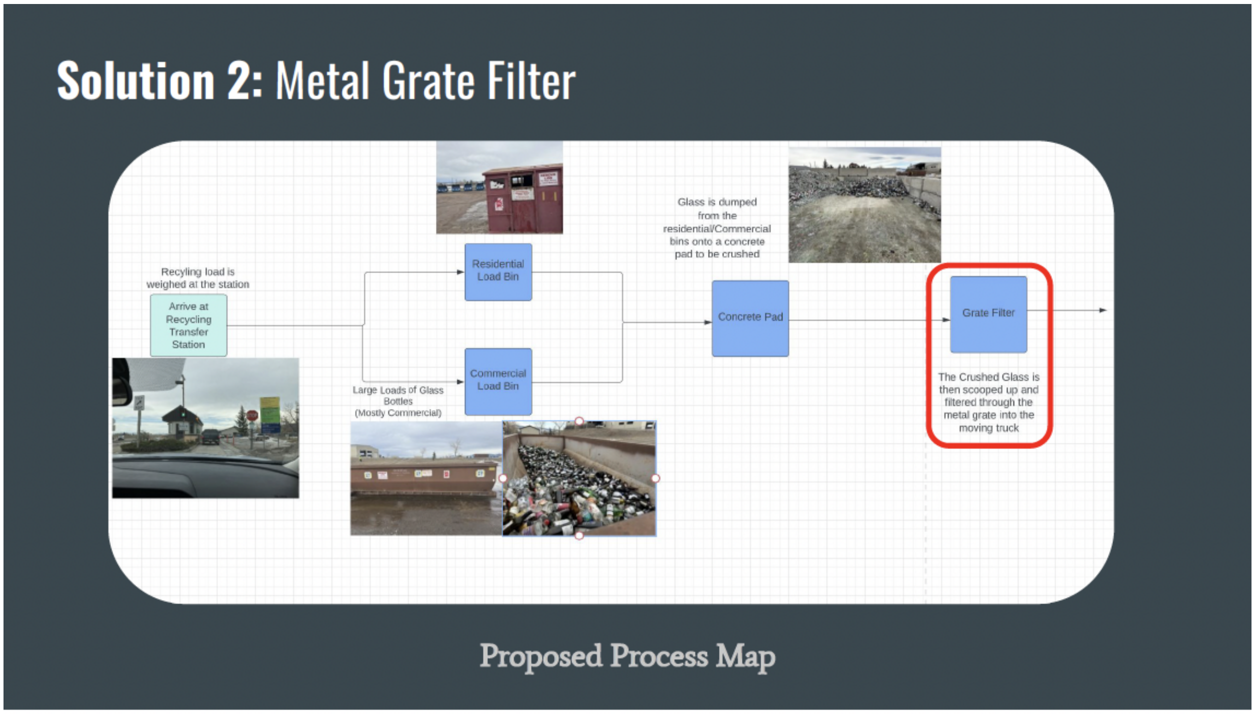
→ Tool on-site

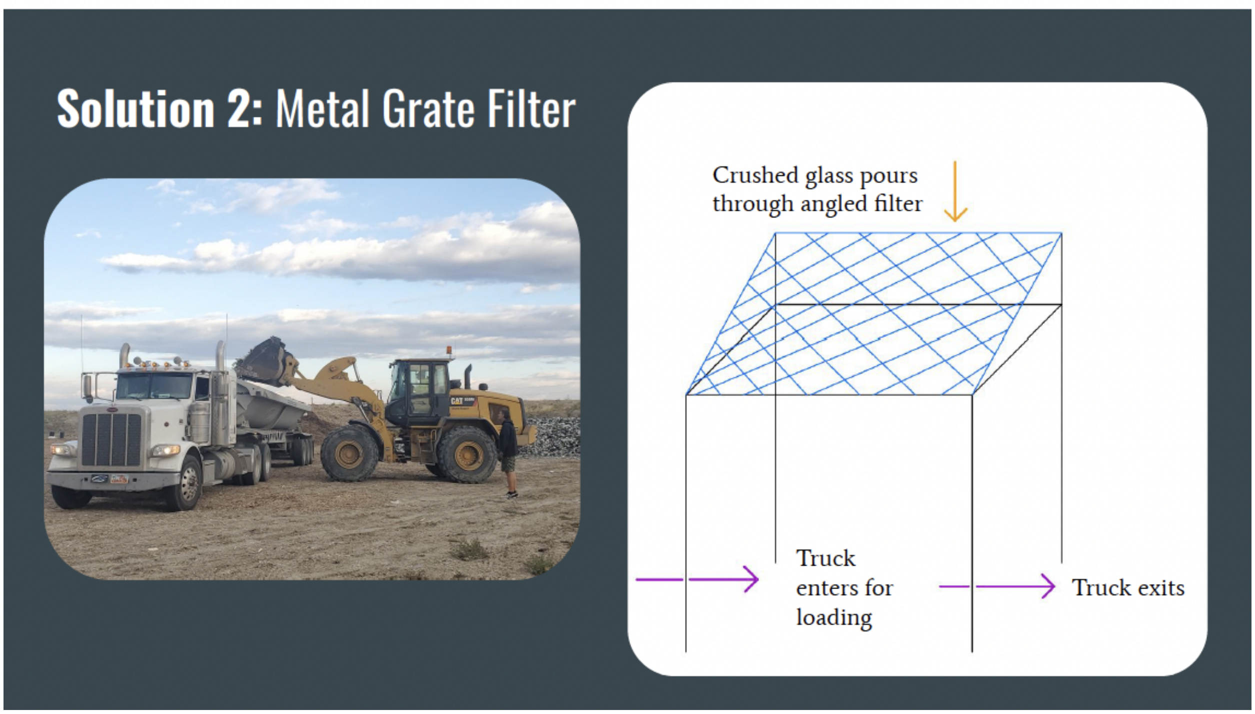


Spike Mail Drop Economic Analysis

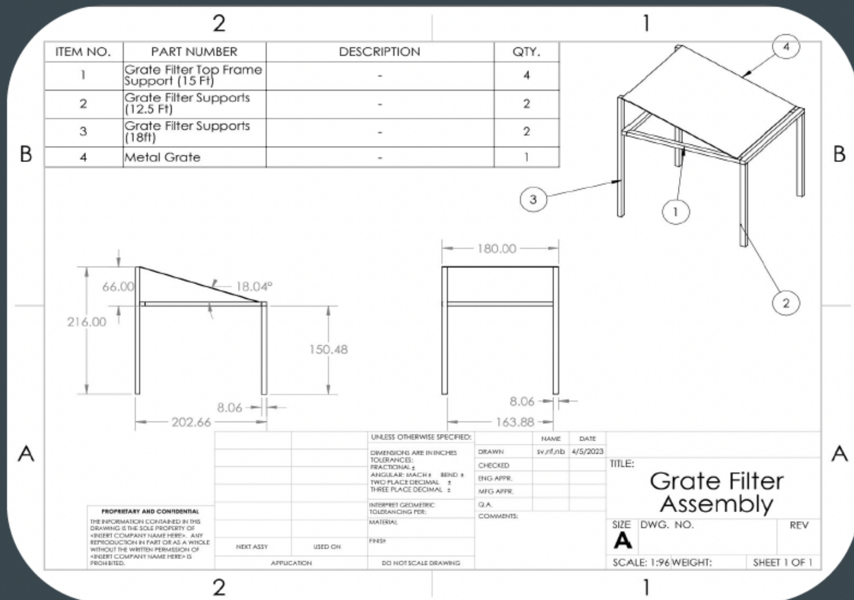


- **NPV Analysis (Based on 10-year horizon, 7% ROI):**
- (P/A, 7%, 10) = 7.02358
- (P/F, 7%, 10) = 0.50835
- NPV = (7.02358 * -$189.00) + (0.50835 * -$927.98) - $1,398.54 = -**$3,197.74**
- Compare to -**$266,896.04**

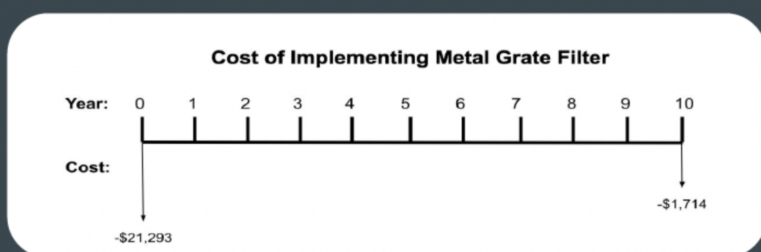

Solution 2: Metal Grate Filter
Recyling load is weighed at the station
Arrive at Recycling Transfer Station
Residential Load Bin
Commercial Load Bin
Large Loads of Glass Bottles (Mostly Commercial)
Glass is dumped from the residential/Commercial bins onto a concrete pad to be crushed
Concrete Pad
Grate Filter
The Crushed Glass is then scooped up and filtered through the metal grate into the moving truck
Proposed Process Map


Solution 2: Metal Grate Filter
Crushed glass pours through angled filter
Truck enters for loading
Truck exits

In Depth Metal Grate Filter Drawing

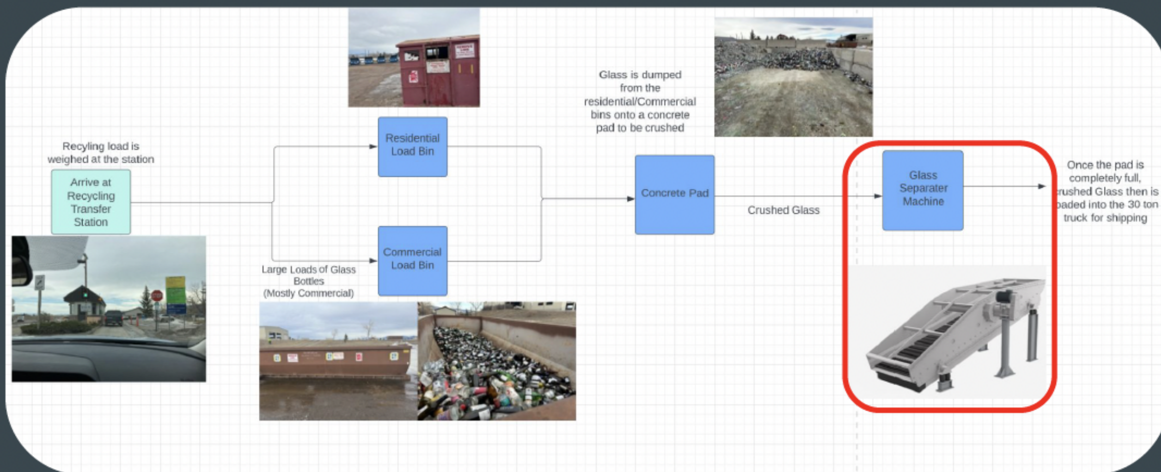


Metal Grate Filter Economic Analysis



- **NPV Analysis (Based on 10-year horizon, 7% ROI):**
- (P/F, 7%, 10) = 0.50835
- NPV = 0.50835 * -$1714.52 - $21,293.04 = -**$22,164**
- Compare to -**$266,896.04**

Solution 3: Industrial Sorting Solution



Proposed Process Map

Solution 3: Industrial Sorting Solution

- Beneficiation for granular sorting
  - Contaminants sorted via optical color sorting, size screening, density sorting with pressurized air, etc
  - Beyond the scope of Machinex solutions
- Glass Aggregate Solutions
- Binder+Co
- Sesotec
- Possible down-the-road solution in a full-scale recycling facility

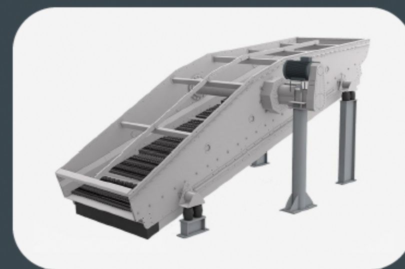
Glass Aggregate Systems

binder+co
we process the future

sesotec
SEPARATION AND SORTING

Solution 3: Industrial Sorting Solution

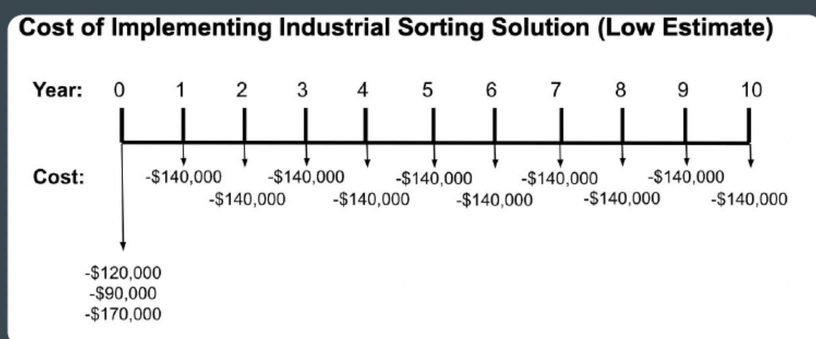
Sesotec



Binder+Co

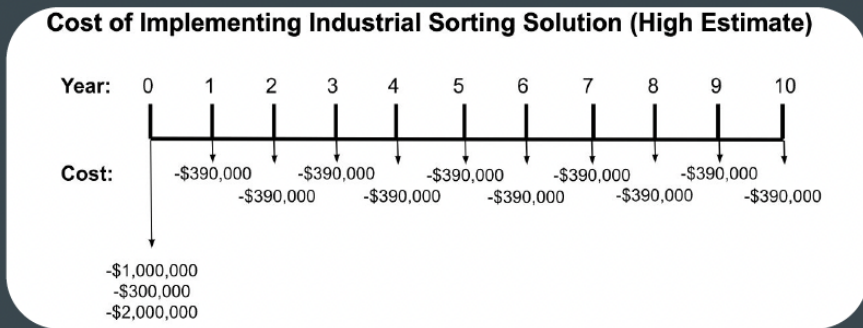
Glass Aggregate Solutions

Industrial Sorting Solution Economic Analysis (Low Estimate)



- **NPV Analysis (Based on 10-year horizon, 7% ROI):** (P/A, 7%, 10) = 7.02358
- NPV = -$120,000 - $90,000 - $170,000 + 7.02358 * -$140,000 = -**$1,363,301.20**
- Compare to -**$266,896.04**

Industrial Sorting Solution Economic Analysis (High Estimate)



- **NPV Analysis (Based on 10-year horizon, 7% ROI):**
- (P/A, 7%, 10) = 7.02358
- NPV = -$1,000,000 - $300,000 - $2,000,000 + 7.02358 * -$390,000 = -**$6,039196.20**
- Compare to -**$266,896.04**

Environmental Assessment Maildrop & Grate Filter Solutions

Outcome	Greenhouse Gas Emissions Per Year (lb CO2)	Greenhouse Gas Emissions Per Year (Tons CO2)
Spike Mail Drop	300	0.15
"Do Nothing" Solution	14511	7.26

*For reference, MSU's annual emissions are ~50,000 metric tons CO2 equivalent

- Comparing greenhouse gas emissions baseline to solution (transportation emissions)
    - Assuming 6 miles per gallon for Peterbilt 389X moving truck = **647 Gallons of Diesel Fuel required**
    - Using estimation of 22.44lbs of CO2 emissions per gallon of diesel fuel, 22.44*647 = **14511.2 lbs of CO2 per year** to transport to Salt Lake
    - **300 lbs CO2 per year** to transport to Ash Grove Cement

Environmental Assessment Industrial Sorting Solution

Comparison of Industrial Sorting and "Do Nothing" Solutions

Outcome	Greenhouse Gas Emissions (lb CO2)	Greenhouse Gas Emissions (tons CO2)
Industrial Sorting Solution	8,816	4.41
"Do Nothing" Solution	14,511	7.26

*For reference, MSU's annual emissions are ~50,000 metric tons CO2 equivalent

- Same baseline comparison for transporting to Salt Lake City
- Industrial sorting solution takes into account the greenhouse gas emissions associated with glass processing energy use in a full-scale recycling facility: **8,816 lbs CO2 per year**
  - Based on NorthWestern Energy generation portfolio breakdown
  - In addition to emissions from transporting to Ash Grove Cement

Spike Mail Drop Pros And Cons

Spike Mail Drop

- Pros →
  - Pretty easy to implement
  - Completely solves problem for residential dump
- Cons →
  - May still be contamination from the commercial dump → need for extra permitting
  - Citizens of Helena may not like the design
  - Project implementation would most likely need the support of a Mechanical Engineering Capstone team

Metal Grate Filter Drop Pros And Cons

Metal Grate Filter

- Pros →
  - Would take care of glass from both residential and commercial flows
  - No additional glass process once implemented
- Cons →
  - Would sacrifice some quantity of glass
  - Would need prototyping to determine size of grate filter holes
  - Would require more added infrastructure than other solutions
  - Gravity alone might not be enough to bring the glass through the filter
  - Need the assistance of an additional capstone team (Civil Engineering) for implementation

Industrial Sorting Solution Pros and Cons

Industrial Sorting Solution

- Pros →
  - Industry-proven solutions from experienced companies
  - Work with the company as a valued partner to deliver a high-quality solution to guarantee plastic is separated fully.
- Cons →
  - Very Costly
  - Must add an additional processing step once the glass has been crushed
  - Sorting mechanism must be able to withstand Helena weather (or part of full-scale facility)
  - Many Unknowns

Next Steps...

- Final Report Handoff
- Recommended Course of Action
  - “Maildrop” Spike & Bulk Drop Permitting
    - Recommended Solution
    - Mechanical Engineering/Mechanical Engineering Technology Capstone Team
  - Metal Grate Filter
    - More questions to answer through prototyping.
    - Civil Engineering Capstone Team
  - Industrial Sorting Solution
    - Part of full-scale recycling facility for City of Helena

Thank You!

Appendix G: Project Management in Smartsheet

1	**Sprint 1 — PM Norris**	NF Nicholas Fitzmaurice NB	01/18/23	02/05/23	Complete	
2	Statement of Work		01/20/23	02/05/23	Complete	
3	First Draft		01/20/23	01/30/23	Complete	
4	Title Page	NF Nicholas Fitzmaurice NB			Complete	
5	Background	ST Sven Tate			Complete	
6	Project Description	ST Sven Tate			Complete	
7	Stakeholder Needs Assessment	NF Nicholas Fitzmaurice			Complete	
8	Project Approach	NF Nicholas Fitzmaurice			Complete	
9	Deliverables	NB Norris Blossom			Complete	
10	Budget	NB Norris Blossom			Complete	
11	Confidentiality	NF Nicholas Fitzmaurice NB			Complete	
12	SOW Sign-Off		01/30/23	02/05/23	Complete	
13	First review with Professor Cook		01/30/23	01/31/23	Complete	
14	SOW Revisions — 1st	NF Nicholas Fitzmaurice NB	01/31/23	02/01/23	Complete	
15	Sign Off from Professor Cook	NB Norris Blossom	02/01/23	02/02/23	Complete	
16	First review with Helena Recycling	NB Norris Blossom	02/02/23	02/03/23	Complete	
17	SOW Revisions — 2nd	NF Nicholas Fitzmaurice NB	02/03/23	02/05/23	Complete	
18	Sign Off with Helena Recycling	NB Norris Blossom	02/05/23	02/05/23	Complete	
19	Project Team Signoff	NF Nicholas Fitzmaurice NB	02/05/23	02/05/23	Complete	
20	Project Management Plan	NF Nicholas Fitzmaurice NB	01/30/23	02/05/23	Complete	
21	Work Breakdown Structure	NB Norris Blossom			Complete	
22	Project Schedule	NF Nicholas Fitzmaurice			Complete	
23	Yodiz Project Management System	ST Sven Tate			Complete	
24	**Sprint 2 — PM Nick**	NF Nicholas Fitzmaurice NB	02/06/23	02/19/23	Complete	
25	Sprint 2 Plan	NF Nicholas Fitzmaurice	02/03/23	02/06/23	Complete	2 Hours
26	Helena Cite Visit	NF Nicholas Fitzmaurice NB	02/07/23	02/07/23	Complete	8 Hours
27	Obtain and analyze regulator frequency data	NB Norris Blossom	02/07/23	02/10/23	Complete	1 Hour
28	Ask clarifying questions on glass processing	ST Sven Tate	02/07/23	02/07/23	Complete	1 Hour
29	Clarify what plastic needs to be removed	NF Nicholas Fitzmaurice	02/07/23	02/07/23	Complete	1 Hour
30	Document glass process (photos and notes)				Complete	2 Hours
31	Compile and synthesize findings from site visit into document	NF Nicholas Fitzmaurice NB	02/08/23	02/08/23	Complete	2 Hours
32	Check-in with Professor Cook	NF Nicholas Fitzmaurice	02/07/23	02/07/23	Complete	1 Hour — Bi-Weekly Check-in
33	Data Needs Assessment		02/06/23	02/10/23	Complete	2 Hours
34	Sprint 2 Deliverables — Solution Ideation	NF Nicholas Fitzmaurice NB	02/06/23	02/19/23	Complete	6 Hours
35	Structured brainstorm list	NF Nicholas Fitzmaurice NB	02/10/23	02/15/23	Complete	2 Hours
36	Identify distinct solutions	NF Nicholas Fitzmaurice NB	02/13/23	02/17/23	Complete	2 Hours
37	First round of solution ideation consolidated and documented	NF Nicholas Fitzmaurice NB	02/10/23	02/17/23	Complete	2 Hours
38	Sprint 2 Deliverables Slides	NF Nicholas Fitzmaurice NB	02/15/23	02/17/23	Complete	2 Hours

39	**Sprint 3 — PM Sven**	NF Nicholas Fitzmaurice NB	02/20/23	03/05/23	Complete	
40	Sprint 3 Plan	ST Sven Tate	02/17/23	02/20/23	Complete	Completed by sprint project manager: 2 Hours
41	Check-in with Professor Cook	NF Nicholas Fitzmaurice NB	02/21/23	02/21/23	Complete	4 Hours
42	Prepare for meeting	NF Nicholas Fitzmaurice NB	02/20/23	02/20/23	Complete	2 Hours
43	Meeting	NF Nicholas Fitzmaurice NB	02/21/23	02/21/23	Complete	1 Hour
44	Synthesize points discussed in meeting	NF Nicholas Fitzmaurice NB	02/22/23	02/22/23	Complete	1 Hour
45	Virtual Presentation to Helena Recycling	NF Nicholas Fitzmaurice NB	02/24/23	02/24/23	Complete	16 Hours
46	Schedule Presentation	ST Sven Tate	02/15/23	02/15/23	Complete	1 Hour
47	Create Presentation of potential solutions	NF Nicholas Fitzmaurice NB	02/17/23	02/22/23	Complete	6 Hours
48	Develop concept outline				Complete	2 Hours
49	Derive slide content				Complete	2 Hours
50	Create Slides				Complete	2 Hours
51	Team meeting brainstorm and work	NF Nicholas Fitzmaurice NB	02/20/23	02/20/23	Complete	2 Hours
52	Practice Presentation	NF Nicholas Fitzmaurice NB	02/20/23	02/22/23	Complete	2 Hours
53	Give Presentation	NF Nicholas Fitzmaurice NB	02/22/23	02/22/23	Complete	1 Hour
54	Elicit client feedback	ST Sven Tate	02/22/23	02/24/23	Complete	2 Hours
55	Synthesize Client Feedback	NF Nicholas Fitzmaurice NB	02/24/23	03/01/23	Complete	2 Hours
56	Sprint 3 Deliverables — Solution Selected	NF Nicholas Fitzmaurice NB	02/20/23	03/03/23	Complete	6 Hours
57	Solution ideation presentation slide deck	ST Sven Tate	02/20/23	02/22/23	Complete	2 Hours
58	Document synthesizing feedback from City of Helena on ideation presentation	ST Sven Tate	02/22/23	03/01/23	Complete	2 Hours
59	Solutions to pursue further selected and documented from client feedback	NF Nicholas Fitzmaurice NB	02/27/23	03/03/23	Complete	2 Hours
60	**Sprint 4 — PM Norris**		03/06/23	03/26/23	Complete	
61	Sprint 4 Plan	NB Norris Blossom	03/03/23	03/06/23	Complete	Completed by sprint project manager - 2 Hours
62	Check-in with Professor Cook		03/07/23	03/07/23	Complete	1 Hour
63	Check-in with Professor Cook		03/21/23	03/21/23	Complete	1 Hour
64	Project Interim Presentation	NF Nicholas Fitzmaurice NB	03/06/23	03/27/23	Complete	15 Hours
65	Invite City of Helena Recycling to Presentation	NB Norris Blossom	03/06/23	03/06/23	Complete	1 Hour
66	Create Presentation Outline	NF Nicholas Fitzmaurice NB	03/20/23	03/21/23	Complete	2 Hour
67	Draft Presentation Slide Deck	NF Nicholas Fitzmaurice NB	03/21/23	03/22/23	Complete	2 Hour
68	Finalize Presentation Slide Deck	NF Nicholas Fitzmaurice NB	03/22/23	03/23/23	Complete	2 Hour
69	Write-up speaker notes	NF Nicholas Fitzmaurice NB	03/21/23	03/23/23	Complete	2 Hour
70	Divide presentation content	NF Nicholas Fitzmaurice NB	03/22/23	03/24/23	Complete	2 Hour
71	Practice presentation	NF Nicholas Fitzmaurice NB	03/24/23	03/27/23	Complete	2 Hour
72	Deliver presentation	NF Nicholas Fitzmaurice NB	03/27/23	03/27/23	Complete	2 Hour
73	Selected solution deep-dive	NF Nicholas Fitzmaurice NB	03/06/23	03/24/23	Complete	
74	Metal spike mail drop	ST Sven Tate	03/06/23	03/24/23	Complete	14 Hours
75	Research options for mail drop solution	ST Sven Tate	03/06/23	03/08/23	Complete	2 Hour
76	Research tools for plastic flow regulator removal	ST Sven Tate	03/08/23	03/10/23	Complete	2 Hour
77	Sketch model for spike mail drop mechanism	NB Norris Blossom	03/20/23	03/22/23	Complete	2 Hour
78	Create process flow map	NB Norris Blossom	03/20/23	03/22/23	Complete	2 Hour
79	Technical feasibility explored	NF Nicholas Fitzmaurice	03/20/23	03/22/23	Complete	2 Hour
80	Document strengths and weaknesses	NF Nicholas Fitzmaurice	03/20/23	03/22/23	Complete	2 Hour
81	Summarize metal spike mail-drop findings	NF Nicholas Fitzmaurice	03/22/23	03/24/23	Complete	2 Hour

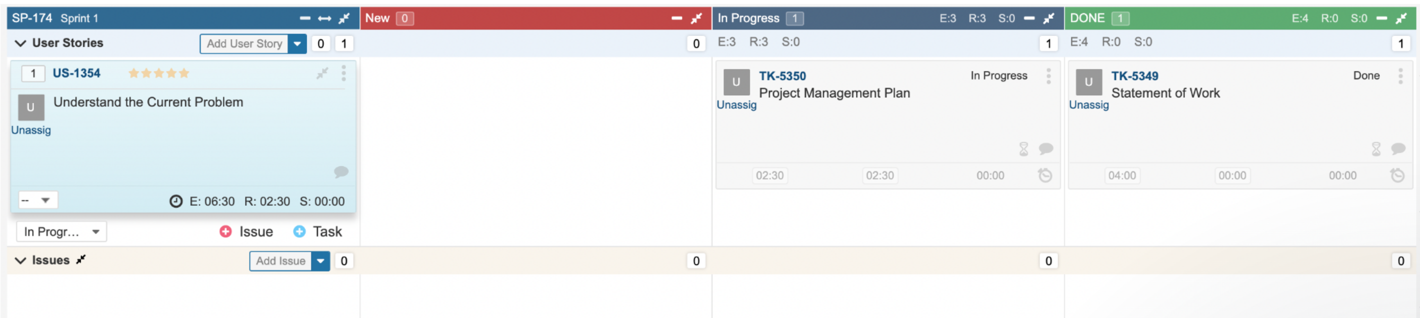
82	Grate Filter	NB Norris Blossom	03/06/23	03/24/23	Complete	6 Hours
83	Research options for grate filter solution	NB Norris Blossom	03/06/23	03/08/23	Complete	1 Hour
84	Diagram Solution	NB Norris Blossom	03/08/23	03/10/23	Complete	1 Hour
85	Create process flow map	ST Sven Tate	03/20/23	03/22/23	Complete	1 Hour
86	Technical feasibility explored	ST Sven Tate	03/20/23	03/22/23	Complete	1 Hour
87	Document strengths and weaknesses	ST Sven Tate	03/20/23	03/22/23	Complete	1 Hour
88	Summarize grate filter findings	ST Sven Tate	03/22/23	03/24/23	Complete	1 Hour
89	Machinex Quote	NF Nicholas Fitzmaurice	03/06/23	03/24/23	Complete	3 Hours
90	Contact Machinex	NF Nicholas Fitzmaurice	03/06/23	03/08/23	Complete	.5 Hour
91	Document findings from Machinex	NB Norris Blossom	03/08/23	03/10/23	Complete	.5 Hour
92	Document flow map for Machinex solution	NB Norris Blossom	03/20/23	03/22/23	Complete	.5 Hour
93	Explore technical feasibility for Machinex Solution ($$$, Space)	NB Norris Blossom	03/20/23	03/22/23	Complete	.5 Hour
94	Document strengths and weaknesses	NB Norris Blossom	03/20/23	03/22/23	Complete	.5 Hour
95	Summarize Machinex findings	NB Norris Blossom	03/22/23	03/24/23	Complete	.5 Hour
96	Sprint 4 Deliverables — Detailed Solutions	NF Nicholas Fitzmaurice NB	03/20/23	02/26/23	Complete	
97	Detailed summaries of each selected solution	NF Nicholas Fitzmaurice NB	02/24/23	03/03/23	Complete	8 Hours
98	Process flow maps for each solution	NF Nicholas Fitzmaurice NB	03/20/23	03/24/23	Complete	2 Hours
99	Technical feasibility explored and documented for each solution	NF Nicholas Fitzmaurice NB	03/20/23	03/24/23	Complete	2 Hours
100	Strengths and weaknesses assessed and documented for each solution	NF Nicholas Fitzmaurice NB	03/20/23	03/24/23	Complete	2 Hours
101	Communicate deliverables with Helena Recycling	NF Nicholas Fitzmaurice NB	03/24/23	03/26/23	Complete	1 Hour
102	Communicate deliverables with Professor Cook	NF Nicholas Fitzmaurice NB	03/24/23	03/26/23	Complete	1 Hour
103	**Sprint 5 — PM Nick**		03/27/23	04/09/23	Complete	39 Hrs
104	Sprint 5 Plan	NF Nicholas Fitzmaurice	03/24/23	03/27/23	Complete	Completed by sprint project manager
105	"Maildrop" Spike Solution Economic Analysis	NB Norris Blossom	03/27/23	04/07/23	Complete	11 Hours
106	Outline all material needs for solution	NB Norris Blossom	03/27/23	03/31/23	Complete	1 Hr
107	Determine material costs	NB Norris Blossom	03/27/23	03/31/23	Complete	1 Hr
108	Outline all labor needs for solution	NB Norris Blossom	03/27/23	03/31/23	Complete	1 Hr
109	Determine labor costs	NB Norris Blossom	03/27/23	03/31/23	Complete	1 Hr
110	Outline maintenance needs for solution	NB Norris Blossom	03/27/23	03/31/23	Complete	1 Hr
111	Determine maintenance costs	NB Norris Blossom	03/27/23	03/31/23	Complete	1 Hr
112	Conduct economic analysis of overal solution costs	NB Norris Blossom	04/03/23	04/07/23	Complete	2 Hr
113	Compare economic analysis to "do nothing" solution (shipping to salt lake)	NB Norris Blossom	04/03/23	04/07/23	Complete	1 Hr
114	Synthesize "Maildrop" Spike Solution economic analysis document	NB Norris Blossom	04/03/23	04/07/23	Complete	2 Hr
115	Metal Grate Filter Economic Analysis	ST Sven Tate	03/27/23	04/07/23	Complete	11 Hours
116	Outline all material needs for solution	ST Sven Tate	03/27/23	03/31/23	Complete	1 Hr
117	Determine material costs	ST Sven Tate	03/27/23	03/31/23	Complete	1 Hr
118	Outline all labor needs for solution	ST Sven Tate	03/27/23	03/31/23	Complete	1 Hr
119	Determine labor costs	ST Sven Tate	03/27/23	03/31/23	Complete	1 Hr
120	Outline maintenance needs for solution	ST Sven Tate	03/27/23	03/31/23	Complete	1 Hr
121	Determine maintenance costs	ST Sven Tate	03/27/23	03/31/23	Complete	1 Hr
122	Conduct economic analysis of overal solution costs	ST Sven Tate	04/03/23	04/07/23	Complete	2 Hr
123	Compare economic analysis to "do nothing" solution (shipping to salt lake)	ST Sven Tate	04/03/23	04/07/23	Complete	1 Hr
124	Synthesize Grate Filter economic analysis document	ST Sven Tate	04/03/23	04/07/23	Complete	2 Hr

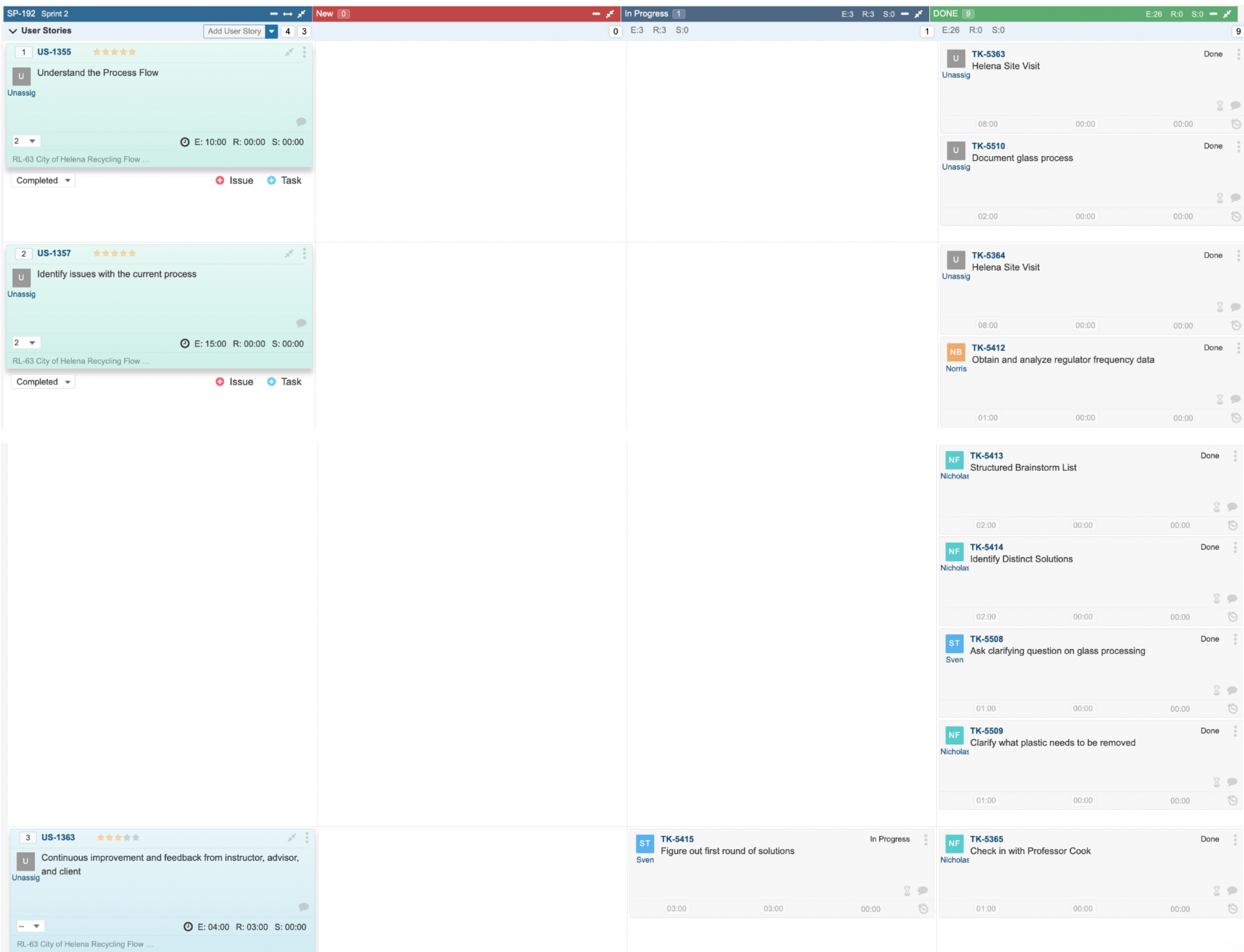
125	Industrial Sorting Solution Economic Analysis	NF Nicholas Fitzmaurice	03/27/23	04/07/23	Complete	5 Hours
126	Outline needs for solution	NF Nicholas Fitzmaurice	03/27/23	03/31/23	Complete	1 Hr
127	Determine rough estimate costs for solution	NF Nicholas Fitzmaurice	03/27/23	03/31/23	Complete	1 Hr
128	Conduct economic analysis of overal solution costs	NF Nicholas Fitzmaurice	04/03/23	04/07/23	Complete	1 Hr
129	Compare economic analysis to "do nothing" solution (shipping to salt lake)	NF Nicholas Fitzmaurice	04/03/23	04/07/23	Complete	1 Hr
130	Synthesize Industrial Sorting Solution economic analysis document	NF Nicholas Fitzmaurice	04/03/23	04/07/23	Complete	1 Hr
131	Compare economic analyses of different solutions	NF Nicholas Fitzmaurice	04/03/23	04/07/23	Complete	1 Hr
132	Higher-Fidelity "Maildrop" Spike Solution Drawings	NF Nicholas Fitzmaurice NB	04/03/23	04/07/23	Complete	4 Hours
133	Determine key dimensions (not values) that will need to be included	NB Norris Blossom	04/03/23	04/07/23	Complete	1 Hr
134	Estimate values for these dimensions based on information available	NB Norris Blossom	04/03/23	04/07/23	Complete	1 Hr
135	Draw solution, including key dimensions	NF Nicholas Fitzmaurice	04/03/23	04/07/23	Complete	2 Hr
136	Higher-Fidelity Metal Grate Filter Drawings	NF Nicholas Fitzmaurice ST	04/03/23	04/07/23	Complete	4 Hours
137	Determine key dimensions (not values) that will need to be included	ST Sven Tate	04/03/23	04/07/23	Complete	1 Hr
138	Estimate values for these dimensions based on information available	ST Sven Tate	04/03/23	04/07/23	Complete	1 Hr
139	Draw solution, including key dimensions	NF Nicholas Fitzmaurice	04/03/23	04/07/23	Complete	2 Hr
140	Check-in with Professor Cook	NF Nicholas Fitzmaurice NB	04/04/23	04/04/23	Complete	1 Hr
141	Sprint 5 Deliverables	NF Nicholas Fitzmaurice	03/27/23	04/09/23	Complete	2 Hr
142	"Maildrop" Spike Solution Economic Analysis Document	NF Nicholas Fitzmaurice	03/27/23	04/09/23	Complete	-
143	Metal Grate Filter Economic Analysis	NF Nicholas Fitzmaurice	03/27/23	04/09/23	Complete	-
144	Industrial Sorting Solution Economic Analysis	NF Nicholas Fitzmaurice	03/27/23	04/09/23	Complete	-
145	Higher-Fidelity "Maildrop" Spike Solution Drawings	NF Nicholas Fitzmaurice	03/27/23	04/09/23	Complete	-
146	Higher-Fidelity Metal Grate Filter Drawings	NF Nicholas Fitzmaurice	03/27/23	04/09/23	Complete	-
147	Communicate with Helena Recycling	NF Nicholas Fitzmaurice	04/07/23	04/07/23	Complete	1 Hr
148	Communicate with Professor Cook	NF Nicholas Fitzmaurice	04/07/23	04/07/23	Complete	1 Hr

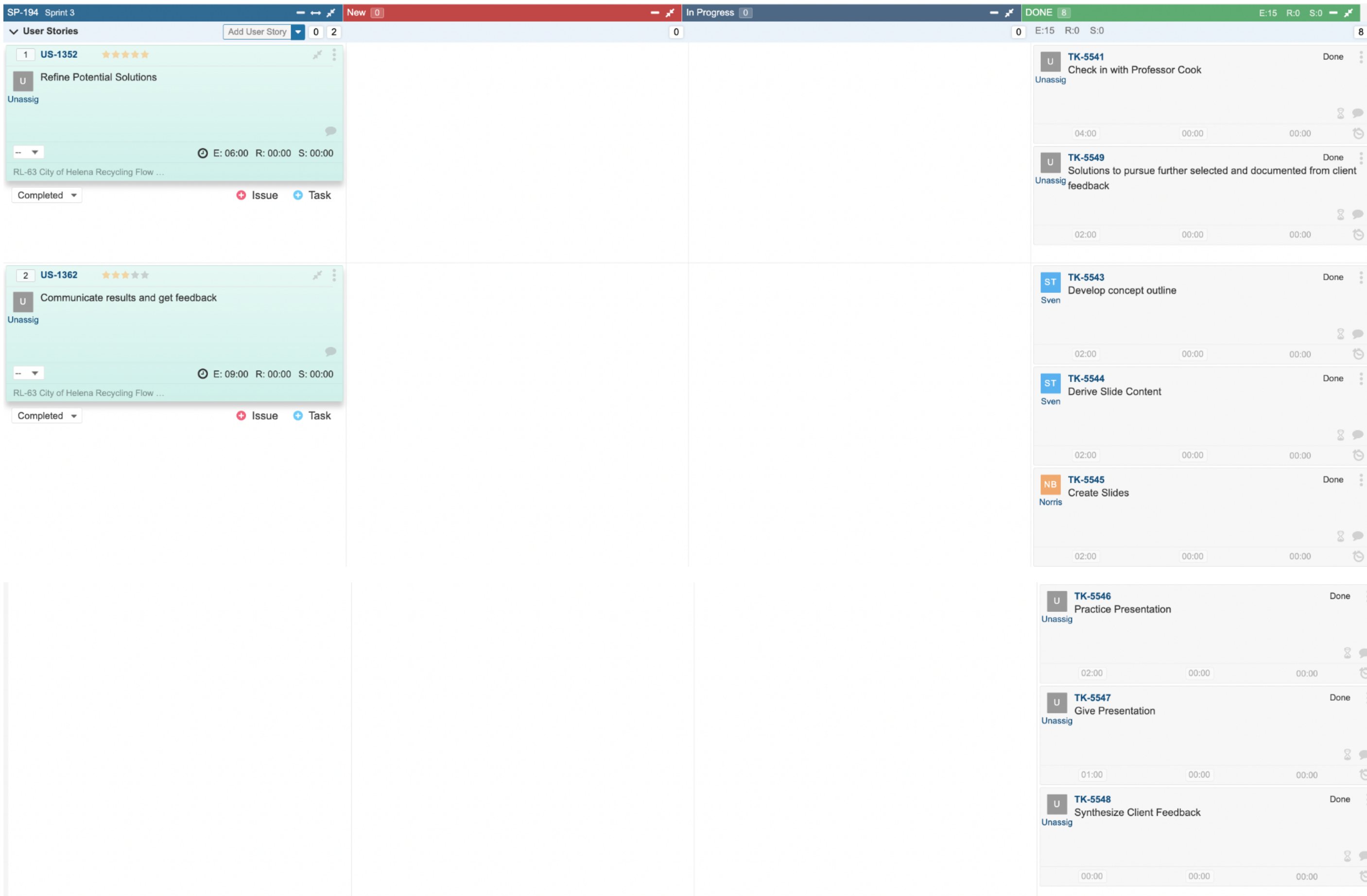
149	**Sprint 6 — PM Sven**		04/10/23	04/23/23	Complete	28.5 Hrs
150	Sprint 6 Plan	ST Sven Tate	04/07/23	04/10/23	Complete	Completed by sprint project manager: 1 Hr
151	Check-in with Professor Cook	NF Nicholas Fitzmaurice NB	04/18/23	04/18/23	Complete	1 Hr
152	Baseline environmental impact assessment of shipping glass to salt lake	NB Norris Blossom	04/10/23	04/14/23	Complete	2.5 Hr
153	Determine number of trips to salt lake (round trip?)	NB Norris Blossom	04/10/23	04/14/23	Complete	0.25 Hr
154	Determine mileage to/from salt lake	NB Norris Blossom	04/10/23	04/14/23	Complete	0.25 Hr
155	Determine truck type for transportation	NB Norris Blossom	04/10/23	04/14/23	Complete	0.25 Hr
156	Determine mpg for truck	NB Norris Blossom	04/10/23	04/14/23	Complete	0.25 Hr
157	Determine emissions per gallon diesel combustion	NB Norris Blossom	04/10/23	04/14/23	Complete	0.25 Hr
158	Determine annual GHG emissions for transporting glass to salt lake	NB Norris Blossom	04/10/23	04/14/23	Complete	0.25 Hr
159	Synthesize environmental impacts assessment document	NB Norris Blossom	04/10/23	04/14/23	Complete	1 Hr
160	"Maildrop" Environmental Impact Assessment	ST Sven Tate	04/10/23	04/14/23	Complete	3 Hr
161	Determine emissions (if any) associated with developing and implementing solution	ST Sven Tate	04/10/23	04/14/23	Complete	.25 Hr
162	Determine number of trips to ash grove cement (round trip?)	ST Sven Tate	04/10/23	04/14/23	Complete	.25 Hr
163	Determine mileage to/from ash grove	ST Sven Tate	04/10/23	04/14/23	Complete	.25 Hr
164	Determine truck type for transportation	ST Sven Tate	04/10/23	04/14/23	Complete	.25 Hr
165	Determine mpg for truck	ST Sven Tate	04/10/23	04/14/23	Complete	.25 Hr
166	Determine emissions per gallon diesel combustion	ST Sven Tate	04/10/23	04/14/23	Complete	.25 Hr
167	Determine annual GHG emissions for transporting glass to ash grove	ST Sven Tate	04/10/23	04/14/23	Complete	.25 Hr
168	Compare impact of solution to baseline	ST Sven Tate	04/10/23	04/14/23	Complete	.25 Hr
169	Synthesize environmental impacts assessment document	ST Sven Tate	04/10/23	04/14/23	Complete	1 Hr
170	Metal grate filter environmental impact assessment	NF Nicholas Fitzmaurice	04/10/23	04/14/23	Complete	3 Hr
171	Determine emissions (if any) associated with developing and implementing solution	NF Nicholas Fitzmaurice	04/10/23	04/14/23	Complete	.25 Hr
172	Determine number of trips to ash grove cement (round trip?)	NF Nicholas Fitzmaurice	04/10/23	04/14/23	Complete	.25 Hr
173	Determine mileage to/from ash grove	NF Nicholas Fitzmaurice	04/10/23	04/14/23	Complete	.25 Hr
174	Determine truck type for transportation	NF Nicholas Fitzmaurice	04/10/23	04/14/23	Complete	.25 Hr
175	Determine mpg for truck	NF Nicholas Fitzmaurice	04/10/23	04/14/23	Complete	.25 Hr
176	Determine emissions per gallon diesel combustion	NF Nicholas Fitzmaurice	04/10/23	04/14/23	Complete	.25 Hr
177	Determine annual GHG emissions for transporting glass to ash grove	NF Nicholas Fitzmaurice	04/10/23	04/14/23	Complete	.25 Hr
178	Compare impact of solution to baseline	NF Nicholas Fitzmaurice	04/10/23	04/14/23	Complete	.25 Hr
179	Synthesize environmental impacts assessment document	NF Nicholas Fitzmaurice	04/10/23	04/14/23	Complete	1 Hr
180	Industrial sorting solution environmental impact assessment	NF Nicholas Fitzmaurice NB	04/10/23	04/14/23	Complete	3 Hr
181	Determine rough estimate of emissions associated with building industrial recycling facility	NF Nicholas Fitzmaurice NB	04/10/23	04/14/23	Complete	2 Hr
182	Synthesize environmental impacts assessment document	NF Nicholas Fitzmaurice NB	04/10/23	04/14/23	Complete	1 Hr
183	Begin drafting presentation slide deck for City of Helena Recycling presentation on 4/26	NF Nicholas Fitzmaurice NB	04/17/23	04/21/23	Complete	8 Hr
184	Create outline	NF Nicholas Fitzmaurice NB	04/17/23	04/21/23	Complete	2 Hr
185	Start Filling Slides	NF Nicholas Fitzmaurice NB	04/17/23	04/21/23	Complete	2 Hr
186	Divide content among presenters	NF Nicholas Fitzmaurice NB	04/17/23	04/21/23	Complete	2 Hr
187	Practice Presentation	NF Nicholas Fitzmaurice NB	04/17/23	04/21/23	Complete	2 Hr
188	Begin drafting final report	NF Nicholas Fitzmaurice NB	04/17/23	04/21/23	Complete	6 Hr
189	Create outline	NF Nicholas Fitzmaurice NB	04/17/23	04/21/23	Complete	2 Hr
190	Start filling content	NF Nicholas Fitzmaurice NB	04/17/23	04/21/23	Complete	2 Hr
191	Determine further needs	NF Nicholas Fitzmaurice NB	04/17/23	04/21/23	Complete	2 Hr

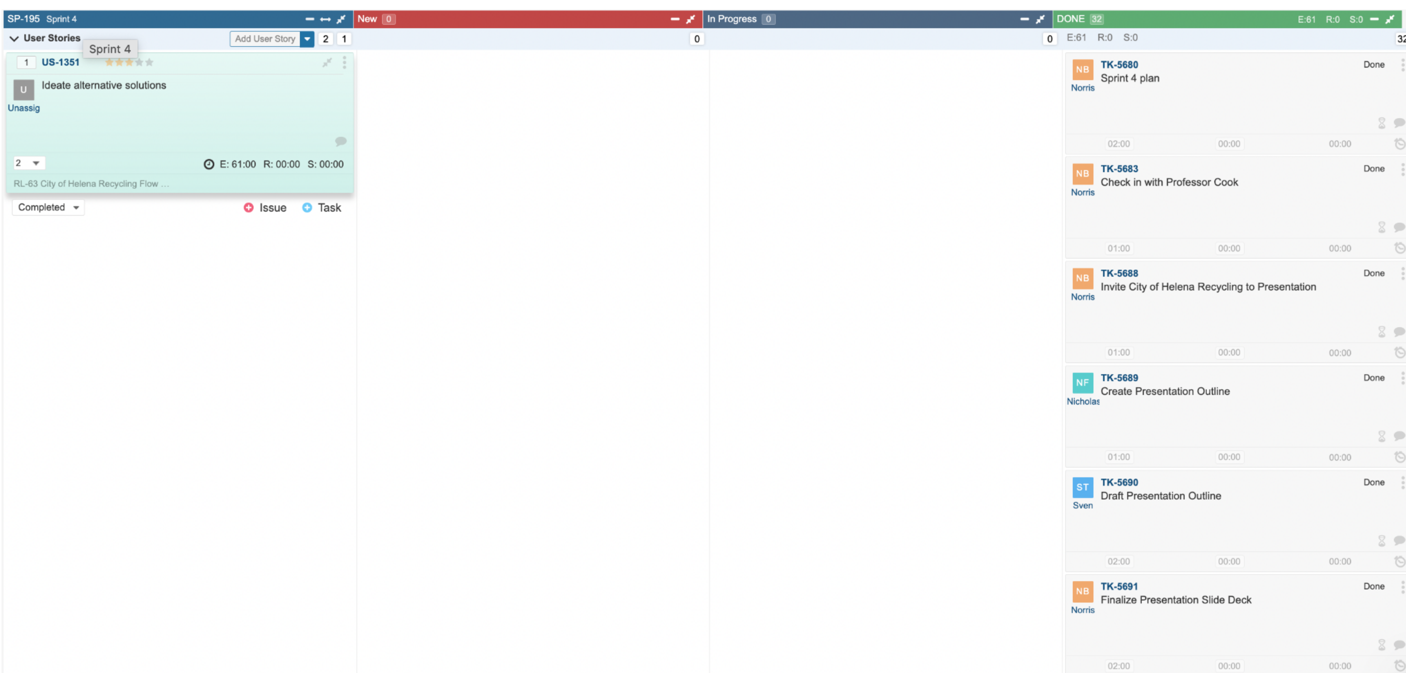
192	Sprint 6 Deliverables	NF Nicholas Fitzmaurice NB	04/17/23	04/23/23	Complete	1 Hr
193	Environmental impact assessments baseline document for shipping glass to salt lake city	NF Nicholas Fitzmaurice NB	04/17/23	04/23/23	Complete	N/A
194	Environmental impact assessment document for maildrop solution	NF Nicholas Fitzmaurice NB	04/17/23	04/23/23	Complete	N/A
195	Environmental impact assessment document for metal grate filter solution	NF Nicholas Fitzmaurice NB	04/17/23	04/23/23	Complete	N/A
196	Environmental impact assessment document for industrial sorting solution	NF Nicholas Fitzmaurice NB	04/17/23	04/23/23	Complete	N/A
197	Communicate with Professor Cook	NF Nicholas Fitzmaurice NB	04/19/23	04/23/23	Complete	0.33 Hr
198	Communicate City of Helena Recycling	NF Nicholas Fitzmaurice NB	04/19/23	04/23/23	Complete	0.33 Hr
199	Communicate with Dr. Kittleman (D2L submission)	NF Nicholas Fitzmaurice NB	04/19/23	04/23/23	Complete	0.33 Hr
200	**Sprint 7 — PM Norris**		04/24/23	05/05/23	Complete	34.75 Hrs
201	Sprint 7 Plan	NB Norris Blossom		04/24/23	Complete	Completed by sprint project manager - 2 Hr
202	Final Check-in with Professor Cook	NF Nicholas Fitzmaurice NB	05/02/23	05/02/23	Complete	1 Hr
203	Final report and presentation delivered to Helena Recycling	NF Nicholas Fitzmaurice NB	04/24/23	04/28/23	Complete	21 Hr
204	Final Report	NF Nicholas Fitzmaurice NB	04/17/23	04/28/23	Complete	14 hr
205	Outline final report	NF Nicholas Fitzmaurice	04/17/23	04/21/23	Complete	2 Hr
206	Draft Final Report	NB Norris Blossom	04/19/23	04/26/23	Complete	6 Hr
207	Import Appendices and References	ST Sven Tate	04/24/23	04/26/23	Complete	2 Hr
208	Finalize Report	NF Nicholas Fitzmaurice NB	04/26/23	04/28/23	Complete	4 Hr
209	Final Presentation to Helena Recycling	NF Nicholas Fitzmaurice NB	04/17/23	04/26/23	Complete	7 Hr
210	Outline final presentation	ST Sven Tate	04/17/23	04/21/23	Complete	2 hr
211	Draft Final Presentation	NF Nicholas Fitzmaurice	04/24/23	04/24/23	Complete	2 hr
212	Finalize Final Presentation	NB Norris Blossom	04/25/23	04/25/23	Complete	1 hr
213	Practice Presentation	NF Nicholas Fitzmaurice NB	04/25/23	04/25/23	Complete	1 hr
214	Give Presentation	NF Nicholas Fitzmaurice NB	04/26/23	04/26/23	Complete	1 hr
215	Design Fair Poster Sessions	NF Nicholas Fitzmaurice NB	04/24/23	05/04/23	Complete	9 Hr
216	Draft design fair poster	ST Sven Tate	04/24/23	04/28/23	Complete	2 Hr
217	Finalize poster	NF Nicholas Fitzmaurice	04/28/23	05/01/23	Complete	2 Hr
218	Print poster	NB Norris Blossom	05/01/23	05/03/23	Complete	1 Hr
219	Practice elevator pitch	NF Nicholas Fitzmaurice NB	05/01/23	05/04/23	Complete	2 Hr
220	Design Fair	NF Nicholas Fitzmaurice NB	05/04/23	05/04/23	Complete	2 Hr
221	Sprint 7 Deliverables	NF Nicholas Fitzmaurice NB	05/01/23	05/10/23	Complete	1.75 Hr
222	Final Presentation Slide Deck	NF Nicholas Fitzmaurice NB	05/01/23	05/10/23	Complete	.25 Hr
223	Final Report	NF Nicholas Fitzmaurice NB	05/01/23	05/10/23	Complete	.25 Hr
224	Design Fair Poster	NF Nicholas Fitzmaurice NB	05/01/23	05/10/23	Complete	.25 Hr
225	Submit report & presentation to D2L	NF Nicholas Fitzmaurice NB	05/01/23	05/10/23	Complete	.25 Hr
226	Send Report & Presentation to Professor Cook	NF Nicholas Fitzmaurice NB	05/01/23	05/10/23	Complete	.25 Hr
227	Send Report & Presentation to City of Helena	NF Nicholas Fitzmaurice NB	05/01/23	05/10/23	Complete	.25 Hr
228	Send report to Honors College	NF Nicholas Fitzmaurice NB	05/01/23	05/10/23	Complete	.25 Hr

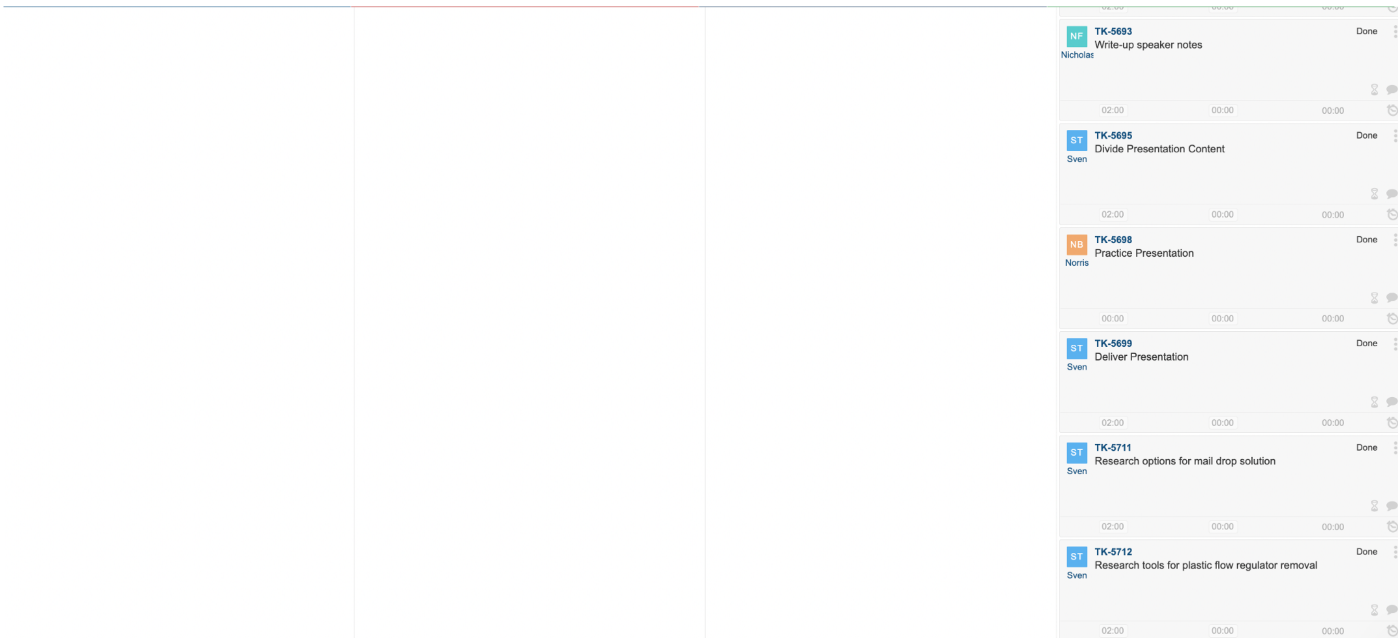
Appendix H: Yodiz Project Management



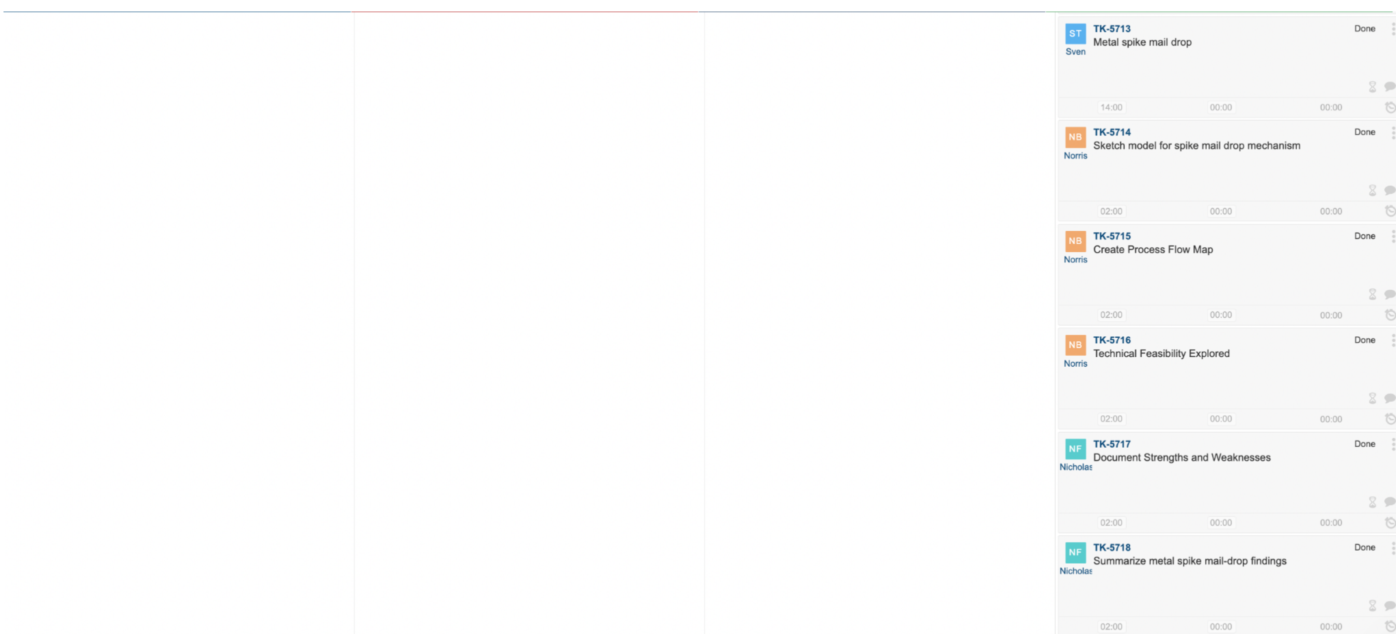



SP-194 Sprint 3
New 0
In Progress 0
DONE 8
E:15 R:0 S:0
User Stories
Add User Story
1 US-1352
Refine Potential Solutions
Unassig
E: 06:00 R: 00:00 S: 00:00
RL-63 City of Helena Recycling Flow ...
Completed
Issue
Task
TK-5541 Check in with Professor Cook
Done
Unassig
04:00 00:00 00:00
TK-5549 Solutions to pursue further selected and documented from client feedback
Done
02:00 00:00 00:00
2 US-1362
Communicate results and get feedback
Unassig
E: 09:00 R: 00:00 S: 00:00
RL-63 City of Helena Recycling Flow ...
Completed
Issue
Task
TK-5543 Develop concept outline
Done
Sven
TK-5544 Derive Slide Content
Done
Sven
TK-5545 Create Slides
Done
Norris
TK-5546 Practice Presentation
Done
Unassig
TK-5547 Give Presentation
Done
Unassig
01:00 00:00 00:00
TK-5548 Synthesize Client Feedback
Done
Unassig
00:00 00:00 00:00

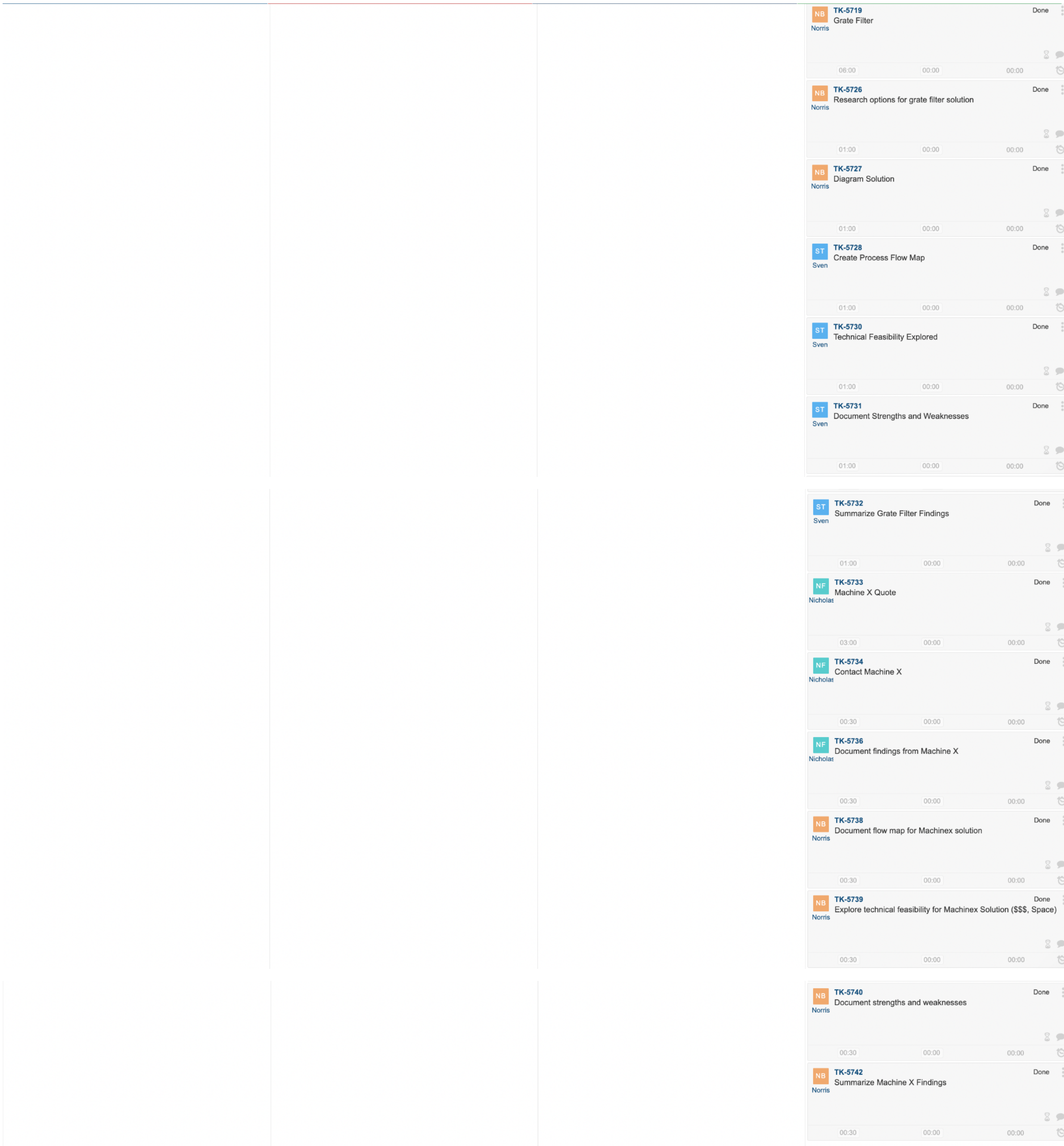

SP-195 Sprint 4
New 0
In Progress 0
DONE 32
E:61 R:0 S:0
User Stories
Sprint 4
Add User Story
1 US-1351
Ideate alternative solutions
Unassig
E: 61:00 R: 00:00 S: 00:00
RL-63 City of Helena Recycling Flow ...
Completed
Issue
Task
TK-5680 Sprint 4 plan
Done
Norris
02:00 00:00 00:00
TK-5683 Check in with Professor Cook
Done
Norris
01:00 00:00 00:00
TK-5688 Invite City of Helena Recycling to Presentation
Done
Norris
01:00 00:00 00:00
TK-5689 Create Presentation Outline
Done
Nicholas
01:00 00:00 00:00
TK-5690 Draft Presentation Outline
Done
Sven
02:00 00:00 00:00
TK-5691 Finalize Presentation Slide Deck
Done
Norris
02:00 00:00 00:00

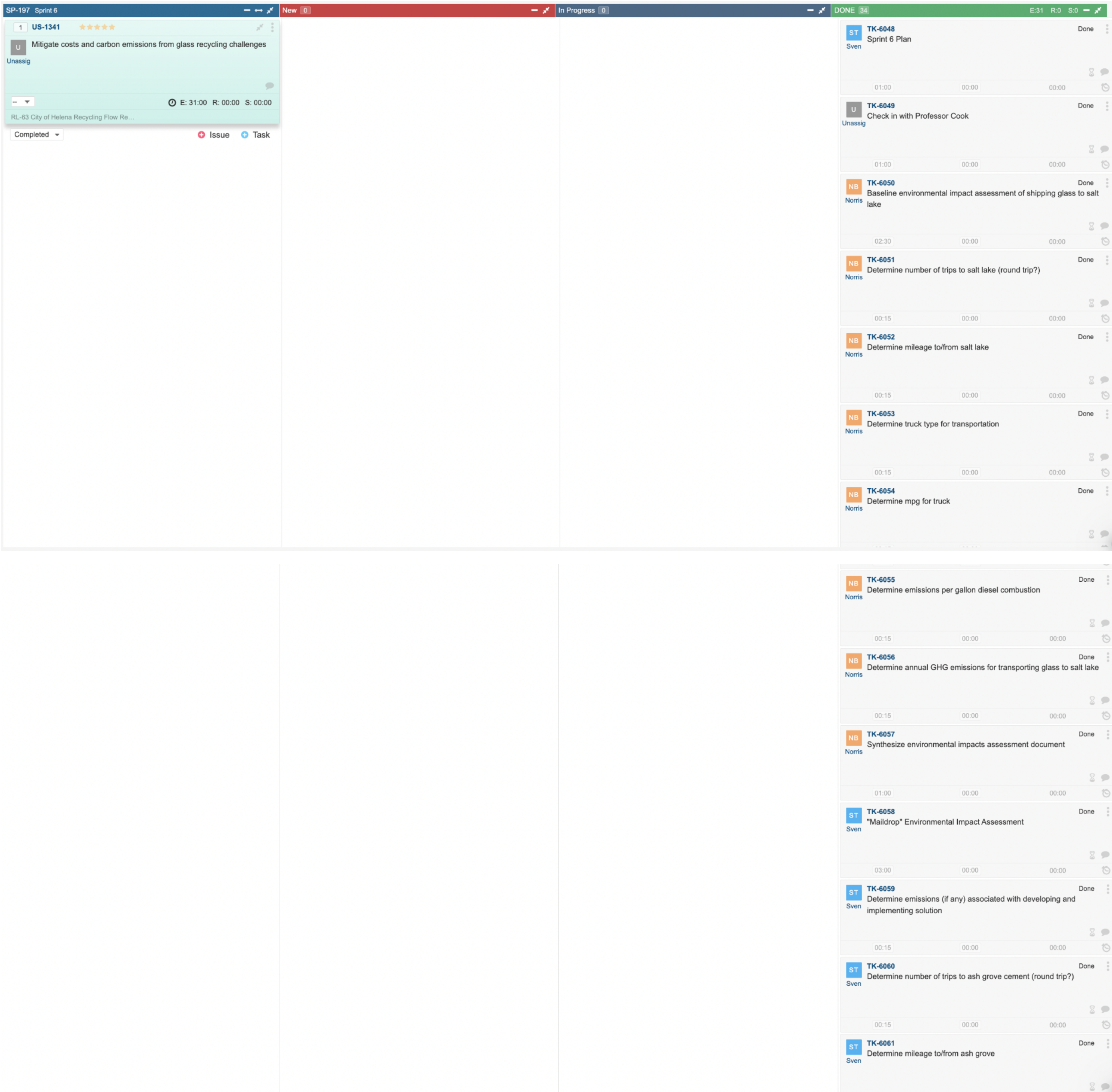


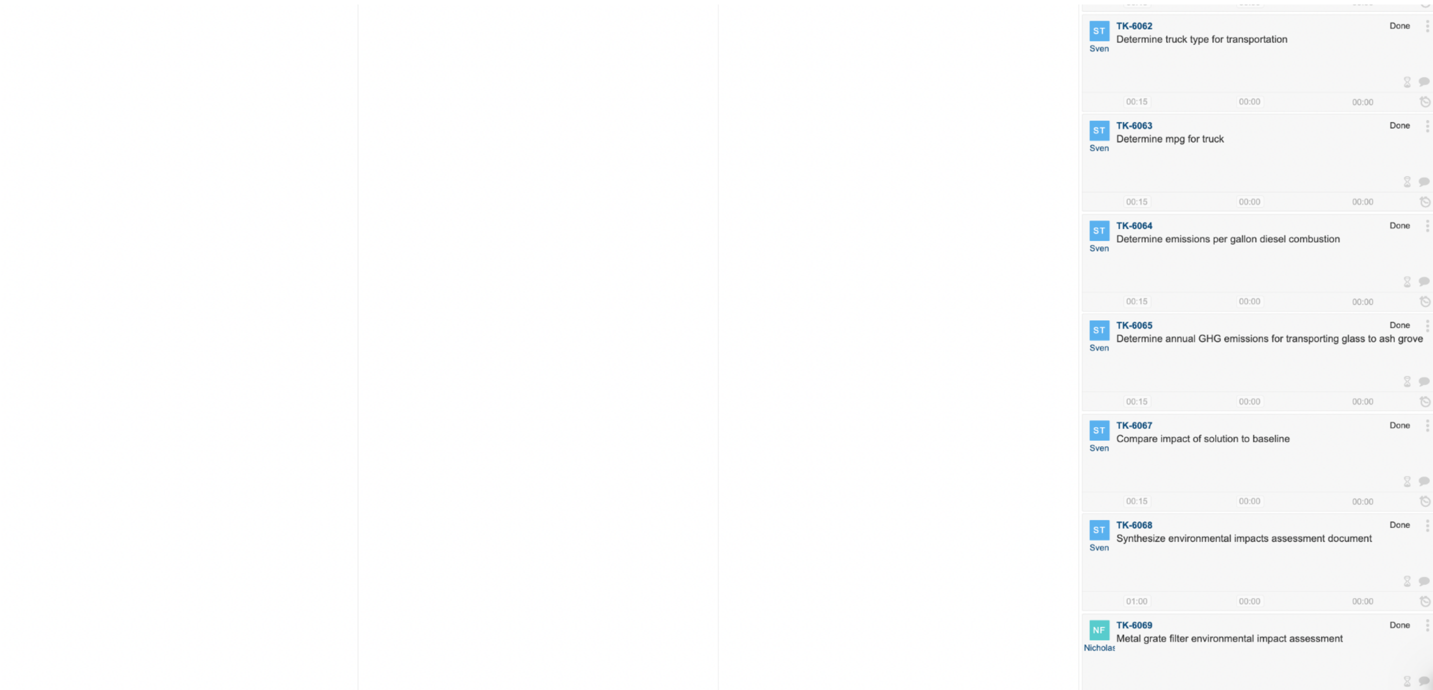
NF
Nicholas
TK-5693
Write-up speaker notes
Done
02:00
00:00
00:00
ST
Sven
TK-5695
Divide Presentation Content
Done
02:00
00:00
00:00
NB
Norris
TK-5698
Practice Presentation
Done
00:00
00:00
00:00
ST
Sven
TK-5699
Deliver Presentation
Done
02:00
00:00
00:00
ST
Sven
TK-5711
Research options for mail drop solution
Done
02:00
00:00
00:00
ST
Sven
TK-5712
Research tools for plastic flow regulator removal
Done
02:00
00:00
00:00

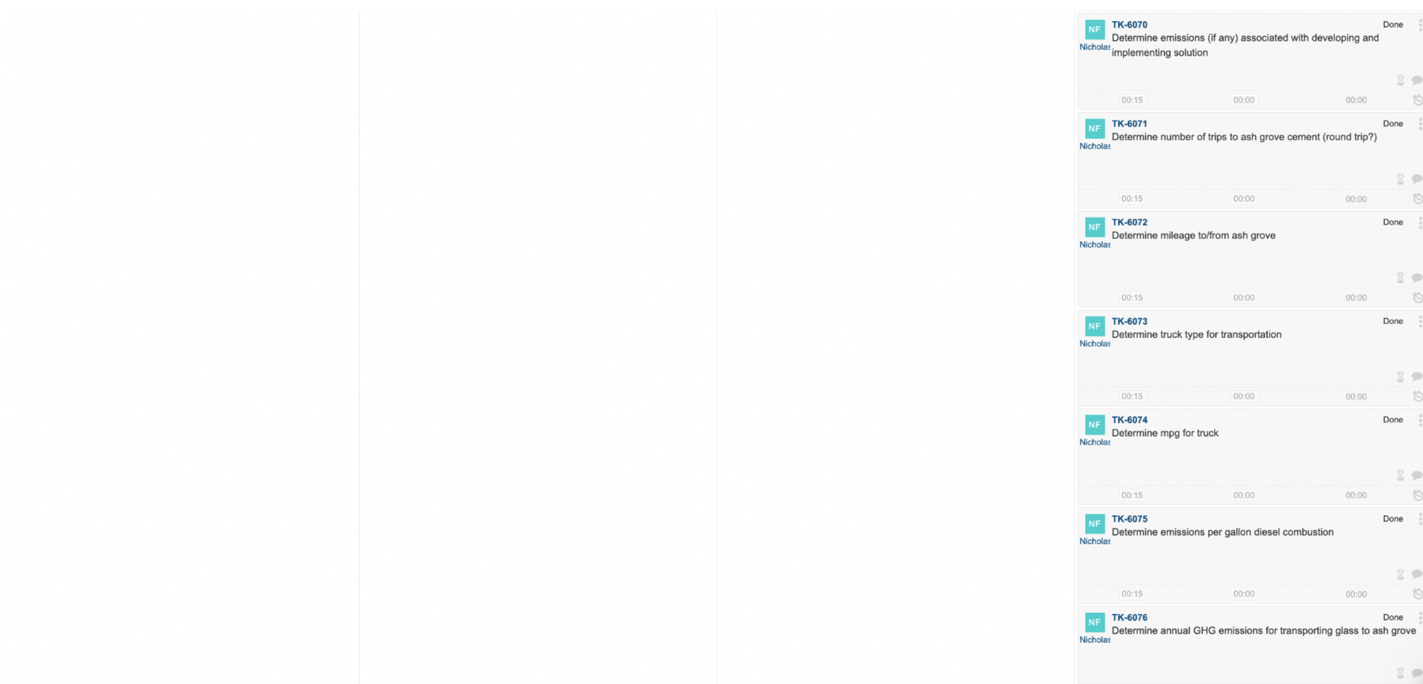


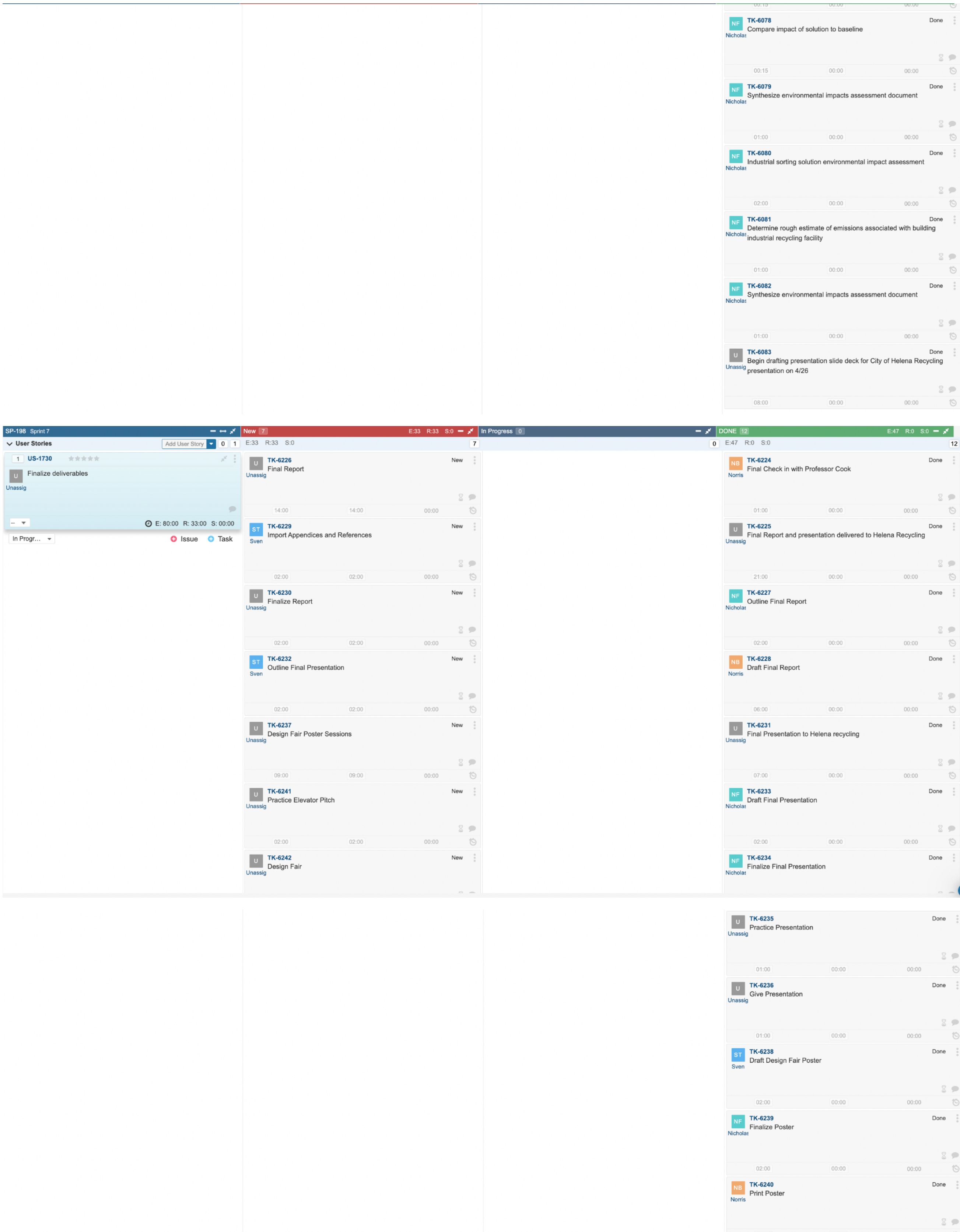
ST
Sven
TK-5713
Metal spike mail drop
Done
14:00
00:00
00:00
NB
Norris
TK-5714
Sketch model for spike mail drop mechanism
Done
02:00
00:00
00:00
NB
Norris
TK-5715
Create Process Flow Map
Done
02:00
00:00
00:00
NB
Norris
TK-5716
Technical Feasibility Explored
Done
02:00
00:00
00:00
NF
Nicholas
TK-5717
Document Strengths and Weaknesses
Done
02:00
00:00
00:00
NF
Nicholas
TK-5718
Summarize metal spike mail-drop findings
Done
02:00
00:00
00:00


NB
Norris
TK-5719
Grate Filter
Done
06:00
00:00
00:00
NB
Norris
TK-5726
Research options for grate filter solution
Done
01:00
00:00
00:00
NB
Norris
TK-5727
Diagram Solution
Done
01:00
00:00
00:00
ST
Sven
TK-5728
Create Process Flow Map
Done
01:00
00:00
00:00
ST
Sven
TK-5730
Technical Feasibility Explored
Done
01:00
00:00
00:00
ST
Sven
TK-5731
Document Strengths and Weaknesses
Done
01:00
00:00
00:00
ST
Sven
TK-5732
Summarize Grate Filter Findings
Done
01:00
00:00
00:00
NF
Nicholas
TK-5733
Machine X Quote
Done
03:00
00:00
00:00
NF
Nicholas
TK-5734
Contact Machine X
Done
00:30
00:00
00:00
NF
Nicholas
TK-5736
Document findings from Machine X
Done
00:30
00:00
00:00
NB
Norris
TK-5738
Document flow map for Machinex solution
Done
00:30
00:00
00:00
NB
Norris
TK-5739
Explore technical feasibility for Machinex Solution ($$$, Space)
Done
00:30
00:00
00:00
NB
Norris
TK-5740
Document strengths and weaknesses
Done
00:30
00:00
00:00
NB
Norris
TK-5742
Summarize Machine X Findings
Done
00:30
00:00
00:00


SP-197 Sprint 6
New 0
In Progress 0
DONE 34
E:31 R:0 S:0
1 US-1341
Mitigate costs and carbon emissions from glass recycling challenges
Unassig
E: 31:00 R: 00:00 S: 00:00
RL-63 City of Helena Recycling Flow Re...
Completed
Issue
Task
TK-6048 Done
Sprint 6 Plan
Sven
01:00 00:00 00:00
TK-6049 Done
Check in with Professor Cook
Unassig
01:00 00:00 00:00
TK-6050 Done
Baseline environmental impact assessment of shipping glass to salt lake
Norris
02:30 00:00 00:00
TK-6051 Done
Determine number of trips to salt lake (round trip?)
Norris
00:15 00:00 00:00
TK-6052 Done
Determine mileage to/from salt lake
Norris
00:15 00:00 00:00
TK-6053 Done
Determine truck type for transportation
Norris
00:15 00:00 00:00
TK-6054 Done
Determine mpg for truck
Norris
TK-6055 Done
Determine emissions per gallon diesel combustion
Norris
00:15 00:00 00:00
TK-6056 Done
Determine annual GHG emissions for transporting glass to salt lake
Norris
00:15 00:00 00:00
TK-6057 Done
Synthesize environmental impacts assessment document
Norris
01:00 00:00 00:00
TK-6058 Done
"Maildrop" Environmental Impact Assessment
Sven
03:00 00:00 00:00
TK-6059 Done
Determine emissions (if any) associated with developing and implementing solution
Sven
00:15 00:00 00:00
TK-6060 Done
Determine number of trips to ash grove cement (round trip?)
Sven
00:15 00:00 00:00
TK-6061 Done
Determine mileage to/from ash grove
Sven


ST Sven
TK-6062
Determine truck type for transportation
Done
00:15 00:00 00:00
ST Sven
TK-6063
Determine mpg for truck
Done
00:15 00:00 00:00
ST Sven
TK-6064
Determine emissions per gallon diesel combustion
Done
00:15 00:00 00:00
ST Sven
TK-6065
Determine annual GHG emissions for transporting glass to ash grove
Done
00:15 00:00 00:00
ST Sven
TK-6067
Compare impact of solution to baseline
Done
00:15 00:00 00:00
ST Sven
TK-6068
Synthesize environmental impacts assessment document
Done
01:00 00:00 00:00
NF Nicholas
TK-6069
Metal grate filter environmental impact assessment
Done


NF Nicholas
TK-6070
Determine emissions (if any) associated with developing and implementing solution
Done
00:15 00:00 00:00
NF Nicholas
TK-6071
Determine number of trips to ash grove cement (round trip?)
Done
00:15 00:00 00:00
NF Nicholas
TK-6072
Determine mileage to/from ash grove
Done
00:15 00:00 00:00
NF Nicholas
TK-6073
Determine truck type for transportation
Done
00:15 00:00 00:00
NF Nicholas
TK-6074
Determine mpg for truck
Done
00:15 00:00 00:00
NF Nicholas
TK-6075
Determine emissions per gallon diesel combustion
Done
00:15 00:00 00:00
NF Nicholas
TK-6076
Determine annual GHG emissions for transporting glass to ash grove
Done



TK-6078
Compare impact of solution to baseline
Done
Nicholas
TK-6079
Synthesize environmental impacts assessment document
Done
Nicholas
TK-6080
Industrial sorting solution environmental impact assessment
Done
Nicholas
TK-6081
Determine rough estimate of emissions associated with building industrial recycling facility
Done
Nicholas
TK-6082
Synthesize environmental impacts assessment document
Done
Nicholas
TK-6083
Begin drafting presentation slide deck for City of Helena Recycling presentation on 4/26
Done
Unassig
SP-198 Sprint 7
User Stories
Add User Story
US-1730
Finalize deliverables
Unassig
E: 80:00 R: 33:00 S: 00:00
In Progr...
Issue
Task
New 7
E:33 R:33 S:0
In Progress 0
DONE 12
E:47 R:0 S:0
TK-6226
Final Report
New
Unassig
TK-6229
Import Appendices and References
New
Sven
TK-6230
Finalize Report
New
Unassig
TK-6232
Outline Final Presentation
New
Sven
TK-6237
Design Fair Poster Sessions
New
Unassig
TK-6241
Practice Elevator Pitch
New
Unassig
TK-6242
Design Fair
New
Unassig
TK-6224
Final Check in with Professor Cook
Done
Norris
TK-6225
Final Report and presentation delivered to Helena Recycling
Done
Unassig
TK-6227
Outline Final Report
Done
Nicholas
TK-6228
Draft Final Report
Done
Norris
TK-6231
Final Presentation to Helena recycling
Done
Unassig
TK-6233
Draft Final Presentation
Done
Nicholas
TK-6234
Finalize Final Presentation
Done
Nicholas
TK-6235
Practice Presentation
Done
Unassig
TK-6236
Give Presentation
Done
Unassig
TK-6238
Draft Design Fair Poster
Done
Sven
TK-6239
Finalize Poster
Done
Nicholas
TK-6240
Print Poster
Done
Norris