IDDS Botswana 2016
Project Report C'EE KG'AM

SUSTAINABLE TEA MAKER

Background and Community Description

D'Kar is Located in Ghanzi district of Botswana. It is a farm owned by the Reformed church in Botswana it is part of privately owned farms which were allocated before Botswana's 1966 independence. The predominately San population of D'Kar far much exceeds what the population of a farm should be. The first owner of D'Kar constructed a church, a school and a clinic and might be the cause of the current population of D'Kar. Most D'Kar residents rely on government income and programs to provide their daily needs. The village has local artisans who make local craft as a substance means of generating income.

Tea is an important part in the lives of most residents of D'Kar, although others brew it two to three times a day some brew it throughout the day. The major source of energy used in the making of tea is firewood but with deforestation has become a major concern within the community as people go out for long distances to collect wood at least twice a week. Some people that can afford have to hire donkey charts to collect wood for them. There is awareness of alternative energies such as solar, gas and electricity but neither the fires made out of wood are not just affordable are culturally important than other alternatives and most people don't see the possibility of not having a fire. This is what prompted IDDS 2016 to come up with a project that will try and address issues surrounding tea making by coming up with a device that is appropriate to the community, the device should help the community reduce fuel(wood) consumption or use alternative form of fuel

Stakeholders/
The major stake holders of the project are first the Tea drinkers in the community of D'Kar, the environment because it's the source of the fuel that is being used to cook amongst many other uses

Path Statement
Families in D'kar find that firewood is becoming scarce and harder to find, but the outdoor fire is central to life in the Kalahari. We have sought to create fuel briquettes from agricultural and animal waste (maize stalks and donkey waste). We have also created a stove to efficiently use this fuel and firewood more efficiently. While not expecting to fully replace the morning and evening family fire, these products will be especially valuable for

smaller quantities of water boiled throughout the day, making already stretched resources go further.

Design Process

Summary of design process

The team developed a questionnaire which was delivered in a conversational manner with community members. Whilst in the community member's homes information was also gathered through observation of the communities' current process of tea making and fireplaces. The feedback was used to frame the problem statement and start ideating.

Group members individually ideated and brought these together to the group with sketches of different ideas. It became clear that because of the communities focus on wood fires a means of using wood efficiently was needed, but there was also a desire from the ideation process to explore alternative fuel types because of fire wood scarcity. At this time it was decided that in addition to research on stoves, research and experimentation would also be carried out on using available alternative sources of fuel.

i. Wood efficiency

The research on efficient wood use focused on 'wood burning rocket stoves' and key design principles such as; transmission of heat to the pot; insulation types; consistency of heat flow; efficient combustion of fuel; shorter chimney means hotter gasses but less efficient and more harmful emissions and vice versa.

An initial prototype was made from a paint-can and food tins. As well as a smaller hand held 'ember-powered' single cup heater. Also a brick rocket stove was created.

These were both displayed at a community review day where we were given feedback on the prototypes.

ii. Alternative fuels

The community has experience with gas, electricity and solar but these are rarely used as they are seen as too expensive. Therefore the focus was on the creation of charcoal briquettes from agricultural 'waste products' specifically from maize stalks, donkey dung, and grass.

These were shaped using various presser shapes and sizes and binding agents of pounded sorghum and clay, varying the percentage ratio of binder: charcoal powder to make briquettes.

After completing some experiments and drawing upon user feedback we ranked categories of user need and rated each concept according to a declining scale based on priorities established. After the concept evaluation we selected a rocket stove as our final prototype concept.

Evaluation Matrix + Brief Description of each of the concepts

Criteria	Datum (scale i.e. rating out of X)	Dual Pipe water tank	Standard rocket stove	Hand held single cup	Brick stove
Efficiency	10	5.5	7.5	6	5.4
Safety	9	3	7.4	5.6	7.4
Affordability	8	3.8	6	7.4	6.6
Ability to construct	7	3.2	5	6.2	6.6
Ease of operation	6	3.8	5	4.8	4.8
Flexibility	5	2.9	3.8	4	2.8
Durability	4	1.9	2.9	2.8	3.6
Total	49	24.1	37.6	36.8	37.2

Concept 1: Dual Pipe water tank rocket stove
This concept involves two rocket stoves either side of a central water tank. The theory being that the stoves would heat a central water tank between the rocket stoves and also heat a pot of water on the top of the stove.

Concept 2: Standard rocket stove
The concept of this stove is to have the equal cross section of heat flow from entry of air through to escape of hot air. This allows the heat from the fire in the combustion chamber to create a vacuum and suck the air through into the pipe causing a very efficient burning of the wood resulting in complete combustion. Other technical features include the need for a stand to be created so that only the tips of any sticks fed into the stove are burnt that air flows underneath the sticks. Also the entry pipe to chimney ratio must be 1:3 to allow the efficient burning. The rocket stove principle in this concept evaluation did not have a particular discussion around size of stove. As can be seen the paint-can stove and the final prototype produced the principles are the same but the size and materials are different.

Concept 3: Hand held single cup
This concept could heat one-two cups of water and would rely upon a pre-lit fuel such as an ember from the fire or a lit briquette. The heater relies upon close contact of the fuel in a chamber under the cup and a blower pipe/pump to feed the fuel with oxygen and heat the cup. This chamber would be insulated and would also have a skirt extending to cover the cup and pass the hot gasses around the cups sides.

Concept 4: Brick rocket stove
The brick stove follows the same principles of the rocket stove, with an inlet channel and a 1:3 ratio of gas channel from the combustion chamber, creating a vacuum effect and drawing air in to efficiently burn the fuel. The stove would be made of 18 bricks assembled in the correct shape, leaving a channel through the middle. The main advantages being ease

of construction and cheap materials. The disadvantages being that the bricks would absorb a lot of the heat instead of transferring the heat to the pot.

Analysis and experimentation

Experiments were done on alternative sources of fuel to make briquettes. These were done using locally available waste; donkey dung, grass and maize stalks. Results show that briquettes made from donkey dung were most effective and lasted longest compared to those made from maize stalks and grass. Mixing clay with the briquettes made them last longer but did not burn easily or as hot compared to sorghum powder binder. The briquettes with hollows in the center burnt faster and were easier to light, as compared to the solid ones of the same mixture. It is assumed that they burn hotter but this has not been measured. These tests were carried out on a simple 3 stone fire.

Regarding the stove, wood sticks and briquettes were tested on the final prototype and it proved that firewood was more effective than briquettes, because it burned more cleanly and hotter. It is uncertain whether this failure for briquettes to reach the efficiencies of the 3-stone fire testing is due to the height of the rocket stove chimney being too far for the heat to travel from combustion chamber to the pot or if the rocket stove principle itself doesn't work due to no flames and therefore a vacuum not being created.

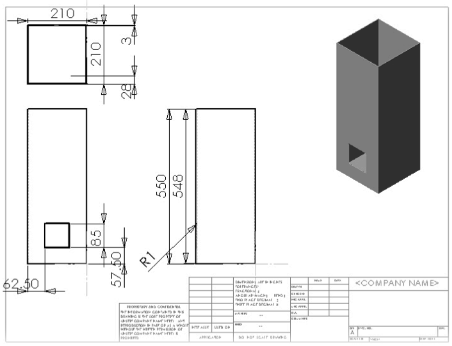
The stove will boil 1 liter of water in a cast iron 3-legged pot within 10-15 minutes and 350 grams of dry sticks would keep the fire burning for approximately 45 minutes.

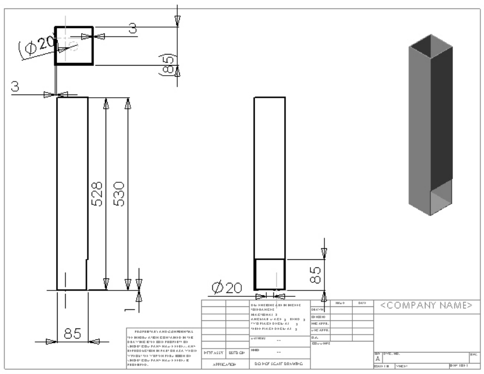
<u>Technology/Final Prototype</u>

User needs and design requirements

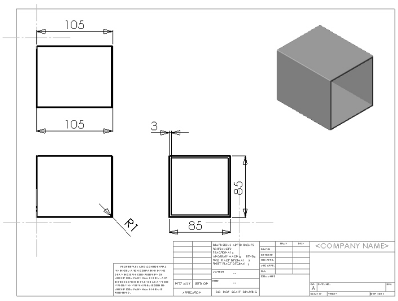
User need	What are you going to measure	How to measure it? units	Good value	Better value
Efficiency	Amount of fuel	Weight of wood		
		Weight of coal		
	Time taken to boil	Time (x fuel)		
	Temperature	Wood= degrees centigrade		
	Heat lost over time			
Safety	Pot stability	Three-legged pot support	yes	Yes
	Heat at surface	Degrees centigrade	40-45degrees	25-35 degrees
	Gasses	Wood= color of smoke	Clear smoke in 2min	Clear smoke in 1min
	Portable (hot firing)	Suitable handles	yes	Yes
Affordability	cost of product	pula	200-250	150 or less
	maintenance	Pula/ time	100 or less in a	100 or less in 5

			year	years
Ability to construct	Availability of raw materials	availability	Available and affordable	Available and 50% scavenge able
	Ease of construction	Skill level	Basic skills	Novice
Ease of operation	Cleaning of ash	Time	Less than 3minutes	Less than 1minute
	Easy to light	time	Less than 5minutes	Less than 1minute
	Seeing if fire is on	Time	Less than 10seconds	Less than 2seconds
	Ability to learn easy	time	5minutes	2minutes
Flexibility	Size of pot	Pot varieties	2-3 pot types/sizes	3-4 pot types/sizes
	In rain	Capability		Yes
	Outdoor	Capability		Yes
	Indoor	capability		Yes
	Portability	Dimensions (length X width)	45-50	50-55
		Weight	Less than 5kg	Less than 3kg
	Fuel dimension			
Number of fuel types	Ability to use coal/wood	uses	yes	yes
Number of interactions	Blowing			
	Feeding			
Durability		time	2-3years	3years or more
Others	Heating		No	Yes
	Cooking		No	yes





How it works



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A rocket stove is very efficient because it burns the fuel at a high temperature. It is fueled by small pieces of wood or briquettes placed horizontally into the burning chamber. One load of wood, approximately 370g, is the amount that can be tightly fit into an 85mm square chamber. This can boil 1liter of water in a 3legged iron cast pot within 10-15minutes and even continue burning. A typical burn session lasts 30-45 minutes and consumes just 1 load. *And yes, the log does continue to burn cleanly with bright flame on its own coals; adequate temperature is maintained by the insulated firebox.)* The wood burns slower and much more efficiently than a traditional stove. Air flows in beneath the wood through the inlet pipe and its preheated. There is ash between the chamber and the outer casing which insulates the combustion chamber thus creating a strong hot draft. Smoke is drawn through the flame and completely combusts preventing harmful emissions from exiting the stove. The hot air current forms a heat skirt around the pot causing it to heat quickly.

The rocket stove also provides heat after fire is no longer burning. The fire transfers heat to surrounding elements of the stove while it is hot. Once the fire is gone, the elements continue to give off heat hours after there is no combustion takes place

Performance

The product achieved its aim of being sustainable; using a small amount of fuel but it can still be replicated and improved upon to perform better. It burns wood twice as efficient as traditional methods used. Ash which is used as insulation in the stove works well but the problem is it makes the stove heavy. Measurements between the top of the combustion chamber and the pot need to be reduced to allow more heat to be directed to the pot instead of it escaping.

Tools and Materials required

Material	**Quantity**
1mm Galvanized steel	550x840mm
2mm Mild steel pipes	340x635mm
Ash compact/loose	No Data

Community engagement
At the start of the project the sustainable tea maker group visited the community to do a mini research to catch a gimps of what the community think about such a project and if they would like to help out with the projects with exception of one many said tea making was not a problem but cooking for it consumed the majority of the fuel but they all said they would love to be a part of the project and phone numbers were exchanged which were used to call the community members and during the community review many community members should interest in the rocket stove concept and the charcoal briquettes which were made out of donkey waste and agricultural waste and the community did input what they would like to see on the rocket stove to make there interaction with the stove easier and more efficient.

User feedback
After the first prototype that was made out of tin cans the community was impressed but they had a few issues that they brought out, they wanted to know how ash will be removed from the stove, and they wanted to find out how much time it would take to boil water, they asked for different sizes of the stove in order for the stove to accommodate different sizes of pots and if the stove would be used to cook meals and not only tea, they wanted to know if the stove would be used inside the house because the stove produced less to no white smoke or as a heater inside the house in winter

Troubleshooting

Trying to find the balance between efficiency, safety, durability and affordability ... where major concerns and because no tests have been done for gas emissions it is still hard to be sure that the stove can be used indoors and the team has not tested how effective the stove would be if used only for heating and the project was concerned about ... and our insulators still remain very heavy because there was limited knowledge and resources available in the area, the team decided to use ash as un insulator because it was light and readily available and was tested first in a compacted state and a loose state, the results were such that the compacted ash provided slow transfer of heat to the outer container of the stove but kept a lot of heat to itself and the loose ash provided faster heat transfer to the required destination but allowed a lot of heat to the casing of the stove then our solution was to have a double insulation where the inner layer is loose ash and the outer layer out of compacted ash which made the stove safe but heavy as well.. Another problem the project team face was to choose what size of pots the stove was going to accommodate, our primary user was a 45-year-old woman named Qasa and she had a family with of 4 kids and lives close to an extended. Qasa required more than one pot for tea making but with the dynamics of the current stove it only allowed a one litter three-legged pot and an aluminum flat pot with a skirt and without a skirt it can allow an extra big pot or two but the performance of the stove is reduced with the skirt the solution to this was not resolved but the team was looking in adding a variety of skirt types or an adjustable skirt and a base of the stove that can accommodate multiple sizes of the three-legged pot.

Project Future

Due to having working prototypes and having received positive interest from the community we believe that this project is viable although we acknowledge certain technical requirements which need to be improved.

The value that the products add for users include; Time is gained in the cooking/boiling process due to the power and heat transfer of the stove. Lots of time is also gained in the users' weekly schedule as the stove uses wood more efficiently and so the need for regular trips to gathering large quantities of fire wood is reduced.
Economic gains are made for the users who purchase firewood due to the need for less fuel and will be greatly reduced by users who adopt the practice of making briquettes from waste materials.
Convenience and lifestyle gains are made due to the portable nature of the stove allowing cooking/boiling to take place inside during rainy seasons. The stove due to being clean burning can also be used inside to heat the house in the winter.
Health gains are made due to less smoke being inhaled from incomplete combustion on the regular fire. Health gains are also made due to reducing the demands on the body and backs of users carrying heavy portions of firewood.

The value for other stakeholders include; the environment: There are gains to the environment due to less wood being used and less CO^{2} being produced. The community: There are gains to the community due to a changed mindset regarding the environment, their 'waste' products and making/innovation.
Technical challenges with the prototype stove include: The current insulation of wet and loose ash is too heavy. Research and experimentation needs to be done with alternative

insulation including: fiberglass; different clay consistencies (with binders such as sawdust or grass). The weight is a challenge – mostly due to the insulation. The height of the stove is perhaps too large and an issue for users. Regarding the efficient use of briquettes, the height of the stove is an issue. Specifically, the chimney pipe, is too long from the combustion chamber and as the briquettes rely upon direct heat rather than flames much of the heat is lost in the chimney. Conversely, the height of the chimney is needed to draw air in via the rocket stove principle for the efficient wood burning. Adaptions to the top of the stove, regarding the pot stand, are needed. Holes in the top to allow 3 legged pots to sink and sit closer to the hot gasses. The current shape of the stove will likely be adapted to circular allowing a tighter fit of pots and skirt allowing the gas flow to move closer and faster around the pots and increase the transfer of heat. Potentially adapting the diameter of the chimney/gas pipe/entrance pipe to a larger or smaller size depending on the size of the overall stove (smaller) or the need for entering larger pieces of wood. There is a desire to create a briquette presser which can make/cut many briquettes at the same time. There is uncertainty about the durability of the 2mm mild steel used for the chimney and research needs to be done into other metals are more suitable/available/affordable.

Continuity/dissemination model

In the coming weeks we will connect with some of the users whose phone numbers have been recorded and who we have started building a relationship with. We will work with them to gain user feedback. This is likely to be in a number of ways, notably loaning them two of the prototypes to trial for a week and give us their views. We will also host a focus group session. 5 out of 6 of our team are from Botswana, of these: 3 are based in the capital city Gaborone and have easy access to the tools and resources of the University of Botswana (UB). 1 participant lives in Raykops, Botswana and is well connected to many community groups for women's empowerment and youth. 1 participant is based in Dkar and will continue using the innovation centre. In the coming months the participants from UB will return to Dkar 1 or 2 weekends in the next 6 months and can lend support including the potential for UB design interns to come and work on packaging etc. The participant from Raykops will be vehemently establishing training on briquette making with his associated community groups in Raycops immediately after the IDDS summit. He will travel to Dkar in the coming months to run a briquette making workshop. The participant from Dkar will aim to recruit 15 people from the village in the coming months to manufacture the stove (once a second prototype has been developed). It is as yet unclear whether or not these people will be expecting to be established as entrepreneurs hoping to sell the product. The participant from Dkar will aim to display the product at next year's Ghanzi district annual agricultural show. The team and specifically the innovation centre in Dkar will reach out and connect with the IDIN chapter in Zambia. We would also like IDIN partner universities to consider using the project for continued research.

Anticipated risks and challenges

Our prototype stove costing approximately USD-$20 to manufacture is likely too expensive for many of our targeted users. There will be a challenge in securing cheaper materials and potentially recycled paint-cans for smaller size stoves.
As both of our products, especially the use of charcoal and the views of agricultural waste, require a change in mindset it is likely that we will find some resistance on adoption of these products.
As our team is spread across Botswana there will be communication challenges and there is a need for finances to allow for travel at key points.

Anticipated needs for mentors and partners

From mentors we will like contact for around 1 day a month to especially help with: business planning and evaluation; and marketing and distribution needs.

Contact Information

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Community partners