Solar Wax Melter with 3D Printed Molds

Designed for SCRAP Humboldt

5/8/2013

Team Super Star

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Humboldt State University

ENGR 215-Spring 2013

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Problem Formulation

1. Introduction

The Problem Formulation section lays forth the introduction of the client, the objective statement which outlines the goal of the project and the black box model. In Figure 1.1 the Black Box Model illustrates the world before and after implementation of our design project.

The client is SCRAP Humboldt, a nonprofit organization dedicated to creative reuse located in Arcata, California. The project is structured on the base principle of SCRAP Humboldt's mission statement "…inspire creative reuse and environmentally sustainable behavior by providing educational programs and affordable materials to the community." (SCRAP)

2. Objective

The objective of this project is to creatively reduce the amount of material waste in Humboldt County. This is to be accomplished using a customized 3D object to transform a waste material into a functional product, thus reducing the need for newly fabricated material.

3. Black Box Model

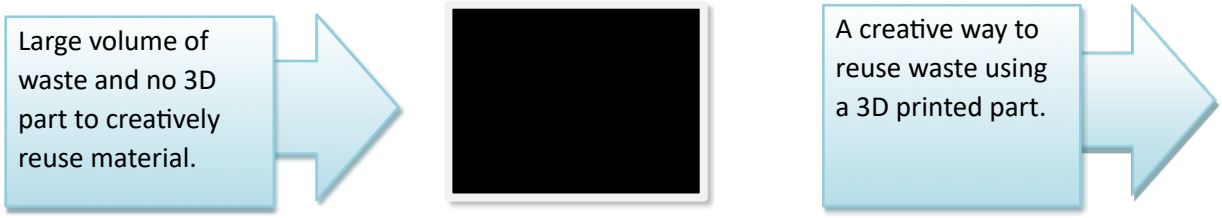

Figure 1.1, the Black Box Model, shows the world before and after implementation of the design.

2. Problem Analysis

2.1. Literature Review

The preliminary literature review is designed to gain an understanding of many potential aspects of the project. Design decisions are not made, however the information presented will assist in finalizing designs.

2.2. Introduction

The following literature review is the preliminary research regarding the design project for Humboldt SCRAP, as a part of the spring 2013 Engineering 215 class. This document references 3D printed objects. Technological developments have made it possible to design and object in a digital 3D graphic designer (CAD programs) and send a digital file to a printer. It is then translated in horizontal layers and formed in plastic. This review focuses on electronic waste (e-waste) and old media types such as vinyl records and cassette tapes, and the potential projects and hazards involved with up-cycling and reusing each material.

2.3. Client Criteria

The client is SCRAP Humboldt, a non-profit organization operated by co-directors Tibora Bea Girczyc-Blum, Patti Johnson, and Spring Garrett. Their mission statement: "inspire creative reuse and environmentally sustainable behavior by providing educational programs and affordable materials to the community." (scraphumboldt.org) The project for SCRAP Humboldt is to use a 3D printed object to easily transform used materials into valuable objects again.

2.3.1. Client Interview, 2/22/2013

Friday 2/22/2013, an initial interview was held with Tibora to outline the design project. Ky Wagner and Mary Krieger attended as representatives of SuperStar.

The design is to be applicable to Humboldt as well as adaptable for a global use. Either function or education should be the focus.

The goal is to easily transform a single or collection of used materials with a small, inexpensive 3D printed object. The piece should be a customized object currently unavailable. It would be beneficial if it was possible to carve the piece from wood or construct from other materials. The 3D object should be a functional portion which integral to the transformation of the material. Also to invest less money and energy than the finished product is valued.

The products of this design are intended be available on open sources (such as Appropedia). The idea was proposed that SCRAP Humboldt could sell the inexpensive integral part and free instructions, also to offer workshops to build product.

Ideas to use old media, printer feet, bottle caps, black heavy duty paper clips, records, samples, (should go to look at their storage units to see what is available) things that are traditionally difficult to up-cycle.

The materials used should not be downgraded or down-cycled so that after the materials have 'lived their second lives' the object can be taken apart to be recycled or reused again.

Places to look for materials and inspiration; let SCRAP Humboldt know for specific materials to request in donations. Raft in San Jose – a teacher resource, Freecycle.com/org , craigslist, and local businesses.

2.4. 3D Printing

3D printing (also known as a rapid prototyping) is an emerging technology that can form solid 3D objects by layering plastic from a CAD (Computer Aided Design) file. Although this process has been around for many years, it is now becoming available for consumers, opening up many possibilities for new products and customized tools (Pearce, 2010). The most common personal 3D printer is the MakerBot. The more professional rapid prototype Humboldt State University has accesses to is a Stratuss, a sub company of HP.The difference between these two devices is the quality of it finished product, also called its resolution. The quality of these prints is measured in microns. The Makerbot can print at a resolution of 100 microns while the printer we will be using prints at 254 microns (Makerbot 2013).

2.4.1. ABS Plastics

Acrylonitrile Butadiene Styrene Plastic, also known as ABS Plastic, is used in Humboldt State University's 3D printer. The plastic is normally injection molded and is used in piping, toys, medical devices, musical instruments, and golf clubs. It is resistant to most acids, alkalis, and oils. However, ABS plastics break down in sunlight, making them not ideal for exposed outdoor locations. The forming temperature is relatively high for a plastic, making it ideal for rapid prototyping (3D printing). It is relatively toxic, it will release Volatile Organic Compounds (VOCs) when burned, and the only toxic fume is hydrogen cyanide. (Rutkowski, 1986). ABS is also recyclable (Plastics Recycling, 2011).

2.4.2. PLA Plastics

Polylactic acid, or PLA, is an easier print material to work with for the Makerbot Replicator (Deutsch, 2012). PLA and ABS plastic are the same price; $48.00/Kg (MakerBot Industries, 2011). PLA has a lower melting point, so printers that use it have lower resolution (Anders Södergård, 2012). PLA is a more environmentally friendly option. It is made from cornstarch.

2.5. The need and benefit of reuse

The state of California generates about 78 million tons of waste a year (Calrecycle, 2009). As a commitment to divert waste from landfills, The Integrated Waste Management Act of 1989, known as AB 939 requires cities, counties and regional agency to annually divert 50 percent of their municipal solid waste from landfills (Calrecycle, 2009). Reuse requires fewer resources, less energy and less labor compared to recycling, disposal or the manufacture of new product from virgin materials. Reusers, with little or no processing, keep waste materials out of the waste stream by passing the goods they collect on to other (Crosson, 2012).

2.6. Common Waste Materials

The following is a list of materials in the waste stream that are commonly found in high volumes. Some creative reuse ideas and potential complications associated with the materials are presented.

2.6.1. Wood Waste

In California, about thirty percent of approximately 3.8 million tons of wood waste entering the waste stream come from used lumber, wood trim, shipping pallets and organic materials. The most desirable option for wood waste management would be for re-use (Calcycle, 2009).

2.6.1.1. Commercial Reuse

ArborPellet is a company that makes wood pellets for residential heating. The fibers used are largely from urban wood waste, generally in form of wood pallets used for shipping. Around one million U.S. homes are being heated by wood pallets, according to the Pellet Fuels Institute (Allred, 2011). Other uses for recycled wood waste or organics can be used as feedstock for engineered woods, landscape mulch, soil conditioner, animal bedding, compost additive, sewage sludge and boiler fuel. (Calcycle, 2009)

Figure 21: Small mountain of shipping pallets at the ArborPallet plant https://www.forestbusinessnetwork.com/2241/wood-pellets-a-growing-industry/

2.6.1.2. Creative Reuse

Once carefully and safely select the wood waste to make sure they're free of toxic chemical, the idea for creative reuse are limitless

2.6.1.2.1. Furniture

The wood waste, such as shipping pellets, can be cleaned, painted and redesigned to be functional items such as coffee table, bed frame, pallet swing chair and even a picnic table (Shayla, 2011)

Figure 22: Shipping pallet painted lime green and used as coffee table
http://www.designfinch.com/2011/05/21/family-room-makeover/

2.6.1.2.2. Pallet Garden

This creative reuse not only takes the wood waste out of the waste stream it also adds green space for the homes and offices. The supplies needed are the shipping pallets, 2 large bags of potting soils, 16 packs of annual flowers, a small roll of landscape fabric, a staple gun, staples and sand paper. (Fern, 2011)

Figure 23: Wood pallet can be use as garden for small urban space
http://lifeonthebalcony.com/how-to-turn-a-pallet-into-a-garden/#more-4806

2.7. Green Space

Green space is a term for natural landscapes or planted environments within a city. Most cities have numerous green spaces; the most obvious being parks and trails that the general population can visit.

2.7.1. Health Benefits of Green Space

Due to the multiple health benefits related to living in a community with more green space it has been found that there is relationship between green space areas and an increase in psychological and physical health.

2.7.1.1. Psychological Health

There appears to be a correlation between the reduction of stress and anxiety for people who live within a one kilometer radius of, more than usual, green space. There was also a significant correlation between the total reductions of reported depression by people who live within similar one kilometer area. (JECH, 2009). The tables below show the effects of green space for a population with minimal green space, a population with ten percent more green space, and a population for ninety percent more green space. This shows that the presence of increased green space may have a direct impact on a person's or a communities overall psychological health.

Cluster	ICPC codes	N (abs)	Per 1000
Cardiovascular			
High blood pressure (n = 273 925)	K85 K86 K87	24778	90.5
Cardiac disease	K71 K73 K74 K77 K78 K79 K80 K81 K82 K83 K84	9044	26.2
Coronary heart disease (n = 240 825)	K74 K75 K76	5804	24.1
Stroke, brain haemorrhage (n = 240 825)	K89 K90	2549	10.6
Musculoskeletal			
Neck and back complaints	L01 L02 L03 L84 L86	32346	93.7
Severe back complaints	L02 L03 L85 L86	25230	73.1
Severe neck and shoulder complaints	L01 L08 L83 L92	21236	61.5
Severe elbow, wrist and hand complaints	L10 L11 L12 L72 L74	7698	22.3
Osteoarthritis (n = 240 825)	L89 L90 L91	4521	18.8
Arthritis (n = 240 825)	L88 T92	3170	13.2
Mental			
Depression	P03 P76	8859	25.7
Anxiety disorder	P01 P74	8033	23.3
Respiratory			
Upper respiratory tract infection	A77 R72 R74 R75 R76 R80	31457	91.1
Bronchi(oli)tis/pneumonia	R78 R81	10806	31.3
Asthma, COPD	R91 R95 R96	12813	37.1
Neurological			
Migraine/severe headache	N01 N02 N03 N89 N90 N92	10629	30.8
Vertigo	N17	4023	11.7
Digestive			
Severe intestinal complaints	D81 D85 D86 D92 D93 D94	5264	15.3
Infectious disease of the intestinal canal	D70 D73	3816	11.1
Miscellaneous			
MUPS	A01 A04 D01 D08 D09 D12 D18 D21 D93 K01 K02 K04 L01 L02 L03 L08 L09 L14 L20 N01 N02 N17 P06 P20 R02 R21 T03 T07 T08	75774	219.5
Chronic eczema	S86 S87 S88	22303	64.6
Acute urinary tract infection	U70 U71 U72	13303	38.5
Diabetes (n = 290 479)	T88 T90	9260	31.9
Cancer	A79 B72 B73 B74 D74 D75 D76 D77 F74 H75 K72 L71 N74 R84 R85 S77 S80 T71 T73 U75 U76 U77 U79 W72 X75 X76 X77 X81 Y77 Y78	6086	17.6

Figure:2-4 Population with Minimal Green Space (JECH, 2009)
http://jech.bmj.com/content/63/12/967.full.pdf+html

Cluster	Prevalence per 1000	
	10% green space	90% green space
Cardiovascular		
High blood pressure	23.8	22.4
Cardiac disease	4.7	4.0
Coronary heart disease	1.9	1.5
Stroke, brain haemorrhage	0.92	0.76
Musculoskeletal		
Neck and back complaints	125	106
Severe back complaints	99.2	65.8
Severe neck and shoulder complaints	75.6	63.3
Severe elbow, wrist and hand complaints	23.0	19.3
Osteoarthritis	21.8	21.3
Arthritis	6.7	6.2
Mental		
Depression	32	24
Anxiety disorder	26	18
Respiratory		
Upper respiratory tract infection	84	68
Bronchi(oli)tis/pneumonia	16.0	14.7
Asthma, COPD	26	20
Neurological		
Migraine/severe headache	40	34
Vertigo	8.3	6.6
Digestive		
Severe intestinal complaints	14.9	12.3
Infectious disease of the intestinal canal	6.5	5.1
Miscellaneous		
MUPS	237	197
Chronic eczema	5.5	4.9
Acute urinary tract infection	23.2	19.4
Diabetes Mellitus	10	8
Cancer	4.9	4.4

Figure 2-5: Populations with 10% and 90% Increased Green Space (JECH, 2009) http://jech.bmj.com/content/63/12/967.full.pdf+html

2.7.1.2. Physical Health

Areas with more than normal green space tend to promote more physical activity, and therefore, an increase in physical health. For communities that live in lower socioeconomic conditions, the prevalence of green space can lower mortality rates and reduce circulatory disease. (The Lancet, 2008).

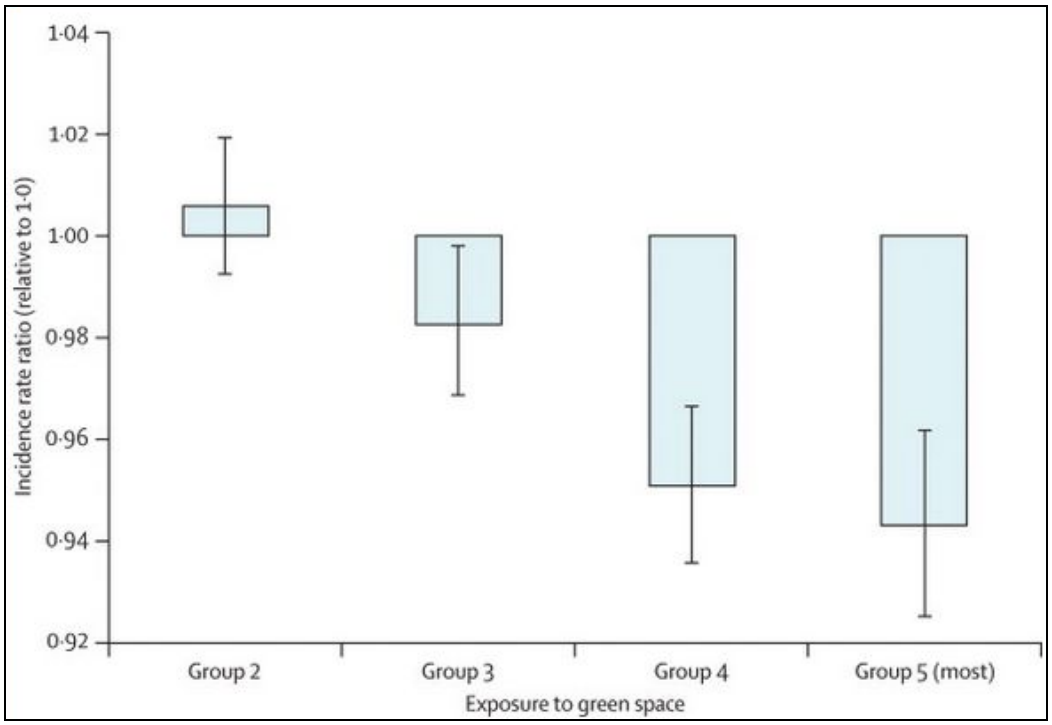

Figure:2- 6: Exposure to Green Space can lower Mortality (The Lancet, 2008) http://www.sciencedirect.com/science/article/pii/S014067360861689X

2.7.2. Environmental Benefits of Green Space

Urban green spaces can provide several environmental benefits as well; these include heat reduction and CO_2 reduction.

2.7.2.1. Heat Reduction

Green spaces within cities promote heat reduction. This is because natural environments can release heat quickly during the night while many building materials release heat at a much slower pace. (Global Environmental Change, 2005)

2.7.2.2. CO_2 Reduction

City green space will help reduce in the total reduction of CO_2 in the atmosphere. This is because large plants, such as trees, absorb more CO_2 during photosynthesis than when they release it during respiration. Also, because city green space can reduce heat (see 1.3.2.1), CO_2 is also reduced due to the reduced use of cooling systems such as air conditioning. (USDA, 1999).

2.7.3. Plastic Waste

According to the EPA, 31 million tons of plastic wastes were generated in 2010, representing 12.4 percent of total MSW. Of that number only about eight percent was recovered for recycling (EPA, 2012).

2.7.3.1. Commercial Reuse

At Argonne, chemist Vilas Pol has devised an environmentally green method that breaks down plastics and transforms them into a highly usable substance. In Dr. Pol's solvent-free process, plastic bags are insert into a specially design reactor and heated to 700 degrees Celsius, forming a black power. The power contains tiny carbon spheres around two to five to 5 micrometers wide and one-twentieth the width of human hair. If a cobalt-base catalyst is added during the heating, the power forms microscopic carbon nanotubes. Both substances have numerous industrial applications. They are used to manufacture lithium-ion batteries, which power cell phones, laptops and other products. The batteries also serve as the power source for electric cars. Moreover, the properties of carbon microspheres make them useful in water purification and the tire industry, as well as in the manufacturer of paint, printer inks and toners. (Argonne National Laboratory, 2012)

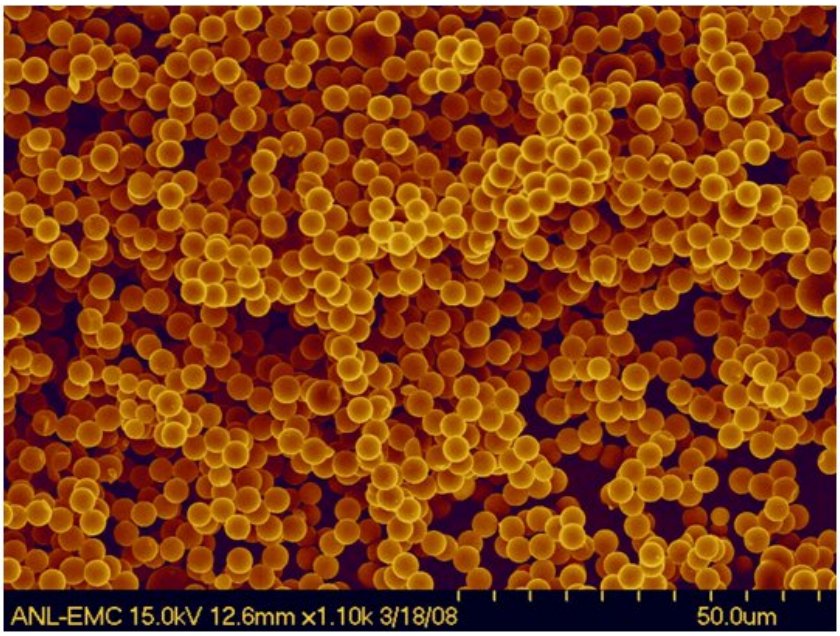

Figure 2-7: Carbon microspheres have numerous industrial applications, ranging from lithium-ion batteries to water purification to printer inks and toners.
http://techportal.eere.energy.gov/technology.do/techID=424

2.7.3.2. Creative Reuse

Plastic can also be easily reused without extra cost to the consumers or the environment by simply turning them into functional household items.

2.7.3.2.1. Juicer

Cut the bottom off some types of two-liter soda bottles and use it to squeeze fresh orange juice and lemonade. (Yeager, 2009)

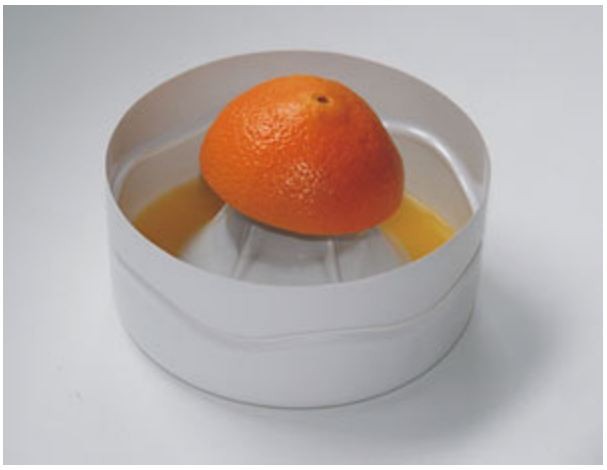

Figure 8: DIY juicer
http://www.thedailygreen.com/living-green/blogs/save-money/reuse-plastic-bottles-460709

2.7.3.2.2. Toilet Tank Trick

Drop a plastic bottle or two filled with water into the water tank and save a half to a gallon with every flush. (Yeager, 2009)

Figure 29: Save water with every flush by placing water bottle in the tank
http://www.thedailygreen.com/living-green/blogs/save-money/reuse-plastic-bottles-460709

2.7.3.2.3. Magazines and newspapers holder

Few extra bottles connected in one line can make excellent organized shelves for newspapers, magazine, and bills.

Figure 210: Organize bills and newspaper creatively
http://www.squidoo.com/5-creative-ways-to-reuse-plastic-bottles-and-jugs

2.7.3.2.4. Fused Plastic bags

This is the process of layering seven or eight disposable store bags and heating them together with an iron. The finished product is a stronger, more durable plastic which can be used to make re-usable totes, wallets and floor cushions. It's also an inexpensive way to make waterproof linings for beach bags and make up clutches. (Amanda, 2007)

Figure 2-11: Stronger reusable bag made from disposable store bags

2.7.3.2.5. Plarn

Plastic bags made into usable yarn = Plarn. Plarn is a creative way to recycle plastic bags by turning it into yarn, which then used to crochet and knit all sort of item such as rugs, sculptures, bags or even clothes.

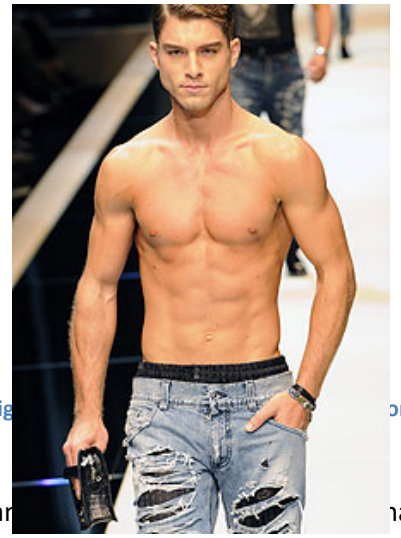

Fig omen

2.8. E-waste

There is an ever increasing ar nased and therefor a constant increase of electronics in the waste stream. Recycling electronics is inherently difficult due to the combinations of valuable metals and materials and toxic compounds. There are ways to recycle and decommission e-waste which is not harmful to humans, however most of the recycling plants are located in countries which do not have strict hazardous waste disposal laws and pose a hazard to those who collect and work in recycling facilities. In addition when poor methods of disposal are implemented contamination of soil, water and air is imminent. (Robinson 2009)

Figure 213: Electronic waste pile, most e-waste is exported from the source to less developed countries. http:// www.planetmattersandmore.com/tag/cutting-down-on-e-waste/

2.8.1. Satellite Dishes

The cable company doesn't collect a satellite dish when the customer cancels. The responsibility for disposing of the dish is that of the owner, industrial official said, since the dish become the property of the customer when the service was subscribed (Macmillan, 2012) Federal guidelines do not regulate circuit boards as hazardous waste, according to the environmental Protection Agency.

Figure 2124 Satellite dishes left behind by cancelled subscribers
http://green.blogs.nytimes.com/2012/07/11/the-satellite-dish-as-triple-threat/

2.9. School and Office Supplies Waste

2.9.1. Crayons

Crayons are made of paraffin, a petroleum-based wax, pigment, and sometimes fragrance and sparkles for the fancier ones. Crayola estimates that the average child wears down 730 crayons by age ten (EPA, 2013). There are crayon recycle program such as, CrazyCrayon, which small bits of crayon maybe send to be reformed and sell to be used again. An organization, Crayon for Cancer, also collect and reformed crayons into fun shapes.

Figure 25: Animal shaped crayons children may collect from the treasure box at the Children hospital.
http://www.crayonsforcancer.org/

3. Search for Alternative Solutions

3.1. Introduction

Section three discusses the possible alternative solutions to solve the problem of excess waste in Humboldt County. Several sessions of brainstorming was conducted by team SuperStar regarding the client's criteria, requests and constraints. Many options were presented and have been narrowed down to seven realistic projects concerning the time constraint of 13 weeks and the available resources. These project ideas are appropriate for the specified criteria and the client's requests. The following sections present the documents and discuss the resulting options in figures and descriptions.

3.2. Brainstorming

The brainstorming sessions happened mostly during group meetings as well as during lab periods. The initial brainstorm brought general ideas about materials in excess in the waste stream. The remaining sessions followed another interview with SCRAP and focused on items of use which could be easily fabricated of simple materials. Throughout the brainstorming sessions the team sought alternative forms of inspiration such as unusual locations, people watching etc. to refrain from channeled thinking. Brainstorming documents can be found in Appendix B.

3.3. Alternative Solutions

The following list refers to the projects proposed by team SuperStar to reduce the waste material in Humboldt County. Each project proposal has a brief explanation of the design and is accompanied by conceptual drawings produced by team members. Proposals are listed in the same order that they are described.

1. Plarn+ Vertical Garden
2. Solstice Sauna
3. Plarn Maker
4. Bag o' Water
5. Parabolic Heater
6. Coin Twist
7. Milk Buoy

3.3.1. Plarn+ Vertical Garden

The Plarn+ Vertical Garden utilized the abundance of wood shipping pallets and grocery store plastic bags. The garden can be made from one wood pallet for a wall display or made from two pallets propping against each other for a freestanding floor display system. The Plarn (plastic + yarn) would be

woven into baskets that would hold the soil or other light weight growing medium for the plants and allow for water to flow through, reducing the concern for mold or rot. A slow drip system would be incorporated into the design for ease of maintenance. The garden can be used as a decorative indoor flower bed or for vegetables and herbs for a healthy option. The size of the vertical garden would follow the standard size of the shipping pallets of 48”x40” according to the Grocery Manufacturers Association (GMA).

As shown in Figure 3.1 the Plarn+ Vertical Garden can add usable green space to a small living or working quarter.

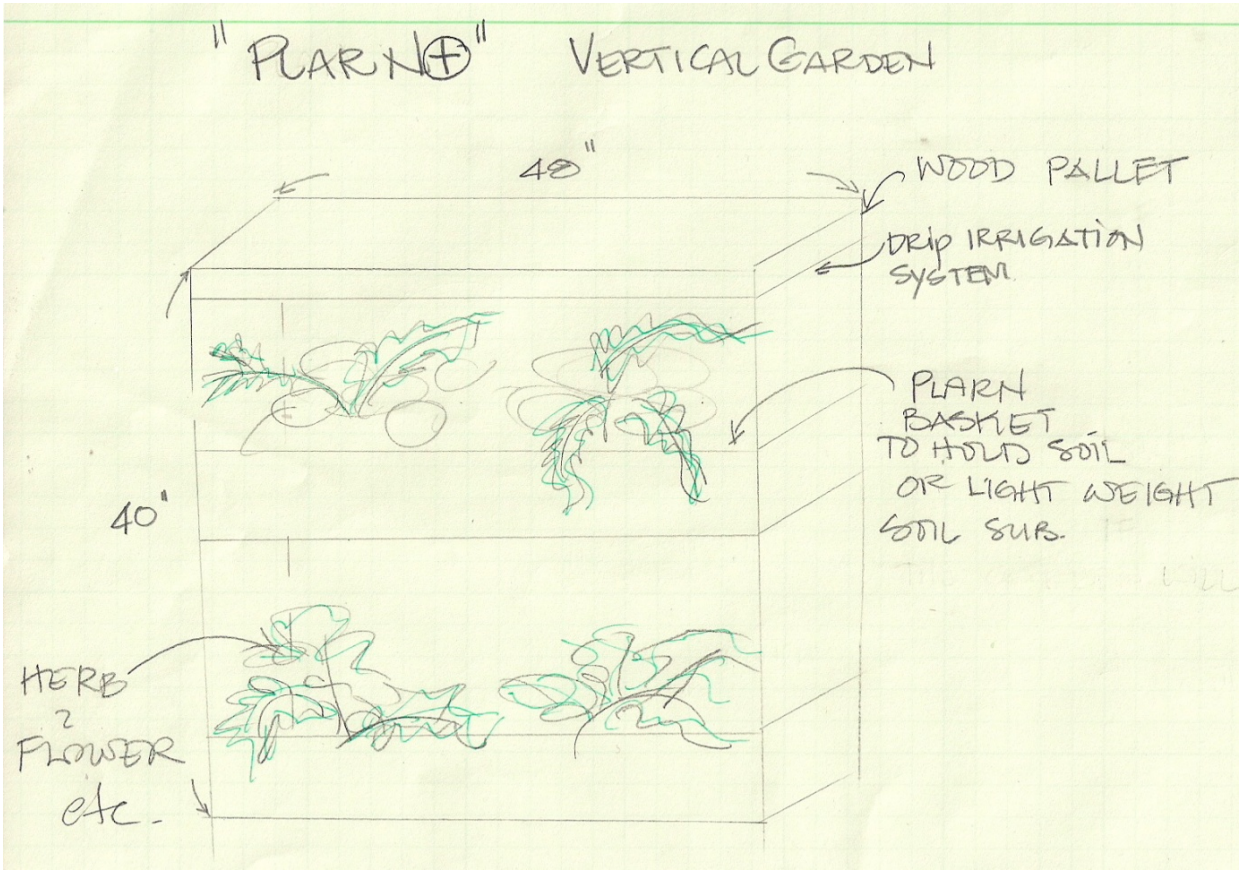

Figure3.1: Plarn+ vertical garden, sketched by Jenny Kunna

3.3.2. Solstice Sauna

The Solstice Sauna is a sauna that operates on the renewable energy of the sun. This sauna combines the open source technology of the flower, harvesting the sun heat using up-cycled materials, and ecoladrillo, found on Appropedia, into an amazing functional and earth-friendly relaxing tool with many health benefits. The walls of the Solstice Sauna are made from glass bottles and plaster. The glass bottle option was considered into the design because of the potential heat used within the sauna.

As shown on Figure 3.2 the solar collector placed on the roof would be the major heat source for the Solstice Sauna. The tutorial and step by step instructions to build the collector can be found at solarflower.org. The finished dimension of the Solstice Sauna is 4'x5'x9'.

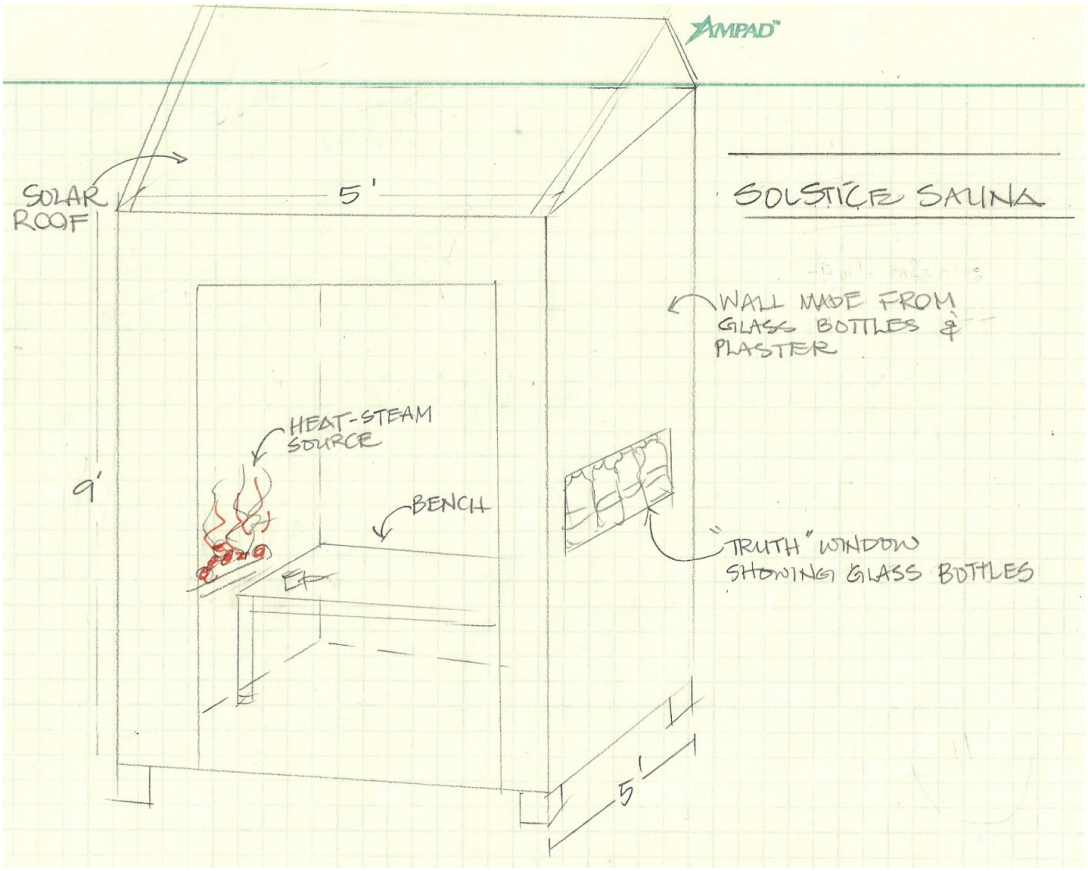

Figure3.2: Solstice Sauna combines the technology of the solar flower and ecoladrillo. Sketched by Jenny Kunna

3.3.3. Plarn Maker

Plarn is plastic bags which have been sliced into one inch strips and tied into a continuous piece to make plastic yarn. This plarn can be used as yarn is to make bags, table covers, floor mats, etc. The Plarn Maker is a machine that enables faster plarn making. The design in Figure 3.3 utilizes a gutted laptop computer skeleton as the case, the older the laptop the larger the case. Binder clips are used to hold several layers of bags inside the computer case at the corners and the lid closes to hold the pile flat. Using a custom handle the row of cutters is scored across the bags to produce one inch strips to be tied to make the plarn. The second aspect of this design would be a simple loom which the plarn strips could be woven by to be made into ropes.

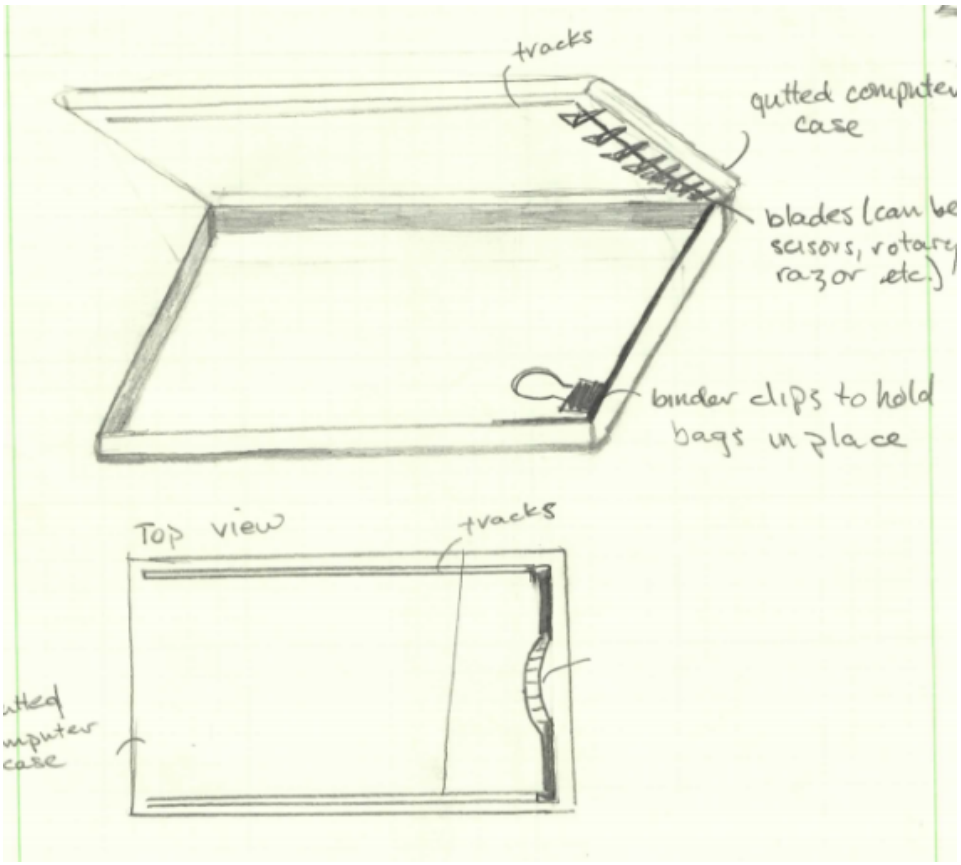

Figure3.3: 'Plarn Maker' combines E-waste and grocery bags. Sketched by Mary Krieger

3.3.4. Bag o' Water

Bag o' water is a design for a variably sized water/beverage container. This design incorporates plastic grocery bags, an old Nalgene lid and a custom 3D printed lip. The customized 3D printed piece is the threaded lip opening that would couple with a standardly sized, reusable screw bottle top, such as a 2L plastic bottle, or Nalgene lid. This piece would nest between layers of fused plastic bags, making a sealed liquid container. Figure 3.4 shows a bottle that could be constructed using a rectangle of fused plastic bags, the specified 3D part and an old Nalgene lid.

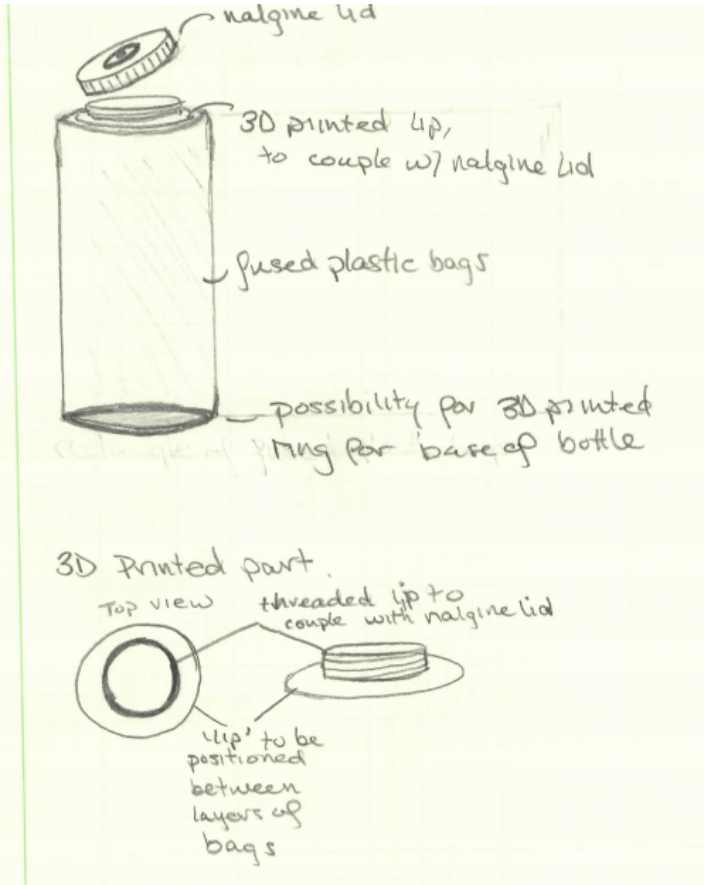

Figure 3.4: Bag o' Water used plastic bags and screw top lids to make new bottles. Sketched by Mary Krieger

3.3.5. Parabolic Heater

The Satellite Dish Parabolic Water Heater was thought up during a group brainstorming session while discussing the possibility of a solar hot water heater. Many different methods of building parabolic solar heaters have been attempted and so instructions for many different designs are readily available. When the idea was pitched to the client, SCRAP Humboldt, it was met with enthusiasm due to the client's knowledge of an excess of satellite dishes in Humboldt County, in reference to a large pile near Redwood Curtain Brewery. The excess comes from the need to upgrades a dish every few years so a customer can enjoy new features that require different equipment. The dishes are not reused and are thrown away after being removed from a building.

The design of the Parabolic Solar Heater, as depicted in Figure 3.5, consists of three major parts. The first is the used satellite dish with a reflective coating. A heat collector is mounted on the existing arm of the dish at its focal point. The final part is the 3D printed mold the hot liquid passes through. This mold is designed for the client specifically and can be used to melt candles or crayons so they can be recast without wasting energy.

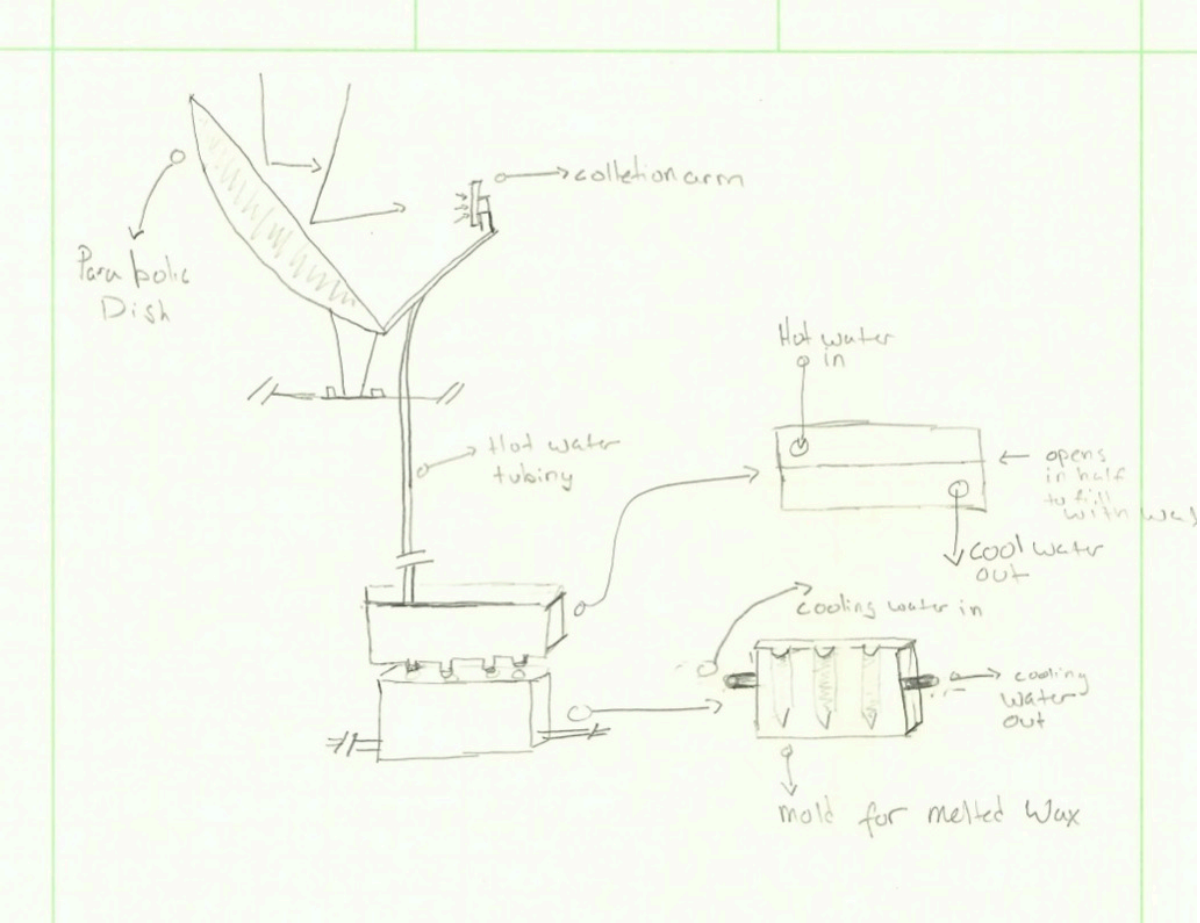

Figure 3.5 The Parabolic Heater, sketched by Ky Wagner

3.3.6. Coin Twist

The Coin Twist presented in Figure 3.6, is a unique device that utilizes the precision of 3-D printed objects and combines it with an interesting mix of up-cycled materials that allows the user to separate excess coins using rotational energy. The Coin Twist consists of four plastic bottles for the coins to be sorted into, and a 3D printed part with differently sized openings to allow for the specific coin to pass through.

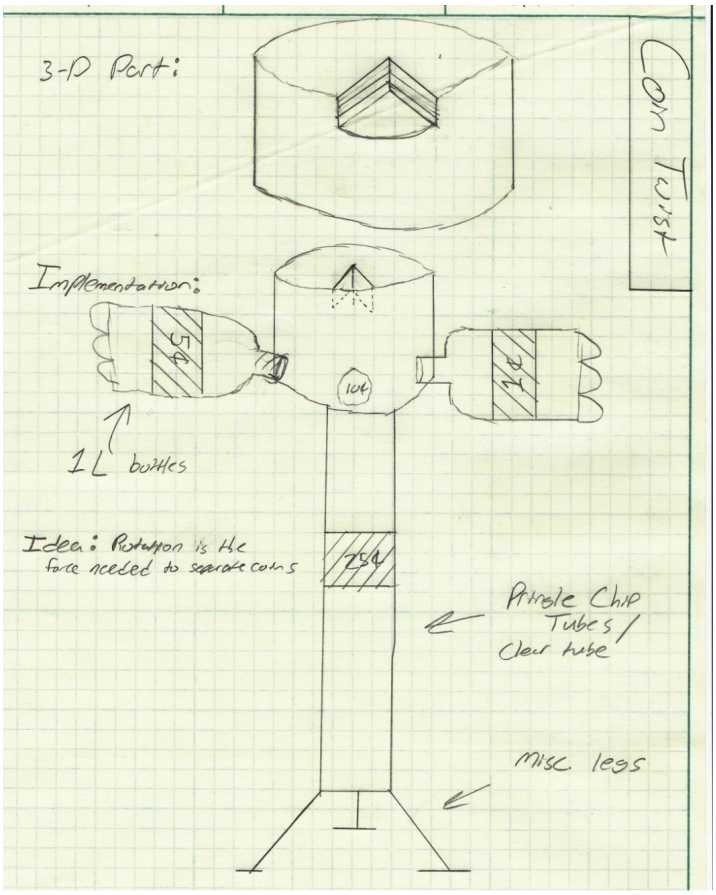

Figure 3.6: The Coin Twist- sketched by Josh Martinez- shows a coin sorter that works off of rotational energy.

3.3.7. Milk Buoy

The goal of the Milk Buoy design is replace standard pool dividers with the substitute of up-cycled gallon milk jugs, or other large plastic bottles such as 2L bottles. This simple design shown in Figure 3.7 seals the milk gallon with the 3-D printed part, which also functions as a loop so that strings of these components can be attached.

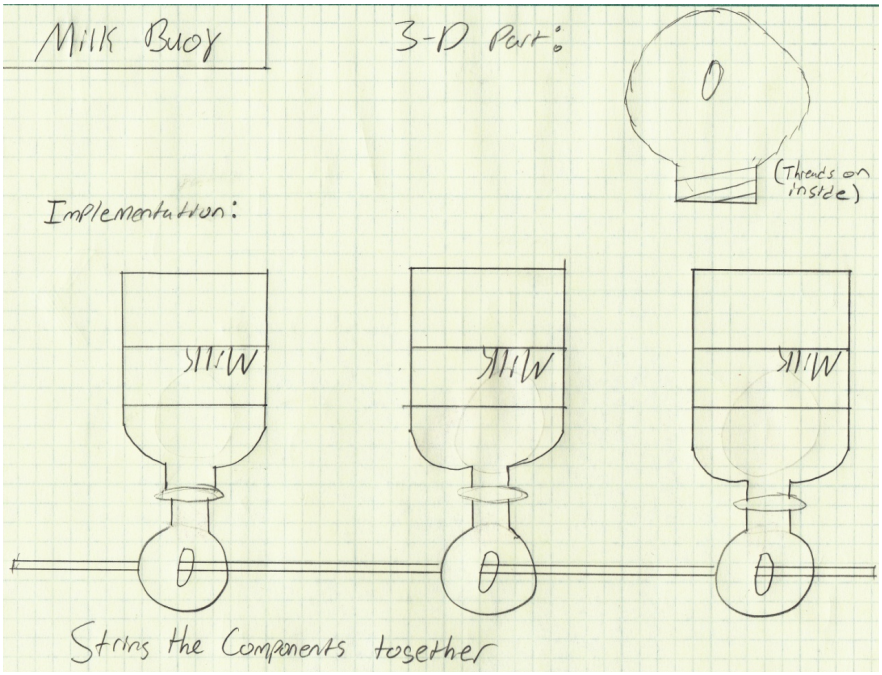

Figure 3.7: The Milk Buoy-sketched by Josh Martinez- displays a pool divider made from the common waste item milk gallons.

4. Decision Phase

4.1. Introduction

After proposing several solutions that met the criteria a final project was chosen. The team utilized the Delphi method which weighs the criteria previously discussed to select the final project solution. The final decision has been carefully chosen by the team to resonate with the client's mission of creative reuse. The problem analysis, literature review, alternative solutions and the client feedback were taken into careful consideration during this process.

4.2. Criteria Definition

The criteria presented in Section 2 are defined below and are used to establish the best alternative solution for SCRAP Humboldt. The criteria used to evaluate our project are as follows:

- Aesthetics: Must be a marketable product, comparable to a similar product made of new materials.
- Reusability: The materials used in the final project should not be down-graded in that the materials are still reusable or recyclable after the intended reuse.
- Replicatability: The final product should be easily reproduced, meaning that the materials and procedures used in construction are simple, safe, require few tools and can be made by anyone age 16 and up.
- Functionality: The product should be a useful object, having one or more specific uses as well more than a 'one time use' object.
- Durability: Final constructed product should be able to survive outdoor conditions for at least two years.
- Ease of Use: The product should be constructed in a way that enables use by all ages, including children with adult supervision.
- Level of upcycle: The product, and project materials, should be at least 75 per cent up-cycled materials or materials removed from the waste stream.
- Cost: Ideally the cost to make the product should be no greater than $ 20.00; this includes other materials purchased and the 3D printed part.
- Accessibility: The final product will be available on Appropedia for open source information sharing and to promote awareness of reuse and the waste stream. It is intended to make the project available on other open source sites as well.

4.3. Decision Process

The criteria were weighted from zero-to-ten by team consensus, ten being the most important and zero being the least important. Each solution was then given a score on how well it met the criteria between zero-and-fifty also by team consensus, fifty being the best fit. The weight was then multiplied against the score and then added to get a total score for each solution. The total scores were compared and the solution with the highest score would be the final project as it would meet the specified criteria the best.

Table 41: List of Criterion and Constainsts considered to best fit the client's over all mission of creative reuse

Criteria	Constraint	Weight
	Use at least 75% up-cycled materials	10
Safety	Safe for children to be around with supervision	10
Reusability	At least 50% of materials used can be recycled	9
Cost	Less than $20 in materials	8
Aesthetics	Final product should be comparable to a new item	7
Functionality	Have more than one use	5
Accessibility	Enable open sharing (Appropedia, ThingyVerse)	5
Replicability	Anyone 18 years old can reproduce	4

4.4. Final Decision Justification

The Parabolic Heater scored the highest out of all the possible alternative solutions. Because this solution best fit all of our criteria, we chose to select it for our project.

5. Specification of Solution

5.1. Introduction

The specification of solution section covers the final aspect of the design process. The following specifications include cost analysis, a detailed description of the Solar Heater and 3D Printed Molds and a brief construction guide. The cost analysis involves design cost, measured in hours, construction materials purchased and projected maintenance costs. The instruction and implementation section gives details on how the Solar Heater and 3D Printed Molds is intended to be used and the steps needed for the reproduction the device. The performance of the prototype concludes the document.

5.2. Solution Description

The solution is Solar Heater and 3D Printed Molds, which includes a parabolic heater, a thermal syphon, the heat transfer unit, and molds that can be used for making both crayon and candles. Figure 5.1 shows the Solar Heater and 3D Printed Molds on a sunny day melting crayons down to moldable wax to create new custom supplies.

Figure 51 Completed Solar Heater with assorted crayons to be melted. Sun is reflected off the dish and focused down on to the vessel containing wax.

5.2.1. Parabolic Heater

The parabolic heater is the tool for melting the crayon and candle ends. As is shown in Figure 5.2 the parabolic heater is constructed from an old DISH® satellite. The grey finish is removed with sandpaper to expose the underlying metal; the surface is then polished to increase the reflectiveness. A

blackened water container, such as an old pot, is positioned at the focus point to collect the reflected solar energy via boiling water. The heated water is used to melt crayons or candle wax.

Figure 52 Sanding a DISH satellite to expose the reflective metal surface (respiratory and eye protection required).

5.2.2. Thermal transfer unit

A thermal transfer unit was considered, and several experiments were run, but it was determined that there was not a large enough budget and not enough heat generated by the small satellite dish for it to be practical. A thermal transfer unit is made when water being heated is forced through copper tubing, a thermal siphon then moves the water from the focus point to an insulated chamber behind the parabolic heater. A thermal transfer occurs between the water in the copper tubing and a water bath inside the chamber. This water can be used to melt wax from crayons and candles.

5.2.3. Forms and molds

Using design software and the 3-D printer at Humboldt State University custom molds were designed according to the clients specifications. After the candles or crayons have been melted with the Solar Wax Melter the liquid wax is transferred into the forms to cool. These molds are interchangeable between candles and crayons, further reducing the amount of waste produced in Humboldt County.

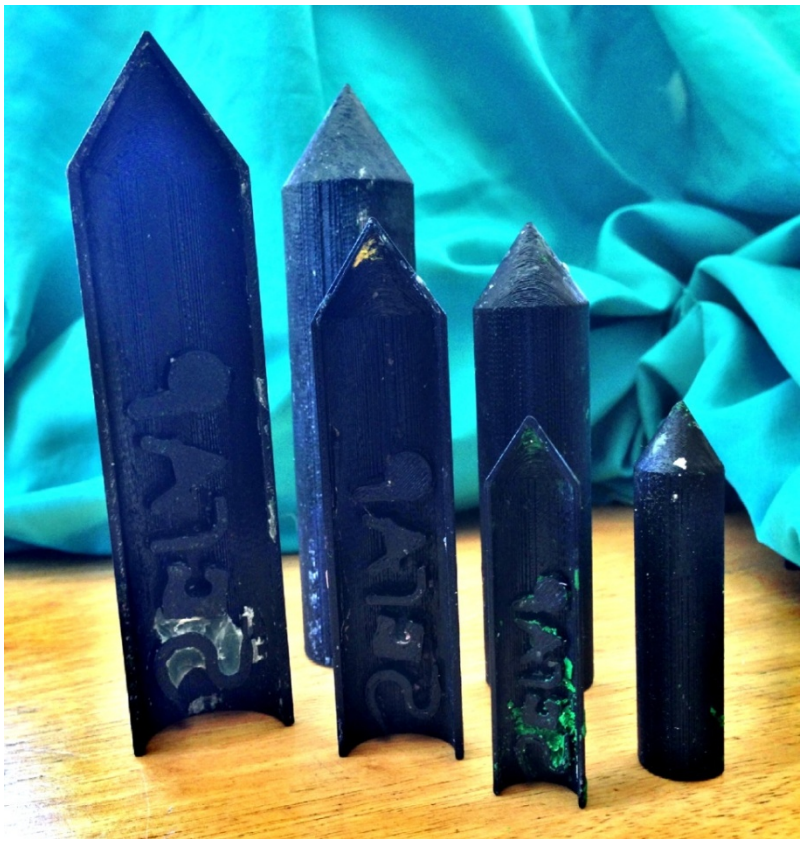

Figure 53: 3-D printed molds for both candles and crayons designed by team SuperStar.

5.3. Cost Analysis

The following cost analysis is divided into three major components. 1.) The design time to complete the project for team SuperStar. 2.) The cost of materials for construction of the Solar Wax Melter with 3D Printed Molds. 3.) The expected maintenance cost associated with the finalized product. The research costs are not included in this document.

5.3.1. Design

The total design and testing time recorded by team SuperStar was 207 hours. Table 5.4 shows the total time for all team members divided by design phases. These phases are; defining the problem, gathering information, searching for alternative solutions, selecting a final solution, and testing and implementation of the design.

Figure 54 Total design hours for team SuperStar, time is divided by design phases.

5.3.2. Construction

Construction costs cover all materials required to build the Solar Wax Melter with 3D Printed Molds and are illustrated in Table 5.1. All occurrences of $0.00 in the row titled 'Our Cost' indicate a

material removed from the waste stream, the retail cost is also indicated for compatible new materials. Only items which are necessary in the implementation of the final design are depicted in Table 5.1.

Table 51 Materials purchased during construction. $0.00 indicates material removed from waste stream.

Material Cost		
Item Description	Retail Cost	Our Cost
Sattelite Dish	$100.00	$0.00
Assorted Sand Paper	$9.22	$9.22
Candle Wick	$5.99	$0.00
3-D molds	$45.00	$0.00
Used Tire	$20.00	$0.00
Total	**$180.21**	**$9.22**

5.3.3. Maintenance

The maintenance of the Solar Heater and 3D Printed Molds includes periodically re-sanding, re-polishing or buffing the surface of the parabolic heater to avoid rusting. The frequency that the surface needs to be re-polished depends on the environment the dish is subjected to. The dish should not be stored outdoors as the finish will rust if exposed to high amounts of moisture for extended periods. As SCRAP Humboldt is located in an area that consistently has high humidity levels the dish may require more frequent light sanding to maintain a highly reflective surface. The molds should be scraped clean often to avoid unwanted wax build up. If there is too much wax to simply scrape off submerge the molds in hot water for 20 seconds to soften the wax, then scrape clean.

Table 52: Annual maintenance cost

Maintence Task	Cost
Sanding	$ 9.22
Cleaning Molds	$ -
Total	**$ 9.22**

5.4. Implementation Instructions

The Solar Heater and 3D Printed Molds is a parabolic heater that harnesses the energy from the Sun and uses it to heat water to serve multiple functions. The Solar Heater and 3D Printed Molds is built from repurposed waste and is primarily used to keep certain items (crayons, candles, other waxes) from entering the waste stream. The Solar Wax Melter with 3D printed molds has two main components 1.) The parabolic solar heater is used to gather and redirect the energy from the Sun to melt wax. 2.) The

custom designed candle and crayon molds to reform the melted wax. Complete step-by-step instructions can be found on the project's Appropedia page http://www.appropedia.org/SCRAP_Humboldt_solar_wax_melter_with_3Dprinted_molds

To use the Solar Heater and 3D Printed Molds simply position dish so the reflective surface is facing the sun. Locate the focus point using a piece of paper held above the dish arm. The paper will smoke when it is the correct distance from the dish above the dish arm. The focus point will be just past the existing metal arm. Sort crayons or candles by color to custom design the shade. Place wax pieces in a heat safe container and place in focus point. Wait for the wax to melt completely, extra fine glitter can be added at this time to give crayons a sparkling finish. Coat molds to be used with olive oil or other lubricant, such as Vaseline or 3% silicone spray, to easily release wax from the mold. Close mold using two rubber bands and place upright in the mold holder. When the wax is completely melted it can be poured into the molds to cool.

5.4.1. Preparing the Satellite Dish

A common house satellite dish can be converted into a parabolic heater. The fiberglass layer had to be sanded off of the dish using an assortment of sandpaper. Beginning with a 50 grit wet/dry sandpaper and incrementing up to 1500 grit results in a very reflective surface with minimal scratching left on the surface. The dish must be periodically re-sanded with high grit Sandpaper to maintain the highest reflectivity.

Figure 55 Josh Martinez and Mary Krieger sanding the satellite dish. Surface was sanded by hand due to the concave shape of the dish.

5.4.2. Heat Transfer

Direct heat transfer is used in the Solar Wax Melter and 3D Printed Molds. A blackened heat safe container (for this prototype a tin can) which the crayon or candle wax will be melted in is positioned in the focus point of the satellite dish. The focused heat then directly heats the container and melts the wax into a liquid.

5.4.3. Designing Candle and Crayon Molds

The wax molds were custom designed for the client, SCRAP Humboldt, using two different drafting software; AutoCAD and Solidworks. The files were then sent to the Humboldt State University 3-D printer to be rendered. Many renditions were created before deciding on an appropriate mold. Pictured in Figure 5.6 is the AutoCad design of the most successful molds, these can be used for recasting both crayons and candles and can also be scaled for various purposes. An interchangeable mold further reduces the amount of waste being generated in Humboldt County.

Old silicon ice trays can also be used if a custom piece is not desired, a 3-D printer is not available or if the appropriate software cannot be used or accessed. Once trays have been used for crayons or candles they should not be reused for food purposes again.

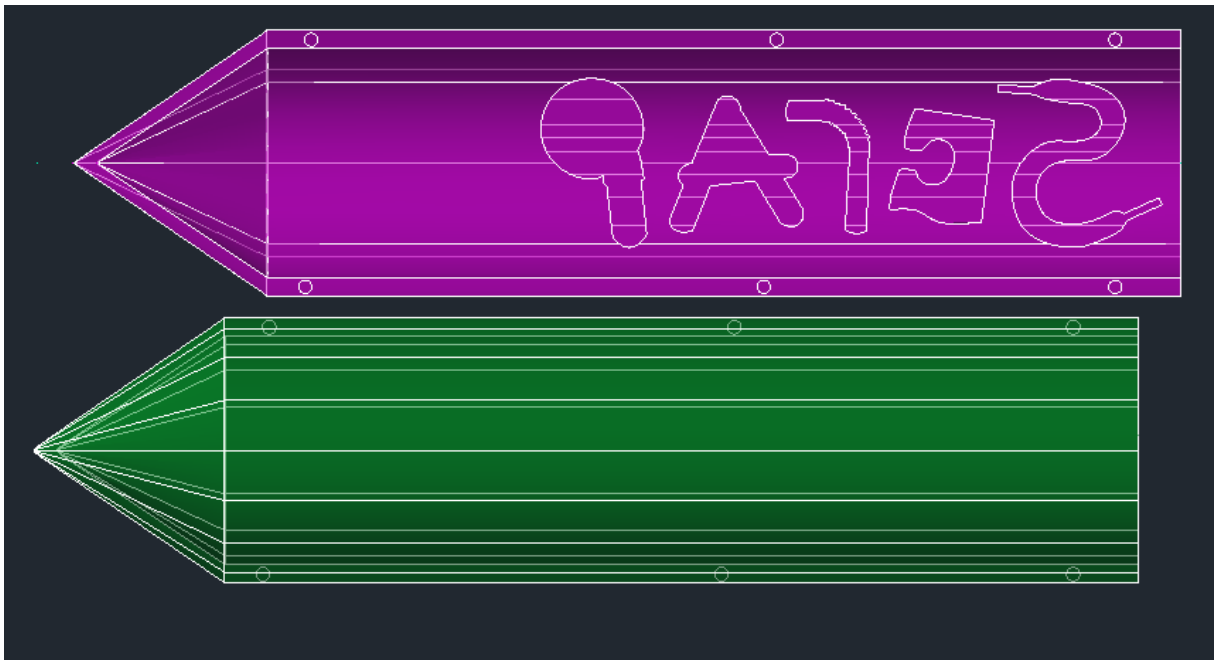

Figure 56 'SCRAP' candle mold rendered in 3-D printer. Designed by Mary Krieger.

5.5. Prototype Performance

Several types of materials (including sandpaper, cardboard and a ping pong ball) have been successfully ignited with parabolic heater. Crayons and candles have been successfully recast using the Solar Wax Melter and 3D Printed Molds. The crayons, pictured in Figure 5.7 have been field tested by HSU students and were found to be "…a nice fit to my hand, and they don't fall apart like regular crayons…" (Peter Whiteman). The candles, as seen in Figure 5.7, have been successfully burned for a short period of time as to not destroy the SCRAP logo. The burn time of recast candles will depend on the material composition of the wax that was melted down.

57 The finished SCRAP crayons and candle made from wax bits that would be going to the landfill.

6. Appendix A

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