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EE2-PRJ E2 Project

Interim Report

Second year group project

Domestic Ventilation System for Underdeveloped Areas

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ABSTRACT

For many generations people in underdeveloped areas have used open wood-fire for cooking; however, it is not until recently that the harmful effects of incomplete combustion have been noticed. Millions of people die each year due to air-pollution from indoor cooking fires [1]. Our project offers a solution to this issue by employing a ventilation system. By pumping out the smoke and encouraging clean air back in, a valuable air exchange will be provided. Our solution is simple, inexpensive and easy to use and it will not require local people to change their cooking habits. A proper implementation of this system will ensure a decrease of the aforementioned lethal figures, ultimately improving the life quality of those in such circumstances.

INTRODUCTION

This project tackles a problem that does not seem obvious or immediate, however the long term effects are substantial and require addressing. When investigating the seriousness of the problems incurred by open wood-fire cooking, we discovered there have been many previous attempts and projects tackling the issue. From seeing successes and failures we realized this cooking method has been employed for many generations, and is an integral part of the culture, so residents are apprehensive to try new, safer cooking techniques. With this in mind, we have designed a solution that fits into a house, providing ventilation to remove smoke and toxic gases and circulate fresh air into the house, without imposing on their current methods of cooking. In designing the ventilation system, simple solutions such as a single hole on the wall seemed plausible, however with simple power generation modules we intend to design an efficient, effective, and sophisticated product to reduce the death toll due to air pollution.

In order to focus and refine our project, we have chosen to base it in Rwanda, as the Imperial College student group E.quinox already has a base there. As well as this useful connection to the area, we have found a lot of useful data as a source of information. Our project design has two major aspects: the electricity generation method and the ventilation system design. In regard to the former, different forms of energy supply have been analysed: solar panels, thermoelectric modules and two E.quinox systems for generating power. For each option we studied the costs, the power needed to operate our system, as well as how well the locals would adapt to such technologies. With regard to the ventilation systems, we analysed different spots for the fan to be mounted around the house and investigated the option of having a second fan with the purpose of injecting more oxygen into the fire. We intend to build a working prototype to present at the end of the project.

Furthermore, testing will be done on the chosen electricity generation method as well as on the ventilation system design. During the whole testing process our clear goal will be to keep the cost as low as possible, which implies keeping the system at a very simplistic level. Finally we intend to build the complete system. Although it will be hard to recreate an environment similar to that in Rwanda, we will test the final system to the best of our capabilities.

BACKGROUND

To ensure the adaptability of the system, research on cultural and environmental aspects in Rwanda has been carried out. Figures have been found showing that 81 % of the population lives in rural areas, out of which 97 % use biomass for cooking indoors and therefore are exposed to indoor air pollution. We also learnt that most of the cooking is done by women, often assisted by girls. Beans are an integral ingredient in the Rwandan diet as they are the most widely available source of protein, however they take multiple hours to cook so considerable air pollution is produced [17]. All of these facts support the need for a ventilation system. Taking into account that mains electricity is generally not accessible in our target areas, a different way of generating power has to be found. In Rwanda there are more or less 12 daylight hours throughout the year and a high annual solar radiation of approximately 5150 Wh/m^2/day [6] which indicates that solar energy could be a viable power source.

During our research, we explored other ways to improve the health condition in households of very low income. There are many varieties of cleaner cooking stoves including solar cookers or the 'Canamake' stove, which has been recommended by the Rwandan government. Although they provide a much cleaner fuel combustion, they have often failed due to factors like cost or inadaptability to local cooking traditions [5, 8]. This highlights one of the benefits of our idea: It does not interfere with existing cooking traditions. Furthermore, designing a very simple but effective system that is optimised for this particular application should keep the cost low.

However, there are other factors that make it difficult to implement health improvement solutions in rural areas where the level of education is often low. As only 50% of the Rwandan population are aware of health issues, there is a low acceptance for new ideas improving the standard of health [5]. Therefore, when putting our project into practice, we would have to devise a very good marketing strategy to convince possible customers of the benefits that our product provides. A strategy for this could be intensive local 'door to door' marketing [5].

Our main challenge in this project is the distance to our target areas. Even though the Internet is a vast source of information, it lacks some key data that could only be acquired from the local people. For this reason we chose to focus on rural Rwanda, as E.quinox, a student-led group at Imperial College, is working to implement electrification in this areas. They have provided us with valuable information and experiences from their project. Currently, the team is on an expedition to the area and are also collecting some data specifically for our project. The full list of the questions that we had can be found in appendix 5.

PRODUCT DESIGN SPECIFICATION

Below, we will describe the 8 most important aspects defined in the PDS. The full list of criteria can be found in appendix 2.

PERFORMANCE

The product must:

- Reduce smoke and fumes created by open-fires in homes.
- Be powered by renewable sources.
- Provide an air exchange rate between 10 and 20 cubic feet per minute.

The product could:

- Manage any surplus power for other domestic uses.

ENVIRONMENT

The product must:

- Withstand temperatures in its close environment - outdoors as well as e.g. close to the fire, which can have up to 300°C.
- Be resilient to dirt, smoke and insects.
- Ensure any components placed outdoors are weather-proof.

MAINTENANCE

- Fans pumping smoke will get dirty and will need periodic cleaning, no more than once weekly.
- All parts should be replaceable and relatively easy to source or make. Local materials and techniques should be employable.

ERGONOMICS

- There should be little need to interact with the product once it is installed except for maintenance and it should not impede the user. Design should be unobtrusive so there is little or no change to the user's way of living.

The product could:

- Encourage healthier posture or enhance cooking experience

TARGET PRODUCT COST

- The product must cost no more than £7 as the target market have very little disposable income.
- The product could be funded through the application of a micro-finance system.

SAFETY

- There should be no access to parts that get hot, ie. heat sinks. This is to protect the user from burns.

SOCIAL IMPLICATIONS

- The product should improve users' well-being by reducing smoke in homes.
- The product could raise awareness about the importance of clean air

MATERIALS

- Materials should be accessible locally and inexpensive

CONCEPT DESIGNS

As a basis for our technical research, we have estimated the air flow necessary to significantly clean the air in the house, in order to look up typical ratings for suitable fans. Considering the amount of wood that is burned, the size of the houses, recommended air exchange rates and other factors we estimate an air exchange rate of about 4cf/m is required if only the smoke from the fire is extracted and 40cf/m if the whole house is continually ventilated. For our further research we used an air exchange rate of 10-20cf/m as a guide value (see full analysis is appendix 4).

In order to work out preliminary designs, we split up into 4 sub-groups and focused on the different methods to generate electricity. We considered solar panels mounted on the roof of the house, the battery-boxes and standalone photovoltaic modules produced by E.quinox as well as thermoelectric modules as a way to generate electricity from the heat of the cooking fire.

ELECTRICITY GENERATION METHODS

SOLAR PANELS

Solar panels work using the principle of the Photoelectric Effect which, put simply, is the emission of electrons from a surface due to the absorption of energy from the sun.

A simple photovoltaic cell consists of two differently doped semiconductor layers, one n-type and the other p-type. As a photon hits the layers it frees electrons causing a current to flow through the circuit connected to the semiconductor layers. When electrons enter the p-type material, the electric field between the layers drives them into the n-type material again. This describes the Photovoltaic Effect.

The typical power efficiency of a solar panel is 15%-19% at most [13]. This could be a concern for us, as a lower efficiency may require more arrays of cells to generate the desired power. The main 4 factors affecting the efficiency are:

Panel orientation → Ideally facing south
Roof and panel pitch → Solar tracking systems to maximize the number of hours of sunlight
Temperature → Panels become less efficient at higher temperatures
Shade → Shade limits the light incident to the solar panel so less power is generated

Apart from this, we could consider more advanced panels such as multi-junction cells but this would raise the cost of the system substantially. Hence, we decided to come up with an idea to rotate the panel to follow the sun path so that it will absorb as much sun as possible [14].

Components we need:

One stepper motor, LDRs, Analogue to Digital Converter (ADC), Microcontroller

The process is as follows: The amount of sunlight each LDR detects is compared and the signal is sent through the ADC in order to be read by the microcontroller. Then, the stepper motor will turn the panel to the appropriate direction.

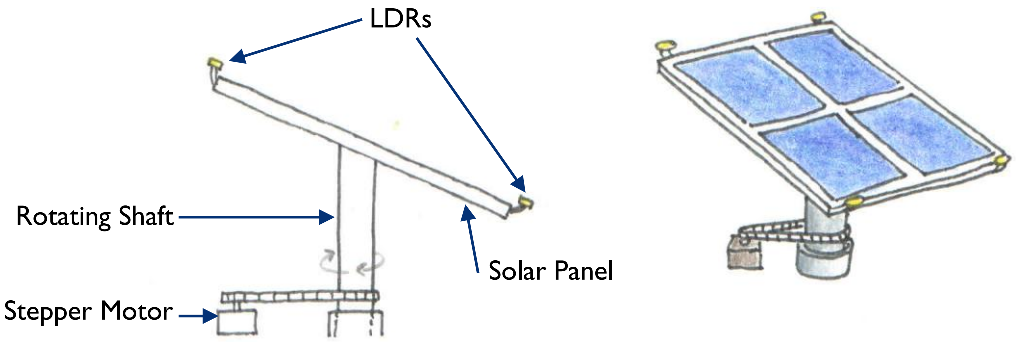

Figure 1: Rotating Solar panel arrangement

Solar panels can be implemented in our system for the purpose of power generation, as they are self-sustainable and renewable. However, there are a few problems with this method. Firstly, we will have to place arrays on the owner's roof which they may object to as it will change the look of their house immensely. Secondly, the arrays are exposed to possible theft. Another issue is that the power output is not steady as there are many factors affecting it.

In terms of cost, it is difficult to calculate a precise sum. However, our estimation shows that we will not need more than 5W to operate the system. Through research, we found a panel on sale that generates 5W and costs £12 [15].

THERMOELECTRIC MODULES

The term thermoelectric module refers to devices that are capable of transforming thermal energy into electrical energy. Thermoelectric generators (TEGs) consist of a collection of n and p diode pillars placed between two insulating plates, the hot and cold sides of the device. They make use of the Seebeck effect: Voltages between the hot and cold plate are induced as a result of a temperature difference. This occurs because the charged carriers on the hot side have more energy and therefore drift from hot to cold. The voltage produced is proportional to temperature difference: The bigger the difference, the larger the voltage. [7]

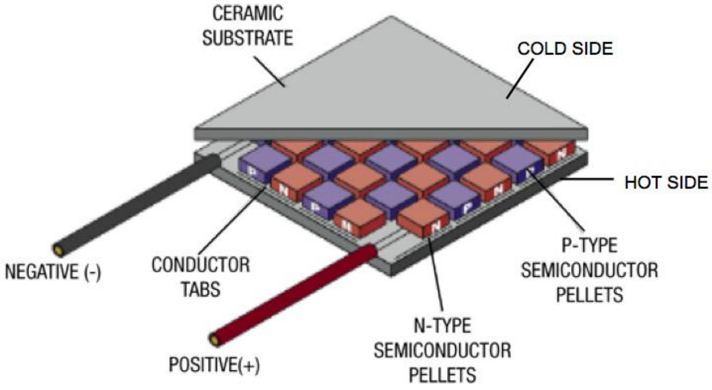

Figure 2: Operating principle of thermoelectric modules [10]

In our project, the hot side would be connected to a heat probe reaching into the cooking fire and the cold side could be connected to a heat sink at ambient temperature. The power that results from this temperature difference will be used to run an extractor fan in the roof or wall in charge of removing all the unwanted products of combustion.

Thermoelectric modules are considered very cheap in manufacturing but have a lower power efficiency than other generation methods (about 6-7%) [4]. However, this should not be critical in our case as the fans we require will only consume between 1-5W, which is small compared to the power of an open fire. The output voltage that can be obtained typically ranges from less than a volt to a few volts [12]. We could use USB-fans which run on 5V. Experiments have shown that this principle can already work with the power from candles [11], which makes it a viable option considering that a cooking fire can provide much more power. For our purpose, we might consider putting 2 devices in series in order to provide stable operation.

Another advantage that this technology has is that the voltage only changes gradually as the temperature changes so there is no risk of voltage spikes that may damage the fan. The average temperature of the fire can be considered to be stable, so we can assume that the power generated is approximately constant as long as the fire is burning. When the fire is put out, the temperature of the heat probe would gradually cool down so the voltage generated will decrease until it can no longer drive the fan. This delayed turn-off time is advantageous as the fan will continue to pump the remainder of the smoke in the house out once the fire has stopped producing more smoke.

Therefore electricity is generated exactly as required and this process is independent of weather conditions or other resources.

EQUINOX SOLUTIONS

Another option for powering our ventilation system is to use the technologies already developed by E.quinox. These are already integrated into Rwandan culture and are self-sustainable, so this would decrease complications in the implementation process of our project. In the areas where E.quinox is already operating, locals have been trained to maintain and operate the systems. Therefore we could pitch our product as an add-on to this, with our ventilation system upheld by the trained locals too.

E.quinox has various solutions for powering off-grid households; we are interested in their solar power solutions: the Battery- and the Standalone Boxes.

The Battery Box has two DC outputs, a 12V output to power lights, and a 5V USB output used for phone charging; rated at 500mA, 84Wh assuming 2W bulbs. There are energy kiosks with solar panels on their roofs in five different locations in Rwanda. People visit the kiosks to rent battery boxes for use in their households, these are returned when the power runs out. Normally the boxes need recharging 4-6 times per month, however if they were also used for ventilation then this number would increase. For people that live far away from the Energy Kiosks, this is a hassle, and for this reason the Standalone solution is interesting to us.

Figure 3: Standalone Solution [3]

The Standalone solution uses the same type of battery box, but comes with its own solar panel, so there is no need to go anywhere to get it charged. It has a 12V 7Ah battery matched with a $7W_P$ foldable PV panel, with three 12V DC power outputs for lighting and two 5V USB DC power outputs [2]. In addition, there is an LCD screen and a numerical tactile keypad for controlling the operation. The total cost of a box is 65.5 GBP, but the high cost is circumvented using a mobile payment based, pay-as-you-go scheme [3]. The customers pay about 80p per week until the battery box is paid off, after which they become the owners of the box. The standalone integrates a 2A intelligent interrupted charge controller, which increases battery lifetime by up to 400% [2]. This gain in lifetime comes from reduction in overcharging.

From looking at the E.quinox systems for generating power, the Standalone solution is more suitable for us, because this avoids the need to go to an Energy Kiosk to recharge the battery box. The Standalone is definitely a viable solution for powering our ventilation system. It would be easy for us to design a ventilation system that fits with the spec of the Standalone, and implementing our product into Rwanda would be a lot simpler if it was just an add on to E.quinox's already existing project. However, developing our own power generation technology, alongside designing the ventilation system itself, would be more challenging for us and would make our project more substantial.

SYSTEM DESIGNS

For every generation method that is described above, the generation system has to be connected to appropriate fans. According to our air flow estimate we have found that typical fan power ratings range from 1-5W maximum, either running from 5V or 12V [19]. We have seen above that all generation methods can produce at least 5V, however a voltage regulator or another voltage-smoothing circuit may be necessary. As it is not crucial if the fan slightly changes in speed, testing will show if such circuitry is necessary.

The positioning of the fan is very important in order to allow maximum efficiency in cleaning the air. A significant amount of polluted air should be extracted as quickly as possible. Therefore we have considered different positions for the fan, either mounted on the wall or the roof. As the fan is driving smoke, it needs to be resistant to the smoke itself as the particles could damage it or make it less effective by creating friction in the bearings.

By introducing a fan on the roof we would create a greater airflow across the house, reducing the levels of toxic gases produced by cooking fires. Our goal is to use the least amount of energy necessary to power this fan using either solar panels or thermoelectric modules. If we decide to use solar panels to power the fan, the roof would be a convenient location to place it due to the proximity to the panels. Furthermore, as the smoke rises up to the ceiling, the fan could be positioned above the fire to drive the smoke directly out of the house.

Roofs in these areas are generally constructed from either metal sheets, clay tiles or thatch. Thatch roofs are becoming less common now as they have been banned by the government due to their flammability and schemes have been set up in order to replace them [20]. We could use the current replacing of these roofs to implement our system when the new roof is installed. We may have trouble sourcing the tools to cut holes in the roof though and it will be difficult to perform on existing roofs.

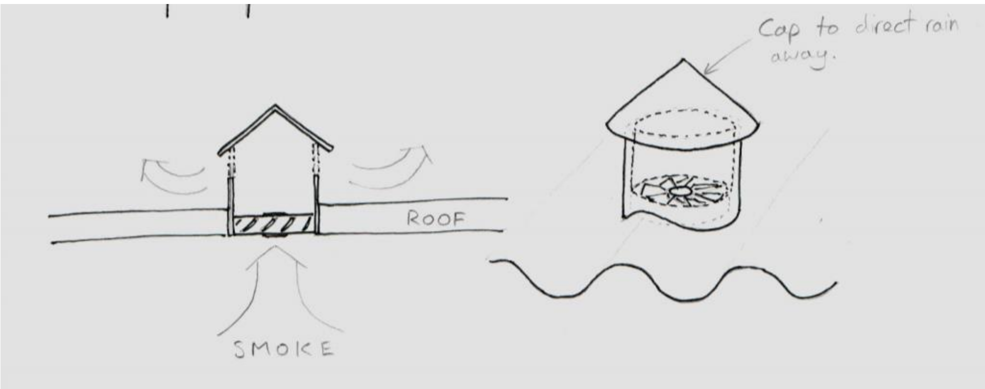

Figure 4: Fan mounted into the roof

Another concept uses a fan at the top of a wall to extract smoke from the home. The smoke created from the fire will rise to the ceiling of the room. The placement of the fan aims to 'tap' the smoke out of the room once it reaches the ceiling. This concept could be implemented in a number of ways which ultimately depends on the specifics of the home. One method is to make a hole in the wall to accommodate the fan and its ducting. This is a difficult job as adobe bricks, which are commonly used to build houses, may crack or shatter in the process of creating a hole. Another method is to exploit ventilator bricks, which are relatively common in Rwandan houses [18], by fitting fans to them which eliminates the need to make any new holes in the wall. Fittings could be designed to clip fans to these bricks.

Ideally, the fan would only target the air at the top of the room but once it is activated, convection currents will swirl the air in the room. The air around the opposite side of the ceiling to the fan will take a long time to be extracted.

The fan is powered using one of the methods outlined above. A cable from the power source could be clipped to run along the wall, this may require drilling into the wall to secure the clips.

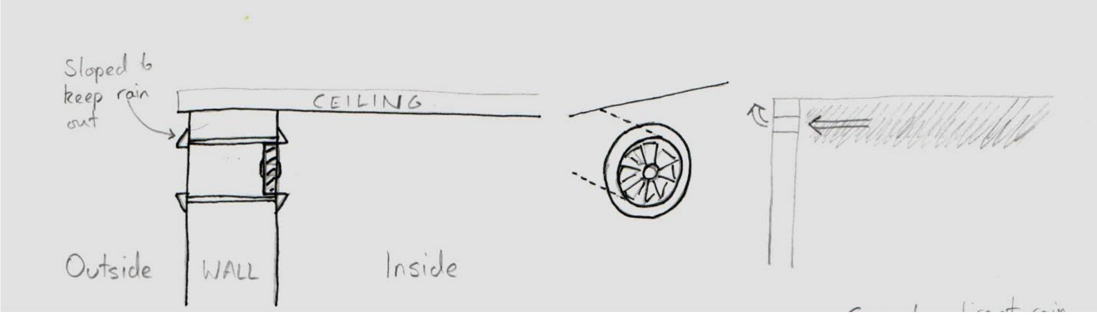

Figure 5: Fan mounted in the wall

A further enhancement that we have considered is adding a second fan to our system, which is mounted so that it injects air into the fire in order to improve combustion. This will reduce the amount of carbon-monoxide that is produced by ensuring a more complete combustion. The air flow will also make the fire burn at a higher temperature which means that food can cook faster and less wood is required. This enhancement is very useful, especially if thermoelectric modules are used. In addition to the higher temperature of the fire, a small fan could also function to cool the heatsink to which the thermoelectric module is mounted.

This fan must have little power consumption to function in addition to an extractor fan. Our research has shown that only a small heat source can easily power a fan through a thermoelectric module [11], and testing will show if we can apply this in practice. This enhancement, which is also inexpensive due to the low cost of low-power fans [19], adds the benefit of possible savings in biomass.

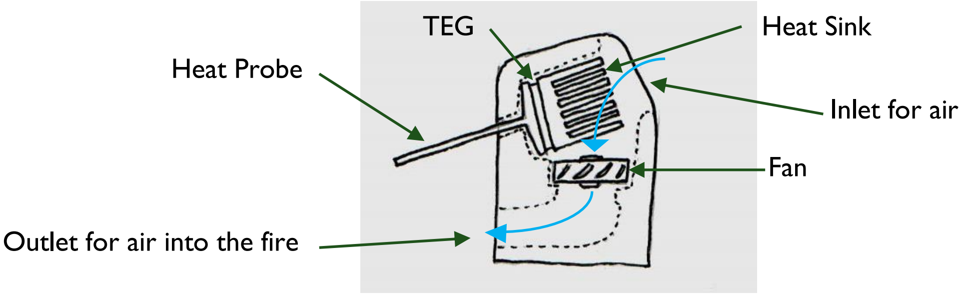

Figure 6: Second-fan integrated into TEG power supply

DISCUSSION

We compared the designs analysed above using the key criteria that we established in the PDS. We first assessed the feasibility of the electricity generation methods and then discussed different system layouts, analysing their strengths and weaknesses and selected the option we considered most feasible out of the proposed methods.

PERFORMANCE

As the above section has shown, all methods can provide enough power and voltage to power one or possibly 2 fans. While E.quinox boxes and solar panels depend on solar radiation, thermoelectric modules only depend on the fire. In the rainy season there might be much lower irradiance than optimal which would mean that less power is produced. TEGs on the other hand work independently of the weather conditions. Solar panels might give a better power output in peak times, but TEGs are more reliable in terms of having a more steady output as long as the fire is on and air needs to be extracted.

COST

The cost of the E.quinox Standalone solution is about 65.5 GBP, and the Solar panels cost about 12 GBP. The cost of TEGs varies with their ratings and can at this stage of the project not be certainly defined, but there are various modules available that cost less than 5 GBP: Due to our target user-group, who are individuals in underdeveloped areas, and our own limited budget the TEG solution seems the most appropriate.

ERGONOMICS

The E.quinox solution seems very plausible and should be simple to connect to the system. However, this means that our product is dependent on their boxes and cannot be adapted in areas where these might not be available. TEG modules and solar panels are more adaptable. While solar panels would be mounted very close to the fan, there would have to be a long cable connecting the TEG to the fan, which may be inconvenient to the owner if it is left dangling and may even present a trip-hazard. However, adding a fan close to the fire to improve combustion is much more practical if TEGs are used.

All in all we have found that the thermoelectric modules provide the most feasible option for our particular idea, in all of the above measures. Therefore we have decided on testing this technology in more detail and if possible design and build a prototype using the obtained results.

MAINTENANCE AND INSTALLATION

The positioning of the fan is not crucial, as long as it is positioned as high as possible and the hole is securely sealed. Maintaining the system, which mainly involves cleaning it from time to time, might be slightly easier if the fan is on the wall, but this depends on the way the house is constructed. The main concern here is the house construction itself, as exchanging wall bricks might be an excessive inconvenience. Therefore the exact positioning should be decided by the customer.

Further testing will also show if a second fan can be used. It is positioned inside the house so sealing or other installation efforts are not of concern.

FUTURE WORK

The Equinox team have recently travelled to Rwanda equipped with a questionnaire that we designed to fill in missing information regarding Rwandan cultural background, allowing us to achieve a better implementation of our product. We will use this information from the team to finalise the logistics of our design and how we will implement it into Rwandan culture.

Now that we have established the technologies that we deem best to implement into our design, the next steps are to get on the way with our testing. There are two key components of our system design that we will be testing in depth. These are the thermoelectric technologies that will provide our power, and the fans that we will use for the ventilation.

THERMOELECTRIC TECHNOLOGIES

We will test the thermoelectric modules that are already available to us here at Imperial, looking to find out what temperature gradients can be achieved, along with the resulting power generation abilities. Once we have collected enough data from these modules, it may be appropriate to invest into finding some more suited thermoelectric devices for the specific requirements of our project.

The testing procedure will include use of a hot plate; this will set up the temperatures similar to the flames of the wood-fire, so we can model how much electrical energy can be produced from the thermal energy provided. We will mount a rod to one side of the thermoelectric module, to collect the heat, and a heat sink to the other, to keep it as cool as possible. This system has the aim to set up the most optimal arrangement for a high temperature gradient.

A temperature probe will be required so that we can monitor how hot the thermoelectric module gets, it is important that we model the heat from flames accurately, and keep the temperature below 300 degrees as required by the thermoelectric module. We will use a power meter and other equipment in the electrical labs to measure the power output from the device under the conditions set up.

VENTILATION SYSTEMS

We will begin by testing small reused fans from computers, investigating what power quantities are needed, and how much ventilation each fan can provide. These tests along with the tests on our power generation system, will provide information on whether we will be able to implement a two-fan design or not. With two fans we will be able to make a multipurpose product that improves the combustion process as well as ventilating the house. For these two purposes, fans with differing ratings may be required so this can be tested too.

We will use a power supply unit to power the fans, and will measure their electrical characteristics as well as measuring the airflow produced, with the use of an air flow meter.

Testing parts of the system separately will indicate key factors to include in the Preliminary Design of the whole system, which will lead us to build and test the functionality of the system as a whole. During the testing and design process, a clear focus must be kept on keeping costs of components low - this includes keeping the design of the system as simplistic as it can be.

In parallel to designing the electrical system, we will design the overall containment and housing of the components, keeping the product as non-imposing to their cooking habits as possible.

Figure 7: Components for testing: Computer fans, TEG and heat sinks

DEVELOPMENTS

We will develop the ventilation system as much as possible in the timeframe that we have, first and foremost to cure any issues that arise in the testing of our Preliminary Design. With a functioning system we can then move on to developing the efficiency and effectiveness of the ventilation system, as well as furthering reductions in the product costs. There are limits to how much we can test the system, as it will be hard to create environments that match those in the houses in Rwanda.

DELIVERABLES

The deliverables in this project are to provide evidence of an in depth investigation into the feasibility of our ventilation system, keeping in mind various factors that would affect its ability to become a successful product, both in solving the problem and in creating an effective business out of it. We will deliver a website that showcases and provides details on our project, and also wish to have a functioning prototype product. The purpose of this will be to showcase the electrical system of generating power and running the ventilation fans. The component housing and designs for how it will be fitted and implemented into the houses may just appear in the form of detailed drawings.

CONCLUSION

Incomplete combustion caused by wood-fires is a worldwide issue, particularly in underdeveloped areas, as it is the cause of millions of deaths each year. To improve the quality of air in houses using wood-fires, we came up with the idea of a ventilation system. This system would be in charge of extracting polluted air from the household at a faster rate as well as replacing it by clean air. Researching the cultural background played a very important role in this project as our product is going to be used in a culture where people have habits and traditions very different to our own. In past efforts, interfering with people's cooking traditions has resulted in only achieving a small uptake so we have to make sure that this is not the case for our project.

Throughout the report, two main analyses were carried out: that of the energy sources and that of the different ventilation systems. Regarding the former, numerous viable energy sources to power the fan were considered: solar panels, thermoelectric modules and E.quinox's power boxes. Despite their objective strengths and weaknesses, the cultural background also plays an important role as people want to maintain their customs. Our most restrictive constraint was cost as our target users are very poor. Only very cheap devices would be feasible for them to purchase. After careful consideration we opted for the thermoelectric modules method due to its low cost while still producing enough power for the fan. More importantly, this energy source is weather-independent unlike the solar options and therefore is very adaptable to a wide range of environments.

Regarding the ventilation system, we will investigate whether the option of powering two fans is plausible depending on our power output, otherwise we will use only one extractor fan. The most efficient positioning for the fan, either on the roof or on the wall, will be decided by the individual customer. This is due to the variety of housing types in rural Rwanda and allows more flexibility in the implementation.

With this project, we hope to achieve a viable solution to decrease the lethal figures that lie under the incomplete combustion of wood-fire cooking in Rwanda. Compiling all of the information gained from research and testing, we hope to build a prototype, and have a fully complete design and context study to back it up, in order to prove the effectiveness of our solution.

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APPENDIX

1 PROJECT PLAN

In order to discuss the progress of our project, we have been meeting on a weekly basis and will keep this meeting frequency throughout next term. In the group meetings we are discussing recent findings and new aspects to consider and we split up our workload in equal sub-groups for each phase of the project. Dr. Steve Wright, our project supervisor, has joined these meetings on a regular basis to give us feedback and new ideas.

Alina has taken on the role as group leader and Xavier is the group secretary, taking minutes of each group meeting.

PROJECT PHASES

MARKET RESEARCH

Firstly, we defined our project and the range of our problem. After deciding on focusing on Rwanda, we split up in sub-groups and conducted market research to learn about living conditions, culture and construction of houses as well as already existing technologies and possible problems in the execution of the project. We used this information to roughly estimate the required power required in our design.

TECHNOLOGY RESEARCH

The next step was to research and compare different possible technologies to put the ventilation system into practice. We focused on different electricity generation methods, which again we analyzed in subgroups. Younghan and Xavier have analyzed solar panels, Alina & Belen have looked into the feasibility of thermoelectric modules and Ella and Bethany have gathered information about the battery boxes that the student project e.quinox sells in Rwanda. Lloyd has taken on the task to make sketches of different scenarios. Finally, we have discussed different ways to reasonably mount fans and compared the advantages and disadvantages of the different methods

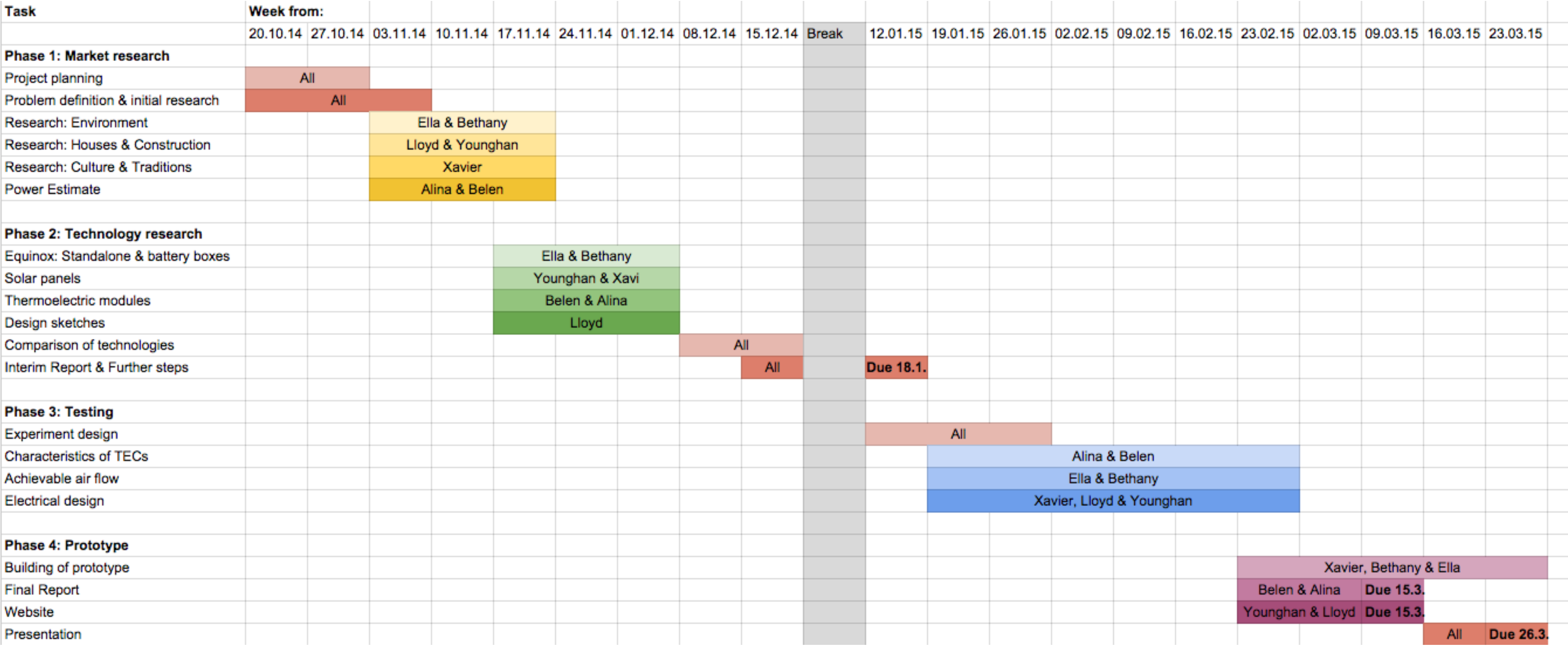
TESTING

We will conduct tests to validate the feasibility of our idea. Again, we are going to split in groups to divide the workload equally. This also includes making reasonable assumptions for testing criteria to simulate the environment our product will be used in.

PROTOTYPE

As the last stage of the project, we aim to build a prototype with which we can demonstrate our idea. This will require some creativity as the environment for testing is very different from the environment in which we want to apply our idea. We are also going to create a website to present the project and produce a final report.

GANTT CHART



Task	Week from:																				
	20.10.14	27.10.14	03.11.14	10.11.14	17.11.14	24.11.14	01.12.14	08.12.14	15.12.14	Break	12.01.15	19.01.15	26.01.15	02.02.15	09.02.15	16.02.15	23.02.15	02.03.15	09.03.15	16.03.15	23.03.15
Phase 1: Market research																					
Project planning	All																				
Problem definition & initial research	All																				
Research: Environment			Ella & Bethany																		
Research: Houses & Construction			Lloyd & Younghan																		
Research: Culture & Traditions			Xavier																		
Power Estimate			Alina & Belen																		
Phase 2: Technology research																					
Equinox: Standalone & battery boxes					Ella & Bethany																
Solar panels					Younghan & Xavi																
Thermoelectric modules					Belen & Alina																
Design sketches					Lloyd																
Comparison of technologies								All													
Interim Report & Further steps									All		**Due 18.1.**										
Phase 3: Testing																					
Experiment design											All										
Characteristics of TECs												Alina & Belen									
Achievable air flow												Ella & Bethany									
Electrical design												Xavier, Lloyd & Younghan									
Phase 4: Prototype																					
Building of prototype																	Xavier, Bethany & Ella				
Final Report																	Belen & Alina		**Due 15.3.**		
Website																	Younghan & Lloyd		**Due 15.3.**		
Presentation																				All	**Due 26.3.**

2 PRODUCT DESIGN SPECIFICATION

PERFORMANCE

The product must:

- Reduce smoke and fumes created by open-fires in homes.
- Be powered by renewable sources.
- Provide an air exchange rate between 10 and 20 cubic feet per minute.

The product could:

- Manage any surplus power for other domestic uses.

ENVIRONMENT

The product must:

- Withstand temperatures in its close environment - outdoors as well as close to the fire, which can have up to 300°C.
- Be resilient to dirt, smoke and insects.
- Ensure any components placed outdoors are weather-proof.

LIFE IN SERVICE

- Ideally service life will be long. Parts will be designed to be durable.
- The product will be used daily.

MAINTENANCE

- Fans pumping smoke will get dirty and will need periodic cleaning, no more than once weekly.
- All parts should be replaceable and relatively easy to source or make. Local materials and techniques should be employable.

TARGET PRODUCT COST

- The product must cost no more than £7 as the target market have very little disposable income.
- The product could be funded through the application of a micro-finance system.

COMPETITION

- Air conditioner units / Cooker hood extractor fans / Clean-burning biomass stoves

QUANTITY

- Ideally 1 Prototype for this project

MANUFACTURING FACILITIES

- N/A

SIZE

- Consider size of homes / fires. Small is desirable.

WEIGHT

- Lighter fixtures would suit wall-mounting better.
- Under 10kg

AESTHETICS, APPEARANCE & FINISH

- Design to suit Rwandan traditional style for easier integration and greater uptake.

MATERIALS

- Materials should be accessible locally.

PRODUCT LIFE SPAN, QUALITY AND RELIABILITY

- The product life span should be long as the product represents a big investment for our target group.
- It should work reliably as long as it is maintained appropriately.

ERGONOMICS

- There should be little need to interact with the product once it is installed except for maintenance and it should not impede the user. Design should be unobtrusive so there is little or no change to the user's way of living.

The product could:

- Encourage healthier posture or enhance cooking experience

CUSTOMER

- The people of Rwanda cooking with open fires in their homes.

SHELF LIFE

- N/A

PROCESSES

- Required processes must not be too complex and should be relatively easy to implement in Rwanda. Ease of implementation will depend upon accessibility to tools.

TIME-SCALE

- October 2014 to March 2015

TESTING

- Testing must be carried out in order to inform design decisions.

SAFETY

- There should be no access to parts that get hot, ie. heat sinks. This is to protect the user from burns.

COMPANY CONSTRAINTS

- N/A

MARKET CONSTRAINTS

- Little awareness of health issues make it difficult to access the market
- Reliance on secondary research due to distance to target market
- Products should be aligned to government programs

PATENTS, LITERATURE AND PRODUCT DATA

- N/A

SOCIAL IMPLICATIONS

- The product should improve users' well-being by reducing smoke in homes.
- The product could raise awareness about the importance of clean air

STANDARDS, SPECIFICATION & LEGAL

The Rwandan government has strict regulations about house construction.

Regulations include positioning and material of chimneys, which might also refer to our system and would have to be considered.

INSTALLATION

- Any holes made in walls, roofs etc must be securely sealed.

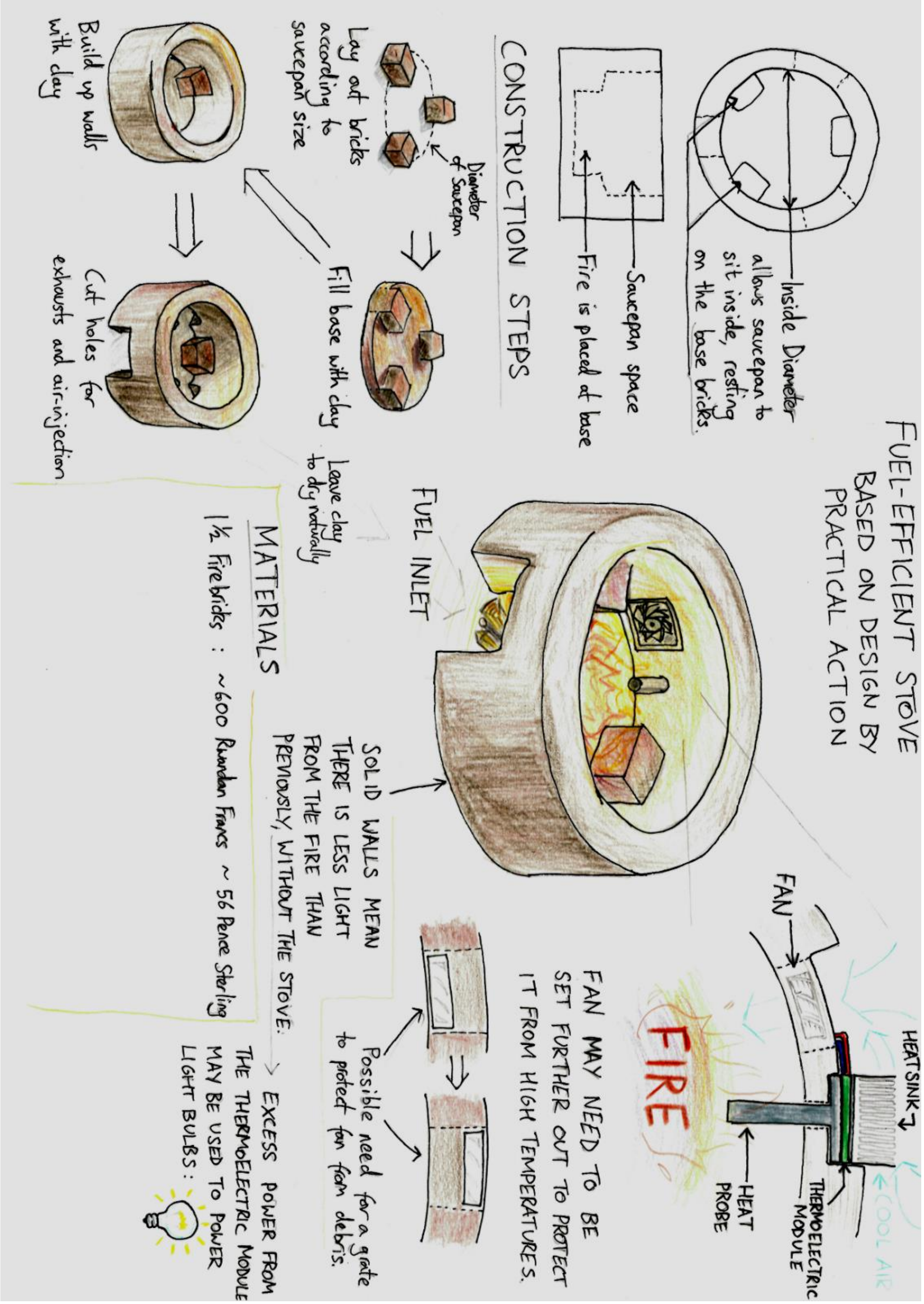
DOCUMENTATION

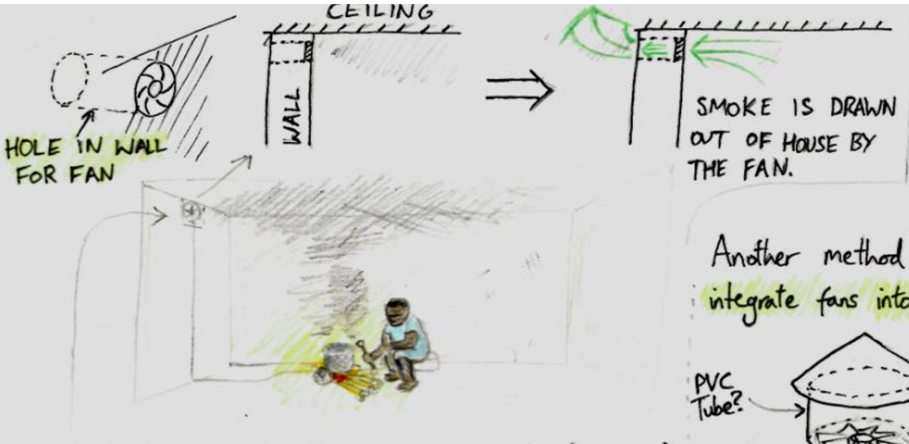
- Instructions should be easy to understand. Possible use of graphics rather than language to improve accessibility.

DISPOSAL

- Recyclability of TEG / PV cells is a concern. Other materials should be non-toxic and ideally recyclable.

3 SYSTEM DESIGN SKETCHES

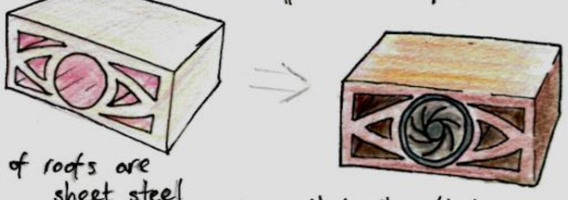




Cutting a hole in existing adobe walls will be difficult and will likely crack the bricks.

- Homes with ventilator bricks could have fans integrated into such bricks

⊖ Difficult to design to fit all different brick patterns



Ventilator placed at top of wall to 'tap-off' smoke that has risen to the ceiling.

Another method is to integrate fans into ceiling/roof.

< Majority of roofs are sheet steel

Could be cut by cold chiselling / holesaw

- Inconvenient in-situ

⊕ CHIMNEY CAN BE PLACED ABOVE FIREPLACE

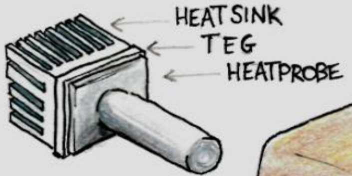
- FAN ONLY NEEDS TO DIRECT A SMALL VOLUME OF SMOKE, WHEREAS TOP-OF-WALL METHOD MUST DIRECT WHOLE CEILING OF SMOKE

⊖ LONGER CABLE

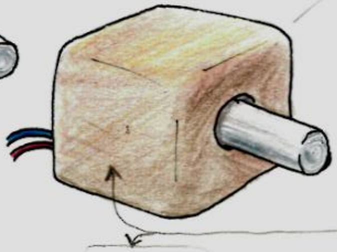
POWER MODULES

Thermo-electric, to be placed by the open fire.

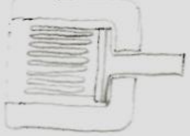
KEY COMPONENTS:



Requires non-flammable, insulating materials for casing.



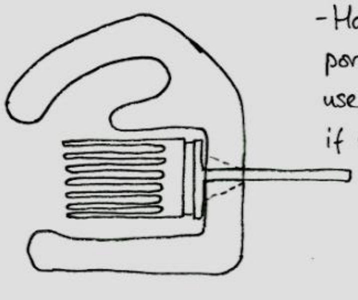
Clay-box casing
- could be used to stand saucepan on.
- should be able to withstand heat



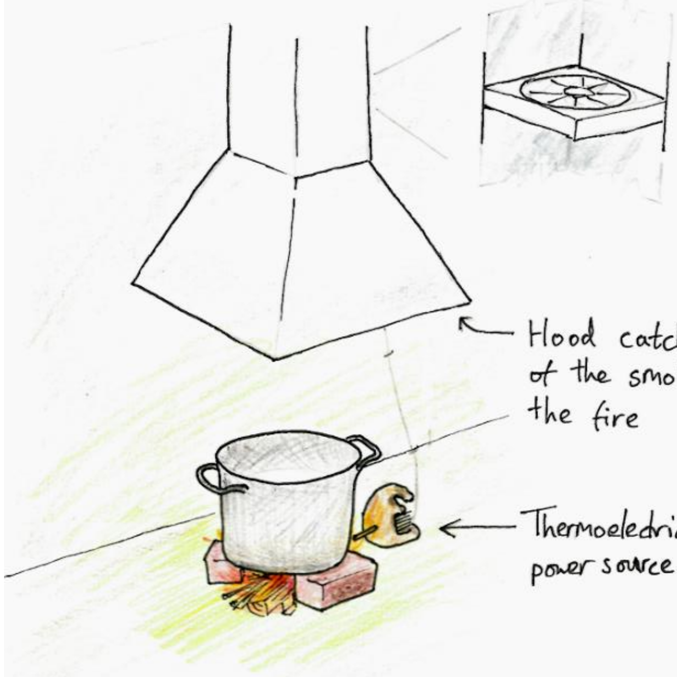
Added vent holes would aid cooling of heat-sink

Clay construction

- Handle allows for easier portability for storage and use, so fire can be moved if necessary.



COOKER HOOD-LIKE SOLUTION

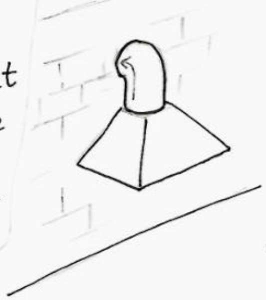


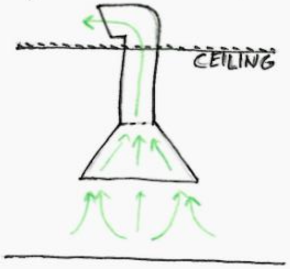
Fan in duct draws the smoke up and out of the home

Hood catches most of the smoke from the fire

Thermoelectric power source

Through chimney in roof or opening in wall (window, ventilation brick...) → Existing openings will likely be more convenient to use rather than creating holes in the ceiling or wall.



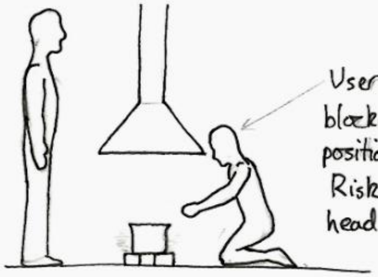


To make this applicable to more homes, flexible ducting could be used.

ERGONOMICS

Sharp corners and edges should be removed as they pose a health risk

Height of the hood must be considered as it may get in people's way



User's vision may be blocked by the position of the hood

Risk of knocking head against it also

MATERIAL REQUIREMENTS

- Lightweight so it can be mounted to the wall.
- Non corroding as it will be exposed to hot steam and smoke.
- Heat resistant so it does not warp or break in normal use.

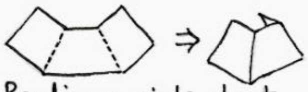
Potential Materials

Aluminium - Performs well to all 3 specifications

Acrylic - Can withstand up to 90°C.

Polycarbonate - Up to 120°C

CONSTRUCTION METHODS



Bending a single sheet

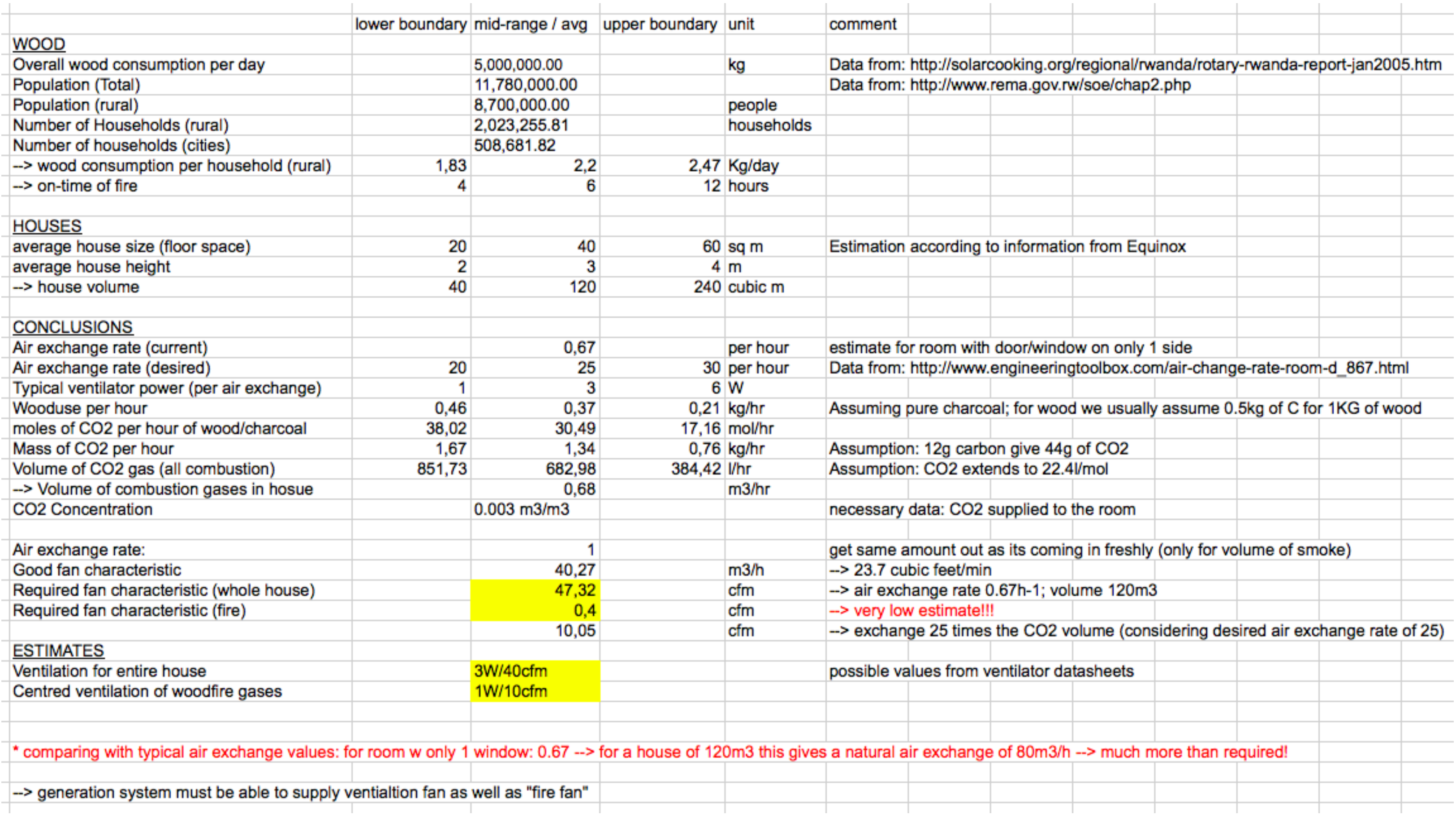
- Suitable for all 3 materials
- Corners can be rounded

For Aluminium: Weld or rivet sheets together

Plastics could be joined using a solvent cement. Not as strong as welded aluminium though.

Vacuum form - Applicable to plastics only

4 WATT ESTIMATE



	lower boundary	mid-range / avg	upper boundary	unit	comment
WOOD					
Overall wood consumption per day		5,000,000.00		kg	Data from: http://solarcooking.org/regional/rwanda/rotary-rwanda-report-jan2005.htm
Population (Total)		11,780,000.00			Data from: http://www.rema.gov.rw/soe/chap2.php
Population (rural)		8,700,000.00		people	
Number of Households (rural)		2,023,255.81		households	
Number of households (cities)		508,681.82			
--> wood consumption per household (rural)	1,83	2,2	2,47	Kg/day	
--> on-time of fire	4	6	12	hours	
HOUSES					
average house size (floor space)	20	40	60	sq m	Estimation according to information from Equinox
average house height	2	3	4	m	
--> house volume	40	120	240	cubic m	
CONCLUSIONS					
Air exchange rate (current)		0,67		per hour	estimate for room with door/window on only 1 side
Air exchange rate (desired)	20	25	30	per hour	Data from: http://www.engineeringtoolbox.com/air-change-rate-room-d_867.html
Typical ventilator power (per air exchange)	1	3	6	W	
Wooduse per hour	0,46	0,37	0,21	kg/hr	Assuming pure charcoal; for wood we usually assume 0.5kg of C for 1KG of wood
moles of CO2 per hour of wood/charcoal	38,02	30,49	17,16	mol/hr	
Mass of CO2 per hour	1,67	1,34	0,76	kg/hr	Assumption: 12g carbon give 44g of CO2
Volume of CO2 gas (all combustion)	851,73	682,98	384,42	l/hr	Assumption: CO2 extends to 22.4l/mol
--> Volume of combustion gases in hosue		0,68		m3/hr	
CO2 Concentration		0.003 m3/m3			necessary data: CO2 supplied to the room
Air exchange rate:		1			get same amount out as its coming in freshly (only for volume of smoke)
Good fan characteristic		40,27		m3/h	--> 23.7 cubic feet/min
Required fan characteristic (whole house)		47,32		cfm	--> air exchange rate 0.67h-1; volume 120m3
Required fan characteristic (fire)		0,4		cfm	--> very low estimate!!!
		10,05		cfm	--> exchange 25 times the CO2 volume (considering desired air exchange rate of 25)
ESTIMATES					
Ventilation for entire house		3W/40cfm			possible values from ventilator datasheets
Centred ventilation of woodfire gases		1W/10cfm			

* comparing with typical air exchange values: for room w only 1 window: 0.67 --> for a house of 120m3 this gives a natural air exchange of 80m3/h --> much more than required!

--> generation system must be able to supply ventialtion fan as well as "fire fan"

5 QUESTIONNAIRE FOR EQUINOX JANUARY EXPEDITION

QUESTIONS TO THE PEOPLE:

Health impact:

- Are you aware of the health impacts smoke inside of households has?
- Do many people in your village suffer from bad cough?

Cooking habits:

- How many people are usually in the room for cooking?
- How long is the fire left on for, per meal?
- How many meals do you have per day?
- What does a typical meal consist of?
- Are fireplaces usually indoors?

House constructions/living conditions:

- Do you use fire as lighting source?
- Do you use fire as heating source?
- How many people usually sleep in the houses?
- Do you usually have a separate kitchen?

Attitude towards changes:

- Would you be willing to invest in a device to introduce cleaner air into the house in order to improve your health?
- Are there easy ways for you to access small credits in order to afford such devices?
- Would you prefer having a ventilator mounted on your roof or on your wall?

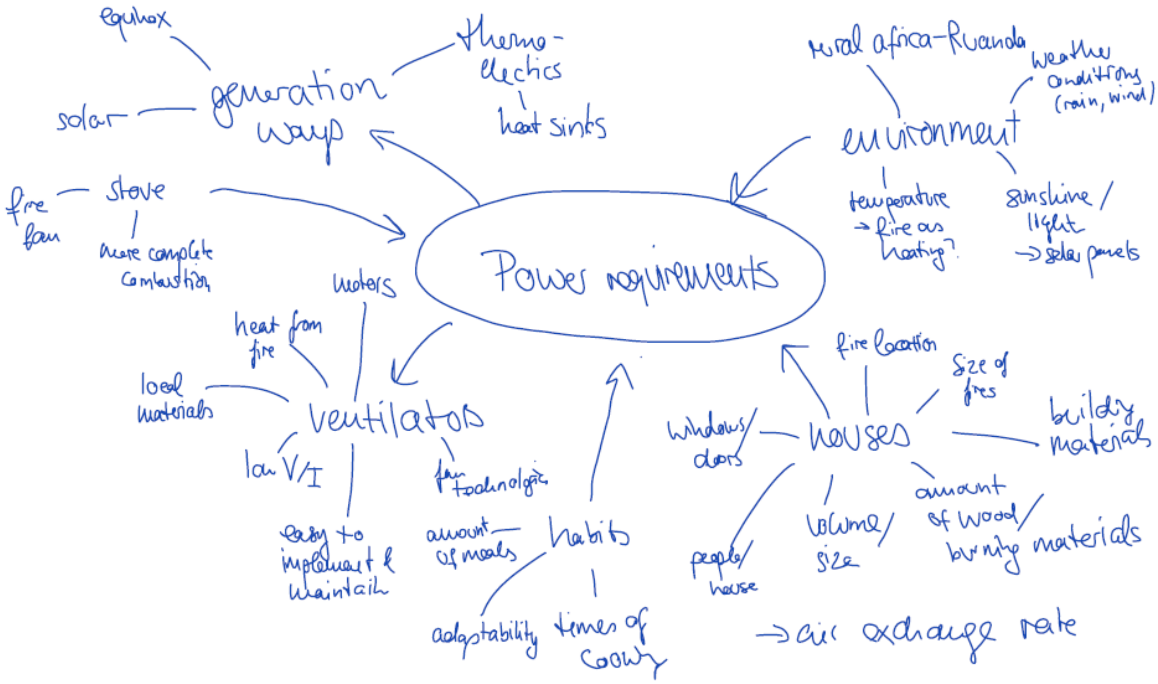
OBSERVATIONS IN THE AREA:

- How large is the fire?
- What does the fire place look like?
- Where is the fire located in the house? (In the middle of the room? By a wall?)
- What aspects are common for fireplaces in different houses?
- How large are the houses?
- Are there any natural ventilation systems?
- Does every house in the village have a fireplace?

6 MINUTES OF MEETINGS

Meetings were held weekly to discuss work done and plan future works.

29 OCTOBER 2014 (PROBLEM DEFINITION):



① Ventilator

② Stove, extractor fan & air into fire

aims:

⇒ reduce carbon-monoxide in house

↳ improve health

(⇒ reduce environ-mental pollution)

⇒ don't take culture away from people

Meetings with E.quinox representatives:

13 NOVEMBER 2014

Temperature: it doesn't get cold enough to use fire for heating, they only use fire for cooking

Size of smaller house: 5mx8m, but varies a lot on income level

Building materials: Mud and sticks, quite insulating. No chimneys

Roof: metal, sheet steel, brick, no thatch roofs anymore

Height of roof: 2.5m-4m

Fire is also main source of light -> placed in the middle

Fires run quite often, but not all day - seen through smoke through the roof

No windows: glass is expensive and it gets cold

Battery box: two 12V outputs, one 5V output, 500mA, 84Wh assuming 2W bulbs

Now the users generally charge up 4-6 times per month. It's ok for most people, but if they live far away it's a hassle. Cost is more important though.

Stand alone: battery box with solar panel to install on roof

Thermoelectrics: good idea

Have to make it as cheap as possible!

They know carbon monoxide is dangerous, but have to plan for now, not for the long term

Compare solutions and analyse them well!

Keep in touch

Ask questions

General meetings at 6 Tuesdays in Gabor Suite

26 NOVEMBER 2014

House construction:

Thatched roofs are prohibited → don't exist any more

Small windows without glass (sometimes wooden closing)

Kitchen are sometimes accommodated in a different part of the house (entrance from outside)

Kitchen walls are “blacker” than other walls

Environment/Culture:

Fire also as light and heating source, it can get quite chilly at night

During dry season: mostly wood for fires

Rain season (moderate rain): more use of charcoal (sometimes produced domestically)

Rural population: ranges from farmers without real income to shop-owners etc. with 100-200 pounds / month

Cooking usually in morning and night

Issues of existing technologies to prevent pollution

In some houses (in other regions): Smoke is needed to prevent parasites from destroying the thatched roof

Wood collection as social activity for women → less wood collection undesired

Solar cookers oppose their tradition and culture

E.quinox projects:

Standalone boxes: 80p/week: as soon as box is payed off, people can keep it

No microfinancing

Tips:

Research around existing solutions and why they have failed (no technology is yet widely used)

Use research papers on culture → they give a much broader overview

Procedure: see how cheap product can be → find a working financing scheme

Aim for a solution that would work anywhere