Solar Cooking for Developing Nations

Final Report

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The Ohio State University
Department of Food, Agricultural, and Biological Engineering

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Global Water Institute
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Dear Michelle Cane,

Attached is a final report for the GWI Solar Cooker which details the final design, cost analysis, and proposed testing. Due to the ongoing COVID-19 pandemic, final testing was unable to be completed but the proposed outline for testing is presented in the report. Careful research and calculations have been performed which led to a final design with the following highlights:

- Repurposed steel and plastic barrels that reduce overall costs
- Increased cooking capacity over currently available designs
- Comparable cooking temperatures and speeds to commercially available cookers

We appreciate your involvement and support with this project, and would like to acknowledge Jeff Melaragno for his support with the project. We would also like to acknowledge Sean Carpenter and Dr. Dennis Heldman for their help and support. Please feel free to contact any of the team members directly with further questions.

Best Regards,

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Executive Summary

GWI would like to introduce the use of solar cookers in Tanzania in order to provide a more sustainable cooking method to the rural Tanzanian people. A solar cooker is a device that harnesses heat energy from the sun and uses it for the purpose of cooking food, therefore there is no need for wood or other types of fuel. GWI has tasked the team with designing a solar cooker capable of being used to cook some meals instead of the regular wood burning stoves. Currently, many people in rural Tanzania cook primarily by open wood fire because they do not have access to electricity or fossil fuels. Widespread wood fire cooking has contributed to rapid deforestation, health problems, and stagnant social economic advancement. The introduction of a solar cooker would lessen the reliance on wood for fuel and would help alleviate these issues.

Throughout the year many ideas were proposed. After researching commercially available solar cooker models, material properties, and availability, the team conceptualized three solar cooker designs: box cooker with panels design, oil barrel design, and in-ground with panels design. Decision matrices were created and research was conducted on material availability and design aspects. The oil barrel design was chosen as the final design. This design was chosen in large part because of the materials that would be used for construction. The materials to be used were deemed to be the most available from recycling common items found around Tanzania.

Calculations were performed to narrow down possible materials of use. The final materials chosen were proven to be the most insulating out of the things that are available. The calculations performed were crucial in truly showing what materials would work the best. Thought was put into materials to be used that the calculations then refuted.

The team managed to draw up a plan for a solar cooker that would be considerably less than the available models on the market. The purchased Sun Oven had a cost of $0.25 per cubic inch while the most ideal team model had a cost of $0.016 per cubic inch. With the construction items being readily available in Tanzania, this cost should decrease significantly even more. While the Sun Oven is a lab tested item, further testing is necessary for the team's ¼ and ½ barrel solar cooker designs. Only hypothetical calculations were performed comparing the cooker designs, with the ¼ barrel cooker replicating the Sun Oven's results the closest.

1.0 Introduction

The Global Water Institute (GWI) at the Ohio State University is a collaboration engine whose primary mission is to provide sustainable systems solutions for communities facing water resource challenges that are economically viable, environmentally sound, socially acceptable, user-driven, and technically maintainable (GWI, 2019). GWI would like to introduce the use of solar cookers in Tanzania in order to provide a more sustainable cooking method to the rural Tanzanian people. A solar cooker is a device that harnesses heat energy from the sun and uses it for the purpose of cooking food, therefore there is no need for wood or other types of fuel. Currently, many people in rural Tanzania cook primarily by open wood fire because they do not have access to electricity or fossil fuels. Widespread wood fire cooking has contributed to rapid deforestation, health problems, and stagnant social economic advancement. The introduction of a solar cooker that would lessen the reliance on wood for fuel would help alleviate these issues. GWI has tasked the team with designing a large scale solar cooker capable of being used to cook large quantities of food for community gatherings. The purpose of this document is to outline the process of creating a preliminary design for a solar cooker that can be adapted to be used for a large community gathering.

1.1 Project Rational

Current cooking methods in rural Tanzania are hazardous to the health of those living in the household. In some areas, people in Tanzania currently cook indoors in an oil barrel using wood that they've found. In other areas, the three stone method uses three stones of around the same size to hold a pot while a wood fire burns below. Due to deforestation, wood is becoming scarcer and prices for wood continue to increase as a result. Tanzania itself is approximately 40% forest cover and continues to decrease 1%, or 400,000 hectares annually (Heist, 2015). Many women and children spend hours looking for wood and water. The norm in Tanzania is for men to raise livestock, work in the fields, mine, and other manual labor while women and children take care of the house.

Most houses in Tanzania aren't properly ventilated. Roofing is made of sticks and mud, while a few houses have a metal roof; neither are constructed with a chimney system. Smoke and soot created from traditional cooking methods are trapped in the house. This leads to lung irritation and respiratory problems, such as bronchitis and asthma, and could lead to more serious health problems down the line such as cancer (Armstrong, 2019). A solar cooker requires no fuel and releases no emissions since it only relies on the sun. Being located south of the equator, Tanzania receives plenty of sunlight. Currently solar cookers have not been notably implemented in Africa, meaning that very few areas use or even know about them. By educating the Tanzanian people about using solar cookers the team. By using a solar cooker, the burden of finding fuel and the health problems caused by smoke and soot are lessened. The hope is that the solar cooker can be applied to rural areas in need.

In Tanzania most of the diet consists of rice, corn, and grains with some meat dishes thrown in. Researchers gathered data on the common diets of women living in rural Tanzania. The Traditional-inland diet is made up of large amounts of cereals (traditionally cooked rice, maize, or millet), vegetables, and the food group "oil or fat", since vegetables are typically fried or cooked in oil (Keding, 2011). The solar cooker must also be capable of cooking traditional Tanzanian food in large quantities without sacrificing the characteristics of the food, like taste and texture. The time it takes to prepare the traditional meals should not be increased significantly either, or users may be more likely to return to traditional ways of cooking (Otte, 2013). It is customary during celebrations or ceremonial occasions that large plates of food be brought out so the solar cooker should be large enough to help out (Carlson and Pratt). Families, while used to cooking indoors, would have to switch to cooking outside when using the solar cooker to maximize its effectiveness.

1.2 Project Definition and Scope

To help GWI achieve their goal of increasing sustainable cooking practices in Tanzania, the team's primary objective was to develop a solar cooker that was as effective as current models available for purchase. The team focused on using locally available materials in order to ensure that the cookers could be built in country at low cost.

The original problem statement can be found in Appendix A. The qualifications of the team members involved in the project can be found in Appendix E.

2.0 Literature Review

2.1 Background on State of Art

There are two major types of solar cookers in general use, the concentrator-type cooker and the box-type cooker. The first type has been implemented by various researchers on a large, community scale. These large cookers center around a large satellite dish-like concentrator that reflects and focuses sunlight onto an absorber in the center of the dish. These cookers can be used in multiple ways including transferring heat through steam, transferring heat through aluminum bars, and the direct heating of a pot placed in the absorber position. (Franco, 2004).

The major problems with the concentrator-type cooker are the costs to build and maintain the large and complicated systems, it has to be constantly repositioned to align with the sun, and the process can be more dangerous and less efficient due to the constant repositioning. The box-type cooker attempts to fix many of these issues (Nahar, 2002).

The box-type cooker has two major variations: with storage and without storage. The storage that is referred to here is the storage of heat through the use of a storage medium. The heat stored by this medium helps maintain the temperature within the cooker so that cooking may continue when direct sunlight is lost, whether due to a cloudy day or nightfall. A box-type with storage designed by Nahar incorporated, used motor oil as the heat storing material because of its low price and ready availability (Nahar, 2002). The research provided data supporting the hypothesis that adding storage to the box-type cooker allowed for the complete cooking of food and keeping it warm much farther into the evening compared to a cooker without storage.

The major problems with box-type cookers is that they are primarily designed for individual use. As the cooker becomes larger, the heat requirements to cook the food grow exponentially and the box-type cooker will not be as effective in building up the heat required as the concentrator-type cooker.

2.2 Competitive Analysis

Current solar cooker models available are efficient in heating speeds and maximum temperatures due to construction techniques and materials that are not readily available in developing countries. Due to the state-of-the-art technology, prices for an individual cooker are not feasible for purchase in Tanzania.

2.2.1 Parabolic Cookers

One common type of solar cooker is the parabolic dish solar cooker (Figure 1). These cookers are able to reflect a greater amount of sunlight than other models and can maintain high temperatures up to 250°C, or 482°F (GoSun). Parabolic dish models also require low maintenance but do require constant supervision due to the amount of heat it outputs, as well as the need to be readjusted to optimize the amount of reflected sunlight. These models can be large and more expensive compared to other models.

(Source:http://www.solarcooker-at-cantinawest.com/solsource_parabolic_solar_cooker.html)
Figure 1: A parabolic dish cooker with space for access to food cooking by removing a panel. Most parabolic cookers aren't noted for having a gap in the dish for access to food.

2.2.2 Box Cookers

Box cookers (Figure 2) usually have one to four reflective panels that reflect light onto the cooking area. Glass and other magnifiers are used to increase the light intensity. These models can be inexpensively made at home and have a greater cooking capacity than that of the parabolic and vacuum tube models. The choice of materials used can affect the durability, with most home-made models being constructed of cardboard while store bought models could be made out of wood or metal. Box cookers have a moderate cooking speed compared to other models.

(Source:https://wakeup-world.com/2011/07/06/how-to-build-your-own-cheap-simple-solar-oven/)
Figure 2: A basic box cooker made out of cardboard. The insides of these models usually coated in reflective materials.

2.2.3 Panel Cookers

Panel cooker models (Figure 3) are popular for camping because of the small amount of space they require to transport and set-up. Their reflective interior surfaces are able to absorb and reflect heat onto the cooking area. These models are decent in cooking capacity but are not very durable and lack high cooking speeds.

(Source:https://www.amazon.com/Sunflair-Portable-Complete-Dehydrating-Thermometer/dp/B008SGB2KU/ref=sr_1_9?keywords=panel+solar+cooker&qid=1575575160&sr=8-9)
Figure 3: This is the most basic type of panel cookers. Advanced panel cooker models include more sides and resemble a fusion of a basic panel cooker and parabolic dish model.

2.2.4 Vacuum Tube Cookers

Using reflective surfaces, light is directed onto the center cooking tube which consists of two components. The first is an outer glass tube that lets in light and the second is an inner tube that is internally coated with a microscopic layer of aluminum nitride, a powerful semiconductor. This allows the inner tube to absorb light and convert it to heat (GoSun). The space in between the tubes is a vacuum that acts as an insulator. These models are noted as being highly efficient, being able to absorb up to 94% of the sun's energy and convert it to heat (SolarTubs). Their small size also makes them easy to carry and they are easy to operate. As shown in Figure 4, the grill and sport models are able to connect to external devices; however, these models do not have a high cooking capacity so larger meals would be difficult.

(Source:https://inhabitat.com/wp-content/blogs.dir/1/files/2019/01/GoSun-Fusion-300-889x500.jpg)
Figure 4: The GoSun Grill vacuum tube model. There is a grill and sports model.

2.3 Target Markets and Potential Financial Impact

Since the people of Tanzania would be making their own cookers, the major constraint of this project is the cost. The target audience for this project would be an average Tanzanian family looking for an inexpensive alternative method for cooking meals for the family or large gathering. By using solar cookers, the idea is to reduce the people's reliance on inside wood burning stoves and help reduce the rate of deforestation in Tanzania. The goal is to make it possible for Tanzanian communities to see the worth in this cooking method by making it economically viable. If the people in these communities can save a significant amount of time and/or money by not collecting wood, the project will be successful even if the solar cooker is only used a quarter of the cooking days.

2.4 Patent Landscape

The main intention for the team's solar cooker is to be a noncommercial project. The idea is to modify an existing solar cooker model to meet the needs of the Tanzanian people. If there were plans to sell a model a patent would be possible. In order to patent the team's solar cooker, it would have to have a significant difference in concept for its operation than that of the other models described in the competitive analysis section. There are current patents in the areas of solar tracking and energy storage, but these methods are too costly and hard to implement regarding this project. The current patent landscape regarding solar cookers involves old, expired ideas on reflective concentration methods. For example, certain shapes and reflective materials like a parabolic design can be copied.

2.5 External Systems

One of the teams constraining factors is to not add any devices to the cooker, so the only external products of use would be basic cookware as there is no fuel needed. Although storing energy to cook on cloudy days would be helpful, electrical devices will not help for the intended developing regions this project is to be implemented. The only external product needed for cooking will involve having water. Although not the focus of this project, the team knows GWI is implementing systems in Tanzania to deliver clean drinking water. Building a mobile solar cooking structure to cook outside with the ability to be stored inside for longevity is key to keep the device working. Therefore, in terms of external systems for the cooker there are not any because of varying housing in these areas.

2.6 Constraints and Standards

The primary constraint is to minimize costs for the solar cooker. This means that the cost for raw materials should be affordable for a Tanzanian family. The solar cooker must be built using materials that are readily available in rural Tanzania. If there is required maintenance, the cost to replace materials must remain low for the people to be able to afford to continue using the solar cookers. Current solar cookers on the market are smaller, and the team's goal is to at least double the size of a common type of cooker on the market in order to cook more efficiently for large groups.

2.7 Social, Environmental, and Global Issues

This project addresses several environmental and social issues. In terms of environmental problems, the goal is to reduce the rate of deforestation in Tanzania and the amount of air pollution caused by the smoke from cooking fires. As deforestation continues, there is also a chance of climate change within Tanzania. The environmental issues of deforestation, air pollution and climate change also can be transitioned into global concerns. Deforestation and pollution affect air on a global scale and the effects of climate change can spread and affect other areas. For social issues this project aims to help socio-economic deprivation. On days when the solar cooker can be used, women can spend time at home or work to gain additional funds instead of going out to collect or buy wood and children can attend school. Reducing the amount of smoke inhalation trapped in houses will also improve local health. Along with GWI implementing a system for obtaining clean water, the solar cooker's effectiveness in decreasing fuel needs will address these issues. In regard to building the solar cooker, it is highly important that the team weighs the impacts of social norms in Tanzania. For example, it is considered rude to sniff food and makes one look suspicious and is a sign of distaste (TheCultureTrip). Therefore, a favorable design for the solar cooker includes a lid to hold in food aroma.

3.0 Detailed Design Description

3.1 Proposed Designs

After researching commercially available solar cooker models, material properties, availability and cultural restrictions, the team conceptualized three solar cooker designs: box cooker with panels design, oil barrel design, and in-ground with panels design.

3.1.1 Box Cooker with Panels

The box cooker with panels design was based around the box cooker design introduced in section 2.2.2. The design incorporated 4 reflective panels to a base, like one seen in Figure 2, that could be adjusted to reflect a maximum amount of sunlight. These panels reflect more light into the cooker, effectively increasing the area of light absorption without increasing the surface area of the enclosure. The ratio of light absorption area to enclosure surface area is an important one, because the greater the surface area, the more heat lost through the enclosure. By maximizing this ratio, the design maximizes heat intake while minimizing heat lost through the system. The box cooker with panels design also featured a double-walled enclosure, such that insulating material could be added between the interior and exterior walls, retaining more heat.

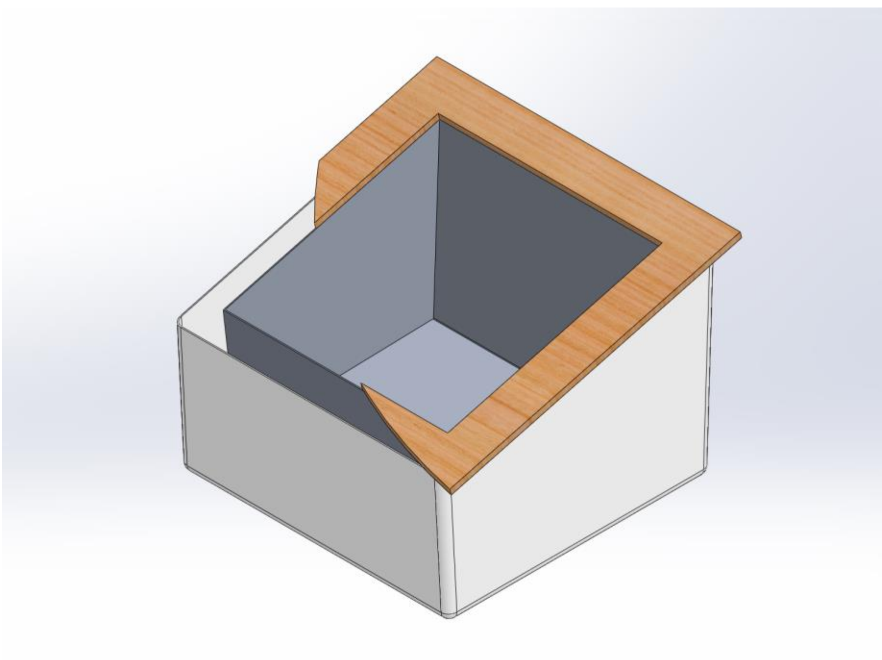

Figure 5: A model of a simple box cooker, showing the double-walled design.

3.1.2 Oil Barrel Design

Using a similar concept to a box cooker, repurposed plastic and steel oil barrels would be used for the body of the cooker. Oil barrels are readily available in Tanzania and would not require special machinery to construct. Repurposing old barrels would reduce the overall cost of the design and increase the sustainability of the model. Using oil barrels also simplifies the construction methods so that the cooker can be feasibly built in Tanzania. Two versions of this design were considered: a "quarter barrel" and a "half barrel" design. The quarter barrel design utilizes a little more than one quarter of each of the plastic and steel barrels, while the "half barrel" design uses half of each barrel.

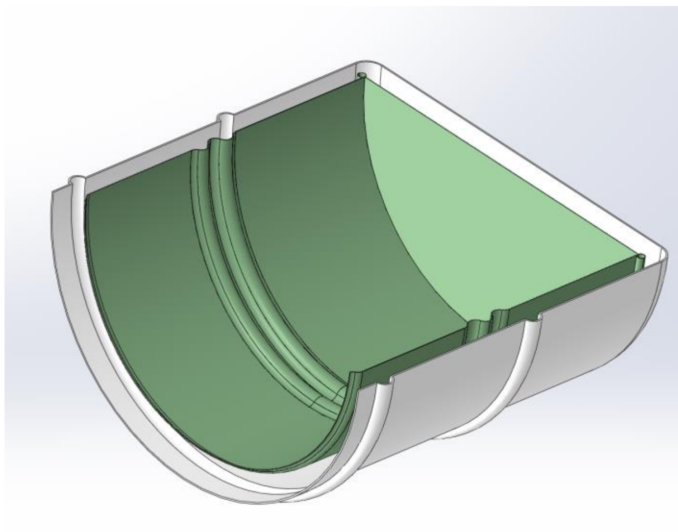

Figure 6: A preliminary model of the oil barrel design, showing the steel and plastic double-walled design.

3.1.3 In-Ground with Panels Design

A third variation of the box cooker with panel design was considered in which the box cooker would be built into a dug-out hole in the ground. This design offered reduced cost and a very simple construction but was deemed to not be feasible due to safety concerns while using the cooker and a lack of portability.

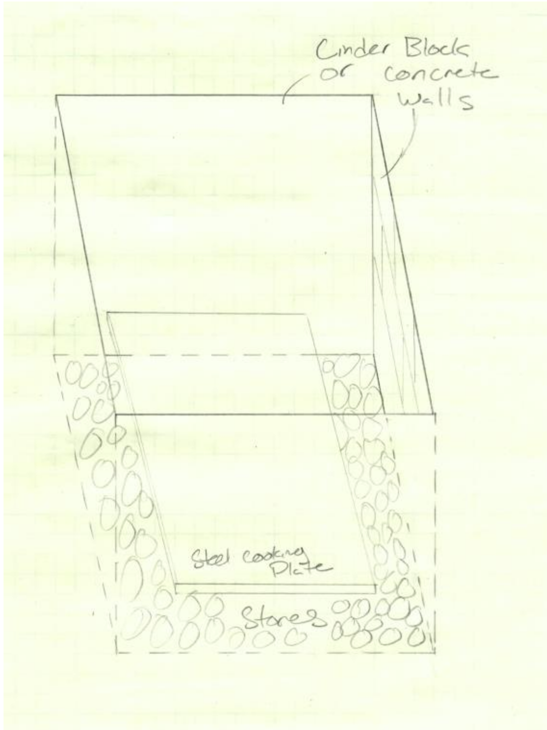

Figure 7: Conceptual Drawing of an in-ground solar cooker

3.2 Final Design and Rationale

Of the proposed designs, the "quarter barrel" oil barrel cooker design offered the best balance of the success metrics discussed further in section 3.5. This design was chosen because it utilized materials that would be readily and cheaply available in Tanzania, simplified cooker construction, and was far safer than the in-ground cooker design.

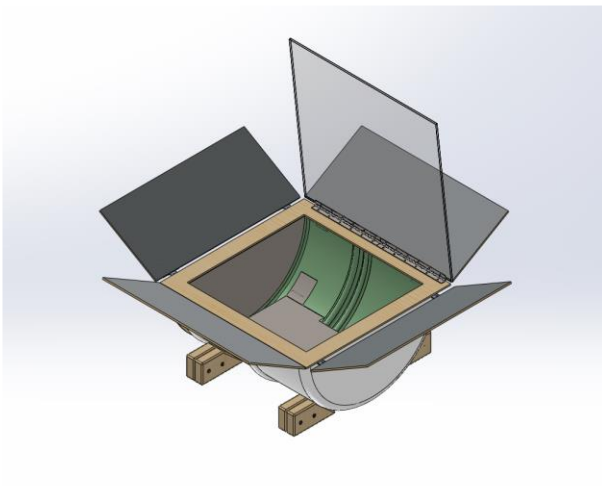

Figure 8: Final Prototype Design

3.3 Design Components

The final design, shown above in Figure 8, consists of two concentric barrels. The outer barrel is made out of plastic and serves as the exterior of the cooker, holding in insulating material and serving as a structural element. The barrels have been cut through their length at their diameter, and then cut down to length leaving roughly one-quarter of the original barrel dimensions. The inner barrel is a steel oil drum which serves as the primary heat collector and dissipator for the system. A one and one quarter inch gap is held between the two barrels by wooden blocks, and is then filled with wool for insulating material. The prototype also features 4 reflective panels, set at a 60° angle from the vertical plain, for optimal solar absorption in the cooker. The following image, Figure 9, shows an exploded view of the above model.

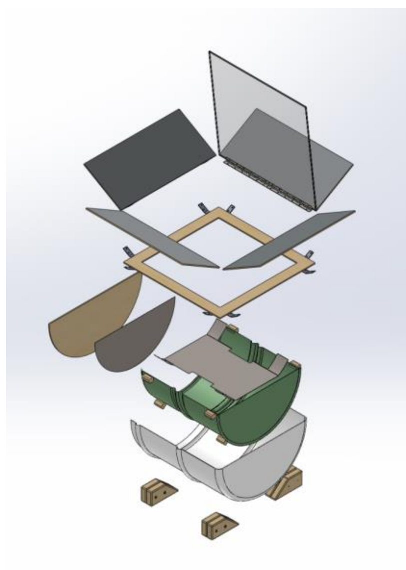

Figure 9: Prototype Exploded View.

Figures 10 - 12, below show dimensions of key components of the cooker, starting with an overview of the design.

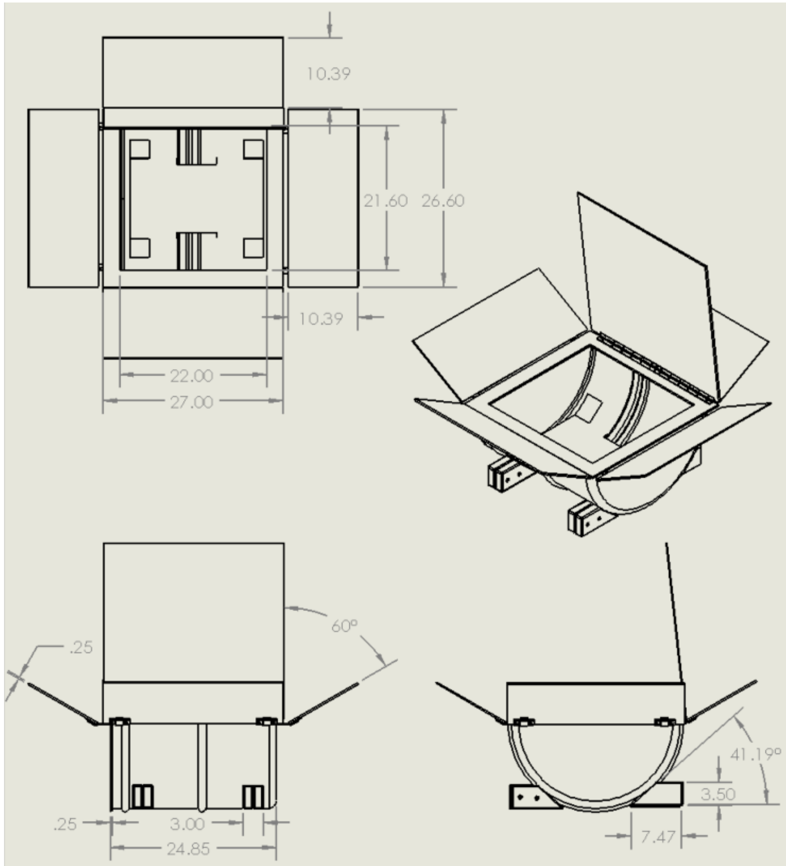

Figure 10: Overall Prototype Dimensions.

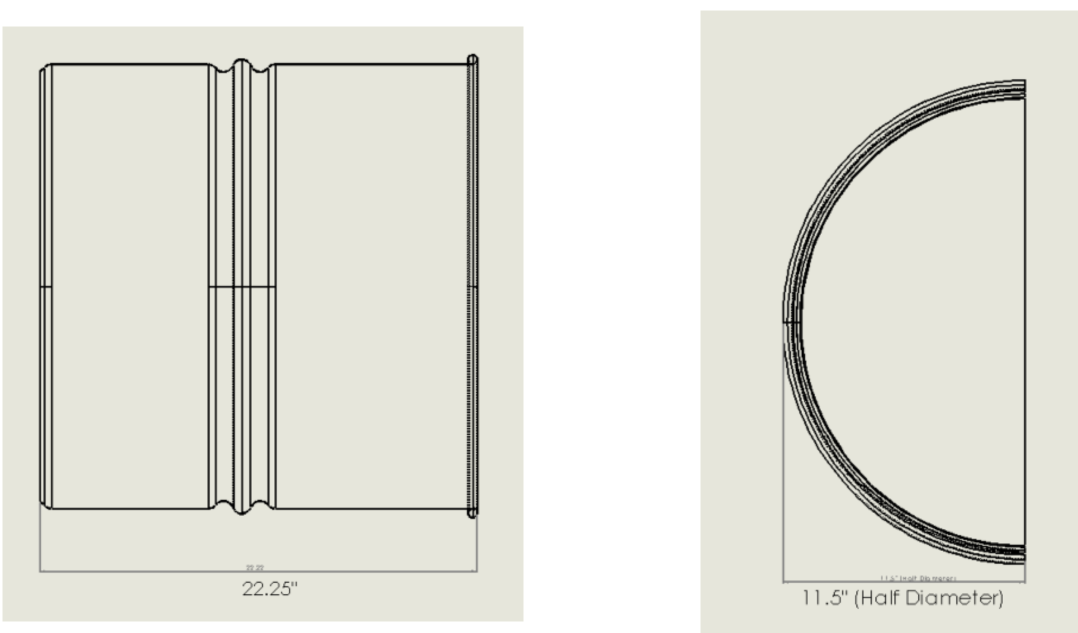

Figure 11: Dimensions of steel drum/ solar cooker inner wall.

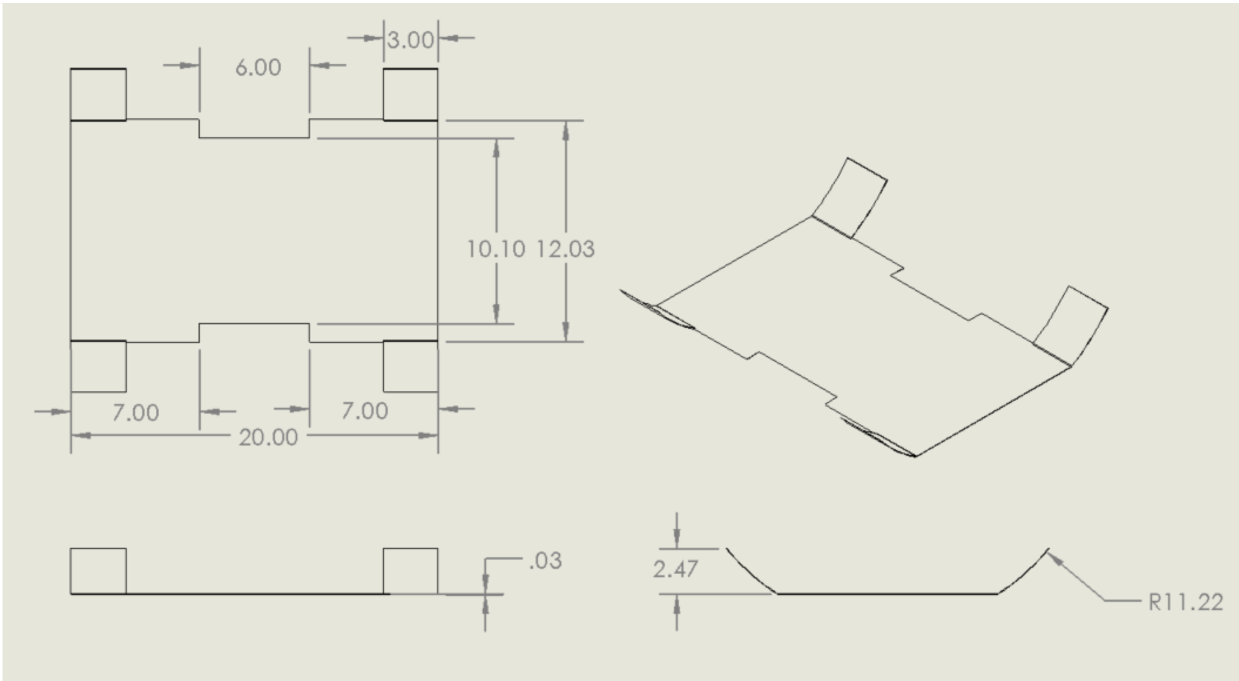

Figure 12: Dimensions of steel pot holder plate.

3.4 Design Variables

As previously mentioned in section 3.1.2, two major variations of the oil barrel design were considered: the “quarter barrel” and the “half barrel” designs. Essentially, the difference between the two design variations comes down to size, and therefore cooking capacity. Through calculations that will be discussed in section 5 of this report, it was determined that the added volume of the “half barrel” design caused too much heat loss, and was ultimately too inefficient compared to the “quarter barrel variation.

3.5 Success Metrics

In a discussion between GWI and capstone advisor Sean Carpenter, it was decided that a successful solar cooker design will be able to cook food at twice the rate as current solar cooker designs. This measure is the volume of food cooked per unit of time, so therefore can be improved either by an increase in cooking capacity, an increase in cooking speed, or a combination of both. To be successful, the cooking rate must be doubled without a significant price increase. Therefore, the design metrics are cost, cooking capacity, and cooking speed.

Table 1: Design Metrics

Design Requirement	**Metric**	**Target Value**	**Acceptable Range**
Cost	$ (USD)	$200	<$200 – $300
Cooking Capacity	Servings	Doubled	10 - 20
Cooking Speed	Hours	1	<3 - 4

Cooking speed was unable to be physically tested, but sample calculations provide a theoretical basis for comparing the speed of each model. Costs were determined and a cost analysis was completed to determine if the team design would meet the design requirement. Cooking capacity was measured using volume measurements for all designs.

4.0 Design Evaluation

The team was unable to perform physical testing on the different solar cooker models. Theoretical calculations were performed to determine heat gains and losses of the models as well as comparisons of materials, size and costs of each model. The calculations gave a good comparison of the Sun Oven vs. ¼ barrel design vs. ½ barrel design.

4.1 Methods

In order to test the cooking speed for each model, heat gain equations were used to calculate the gain of heat in each model over a specified period of time. These theoretical equations can be used to approximate the actual heat gains of each model as the cookers would be tested under the same conditions. An analysis of the data can be found in Section 4.3 and a complete list of equations used can be found in Appendix C.

To evaluate the cost of the models, measurements from the Solidworks drawings were used to calculate surface area and volumes for the team design. Measurements were taken of the Sun Oven, with the retail cost known. The total cost of the team design was calculated and compared to the costs of the Sun Oven, as shown in Section 6.0.

To evaluate the cooking capacity of each model, the interior volume of each model was determined using known measurements and Solidworks drawings. The amount of food that each cooker was capable of cooking was unable to be tested, so interior volume comparisons provide an understanding of the number of pots that could fit in each design.

4.2 Data Collected

In order for the team to determine what materials would be best for maximum heat gain, the team explored multiple materials that could be used to build the cooker. Conduction values were recorded to help determine the heat loss within the cooker. Calculations were performed to see how heat loss was affected through different combinations of materials shown in the Table (2). Combinations included using wooden, plastic, or metal for walling and using different insulators such as cotton, paper, sand, and fiberglass. Both the thickness of the material being used as well as its conduction value helped determine heat loss.

Table 2: Example of the heat flux calculations for different materials. Wool was used as the insulation material.

Wall Material	Heat Flux (W/m2)
Wood	471.89
Metal	625.59
Cardboard	492.25

Another experiment that was performed was a boiling test. In this experiment a liter of water at room temperature was placed into an oven at 200°F. A liter was used since that was determined to be the amount of water necessary for a typical meal of porridge. The purpose of this experiment was just to see how long it would take for the water to get to proper cooking temperature. This experiment was done twice and both resulted in a time of about 50 minutes. Through physical testing, this time would be what the team would be shooting for. The purpose of the test was to try to get closer to an approximate cooking time for a meal.

4.3 Methods Used for Data Analysis

To find the values for heat gain, the specific heat equation described in Appendix C was used to solve for change in temperature. Calculations were done based on Tanzania irradiance values of 4-7 kW*h/m^2. Irradiance values were adjusted from the area of sunlight that the cooker was directed into the cooker and the amount of light that was actually being reflected using the

Hagen-Ruben equation described later in the report. Irradiance values were split into low, medium, and high values. Once all figures were found they were plugged in to Excel to calculate heat gain over the course of an hour. This was done with the commercial Sun Oven, and the teams quarter and half barrel models. The heat gain over time was then plotted to determine how long it would take each of the cookers up to reach a desired temperature.

The next series of calculatulations that was completed was heat loss within the system. The insulation thermal conductivity values were an important factor for these calculations. Ideally, the team would see a high heat gain with low heat loss. The lower the thermal conductivity values for the insulation materials used resulted in less heat loss as temperature rose. The commercial Sun Oven was known to use a fiberglass insulation with a conductivity value of 0.04 W/m^2*K. To compete with this value, the team chose to use wool which had about the same thermal conductivity value. Another consideration, was the use of recycled paper insulation which had an insulation value of 0.05 W/m^2*K.

5.0 Results

Several calculations were performed to find heat gain for the cookers as well as heat loss. From the calculations stated in Section 4.3, the team was able to output multiple tables and graphs to represent the data. Table 3 shows an example of the results of heat gain for the Sun Oven. Also included is Figure 14 to show how each oven performed at average irradiance. Table 3 gives a closer look into what heat gain values look like over a brief period. Since these ovens are not powered by electricity or gas, heating times are larger than traditional methods.

Table 3: Heat Gain for Sun Oven over 15 minutes for average irradiance

Sun Cook		**Mid range irradiance**	
Intervals (min)	Time (Hr)	Irradiance (Kj/s)*Hr	Heat gain (C)
0	0	0	0
1	0.01666667	0.0685	1.957142857
2	0.03333333	0.137	3.914285714
3	0.05	0.2055	5.871428571
4	0.06666667	0.274	7.828571429

5	0.08333333	0.3425	9.785714286
6	0.1	0.411	11.74285714
7	0.11666667	0.4795	13.7
8	0.13333333	0.548	15.65714286
9	0.15	0.6165	17.61428571
10	0.16666667	0.685	19.57142857
11	0.18333333	0.7535	21.52857143
12	0.2	0.822	23.48571429
13	0.21666667	0.8905	25.44285714
14	0.23333333	0.959	27.4
15	0.25	1.0275	29.35714286

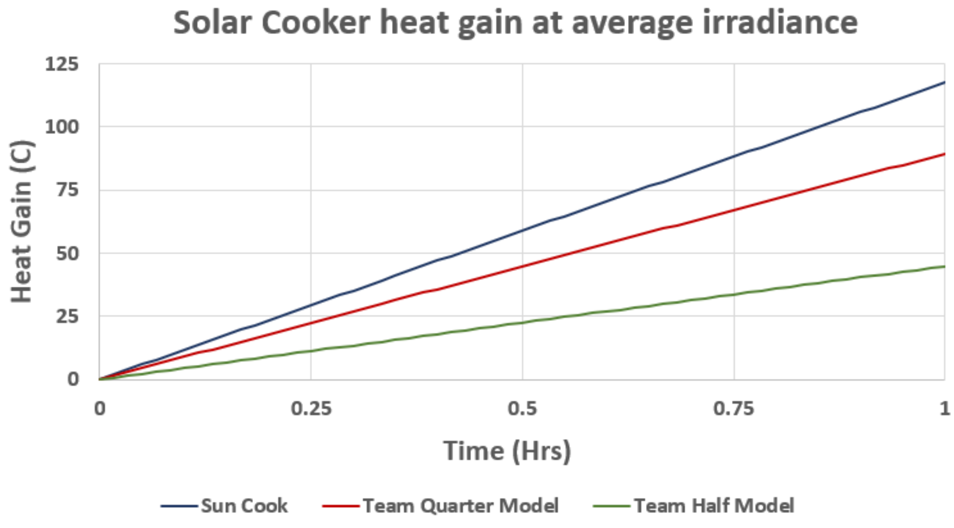

Figure 13: Temperature increase of the ovens at mid irradiance

Figure 13 shows the difference in heating rates between the cookers. The Sun Oven had the fastest hearting times, with the quarter barrel model having 25% lower heat gain over a one hour period, as shown in Figure 14. The half barrel model is significantly larger, leading to longer heating times and a greater difference in final heat gain values. Based on slope data collected from Figure 13, if a desired temperature of 300°F about 150°C is required, it would take the Sun Oven about 1.27 hours while the teams quarter model would take around 1.67 hours.

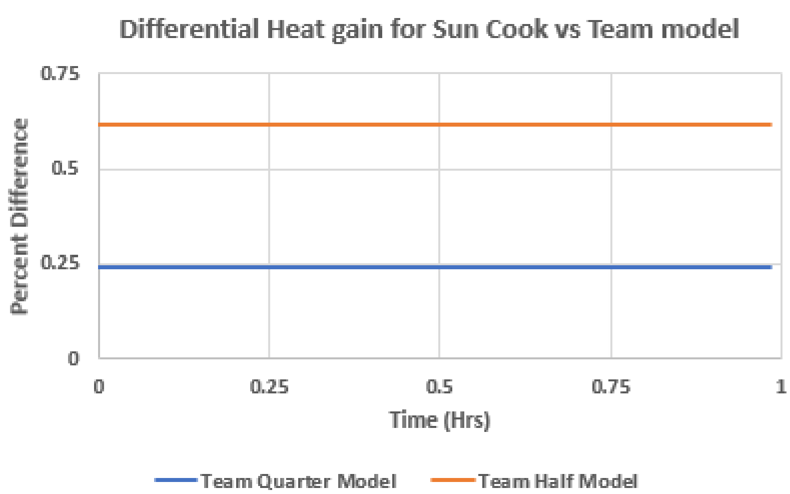

Figure 14: Differential Heat Gain Compared to Sun Oven

Due to the Sun Oven being capable of achieving higher temperatures overall, it had more heat to lose which resulted in higher heat loss values. The teams models performed well in containing heat over the hour. Using a different insulation material would cause the team's model heat loss values to be closer to the Sun Oven, which would not be the desired result. Another reason for the Sun Ovens higher heat loss is due to the conductive material on the interior of the model. The Sun Oven uses sheets of aluminum which have a thermal conductivity of around 235 W/m^2*K. Aluminum is used due to its high conductivity, the walls of the Sun Oven would radiate more energy than the teams model which used steel which had a thermal conductivity of 15 W/m^2*K. This means after sunlight has stopped being directed into the oven the teams model would experience a faster cooling rate.This can be both positive and negative. On the positive side someone using the team cooker has a less likely chance of burning themselves after the cooker has set out for a while and needs to be stored away. But on the other hand during a cloudy day the oven would not stay as hot as long so that means less cooking time during unfavorable weather. Figure 15 gives a visual into the difference of heat loss for the three models.

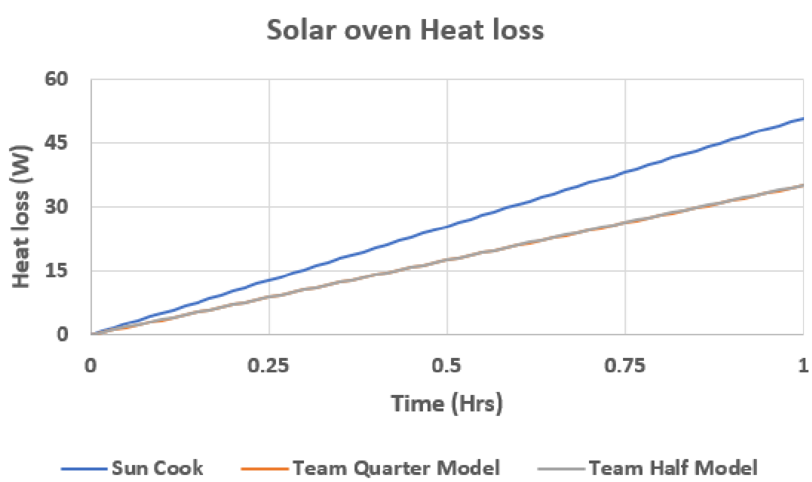

Figure 15: Heat loss of each model. The values for the quarter barrel and half barrel models ended up overlapping.

A complete list of equations and data tables used to create the previous figures can be found in Appendix C.

6.0 Cost Analysis

Economic feasibility is one of the most important factors influencing the design of the solar cooker due to the limited resources and income of those living in rural Tanzania. Due to the fluctuating prices of resources in Tanzania, costs were calculated in USD. Current retail price for the purchased Sun Oven is $389. In order to calculate the overall cost of the team's design, cost per area was determined for each material used. Table 4 shows the cost breakdown for the team quarter barrel design. The overall total cost for the team design was $74.56. This is a significant decrease in cost from the Sun Oven.

Table 4: Cost Breakdown ¼ Barrel Design

Material	total price ($)	design surface area(in^2)	cost/surface area($/in^2)	cost used in design ($)
plastic	121.03	966.01	0.0354	34.2
steel	101.46	966.01	0.02803	27.08
mylar	7.99	950.4	0.00104	0.99
plywood	10.09	950.4	0.00438	4.16
glass	18.48	475.2	0.0171	8.13
			Total Cost	**$74.56**

Table 5 shows the cost per cubic inch for the Sun Oven and the team design. After these costs were calculated, it was determined that the Sun Oven was 15.625 times more expensive than the team's quarter barrel design, on a cost per volume basis. Based on this determination, the team was successful in reaching the metric of creating a low cost alternative to current solar cooker models.

Table 5: Cost per Volume Comparison

model	volume (in3)	total cost ($)	cost/volume
sun oven	1550	389	$0.25 / in3
1/4 barrel	4609.44	74.56	$0.016 / in3

One consideration when calculating total costs is the availability of oil barrels in Tanzania. If the barrels are able to be repurposed for no or a reduced cost, the total cost of the design would be significantly decreased as $61.28, or 82%, of the total costs come from the barrels.

7.0 Further Design Considerations

Many design constraints start to take shape when dealing with a solar cooker designed for a developing nation. It is difficult to imagine all the conditions without directly speaking with residents of these areas and hearing their needs. The main idea behind the cooker is using the sun's energy so that no fuel is needed. Saving money is the biggest constraint, as discussed previously.

7.1 Environmental/sustainability

The weather will not always be sunny so use of the solar cooker is limited to being supplementary. A box cooker with good enough insulation can stop convection heat loss when the wind is a concern. The amount of wool can be supplemented with cotton if necessary. This ensures the maximum productivity out of the solar cooker even if the conditions are not ideal. The use of any electrical equipment is especially restricted because only 2.5% of rural Tanzania is connected to the electrical grid (Massawe et al., 2015). For use in cloudy conditions, the inclusion of a battery or more advanced energy storage models was therefore forgotten. It would either be too difficult to fix or not in an area where battery or electrical use is feasible.

7.2 Manufacturability

Whatever materials chosen need to be cheap enough so that they are easily replaced for maintenance. However, the material quality should not be cheap. In regards to maintenance, another constraint is that the cooker can not be so advanced that it is too difficult to fix.

Panels and glass are not easily replaced materials. Mylar film being used instead of pieces of mirror provides a material that is very cheap and reliable. The film is difficult to rip while easy to wash. It is the preferred material to use for the panels but must be obtained either online or through a garden supply store. The actual assembly of the solar cooker is easily attainable as long as there is access to a hardware store for glass and fastening tools.

7.3 Ethical/health and safety

One health constraint to our project is the repurposing of oil barrels to be used to cook food in. It would be recommended to wash thoroughly within a manual to build the solar cooker. Safety concerns were taken into high consideration in choosing the type of style of solar cooker. The box cooker design limits the potential of being burnt as the concentration of light rays is not directed to a single spot.

7.4 Social/political

Social aspects of Tanzanian culture also impacted our design. A lightweight solar cooker provides a mobile kitchen for use in the shade or for women to get away from the home to converse. Further testing needs to be completed with actually making porridge as the taste can not be vastly different from the way it is cooked traditionally.

8.0 Conclusions and Recommendations

A conceptual design to build a box-type solar cooker out of oil barrels is proposed with theoretical calculations. The quarter barrel design gives the impression to be an effective solution considering the success metrics established in Section 3.5. Calculations based on radiation energy and different thermal conductivities predict a sixteen minute difference in heating to 100℃ between our proposed design and the reference Sun Oven. The quarter barrel concept takes longer than the Sun Oven but triples the internal capacity as the trade off. Considering the reasonable time difference to the boiling point of water, this is a measurable success. A larger capacity will also be able to feed large families. Another success of the proposed design is the cost. The cooker, when used in the quarter barrel design, will cost about seventy-five dollars each which is about five times less than the test Sun Oven. This price can be brought down further if local materials are recycled to be used in the design.

The progress of the project was interrupted by the coronavirus outbreak, but the team recommends going forward with physical testing and modifying the quarter barrel design. Testing needs to be done in a greenhouse with thermocouples to measure temperatures at different points within each cooker. From this point, the measured temperature distributions within the built solar cooker could be looked to improve on. The experiment would also verify that the design confirms the calculations. The experimental conditions do not need to be a direct representation of Tanzanian sun but only need to be the same between the reference and proposed solar cooker for comparison. This experiment will prove how well our solar cooker maintains temperature compared to an established model bought off the market. Further improvements are possible by playing with the amount and shape of a matte black absorbing paint versus more reflective mylar film on the inside of the barrel. These variations change the way the barrel can hold heat or reflect light onto the surface of the pot or area it will sit on.

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Appendices

Appendix A: Original Problem Statement

20	**Project: Developing a solar cooking device large enough to reduce fuel costs in rural Tanzania** **Sponsor: Global Water Institute (GWI)** The Global Water Institute (GWI) (http://globalwater.osu.edu/) at Ohio State is a collaboration engine that provides sustainable systems solutions that are economically viable, environmentally sound, socially acceptable, user-driven, and technically maintainable. Tanzania is one of the fastest growing economies in Africa, yet widespread poverty persists. Tanzania must import most of the fuel and energy needed by its population resulting in high costs. Rural populations and non-profit institutions like schools and orphanages cannot afford the high cost of fuel even for cooking. As a result, a large portion of the country has been deforested to use wood for cooking. Now even wood has become scarce and expensive. Solar power can offset the need for importing fossil fuels and cutting down trees. Small solar cookers have been developed for household use, and larger solar cookers have been developed for community use; however these cookers tend to be too costly. The project aims to develop a system design for a low-cost community-scale solar cooker for use by schools, orphanages and communities in Tanzania. There are small solar cookers for household use that could be modified to meet the needs of the orphanage (https://www.gosun.co/blogs/news/the-ultimate-solar-cooker-guide). The team is expected to evaluate existing designs of smaller scale and determine the best options to inexpensively modify the solar cooker to increase cooking capacity.

While this is the team's original project statement, the focus of the project was changed and the solar cooker was to be used in rural areas instead of the noted school and orphanage.

Appendix B: Team Charter

Team Charter

Team Name: SPF 20		
Team Purpose: Develop an improved community-scale solar cooker for use in rural Tanzanian		
Team Leader(s): Molly Kern		
Stakeholder:	**Expectations:**	
Global Water Institute	A working, easy to maintain and setup, product. Good communication	
Tanzanians receiving the cooker	A working cooker that is easy to use and maintain that improves quality of life and reduces reliance on fossil fuels and wood burning stoves.	
Team Members:	**Strengths/Skills:**	**Expectations:**
Molly Kern	Technical Writing, leadership	The team will communicate well and accomplish expected actions in a timely manner and with an appropriate level of effort.
Deshawn Wilson	Imaginative/ good Researching	
Matthew Blizniuk	Handy/crafty, can do whatever decently	
Weston Clifford	Research skills, quality engineering might be handy	
Lukas Moreland	Mechanical Aptitude and interest in design	
Team Goals: To work well together and to meet sponsor expectations		
Team Member Roles & Responsibilities		
Team member:	**Role:**	**Responsibilities:**
Molly Kern	Team Leader	Keep team on track, keep contact with technical advisor and team sponsor
Deshawn Wilson	Chief Model Research	Conducting and overseeing research of models and existing solutions

Lukas Moreland Matthew Bliznuik Weston Clifford	Structural Engineer Design Engineer Chief Scientific Research	Oversee and ensure structural integrity and feasibility of design Oversee ergonomics and aesthetic design of product Researching materials and scientific theory needed to complete the product
Operations		
Meetings	Expectations: Every is present and participates in attaining goals set out for each meeting.	
Assignments	Expectations: Equal and adequate effort given to complete assignments and to quality standards	
Communication	Expectations: Answering GroupMe and email communications in a timely manner	
Decision making	Expectations: Design will be effective and meet various constraints and regulations	
Conflict resolution	Expectations: Talking to each other and making an effort to resolve conflict peacefully	
Team Member Assessment and Evaluation: Team members will be assessed by genuine effort given as expected to complete tasks. This may include, but is not limited to: - Working on assignments - Completing assigned tasks - Contributing to Meeting notes - Participating at meetings - Fulfilling designated roles and responsibilities		
Shared Accountability		
Team member: Lukas Moreland Deshawn Wilson Molly Kern Matthew Bliznuik Weston Clifford	Signature: *Lukas Moreland* *Deshawn Wilson* *Molly Kern* *Matthew Bliznuik* *Weston Clifford*	Date: 8/30/2019 8/30/2019 8/30/2019 8/30/2019 8/30/2019

Appendix C: Calculations

Surface area, Volume, Air mass

Sun Oven

Total interior Surface Area=757.5 in2=0.488m2

Volume=2306 in3=0.04m3

Air Mass p=m/v pair=1.2 kg/m3p=mvmass=1.2 kg/m3*0.04m3=0.05 kg

Team Oven (*Quarter model*)

Total interior Surface Area= 0.381m2

volume=0.0546m3

Air Mass p=m/v pair=1.2 kg/m3p=mvmass=1.2 kg/m3*0.0546m3=0.0655 kg

Team Oven (*Half model*)

Total interior Surface Area=0.762m2

volume=0.1093m3

Air Mass p=m/v pair=1.2 kg/m3p=mvmass=1.2 kg/m3*0.1093m3=0.131 kg

Radiation

Sunlight capture area=1171.5 in2=0.755m2

Tanzania irradiance=Q=4-7 kW*h/m2

Reflectance Hagens-Ruben equation=1-22*e*wδ

e=vacuum permittivity= 8.85*10-12 Farads/m

w=frequency of light (UV) = 527 W

δ=Thermal Conductivity

Q=e*δ*A*(Tsurface4-Tsurroundings4)

Low irradiance= 4 kW*h/m2*0.755m2*0.99=3.02 kW/hr

Mid-Range irradiance= 5.5 kW*h/m2*0.755m2*0.99=4.11 kW/hr

High irradiance= 7 kW*h/m2*0.755m2*0.99=5.23 kW/hr

Heat Gain

q=m*Cv*ΔT

Cv=specific heat value=0.7 kJ/s

m=mass of air

q=solar radiation (kW)

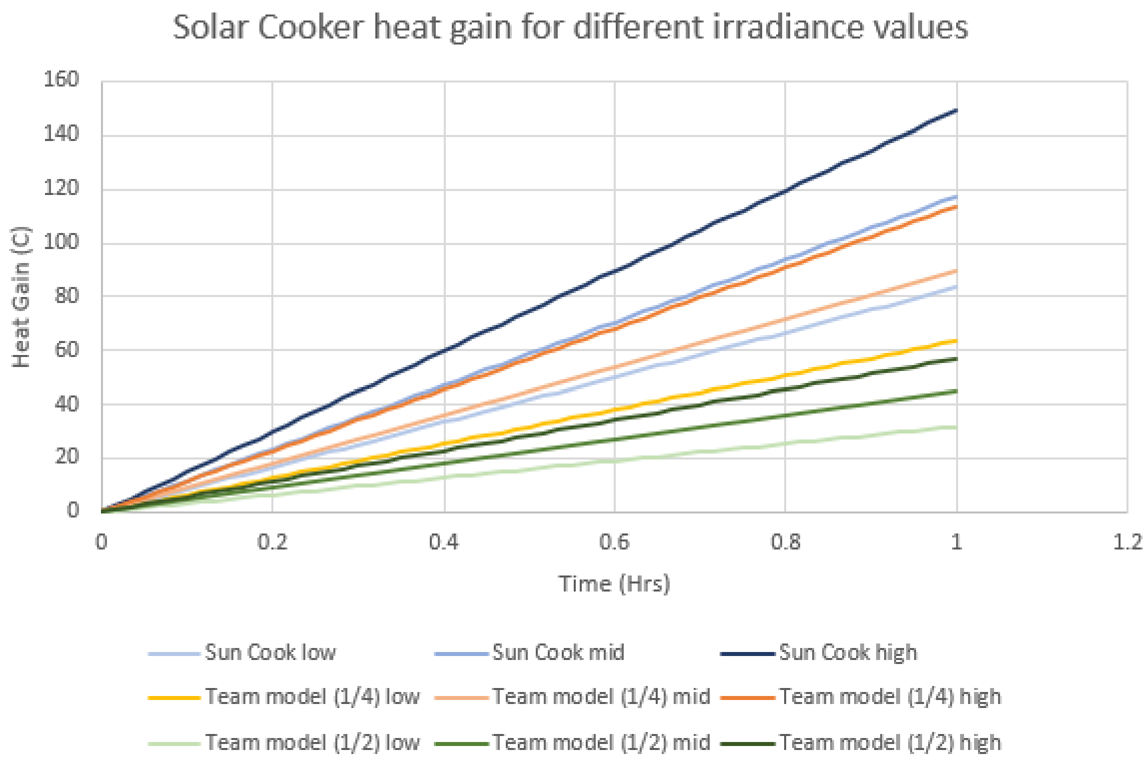

Figure 16: Heat Gain for All Models at Different Irradiances

Heat loss

Sun cook oven Q=A*(T∞1-T∞2)1h+xk+xk+xk+xh

Team Oven Q=2*pi*L*(T∞1-T∞2)1h*r+ln(r0/r1)k+ln(r0/r1)k+ln(r0/r1)k

Theoretical Calculations

Sun Oven slope equation: Temperature=117.43(Hours) + 5e-11

To reach 400 °F about 204 °C =1.73 Hours

Team Quarter Model slope equation: Temperature=89.367(Hours)+7e-14

To reach 400 °F about 204 °C =2.28 Hours

Tables

The following tables show the results of heat gain over time

Sun Oven Heat Gains

Table 6: Sun Oven Heat Gain at Low Irradiance

Sun Oven		Low irradiance	
Intervals (min)	Time (Hr)	Irradiance (Kj/s)*Hr	Heat gain (C)
0	0	0	0
1	0.01666666667	0.04866666667	1.39047619
2	0.03333333333	0.09733333333	2.780952381
3	0.05	0.146	4.171428571
4	0.06666666667	0.1946666667	5.561904762
5	0.08333333333	0.2433333333	6.952380952
6	0.1	0.292	8.342857143
7	0.1166666667	0.3406666667	9.733333333
8	0.1333333333	0.3893333333	11.12380952
9	0.15	0.438	12.51428571
10	0.1666666667	0.4866666667	13.9047619
11	0.1833333333	0.5353333333	15.2952381
12	0.2	0.584	16.68571429
13	0.2166666667	0.6326666667	18.07619048
14	0.2333333333	0.6813333333	19.46666667
15	0.25	0.73	20.85714286
16	0.2666666667	0.7786666667	22.24761905
17	0.2833333333	0.8273333333	23.63809524
18	0.3	0.876	25.02857143
19	0.3166666667	0.9246666667	26.41904762
20	0.3333333333	0.9733333333	27.80952381
21	0.35	1.022	29.2
22	0.3666666667	1.070666667	30.59047619
23	0.3833333333	1.119333333	31.98095238
24	0.4	1.168	33.37142857
25	0.4166666667	1.216666667	34.76190476
26	0.4333333333	1.265333333	36.15238095
27	0.45	1.314	37.54285714
28	0.4666666667	1.362666667	38.93333333

29	0.4833333333	1.411333333	40.32380952
30	0.5	1.46	41.71428571
31	0.5166666667	1.508666667	43.1047619
32	0.5333333333	1.557333333	44.4952381
33	0.55	1.606	45.88571429
34	0.5666666667	1.654666667	47.27619048
35	0.5833333333	1.703333333	48.66666667
36	0.6	1.752	50.05714286
37	0.6166666667	1.800666667	51.44761905
38	0.6333333333	1.849333333	52.83809524
39	0.65	1.898	54.22857143
40	0.6666666667	1.946666667	55.61904762
41	0.6833333333	1.995333333	57.00952381
42	0.7	2.044	58.4
43	0.7166666667	2.092666667	59.79047619
44	0.7333333333	2.141333333	61.18095238
45	0.75	2.19	62.57142857
46	0.7666666667	2.238666667	63.96190476
47	0.7833333333	2.287333333	65.35238095
48	0.8	2.336	66.74285714
49	0.8166666667	2.384666667	68.13333333
50	0.8333333333	2.433333333	69.52380952
51	0.85	2.482	70.91428571
52	0.8666666667	2.530666667	72.3047619
53	0.8833333333	2.579333333	73.6952381
54	0.9	2.628	75.08571429
55	0.9166666667	2.676666667	76.47619048
56	0.9333333333	2.725333333	77.86666667
57	0.95	2.774	79.25714286
58	0.9666666667	2.822666667	80.64761905
59	0.9833333333	2.871333333	82.03809524
60	1	2.92	83.42857143

Table 7: Sun Oven Heat Gain at Medium Irradiance

		Mid range irradiance	
Intervals (min)	Time (Hr)	Irradiance (Kj/s)*Hr	Heat gain (C)
0	0	0	0
1	0.01666666667	0.0685	1.957142857
2	0.03333333333	0.137	3.914285714
3	0.05	0.2055	5.871428571
4	0.06666666667	0.274	7.828571429
5	0.08333333333	0.3425	9.785714286
6	0.1	0.411	11.74285714
7	0.1166666667	0.4795	13.7
8	0.1333333333	0.548	15.65714286
9	0.15	0.6165	17.61428571
10	0.1666666667	0.685	19.57142857
11	0.1833333333	0.7535	21.52857143
12	0.2	0.822	23.48571429
13	0.2166666667	0.8905	25.44285714
14	0.2333333333	0.959	27.4
15	0.25	1.0275	29.35714286
16	0.2666666667	1.096	31.31428571
17	0.2833333333	1.1645	33.27142857
18	0.3	1.233	35.22857143
19	0.3166666667	1.3015	37.18571429
20	0.3333333333	1.37	39.14285714
21	0.35	1.4385	41.1
22	0.3666666667	1.507	43.05714286
23	0.3833333333	1.5755	45.01428571
24	0.4	1.644	46.97142857
25	0.4166666667	1.7125	48.92857143
26	0.4333333333	1.781	50.88571429
27	0.45	1.8495	52.84285714
28	0.4666666667	1.918	54.8

29	0.4833333333	1.9865	56.75714286
30	0.5	2.055	58.71428571
31	0.5166666667	2.1235	60.67142857
32	0.5333333333	2.192	62.62857143
33	0.55	2.2605	64.58571429
34	0.5666666667	2.329	66.54285714
35	0.5833333333	2.3975	68.5
36	0.6	2.466	70.45714286
37	0.6166666667	2.5345	72.41428571
38	0.6333333333	2.603	74.37142857
39	0.65	2.6715	76.32857143
40	0.6666666667	2.74	78.28571429
41	0.6833333333	2.8085	80.24285714
42	0.7	2.877	82.2
43	0.7166666667	2.9455	84.15714286
44	0.7333333333	3.014	86.11428571
45	0.75	3.0825	88.07142857
46	0.7666666667	3.151	90.02857143
47	0.7833333333	3.2195	91.98571429
48	0.8	3.288	93.94285714
49	0.8166666667	3.3565	95.9
50	0.8333333333	3.425	97.85714286
51	0.85	3.4935	99.81428571
52	0.8666666667	3.562	101.7714286
53	0.8833333333	3.6305	103.7285714
54	0.9	3.699	105.6857143
55	0.9166666667	3.7675	107.6428571
56	0.9333333333	3.836	109.6
57	0.95	3.9045	111.5571429
58	0.9666666667	3.973	113.5142857
59	0.9833333333	4.0415	115.4714286
60	1	4.11	117.4285714

Table 8: Sun Oven Heat Gain at High Irradiance

		high irradiance	
Intervals (min)	Time (Hr)	Irradiance (Kj/s)*Hr	Heat gain (C)
0	0	0	0
1	0.01666666667	0.08716666667	2.49047619
2	0.03333333333	0.1743333333	4.980952381
3	0.05	0.2615	7.471428571
4	0.06666666667	0.3486666667	9.961904762
5	0.08333333333	0.4358333333	12.45238095
6	0.1	0.523	14.94285714
7	0.1166666667	0.6101666667	17.43333333
8	0.1333333333	0.6973333333	19.92380952
9	0.15	0.7845	22.41428571
10	0.1666666667	0.8716666667	24.9047619
11	0.1833333333	0.9588333333	27.3952381
12	0.2	1.046	29.88571429
13	0.2166666667	1.133166667	32.37619048
14	0.2333333333	1.220333333	34.86666667
15	0.25	1.3075	37.35714286
16	0.2666666667	1.394666667	39.84761905
17	0.2833333333	1.481833333	42.33809524
18	0.3	1.569	44.82857143
19	0.3166666667	1.656166667	47.31904762
20	0.3333333333	1.743333333	49.80952381
21	0.35	1.8305	52.3
22	0.3666666667	1.917666667	54.79047619
23	0.3833333333	2.004833333	57.28095238
24	0.4	2.092	59.77142857
25	0.4166666667	2.179166667	62.26190476
26	0.4333333333	2.266333333	64.75238095
27	0.45	2.3535	67.24285714

28	0.4666666667	2.440666667	69.73333333
29	0.4833333333	2.527833333	72.22380952
30	0.5	2.615	74.71428571
31	0.5166666667	2.702166667	77.2047619
32	0.5333333333	2.789333333	79.6952381
33	0.55	2.8765	82.18571429
34	0.5666666667	2.963666667	84.67619048
35	0.5833333333	3.050833333	87.16666667
36	0.6	3.138	89.65714286
37	0.6166666667	3.225166667	92.14761905
38	0.6333333333	3.312333333	94.63809524
39	0.65	3.3995	97.12857143
40	0.6666666667	3.486666667	99.61904762
41	0.6833333333	3.573833333	102.1095238
42	0.7	3.661	104.6
43	0.7166666667	3.748166667	107.0904762
44	0.7333333333	3.835333333	109.5809524
45	0.75	3.9225	112.0714286
46	0.7666666667	4.009666667	114.5619048
47	0.7833333333	4.096833333	117.052381
48	0.8	4.184	119.5428571
49	0.8166666667	4.271166667	122.0333333
50	0.8333333333	4.358333333	124.5238095
51	0.85	4.4455	127.0142857
52	0.8666666667	4.532666667	129.5047619
53	0.8833333333	4.619833333	131.9952381
54	0.9	4.707	134.4857143
55	0.9166666667	4.794166667	136.9761905
56	0.9333333333	4.881333333	139.4666667
57	0.95	4.9685	141.9571429
58	0.9666666667	5.055666667	144.447619
59	0.9833333333	5.142833333	146.9380952
60	1	5.23	149.4285714

Team ¼ Barrel Model

Table 9: ¼ Barrel Model at Low Irradiance

¼ Model		Low irradiance	
Intervals (min)	Time (Hr)	Irradiance (Kj/s)*Hr	Heat gain (C)
0	0	0	0
1	0.016666667	0.048666667	1.058201065
2	0.033333333	0.097333333	2.116402109
3	0.05	0.146	3.174603175
4	0.066666667	0.194666667	4.23280424
5	0.083333333	0.243333333	5.291005284
6	0.1	0.292	6.349206349
7	0.116666667	0.340666667	7.407407415
8	0.133333333	0.389333333	8.465608458
9	0.15	0.438	9.523809524
10	0.166666667	0.486666667	10.58201059
11	0.183333333	0.535333333	11.64021163
12	0.2	0.584	12.6984127
13	0.216666667	0.632666667	13.75661376
14	0.233333333	0.681333333	14.81481481
15	0.25	0.73	15.87301587
16	0.266666667	0.778666667	16.93121694
17	0.283333333	0.827333333	17.98941798
18	0.3	0.876	19.04761905
19	0.316666667	0.924666667	20.10582011
20	0.333333333	0.973333333	21.16402116
21	0.35	1.022	22.22222222
22	0.366666667	1.070666667	23.28042329
23	0.383333333	1.119333333	24.33862433
24	0.4	1.168	25.3968254
25	0.416666667	1.216666667	26.45502646
26	0.433333333	1.265333333	27.51322751
27	0.45	1.314	28.57142857
28	0.466666667	1.362666667	29.62962964

29	0.483333333	1.411333333	30.68783068
30	0.5	1.46	31.74603175
31	0.516666667	1.508666667	32.80423281
32	0.533333333	1.557333333	33.86243386
33	0.55	1.606	34.92063492
34	0.566666667	1.654666667	35.97883599
35	0.583333333	1.703333333	37.03703703
36	0.6	1.752	38.0952381
37	0.616666667	1.800666667	39.15343916
38	0.633333333	1.849333333	40.2116402
39	0.65	1.898	41.26984127
40	0.666666667	1.946666667	42.32804234
41	0.683333333	1.995333333	43.38624338
42	0.7	2.044	44.44444444
43	0.716666667	2.092666667	45.50264551
44	0.733333333	2.141333333	46.56084655
45	0.75	2.19	47.61904762
46	0.766666667	2.238666667	48.67724868
47	0.783333333	2.287333333	49.73544973
48	0.8	2.336	50.79365079
49	0.816666667	2.384666667	51.85185186
50	0.833333333	2.433333333	52.9100529
51	0.85	2.482	53.96825397
52	0.866666667	2.530666667	55.02645503
53	0.883333333	2.579333333	56.08465608
54	0.9	2.628	57.14285714
55	0.916666667	2.676666667	58.20105821
56	0.933333333	2.725333333	59.25925925
57	0.95	2.774	60.31746032
58	0.966666667	2.822666667	61.37566138
59	0.983333333	2.871333333	62.43386243
60	1	2.92	63.49206349

Table 10: ¼ Model Heat Gain at Medium Irradiance

		Mid range irradiance	
Intervals (min)	Time (Hr)	Irradiance (Kj/s)*Hr	Heat gain (C)
0	0	0	0
1	0.016666667	0.06850000137	1.489454229
2	0.033333333	0.1369999986	2.978908458
3	0.05	0.2055	4.468362688
4	0.066666667	0.2740000014	5.957816917
5	0.083333333	0.3424999986	7.447271146
6	0.1	0.411	8.936725375
7	0.116666667	0.4795000014	10.4261796
8	0.133333333	0.5479999986	11.91563383
9	0.15	0.6165	13.40508806
10	0.166666667	0.6850000014	14.89454229
11	0.183333333	0.7534999986	16.38399652
12	0.2	0.822	17.87345075
13	0.216666667	0.8905000014	19.36290498
14	0.233333333	0.9589999986	20.85235921
15	0.25	1.0275	22.34181344
16	0.266666667	1.096000001	23.83126767
17	0.283333333	1.164499999	25.3207219
18	0.3	1.233	26.81017613
19	0.316666667	1.301500001	28.29963035
20	0.333333333	1.369999999	29.78908458
21	0.35	1.4385	31.27853881
22	0.366666667	1.507000001	32.76799304
23	0.383333333	1.575499999	34.25744727
24	0.4	1.644	35.7469015
25	0.416666667	1.712500001	37.23635573
26	0.433333333	1.780999999	38.72580996
27	0.45	1.8495	40.21526419
28	0.466666667	1.918000001	41.70471842
29	0.483333333	1.986499999	43.19417265

30	0.5	2.055	44.68362688
31	0.516666667	2.123500001	46.1730811
32	0.533333333	2.191999999	47.66253533
33	0.55	2.2605	49.15198956
34	0.566666667	2.329000001	50.64144379
35	0.583333333	2.397499999	52.13089802
36	0.6	2.466	53.62035225
37	0.616666667	2.534500001	55.10980648
38	0.633333333	2.602999999	56.59926071
39	0.65	2.6715	58.08871494
40	0.666666667	2.740000001	59.57816917
41	0.683333333	2.808499999	61.0676234
42	0.7	2.877	62.55707763
43	0.716666667	2.945500001	64.04653185
44	0.733333333	3.013999999	65.53598608
45	0.75	3.0825	67.02544031
46	0.766666667	3.151000001	68.51489454
47	0.783333333	3.219499999	70.00434877
48	0.8	3.288	71.493803
49	0.816666667	3.356500001	72.98325723
50	0.833333333	3.424999999	74.47271146
51	0.85	3.4935	75.96216569
52	0.866666667	3.562000001	77.45161992
53	0.883333333	3.630499999	78.94107415
54	0.9	3.699	80.43052838
55	0.916666667	3.767500001	81.9199826
56	0.933333333	3.835999999	83.40943683
57	0.95	3.9045	84.89889106
58	0.966666667	3.973000001	86.38834529
59	0.983333333	4.041499999	87.87779952
60	1	4.11	89.36725375

Table 11: ¼ Model at High Irradiance

		high irradiance	
Intervals (min)	Time (Hr)	Irradiance (Kj/s)*Hr	Heat gain (C)
0	0	0	0
1	0.016666667	0.08716666841	1.895339567
2	0.033333333	0.1743333316	3.790679133
3	0.05	0.2615	5.6860187
4	0.066666667	0.3486666684	7.581358266
5	0.083333333	0.4358333316	9.476697833
6	0.1	0.523	11.3720374
7	0.116666667	0.6101666684	13.26737697
8	0.133333333	0.6973333316	15.16271653
9	0.15	0.7845	17.0580561
10	0.166666667	0.8716666684	18.95339567
11	0.183333333	0.9588333316	20.84873523
12	0.2	1.046	22.7440748
13	0.216666667	1.133166668	24.63941437
14	0.233333333	1.220333332	26.53475393
15	0.25	1.3075	28.4300935
16	0.266666667	1.394666668	30.32543307
17	0.283333333	1.481833332	32.22077263
18	0.3	1.569	34.1161122
19	0.316666667	1.656166668	36.01145176
20	0.333333333	1.743333332	37.90679133
21	0.35	1.8305	39.8021309
22	0.366666667	1.917666668	41.69747046
23	0.383333333	2.004833332	43.59281003
24	0.4	2.092	45.4881496
25	0.416666667	2.179166668	47.38348916
26	0.433333333	2.266333332	49.27882873
27	0.45	2.3535	51.1741683
28	0.466666667	2.440666668	53.06950786
29	0.483333333	2.527833332	54.96484743

30	0.5	2.615	56.860187
31	0.516666667	2.702166668	58.75552656
32	0.533333333	2.789333332	60.65086613
33	0.55	2.8765	62.5462057
34	0.566666667	2.963666668	64.44154526
35	0.583333333	3.050833332	66.33688483
36	0.6	3.138	68.2322244
37	0.616666667	3.225166668	70.12756396
38	0.633333333	3.312333332	72.02290353
39	0.65	3.3995	73.9182431
40	0.666666667	3.486666668	75.81358266
41	0.683333333	3.573833332	77.70892223
42	0.7	3.661	79.6042618
43	0.716666667	3.748166668	81.49960136
44	0.733333333	3.835333332	83.39494093
45	0.75	3.9225	85.2902805
46	0.766666667	4.009666668	87.18562006
47	0.783333333	4.096833332	89.08095963
48	0.8	4.184	90.9762992
49	0.816666667	4.271166668	92.87163876
50	0.833333333	4.358333332	94.76697833
51	0.85	4.4455	96.6623179
52	0.866666667	4.532666668	98.55765746
53	0.883333333	4.619833332	100.452997
54	0.9	4.707	102.3483366
55	0.916666667	4.794166668	104.2436762
56	0.933333333	4.881333332	106.1390157
57	0.95	4.9685	108.0343553
58	0.966666667	5.055666668	109.9296949
59	0.983333333	5.142833332	111.8250344
60	1	5.23	113.720374

½ Barrel Model

Table 12: 1/2 Barrel Model at Low Irradiance

SPF model	Half Model	Low irradiance	
Intervals (min)	Time (Hr)	Irradiance (Kj/s)*Hr	Heat gain (C)
0	0	0	0
1	0.016666667	0.048666667	0.5307161069
2	0.033333333	0.097333333	1.061432203
3	0.05	0.146	1.59214831
4	0.066666667	0.194666667	2.122864417
5	0.083333333	0.243333333	2.653580513
6	0.1	0.292	3.184296619
7	0.116666667	0.340666667	3.715012726
8	0.133333333	0.389333333	4.245728822
9	0.15	0.438	4.776444929
10	0.166666667	0.486666667	5.307161036
11	0.183333333	0.535333333	5.837877132
12	0.2	0.584	6.368593239
13	0.216666667	0.632666667	6.899309346
14	0.233333333	0.681333333	7.430025442
15	0.25	0.73	7.960741549
16	0.266666667	0.778666667	8.491457655
17	0.283333333	0.827333333	9.022173751
18	0.3	0.876	9.552889858
19	0.316666667	0.924666667	10.08360597
20	0.333333333	0.973333333	10.61432206
21	0.35	1.022	11.14503817
22	0.366666667	1.070666667	11.67575427
23	0.383333333	1.119333333	12.20647037
24	0.4	1.168	12.73718648
25	0.416666667	1.216666667	13.26790258
26	0.433333333	1.265333333	13.79861868
27	0.45	1.314	14.32933479
28	0.466666667	1.362666667	14.86005089

29	0.483333333	1.411333333	15.39076699
30	0.5	1.46	15.9214831
31	0.516666667	1.508666667	16.4521992
32	0.533333333	1.557333333	16.9829153
33	0.55	1.606	17.51363141
34	0.566666667	1.654666667	18.04434751
35	0.583333333	1.703333333	18.57506361
36	0.6	1.752	19.10577972
37	0.616666667	1.800666667	19.63649582
38	0.633333333	1.849333333	20.16721192
39	0.65	1.898	20.69792803
40	0.666666667	1.946666667	21.22864413
41	0.683333333	1.995333333	21.75936023
42	0.7	2.044	22.29007634
43	0.716666667	2.092666667	22.82079244
44	0.733333333	2.141333333	23.35150854
45	0.75	2.19	23.88222465
46	0.766666667	2.238666667	24.41294075
47	0.783333333	2.287333333	24.94365685
48	0.8	2.336	25.47437296
49	0.816666667	2.384666667	26.00508906
50	0.833333333	2.433333333	26.53580516
51	0.85	2.482	27.06652126
52	0.866666667	2.530666667	27.59723737
53	0.883333333	2.579333333	28.12795347
54	0.9	2.628	28.65866957
55	0.916666667	2.676666667	29.18938568
56	0.933333333	2.725333333	29.72010178
57	0.95	2.774	30.25081788
58	0.966666667	2.822666667	30.78153399
59	0.983333333	2.871333333	31.31225009
60	1	2.92	31.84296619

Table 13: ½ Barrel Model at Medium Irradiance

		Mid range irradiance	
Intervals (min)	Time (Hr)	Irradiance (Kj/s)*Hr	Heat gain (C)
0	0	0	0
1	0.016666667	0.06850000137	0.7470011055
2	0.033333333	0.1369999986	1.494002166
3	0.05	0.2055	2.241003272
4	0.066666667	0.2740000014	2.988004377
5	0.083333333	0.3424999986	3.735005438
6	0.1	0.411	4.482006543
7	0.116666667	0.4795000014	5.229007649
8	0.133333333	0.5479999986	5.976008709
9	0.15	0.6165	6.723009815
10	0.166666667	0.6850000014	7.47001092
11	0.183333333	0.7534999986	8.217011981
12	0.2	0.822	8.964013086
13	0.216666667	0.8905000014	9.711014192
14	0.233333333	0.9589999986	10.45801525
15	0.25	1.0275	11.20501636
16	0.266666667	1.096000001	11.95201746
17	0.283333333	1.164499999	12.69901852
18	0.3	1.233	13.44601963
19	0.316666667	1.301500001	14.19302073
20	0.333333333	1.369999999	14.9400218
21	0.35	1.4385	15.6870229
22	0.366666667	1.507000001	16.43402401
23	0.383333333	1.575499999	17.18102507
24	0.4	1.644	17.92802617
25	0.416666667	1.712500001	18.67502728
26	0.433333333	1.780999999	19.42202834
27	0.45	1.8495	20.16902944
28	0.466666667	1.918000001	20.91603055

29	0.483333333	1.986499999	21.66303161
30	0.5	2.055	22.41003272
31	0.516666667	2.123500001	23.15703382
32	0.533333333	2.191999999	23.90403488
33	0.55	2.2605	24.65103599
34	0.566666667	2.329000001	25.39803709
35	0.583333333	2.397499999	26.14503815
36	0.6	2.466	26.89203926
37	0.616666667	2.534500001	27.63904036
38	0.633333333	2.602999999	28.38604142
39	0.65	2.6715	29.13304253
40	0.666666667	2.740000001	29.88004364
41	0.683333333	2.808499999	30.6270447
42	0.7	2.877	31.3740458
43	0.716666667	2.945500001	32.12104691
44	0.733333333	3.013999999	32.86804797
45	0.75	3.0825	33.61504907
46	0.766666667	3.151000001	34.36205018
47	0.783333333	3.219499999	35.10905124
48	0.8	3.288	35.85605234
49	0.816666667	3.356500001	36.60305345
50	0.833333333	3.424999999	37.35005451
51	0.85	3.4935	38.09705562
52	0.866666667	3.562000001	38.84405672
53	0.883333333	3.630499999	39.59105778
54	0.9	3.699	40.33805889
55	0.916666667	3.767500001	41.08505999
56	0.933333333	3.835999999	41.83206105
57	0.95	3.9045	42.57906216
58	0.966666667	3.973000001	43.32606326
59	0.983333333	4.041499999	44.07306433
60	1	4.11	44.82006543

Table 14: ½ Barrel Model at High Irradiance

		high irradiance	
Intervals (min)	Time (Hr)	Irradiance (Kj/s)*Hr	Heat gain (C)
0	0	0	0
1	0.016666667	0.08716666841	0.9505634505
2	0.033333333	0.1743333316	1.901126844
3	0.05	0.2615	2.851690294
4	0.066666667	0.3486666684	3.802253745
5	0.083333333	0.4358333316	4.752817138
6	0.1	0.523	5.703380589
7	0.116666667	0.6101666684	6.653944039
8	0.133333333	0.6973333316	7.604507433
9	0.15	0.7845	8.555070883
10	0.166666667	0.8716666684	9.505634334
11	0.183333333	0.9588333316	10.45619773
12	0.2	1.046	11.40676118
13	0.216666667	1.133166668	12.35732463
14	0.233333333	1.220333332	13.30788802
15	0.25	1.3075	14.25845147
16	0.266666667	1.394666668	15.20901492
17	0.283333333	1.481833332	16.15957832
18	0.3	1.569	17.11014177
19	0.316666667	1.656166668	18.06070522
20	0.333333333	1.743333332	19.01126861
21	0.35	1.8305	19.96183206
22	0.366666667	1.917666668	20.91239551
23	0.383333333	2.004833332	21.86295891
24	0.4	2.092	22.81352236
25	0.416666667	2.179166668	23.76408581
26	0.433333333	2.266333332	24.7146492
27	0.45	2.3535	25.66521265
28	0.466666667	2.440666668	26.6157761

29	0.483333333	2.527833332	27.56633949
30	0.5	2.615	28.51690294
31	0.516666667	2.702166668	29.46746639
32	0.533333333	2.789333332	30.41802979
33	0.55	2.8765	31.36859324
34	0.566666667	2.963666668	32.31915669
35	0.583333333	3.050833332	33.26972008
36	0.6	3.138	34.22028353
37	0.616666667	3.225166668	35.17084698
38	0.633333333	3.312333332	36.12141038
39	0.65	3.3995	37.07197383
40	0.666666667	3.486666668	38.02253728
41	0.683333333	3.573833332	38.97310067
42	0.7	3.661	39.92366412
43	0.716666667	3.748166668	40.87422757
44	0.733333333	3.835333332	41.82479097
45	0.75	3.9225	42.77535442
46	0.766666667	4.009666668	43.72591787
47	0.783333333	4.096833332	44.67648126
48	0.8	4.184	45.62704471
49	0.816666667	4.271166668	46.57760816
50	0.833333333	4.358333332	47.52817155
51	0.85	4.4455	48.47873501
52	0.866666667	4.532666668	49.42929846
53	0.883333333	4.619833332	50.37986185
54	0.9	4.707	51.3304253
55	0.916666667	4.794166668	52.28098875
56	0.933333333	4.881333332	53.23155214
57	0.95	4.9685	54.18211559
58	0.966666667	5.055666668	55.13267904
59	0.983333333	5.142833332	56.08324244
60	1	5.23	57.03380589

The next table shows the results of heat loss for the three ovens at low irradiance

Table 15: Heat Losses for all Models

Sun Cook heat loss (W)	¼ Model heat loss (W)	½ Model heat loss (W)
0	0	0
0.8500028138	0.5839180922	0.5863901083
1.700005628	1.167836172	1.172780204
2.550008441	1.751754265	1.759170313
3.400011255	2.335672357	2.345560421
4.250014069	2.919590437	2.931950517
5.100016883	3.503508529	3.518340626
5.950019697	4.087426621	4.104730734
6.800022511	4.671344702	4.69112083
7.650025324	5.255262794	5.277510938
8.500028138	5.839180886	5.863901047
9.350030952	6.423098966	6.450291143
10.20003377	7.007017058	7.036681251
11.05003658	7.590935151	7.623071359
11.90003939	8.174853231	8.209461456
12.75004221	8.758771323	8.795851564
13.60004502	9.342689415	9.382241672
14.45004784	9.926607496	9.968631768
15.30005065	10.51052559	10.55502188
16.15005346	11.09444368	11.14141198
17.00005628	11.67836176	11.72780208
17.85005909	12.26227985	12.31419219
18.7000619	12.84619794	12.9005823
19.55006472	13.43011602	13.48697239
20.40006753	14.01403412	14.0733625
21.25007035	14.59795221	14.65975261
22.10007316	15.18187029	15.24614271
22.95007597	15.76578838	15.83253281
23.80007879	16.34970647	16.41892292

24.6500816	16.93362455	17.00531302
25.50008441	17.51754265	17.59170313
26.35008723	18.10146074	18.17809324
27.20009004	18.68537882	18.76448333
28.05009286	19.26929691	19.35087344
28.90009567	19.853215	19.93726355
29.75009848	20.43713308	20.52365364
30.6001013	21.02105118	21.11004375
31.45010411	21.60496927	21.69643386
32.30010693	22.18888735	22.28282396
33.15010974	22.77280544	22.86921407
34.00011255	23.35672353	23.45560417
34.85011537	23.94064161	24.04199427
35.70011818	24.5245597	24.62838438
36.55012099	25.1084778	25.21477449
37.40012381	25.69239588	25.80116458
38.25012662	26.27631397	26.38755469
39.10012944	26.86023206	26.9739448
39.95013225	27.44415014	27.5603349
40.80013506	28.02806823	28.146725
41.65013788	28.61198633	28.73311511
42.50014069	29.19590441	29.31950521
43.35014351	29.7798225	29.90589532
44.20014632	30.36374059	30.49228543
45.05014913	30.94765867	31.07867552
45.90015195	31.53157676	31.66506563
46.75015476	32.11549486	32.25145574
47.60015757	32.69941294	32.83784583
48.45016039	33.28333103	33.42423594
49.3001632	33.86724912	34.01062605
50.15016602	34.4511672	34.59701615
51.00016883	35.03508529	35.18340626

Appendix D: List of Materials

Table 16: Cost of Materials

Total Spent ($)	333.53		
Item	**Cost($)**	**Shipping**	**Vendor**
cooking pot	18.98	0	walmart
cornmeal	9.91	0	amazon
plywood	10.09	0	lowes
glass 30" x 36"	18.48	0	lowes
high temp tape	5.99	0	amazon
thermal conductive grease	8.99	0	amazon
steel barrel	101.46	30.61 for both barrels	grainger
plastic barrel	121.03		grainger
mylar	7.99	0	amazon

Appendix E: Team Member Qualification

Deshawn Wilson

Email: shawnwilson17@aol.com, tyi.ddreamer14@gmail.com

LinkedIn: www.linkedin.com/in/deshawn-wilson-88bb96158

Phone: Mobile (740)-244-9777, Home(740)-387-0299

Address: 561 Fairpark Ave, Marion, Ohio 43302

Objective- To seek employment in construction and improve upon my skills within the field.

Education-

The Ohio State University

Excepted in May 2021

Bachelor's in Science.

Projects-

· Global Water Institute (GWI) Tanzania solar cooker 2020: Tasked with finding background information about Tanzania in order to promote the importance of implementing the use of solar cookers into rural areas. Also tasked with calculating heat in and out of the solar oven..

Experience- August 2012-present Dukes and Duchess/ Englefield oil

· Cashier

· Painting- Repainted the caution areas around the outside of the store i.e. poles and non-parking zones.

· Stocking

· Reports- Sent financial reports for the store.

· Repair- If shelves broke or other equipment wasn't working properly, I would look at them and work out possible solutions.

Activities-

Harding drama club 2010-2011

Harding swim team 2011-2013

Notable Skills

- Software skills: MATLAB, Microsoft office, AutoCAD, Solid works
- First aid and CPR
- Minor welding
- Basic Spanish and Sign language
- Long term memorization
- Wood working

WESTON CLIFFORD
clifford.155@buckeyemail.osu.edu
440-724-2697
8781 Breckenridge Oval, Broadview Heights, Ohio 44147

Objective: Seeking an internship or co-op preferably within R&D starting May 2019 and open to relocation. Open to learning research topics if necessary as well.

Education: The Ohio State University, Columbus, Ohio
-B.S. Biological Engineering -Expected Graduation: May 2020
-Green Engineering Scholars -102 Credit Hours, 17 in progress
Brecksville-Broadview Heights High School
GPA: 4.245 Graduation, May 2016

Awards/Honors: My most recent and proudest accomplishment was getting an abstract selected for my summer research to attend the 2018 BMES annual meeting in Atlanta.

Involvement: **Sustainable Growing Club (GrOSU)**- A service learning and awareness club that supports sustainable growing in surrounding communities and on campus.
Second-year Transformational Experience Program- Gives the opportunity to receive a fellowship by creating a signature project while teamed up with a faculty member. I received the fellowship and used it to perform research.
Green Engineering Scholars- Program develops skills in engineering to adopt more socially responsible practices and minimize impact on the environment. Also offers plenty of volunteering opportunities.
Medical Innovation Club- Recently had a touching encounter with a girl who has cerebral palsy. After helping her, we found out both of us were in the same club and I will be working on a writing tool design project she is starting.

Work Experience and Qualifications:

- Davis Heart and Lung Research Institute, Columbus, Ohio | Research Assistant from June 2018 to present
  - I conducted cell biology type research on a cancer project looking at the relationship between Myeloid-Derived Suppressor Cells and two cancer cell lines with different phenotypes. I learned to work in a biosafety level 2 environment and used programs like Slidebook and ImageJ.
- The Ohio State University, Columbus, Ohio | Lab Assistant from September 2017 to May 2018
  -During school, I worked 13-15 hours a week in the chemistry prep lab. Made sure the general chemistry labs were stocked and maintained properly. Had training to work with chemical hazards.
- Anchor Manufacturing Group, Cleveland, Ohio | Intern under a Quality Engineer from May to August 2017
  -My main project was creating checksheets to be used by operators for many different metal components and assemblies. This work entailed reading various parts' control plans, analyzing engineering drawings and quality standards, working with tolerances, understanding quality checks, some excel work, and using a manufacturing database called PLEX.
- OWL-C (Ohio State Welcome Leader-Coordinator) | 8/14/17 to 8/19/17
  -Extensive training in leadership, diversity, and inclusion. After my training, I got a flock of kids to lead and help adapt to campus life before the move-in day responsibilities
- Clico Products, Twinsburg, Ohio | Quality Control- June to August, 2016
  -Inspected and cleaned parts going into Cadillacs and Camaros. Had to be meticulous and focused for 8 hour work days.
- Strong computer skills and an ability to learn programs quickly developed through classes such as Engineering CAD I (Auto CAD 14) and Graphic Design (Photoshop). Gained basic coding knowledge in MATLAB through two courses, and I have design skills in Solidworks.

Lukas Moreland
176 E Northwood Ave Columbus, Ohio 43201 | 513-824-5304 | Lukas.moreland@gmail.com

Education
The Ohio State University, Columbus, OH
Bachelor of Science in Food, Agricultural, and Biological Engineering
Specializing in Agricultural Engineering with a focus on Power and Mechanical Systems
Expected Graduation: December 2020
Overall GPA: 3.43/4.0
Dean's List Fall of 2017 and Spring of 2018

Skills & Relevant Coursework
Software: Microsoft Suite, Siemens NX CAD, SOLIDWORKS CAD, MATLAB
General Coursework: Physics: Gravitational and Electricity/Magnetism, Mechanics of Materials, Statics and Dynamics, Fluid Mechanics, Thermodynamics, Surveying, and others

Work Experience
Freelance Audio Engineer, Cincinnati/Columbus (January 2016 – Present)
- Provided Sound mixing services for a diverse customer base
- Assisted Churches and businesses in the setting up of sound equipment
Owner of The Neighborhood Mower, LLC, Cincinnati, OH (March 2011 – November 2018)
- Served customers through lawn care and mobile mower maintenance
- Negotiated services and communicated with customers

Project Experience
Thermodynamic Cooling System Design (October 2018-December 2018)
- Worked with a team of three to design cooling options for the MidOhio Foodbank
Robotics Project (January 2017 - May 2017)
- Collaborated with a team of four to design and build an autonomous robot
- Led the build and design of robot as the lead in CAD drawings and physical machining

Leadership & Involvement
Cru at Ohio State University (April 2017 – Present)
- Led Bible Studies and extracurricular events as a Target-Area Multiplier
- Spent the summer of 2018 working on growing Cru at Illinois Institute of Technology
- Provided weekly audio mixing services as lead sound technician
Boy Scouts of America (August 2009 - July 2016)
- Awarded Eagle Scout in July 2016
- Managed a group of adults and fellow scouts in completing my Eagle Scout Project in which a second story was added to a storage area in my high school, Miami Valley Christian Academy.
Athletic Band (August 2016 – May 2018)
SUSTAINS Learning Community (August 2016 – May 2018)

Molly Kern
kern.325@buckeyemail.osu.edu | 9320 Canterbury Lane, Mentor, OH, 44060 | 440-867-5484

EDUCATION
The Ohio State University, Columbus, Ohio
B.S. Biological Engineering, Expected Graduation May 2020
Honors: Recipient of Provost Scholarship, 2015 - 2017

WORK EXPERIENCE
Cheryl's Cookies, Assistant Manager (May 2017 - Current)
- Responsibilities as Assistant Manager include overseeing a team of 8 employees, creating schedules, payroll, and making sure the store meets sales goals
- Acted as Store Manager during the summer of 2019 and the store consistently exceeded set goals

Heinen's Grocery Store, Mentor, Ohio
Cashier (August, 2013 - December, 2015)
- Worked to provide customers with the best quality customer service and represent the store in a positive way

Parker Hannifin, Wind Turbine Fuel Systems Division, Mentor, Ohio
Intern (May 2015)
- Completed internship for Senior Project
- Worked with each division of engineering to gain insight into what each division contributed to projects in a large company

SKILLS
- Customer Service experience has led to high time management and multitasking capabilities
- Proficient in Matlab, Solidworks, Autocad, and Microsoft Office due to engineering coursework

ACADEMIC ENGINEERING PROJECTS
Advanced Energy Vehicle, January - May, 2016
- Worked with engineers from three different majors, coordinating tasks and schedules to successfully design an AEV that completed the final project tasks

Senior Design Capstone, August 2019 – April 2020
- Acted as team leader of a group of five engineers to successfully develop a solar cooker for use in Tanzania
- Gained valuable experience in design and product development for developing nations through partnership with the Global Water Institute

ACTIVITIES AND INTERESTS
- Buck-I-SERV, Trip volunteer for Medici Atlanta Project, December 2016
    - Volunteered with a group of 20 Ohio State students at nonprofit organizations in the Atlanta community for one week as part of Ohio State's Alternative Break Program
- Women in Engineering, August 2015 – present