

Future solar kitchen design with backup facility

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Preface

I would like to extend my gratitude to Stefan Karnebäck, without whom this thesis would not happen. He gave me a suggestion, introducing me to the unique world of solar cooking in developing countries and, recently, those methods spreading through the countries.

I would also like to thank my supervisor from Luleå University of Technology, Hans Walloschke for providing me with much-needed feedback.

This thesis would also not happen without constant support of my family and friends, who have always been there for me, pushing me forward.

Finally, I would like to express special gratitude to mag. ing. Maja Buha, who has been with me in this project from the start, with her unconditional support and much-appreciated insight.

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Abstract

Firewood has been used as fuel since the beginning of mankind resulted in health problems and deforestation. The solar cooking technology has been first developed in 1767 by Horace-Bénédict de Saussure but did not find development due to lack of reliability. Studies showed the necessity of having a backup facility.

The primary goal of this study is to design a fully functional kitchen for National Park in Nairobi, Kenya. The kitchen will be serving up to 100 people daily.

The study is done with five steps, the first step is literature and exploring of solar cooking products as well as backup facility products around the world. The second step is interviewing a local entrepreneur to get familiar with the parameters of a restaurant in Kenya. The third step is evaluating the solar cooking and backup facility to make an educated decision. The fourth step is integrating the systems into a functional kitchen. The fifth and last step is to analyse and discuss the results to draw conclusions.

As a result, choosing Scheffler reflector as a solar cooker and backed up with a biogas plant would be the chosen solution.

Keywords: Scheffler reflector, Biogas, Solar cooking, Nairobi Kenya, National park

Sammanfattning

Ved har använts som bränsle sedan mänsklighetens början som resulterade i hälsoproblem och avskogning. Solar-matlagningstekniken utvecklades först 1767 av Horace-Bénédict de Saussure men hittade ingen utveckling på grund av bristande tillförlitlighet. Studier visade nödvändigheten av att ha en reservfacilitetenhet.

Det primära målet med denna studie är att designa ett fungerande kök för National Park i Nairobi, Kenya. Köket serverar upp till 100 personer dagligen.

Studien gjordes av fem steg, första är litteraturstudie och utforskning av produkter för sollagning samt reservfacilitet alternativ från hela världen. Andra steget är att intervjua en lokal entreprenör för att bekanta sig med parametrarna för att gestalta en restaurang i Kenya. Tredje steget är att utvärdera olika solkokare-enheter och reservfacilitetsenhet för att fatta ett välgrundat beslut. Fjärde steget är att integrera systemen i ett funktionellt kök. Femte och sista steget är att analysera och diskutera resultaten för att dra slutsatser.

Som ett resultat skulle det vara den bästa lösningen att välja Scheffler reflector som solkokare och biogasanläggning som reservfacilitetsenhet.

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1 Introduction

1.1 Background

Firewood has been used as a fuel since the beginning of mankind. It is easy to produce, transport, and store. However, the downside of firewood is deforestation; which can cause health problems when used for cooking or heating.

In Kenya, the cooking with firewood is done by having a three-stone fire (placing three large stones in a circular way for holding a pot, for example). This technique is quite common in rural and remote areas, as it is considered to be an affordable and simple cooking method. Additional positive qualities for the three-stone cooking technique is that it is considered to provide a better taste than other cooking methods. Also, the smoke helps in chasing the mosquitos away, which in turn helps in avoiding malaria infections that mosquitoes usually carry in these areas. The three-stone cooking technique is favoured in the cold areas as well; it can provide warmth in the cold days and light when it's dark.

Unfortunately, there are more downsides to three-stone cooking than benefits in the long run. According to the Clean Cooking Alliance (2014), the exposure to cooking smoke causes around 4 million premature deaths, out of which are around 22 000 in Kenya annually. Cooking smoke is known to cause various diseases, such as childhood pneumonia, emphysema, lung cancer, bronchitis, cardiovascular disease, and low birth weight. According to the Worlds Health Organization (2018), the most affected by cooking smoke are women and children, since women are mostly the ones in charge of cooking and raising children. The Clean Cooking Alliance (2020) also mentions that almost 5 000 children die annually in Kenya due to respiratory infections caused by their cooking habits.

An additional downside to the three-stone cooking is that only a small amount of heat is generated and directed towards the pot itself, which is even less directed to the food in the pot, which prolongs cooking time. It does not matter how strong the flames underneath the pot are, because the cooking pot is not directly above them, and most of the heat is lost into the surroundings.

By introducing Kenyans ways of solar and fuel-efficient cooking, there would be fewer deaths caused by smoke from cooking and less deforestation, which is one of the main causes of climate change. Additionally, a new approach to cooking would empower women by making their job easier and faster and so as the children; instead of spending hours trying to find firewood for cooking, they would be able to dedicate themselves to the schoolwork.

The solar cooking technology has been first developed in 1767 by Horace-Bénédict de Saussure (Solarcooking, 2020), but unfortunately did not find enough development during the years due to lack of reliability. The other issue was not meeting the user's expectation for it to become a primal source of cooking and a long-lasting solution. But recently, it has shown promising development, as well as, the necessity of combining two cooking method and not relying solely on solar cooker alone (Lizaso, 2020).

According to Narayanaswamy (2001) solar cooking is referred to as "poor people's cooking method" because it is commonly made from household items, i.e. aluminium foil. That makes it unattractive to adopt by the wealthier community. This thesis, focusing on future solar kitchen design, will present the solar cooking method as advanced for both, wealthy and poor communities.

1.2 Aim

Providing a concept, guidelines, and suggestions that help countries with high annual sunshine hours to use solar cooking technology in an indoor kitchen. The indoor kitchen could be used in public places such as schools, hospitals, and restaurants that provide at least one meal a day.

The purpose of this study is to make solar cooking a more attractive method for locals and tourists. Therefore, the research will address difficulties in applying solar cooking method with backup facilities inside a building. This to provide a reliable and long-lasting solution of a kitchen that could be used every day and meets the expectations of both the customers and cooks.

1.3 Research questions

The main research questions regarding sustainability, functionality, and future development will be resolved by detail planning for the client National Park in Kenya.

Leading concentrated solar beam into a building can be dangerous, how could this be tackled to achieve a safety-approved method?

Investing in a new concept, there are risks that must be taken to apply these technologies. What are these risks and how can we tackle them?

1.4 Method

The study will use qualitative methodology to collect information to be able to provide an accurate design that suits the environment of the national park.

The research can be divided into four main study areas. The first step is gathering literature and exploring existing products around the world. The online search engines used for the digital literature studies are Google, Google Scholar, DiVA portal, and ResearchGate. Most frequent words used in this research are: *Solar cooking*, *Scheffler reflector*, *Biogas*, and *Kenya*.

The second step is to do a structured interview with a local entrepreneur through email, to get a grasp on how a restaurant in Nairobi's national park would be constructed and define some restrictions regarding the design. It will be discussed further in the results.

The third step will be evaluating the cooking equipment and the possibility of integrating them into the kitchen. This is done by comparing the collected data and doing a comparison table of the cooking equipment, based on qualities the equipment provides.

The fourth step will be on designing a functional solar kitchen with a backup facility inside a restaurant following requirements for the equipment installed in the kitchen. The restaurant will be placed in Nairobi National Park, Kenya. The design will be created in Autodesk Revit, a building information modeling (BIM) program to be able to present the design.

The fifth step is to analyse and discuss difficulties designing and integrating the cooking equipment, to provide suggestions for the implementation, restrictions, and difficulties.

1.5 Boundaries

The aim of this thesis is on designing a fully functional solar-powered kitchen. The focus will be on the solar source used for main cooking. Within it, electric installations and water source will not be tackled. That also includes solar panels as a backup facility due to its high price and cost of maintenance.

1.6 Validity and reliability

The research relies on information provided by manufacturers and online manuals of existing products. The lack of academic work on each unit gives a limited degree of validity to the research. Interviewing locals and vendors of these products would give hands-on experience, which would result in higher validity and reliability.

2 Theory

This chapter will summarise the information gathered from digital sources, as well as product manufacturers around the globe. Some of them are Solar Cookers International (SCI), GoSun, Solare Brücke, and Solarcooker at Cantinawest.

The theoretical part of this thesis serves as a guideline to all the existing options for solar cooking and backup facilities, as well as how each of them works. It also explains why Scheffler reflector with biogas backup was chosen as an ultimate solution.

2.1 Solar cooking

Solar cookers work on the principle of converting sunlight into heat energy, which is then retained for cooking. It takes advantage of an endless source of energy from the sun, which is beneficial for the environment and economy. Not to mention health advantages since no emissions and bi-products produced during cooking. (Solarcooker at Cantinawest, 2017).

Most solar panel cookers and solar box cookers can reach up to 170 °C (Bazile, 2018). The captured solar radiation passes through a greenhouse enclosure enclosing a dark-coloured cook pot. When solar radiation hits the dark surface, it is converted to heat. That heat is then captured in the enclosure by which it achieves cooking temperature. The efficiency of these types of cookers is dependent on the amount of reflector area gathering the sunlight and the ability of the greenhouse enclosure to receive the available light and help insulate the hot cook pot. (Bazile, 2018)

With parabolic cookers, food can be cooked faster and at higher temperatures, and it is also possible to fry food. However, using parabolic cookers also implies frequent orientation towards the sun. One type that does not require large reflectors, is the evacuated tube solar cookers. It uses an insulated double wall glass tube for their cooking chamber.

There are three most common types of solar cookers: box cookers, parabolic concentrators, and panel cookers. In the next few subchapters, there will be explanation of the following:

- Box ovens
- Parabolic cooker
- Panel ovens
- Haines Solar Cooker 2.0
- Fresnel Lens Cooker
- Vacuum tube
- Scheffler reflector

2.1.1 Box ovens

Cooking temperature for solar box cookers is typically between 90 °C and 200 °C. Timewise, it usually takes them one to three hours to cook different types of food. Multiple pots can be placed inside. The sides and the bottom are insulated; this helps in retaining cooking heat. Some of the simplest solar box cooker designs as shown in figure 1 are the Easy Lid Cooker and Minimum Solar Box Cooker. One of the popular well-constructed solar box cookers is the All-American Sun Oven (Bazile, 2018).

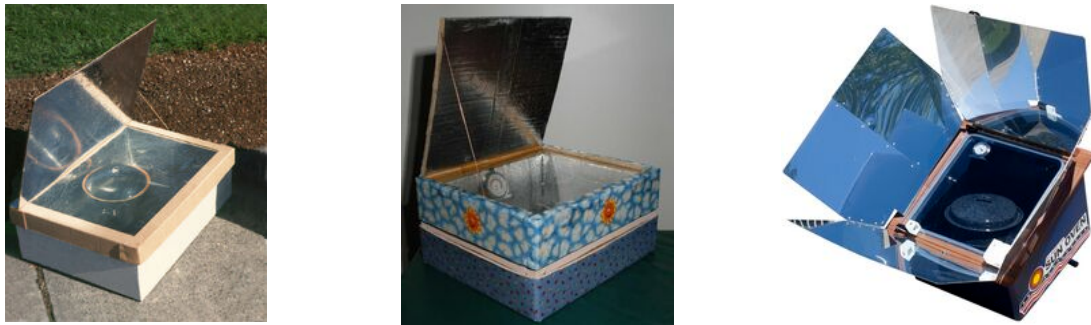


Figure 1 - Easy Lid, Minimum and All-American Solar Box Cooker (Bazile, 2018)

Characteristics:

- Possibility of cooking with multiple pots at the same time.
- Construction can be made from various simple materials (ex. aluminium).
- Most models seldom must be turned to follow the sun.
- It is possible to bake bread and cakes.
- Cooking temperature range is usually between 90 - 200 °C.
- Tilting the cooker towards the sun eliminates partial shading of the cookware.

2.1.2 Parabolic cooker

Parabolic solar cookers got their name from the parabolic shaped reflector as shown in figure 2. That type of reflector is used in directing the sunlight to a small area in order to generate heat for cooking. They can reach high temperatures such as 350 °C or higher, which allow them to be used for grilling and frying. Due to these high temperatures, parabolic cookers can be compared to conventional stoves considering the time spent on cooking (Bazile, 2018).



Figure 2- SolSource parabolic cooker (Bazile, 2018)

Characteristics:

- Cooking time can be compared with a traditional stovetop.
- With accomplishing high temperatures, food can be fried and grilled.
- Periodic reorientation is necessary usually every fifteen minutes, but that can be done with a mechanical solar tracking apparatus.
- The downside is that it is more expensive than the panel and box cookers and requires more storage space.

2.1.3 Panel ovens

Panel solar cookers get their name by using reflective panels that direct the sunlight on a black cooking pot. The panels are usually constructed to be foldable for easy storage and portability, unfolding the panels will retain their angles to direct the light to the cooking pot as shown in figure 3. Panel ovens are usually constructed from household materials; therefore, they are inexpensive to make but also known not to be a long-term solution since they break over time. These ovens have a maximum temperature of 140°C which is low for baking or frying but can be used for warming up and boiling food (GoSun, 2018).

Some of the panel solar cookers companies are, CookKit, Windshield shades, TheHotPot, The Copenhagen Solar Cooker Light.



Figure 3 - Panel oven (Florida Energy Center)

2.1.4 Fresnel Lens Cooker

A Fresnel lens eliminates the bulk of a convex concentrating lens with the use of a series of angled steps in the front surface of an otherwise flat sheet of glass or plastic. The steps are angled in such a way as to concentrate sunlight at the cooking pot as it passes through the lens (Bazile, 2018).

A prototype is built by Bernhard Müller as shown in figure 4.



Figure 4 - The Twin Fresnel Cooker a prototype by Bernhard Müller.

A larger-scale version of this concept is created with a series of reflective concentric rings used to redirect the sunlight onto the cooking pot as shown in figure 5. Essentially, the individual ring angles are similar if one were to cut a parabolic reflector into horizontal sections and stack them concentrically. However, this would cause shading, so the diameters of the rings each need to increase slightly to allow the light to reach the cookpot (NCL, 2013).



Figure 5 - Larger Fresnel Concept (NCL, 2013)

Characteristics:

- Temperatures for boiling and frying can be reached.
- Easy to build on-site.
- Solar radiation needs to be closely monitored.
- May require more storage space.

2.1.5 Vacuum tube

The evacuated tube design holds and retains its heat better than any other solar cooker. It can also heat up very well even in less than optimum conditions. Vacuum tube literally means that

the cooking chamber is constructed of two layers of blown glass in the shape of a sealed tube, where the air has been removed between the layers. Figure 6 shows two examples of vacuum solar cookers (Bazile, 2018).

Heat loss happens primarily by conduction and convection through a medium. With no air between the layers of glass, the chamber is highly insulated, well suited for retaining cooking heat. The chamber often does not require a large reflector to capture sunlight. One end of the tube is left open to allow a slender cooking tray to be inserted. The tray has a handle that seals with a gasket against the glass tube. The opposite end is fitted with a fixed stopper or has had the tube sealed during the manufacturing process. Improvements in glass technology is allowing for larger diameter tubes to be fabricated, which will allow for the use of larger cookware (Bazile, 2018).

However, compared to other solar cookers, the evacuated tube has a rather small cooking interior and regular pots and pans cannot be used



Figure 6 - Vacuum tube solar cooker (Bazile, 2018)

2.1.6 Scheffler reflector

Scheffler reflector cooker is where sunlight is focused by a large reflector to a secondary reflector that heats up the pot. This cooker tracks the sun in an automated fashion. It is also driven either by a photovoltaic or gravity device (Solare Brücke, 2020).

In general, the Scheffler cooker is technically the most advanced type of cooker, but it is expensive and requires skill to make it work well. One advantage is that the secondary reflector can be located inside a building as shown in figure 7, with an opening left for the sun's rays to pass into the building, whilst the cook can work in the shade. Scheffler cookers have a higher output than other cooker types. Several Scheffler cookers can be combined to form sets with an output of several hundred kilowatts. The high output makes Scheffler cookers especially suitable for institutions (Solare Brücke, 2020).

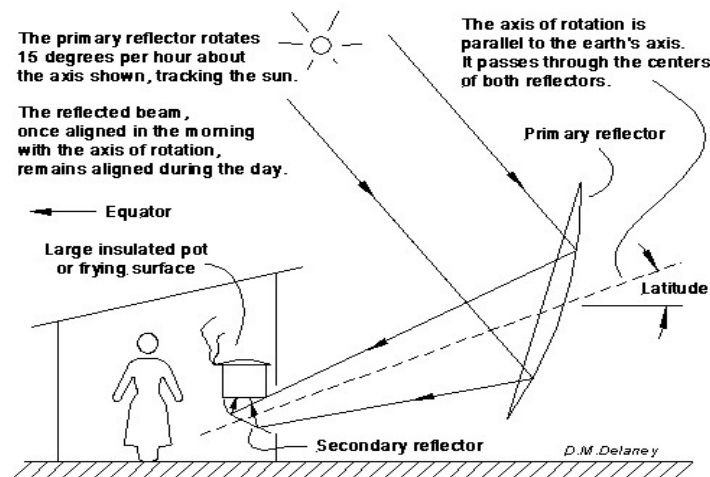


Figure 7 - Scheffler reflector principle (by D.M. Delaney)

2.2 Backup facilities

Cookstoves are commonly called improved cookstoves if they emit fewer emissions or are safer than the traditional cookstoves or three-stone-fires. The term usually points to stoves which are burning firewood, charcoal, agriculture residues, or dung.

2.2.1 Rocket Stove

Rocket stove uses small diameter wood for fuel. It is burned in a combustion chamber that contains an insulated vertical chimney, where it ensures complete combustion before the flames reach the cook's surface as shown in figure 8. Though rocket stove design is used in institutions for large and fixed stoves, it is often used as a portable stove for cooking and for making rocket mass heaters for heat generation (Meadows, & Palmer, 2017).

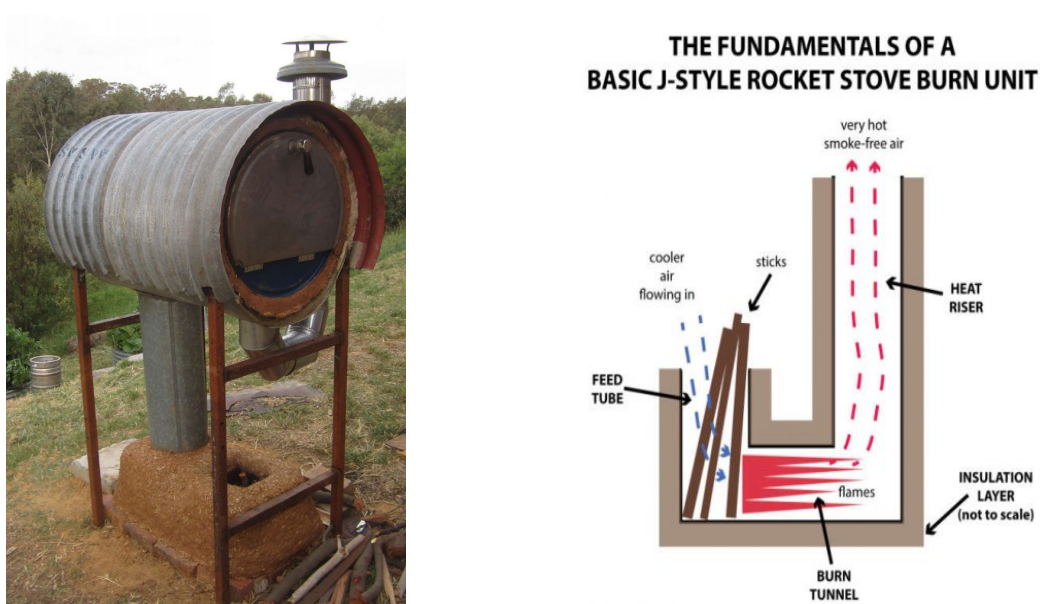


Figure 8 - Drum style and Basic J-Style Rocket Stove (Meadows, & Palmer, 2017)

2.2.2 Baba Moto

The clean-burning cookstove Baba Moto has a double chamber construction, so the flame is fed with secondary air to remove and reduce hazardous contents such as particulate matter or carbon monoxide. Above the combustion chamber, there is a swirling chamber where the flame gets prewarmed secondary air to create a fire vortex in order to provide the clean combustion. Figure 9 shows Baba moto and its principle (Muller, 2020).

The combustion chamber is separated from the swirling chamber with a plate of 14 by 14 cm. The plate has a central hole of 6 cm in diameter (Muller, 2020).



Das Baba-Moto-Prinzip

The Principle of this stove

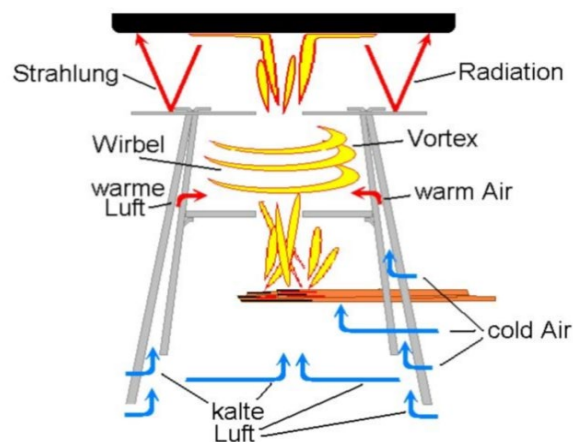


Figure 9 - Baba Moto and its principle (Muller, 2020)

2.2.3 Kenyan ceramic Jiko

The Kenyan Ceramic Jiko (KCJ) is a portable stove that uses charcoal as fuel. Shaped like an hourglass as shown in figure 10, the metal stove has a ceramic lining in its top half, with the bottom half being a collection box for ashes. The coals are placed into the ceramic lining at the top, which is perforated to let the ashes from the coals fall to the bottom of the stove. These ashes can then be collected and disposed of safely. The head of the stove has metal rings that hold a pot in place for cooking (Kammen, 2011).

With proper use and maintenance, the KCJ has shown a reduction in the use of fuel consumption by 30 to 50%. This means less cutting down the trees as less wood needs to be burned, and less labour is required for chopping firewood. The stove also reduces emissions from incomplete combustion, such as toxic gases and particulate matter, resulting in better overall health of the users, which are primarily mothers and children. (Kammen, 2011).



Figure 10 - Kenyan Ceramic Jiko, (Kammen, 2011)

2.2.4 Biogas

United states environmental protection agency (EPA) defined biogas as the following *“Anaerobic digestion is the natural process in which microorganisms break down Picture of microorganisms organic materials. In this instance, “organic” means coming from or made of plants or animals. Anaerobic digestion happens in closed spaces where there is no air (or oxygen).”*.

There are advantages to use biogas according to (Hosseini, & Abdul Wahid, 2014) such as:

- Biogas burns clean and produces fewer pollutants than fuel otherwise used.
- It provides instant heat upon ignition.
- Most biogas burners can regulate the flowrate from high to low.
- It can be used for lighting as well.
- Slurry from the digester can be used as fertilizer.
- Biogas is a renewable fuel that is carbon negative: burning biogas in a cookstove releases fewer greenhouse gases than if the dung was left on the ground to decompose naturally.

2.3 Construction material

According to the interview with Warren Kituyi, a local entrepreneur in Kenya, the most common construction material for buildings in Kenya are the combination of concrete and bricks or concrete and stones. Additionally, the most common kitchen designs are open-air kitchen under a shed of iron sheets or thatched grass.

2.4 Climate

When it comes to climate, it should be taken into account that Kenya’s placement is right below the equator. The weather in Kenya varies depending on the area. In Nairobi, the

warmest period is February to March with an average high temperature of 26.8 °C and an average low of 12.1°C. Oppose to that, the coolest period is July to August with an average high temperature of 22.7 °C and an average low of 9.1 °C. Table 1 shows the average monthly temperature taken from Weather and climate (2020).

Table 1 - Average temperature table

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|-------------------------|------|------|------|------|------|------|------|------|------|------|------|------|
| Temperature high | 25.5 | 26.7 | 26.8 | 25.0 | 23.5 | 22.5 | 22.0 | 22.7 | 25.0 | 25.7 | 24.0 | 24.5 |
| Temperature low | 10.5 | 10.9 | 12.1 | 13.4 | 12.1 | 10.0 | 9.2 | 9.1 | 9.7 | 11.3 | 12.7 | 11.7 |

Table 2 shows the number of sunny and rainy days as well as the average sun hours for each month according to Weather and climate (2020). During summer, it can reach up to an average of 9.5 sun hours per day, while only 4.1 sun hours per day during winter.

Table 2 – Sunny and rainy days in Nairobi

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|-------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-------|
| Sunny days | 27 | 24 | 23 | 15 | 18 | 25 | 28 | 27 | 26 | 24 | 16 | 22 | 275 |
| Runny days | 4 | 4 | 8 | 15 | 13 | 5 | 3 | 4 | 4 | 7 | 14 | 9 | 90 |
| Sun hours | 9.3 | 9.5 | 8.6 | 6.8 | 6.1 | 5.3 | 4.2 | 4.1 | 6 | 7.3 | 6.6 | 8.3 | |

3 Analysis of chosen cooking methods

By comparing all the reviewed solar cooking techniques, as well as the backup facility cooking techniques, the Scheffler reflector for solar cooking has shown itself to be the most optimum solution for the given task. As for backup facilities, biogas was the logical choice to proceed with and to be combined with the Scheffler reflector.

3.1 Interview

The local entrepreneur Warren Kituyi was questioned to get a grasp on the situation of the restaurant regarding connectivity to the water source, electricity, and sewerage system, the expected number of customers, placement and size of the restaurant, and construction materials. The whole interview can be found in Appendix A.

As a result, some restrictions were made to design the restaurant. The restaurant should serve at least 100 people a day, including a dining hall with tables for food to be served on. The construction materials usually used are a combination of concrete and bricks or concrete and stones. The roof that can be used is thatched grass or iron roof.

Regarding the connectivity of the national park, the water source is taken from boreholes from the ground, the sewerage system is constructed within the park, and the electricity is taken from the grid or solar power.

3.2 Choice of solar cookers

This chapter will summarise the collected knowledge of different solar cookers and will be presented in table 3. Then table 4 will present the thoughts and conclusions which are based on the information provided to be able to compare them against each to proceed on the chosen solar cooker.

Table 3 - Comparison table of solar cookers

| | Box ovens | Parabolic cooker | Panel ovens | Fresnel lens cooker | Vacuum tube cooker |
|---------------------------|--|---------------------------------------|--------------------|--|---|
| Cooking time | Slow | Fast | Slow | Fast | Medium |
| Temperature range | 90-200 | Up to 350 C° | Up to 140 C° | Reach boiling and frying Temperature (Exact numbers are unknown) | Enough for cooking and baking. (Exact numbers is unknown) |
| Indoor possibility | No | Yes | No | Yes | No |
| Affordability | Varieties of cheap and expensive units | Mostly expensive units | Cheap units | Medium priced units | Medium-high priced units |
| Durability | Depends on materials, could be long term | Long term | Not long term | Unknown | Long term |
| Information accessibility | Enough information | Enough information | Enough information | Not enough information, could be considered | Not many products are created and lack of information about them |
| Additional observation | Can fit more than one pot | Comparable with regular cooking stove | One pot a time | Too little information regarding this type of solar cooker | Small portion capacity. It requires minimum sun exposure for it to cook |

Table 4 - Evaluation of solar cookers

| Evaluation | |
|---------------------|---|
| Box ovens | Too slow to cook with and does not provide cooking indoor possibilities. Could be durable but not convenient to have in a restaurant since it requires more than one unit to be able to cook with. |
| Parabolic cooker | Fast cooking time and can reach high temperatures that are comparable with a conventional cooking stove. It is on the expensive side, but it is also durable. Additionally, the possibility of cooking indoors is present. |
| Panel ovens | Too slow to cook with and have low-temperature range. It is not possible to use indoors and requires multiple ones to cook with. Despite the fact they are an affordable unit, they don't last long. |
| Fresnel lens cooker | Can provide fast cooking and can reach high temperatures. There is also the possibility of implying it indoors. It has medium affordability, but it lacks information for implementation indoors. |
| Vacuum tube cooker | Medium speed cooker. It can reach temperatures to cook and bake with, but there is not enough information about these products. Prices of these types of units are medium to high. The small cooking capacity is favourable, but it does not require much sun exposure for it to start cooking. |

In conclusion, parabolic solar cookers and Fresnel lens cookers seemed to fit the profile of the conventional cooking stove experience. But Fresnel lens cooker had to be ruled out due to lack of information regarding it. The parabolic cookers provide the most regular cooking stove experience, especially with the possibility of cooking indoors and reaching high temperatures. Despite the high investment cost, it is a reliable cooking method that would last.

3.3 Scheffler reflector

Scheffler reflector is a parabolic cooker, it makes solar cookers much simpler if the cooking place would remain inside of the kitchen. The main reason for choosing the Scheffler reflector for this task is that the reflector can be placed outside to collect sun rays while heating the cooking spot, which would be inside the kitchen.

Scheffler reflector has the possibility of indoor cooking, no need for turning it constantly towards the sun since as it rotates on its own accordingly, and the ability to cook large amounts of food in an acceptable time. Another advantage is that people would not have to change their cooking habits, which is something that sometimes can be hard to adjust to.

The ability to store energy to be used later is a big plus as well. Also, given that the first-ever Scheffler reflector was built in 1986 in North Kenya by Wolfgang Scheffler (Solare Brücke,

2020) himself is still in function up until now, around 2006, a lot about it being by far the best long-term investment.

3.3.1 How does Scheffler reflector work?

Scheffler reflector is constructed of a small lateral section of a large paraboloid, giving it a unique elliptic shape. The section of the paraboloid has its focus located on a certain distance of the reflector where the sunlight gets directed to as shown in figure 11. According to Solare Brücke (2020), the distance between the focal point and the centre of the paraboloid is dependent on the chosen paraboloid.

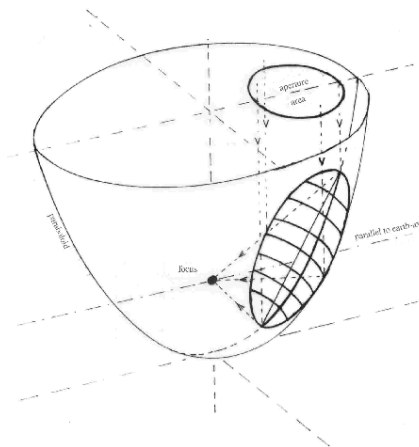


Figure 11 - Working principle (Solare Brücke, 2020)

To maintain the gravitational equilibrium of the reflector and synchronize the tracking device with the sun during a day, the axis of the reflector needs to be placed along the north-south direction, parallel to earth's axis. This allows it to maintain its focus on the rotation axis while the reflector rotates, which makes it easy to direct the sunlight on a fixed point during the day (Solare Brücke, 2020).

The inclination angle of the solar radiation varies between -23.5 and $+23.5$ depending on the season in the year. In order to maintain the reflectors sharp focal point, changes in the shape of the paraboloid need to be done in order to match the inclination-angle of the sun. To make this possible, the reflector-frame is built for the equinox. Meaning that by inclining and elastically deforming the reflector-frame, it is possible to achieve all other parabolas within sufficient accuracy. These changes need to be done every two to three days (Solare Brücke, 2020).

Figure 12 clarify how the seasonal changes would affect the inclination angle of the reflector to maintain the same focal point. More detailed explanation in which how the frame is adjusted and how the mechanic's works can be read on Solare Brücke (2020).

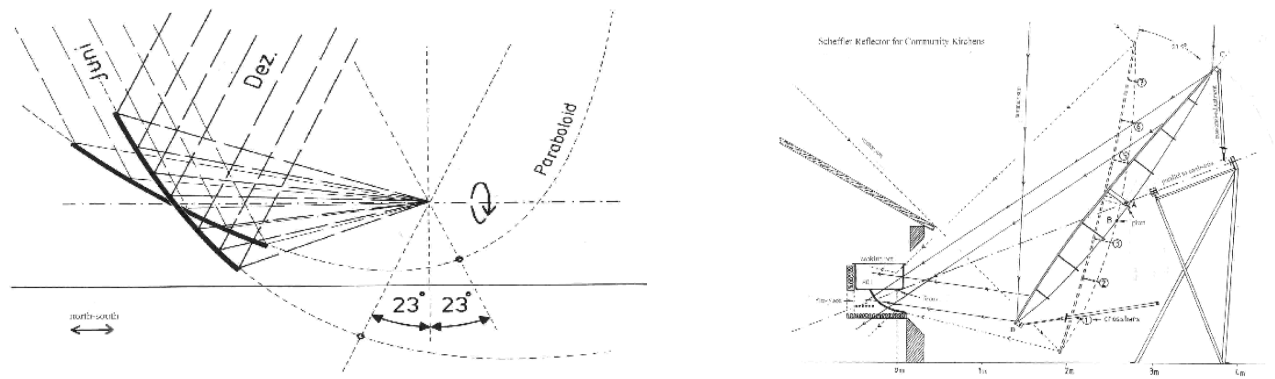


Figure 12 - Angle relation (Solare Brücke, 2020)

The collected sunlight on the focal point can then be redirected through a secondary reflector into a dark coloured pot to be absorbed and transformed into heat. According to Solare Brücke (2020), the efficiency of the reflector may vary between seasons, insulation of the pot and how clean the reflector surfaces are, but it can reach up to 57% and 75% on the focal point. Solare Brücke (2020) also mentions that an elliptical reflector of 2.8m x 3.8m (standard size of 8m²) can collect sunlight of 4.3m² to 6.4m² measured perpendicular to the direction of the incident light. The 8m² sized reflector can heat up 22 litres of water from 25°C to a boiling point within an hour with 700w/m² direct solar radiation according to (Solare Brücke, 2020).

There are several varieties to absorb the collected light on the focal point beside redirecting it through a secondary reflector for instance heating storage, steam generator and backing-over. All of which can directly be placed on the focal point of the reflector to increasing the efficiency and simplifying maintenance (Solare Brücke, 2020).

3.3.2 Mechanical clockwork

According to Solare Brücke (2020), the mechanical clockwork is based on the same concept as a cuckoo clock. The reflector is turned by hand in the morning until the focal point is in the correct position. A weight is pulled up. The weight naturally wants to drop immediately. A pendulum breaks the fall of weight so that the reflector rotates at the same speed as the sun moves across the sky. It gives the weight the opportunity to drop downwards piece by piece at regular intervals. The weight thus provides the driving force for the rotational movement of the reflector. The pendulum period is calculated so that the rotation of the reflector compensates for the Earth's rotation.

3.3.3 Receiver

There are different ways to absorb the sunlight that Scheffler reflector collects. It can be done by simply placing a dark surface or a pot on the reflected light (Tamera, 2020). Another way is to have an actual receiver according to IT Power India (2015) using a dome type absorber as shown in figure 13. *“The receiver works on thermosiphon principle in which cold water sinks*

down from header and hot water/steam moves up to the header” (IT Power India, 2015). This type of receiver can be connected to a steaming system, which have been used in various applications on a larger scale like laundry in hotels, religious and educational institutions, comfort cooling in offices, boiler feed water heating in chemical process industries among others (IT Power India, 2015).



Figure 13 - Dome type receiver (IT Power India, 2015)

3.3.4 Experiences

According to Bazile R. (2018) people are more likely to use solar cookers if they don't have to change their cooking habits from before drastically. By integration of Scheffler reflector into the house, it is ensured that changing habits drastically will not be necessary. Height (similar to conventional stove height) will be comfortable to do the cooking and, most importantly, there will be no smoke inside the house. There will also be a lot of time and money saved, which was before spent on collecting the wood.

The downside of the Scheffler reflector would be in the mechanical clockwork; even that its parts are available everywhere for low prices, once the mechanism breaks, the cook is usually not equipped for repairing it. So, the simplest option for them is to go back to using wood-burning stoves (Bazile, 2018).

The solution to that problem would be maintenance service, though, due to big distances, not available everywhere (Solare Brücke, 2020).

3.4 Biogas

When the sun stops shining, there should be a good fuel-efficient alternative to solar cooking. There are many positive qualities with biogas: environmental, health, economic, social benefits, and international support.

Since cooking occurs every day, there is a lot of food waste that can be used in creating biogas, together with human and animal waste. Also, there would not be a drastic change in the cooking habits of people. Biogas is also environmentally acceptable since it, by burning, creates the same gases as it was left to decompose on the ground.

3.4.1 Biogas benefits

Unlike all other fossil fuels that will eventually disappear, biogas is renewable, which means that we will always be able to produce it when there are sun and plants growing.

The CO₂ that biogas produces is nothing more than what already is produced when organic matter is first grown. Considering that, it has no greenhouse emissions.

As already mentioned, in circumstances without oxygen (anaerobic conditions), methane is produced. It has been estimated that each year between 590 million and 800 million tons of methane is released into the atmosphere. That affects climate more than CO₂ gasses since methane is more formidable. The methane in the biogas system is converted to CO₂ when fuel is burned. Since CO₂, either way, ends up in the atmosphere, it makes biogas a zero net emissions product (Alexander, 2018).

Another benefit of biogas is the usage of waste products created by humans or animals. With the usage of biogas, the amount of food and other organic waste being sent to the disposal area is reduced.

In addition, the slurry that the biogas system produces can be used as a fertiliser for gardens or farms. This can develop increased energy independence, build resilience, and save money.

3.4.2 Biogas chamber size

Macharia and Musungu (2018) mention in their biogas plant installer manual that the physical properties of the substrate and the temperature plays a huge role in the biogas production rate. It also mentions a constructed biogas plant in Kenya, it was built underground to maintain the range of the temperature between 15°C to 35°C which is suitable for production.

The manual (Macharia & Musungu, 2018) explains that the retention time is the period spent on the feed-material inside the digester. The manual suggests having a longer retention time for farmers with a small number of animals, which leads to higher investment costs but also a higher gas production rate. The opposite implies to farmers with a lot of animals, short retention time leading to lower investment and lower gas production rate.

But to decide the size of the plant, it is crucial to determine the average amount of feed material produced per day, which includes water, animal waste, and food waste (Macharia & Musungu, 2018).

Macharia and Musungu (2018) also explain that the biogas plant consists of three main parts as shown in figure 14, a mixing chamber, digester chamber, and expansion chamber. The mixing chamber is where feed-material is mixed with water before redirected into the digester. The digester chamber has two main parts, the digestion chamber where mixed materials undergo the anaerobic decomposition to release methane and other gases which are stored in the second part, the gasholder. The third main part is the expansion chamber which collects the slurry from the digester.

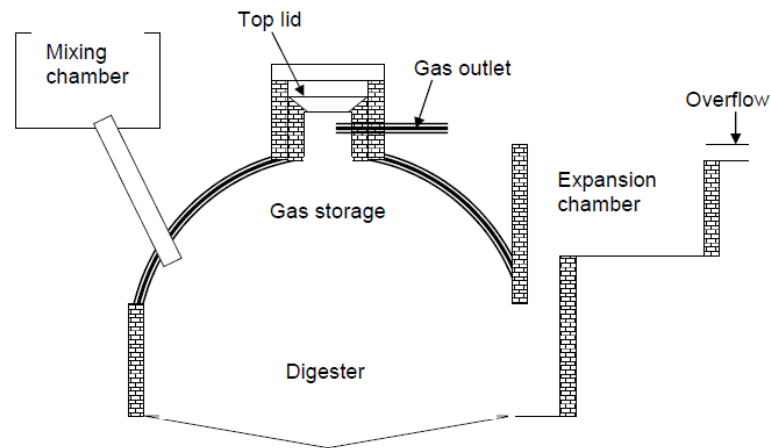


Figure 14 - Biogas plant layout (Macharia & Musungu, 2018)

3.4.3 Consumption of Biogas for Cooking

Household burners consume approximately 200-450 litres of biogas per hour. The gas consumption for cooking per person lies between 300 and 900 litre per day, the gas consumption per 5-member family for 2 cooked meals between 1500 and 2400 litre per day. With 1 kg cattle dung in warm tropical countries approximately 40 litres of biogas can be produced (GTZ/ISAT, 1999).

In Tamera, a research village located in south Portugal that has a goal of becoming a self-sustained village. Their kitchen feeds up to 50 people daily, relying solely on solar cooking methods with biogas digester as a backup facility. Tamera's biogas plant consists of a digester of 3000 litres, which is fed up with 40 to 60 litres of biomass daily. They claim that it can produce up to 90 litres of biogas a day. They also estimate that it is enough for about 10-12 hours on a low flame and 5-6 on a high flame (Tamera, 2020).

3.4.4 Stove technology

Biogas cookstoves and ovens look similar to conventional ones. It usually has a single or double burner with different gas consumption needs. That is determined by the diameter of the inlet pipe and biogas plant.

Jet is a hole that is specifically sized and defines power output for the burner. It controls the amount of gas that goes into the burner. Unlike other gases, biogas needs less air for combustion. That is why conventional gas stoves need a larger gas jet if they are used for biogas combustion. Most of them can be adapted for biogas usage.

Stoves that use biogas have a valve to fuse biogas with the right amount of oxygen, a burner to combust the mixture, and a structure to hold a pot. To transport biogas from the digester to the point of using piping has to be provided (Tumwesigeab, Fulfordc, & Davidsond, 2014).

3.4.5 Positive and negative about Biogas

Advantages:

- Biogas burns clean and produces fewer pollutants than fuel otherwise used.
- It provides instant heat upon ignition.
- Most biogas burners can regulate the flowrate from high to low.
- It can be used for lighting as well.
- Slurry from the digester can be used as fertilizer.
- Biogas is a renewable fuel, burning it in a cookstove releases fewer greenhouse gases than if the dung was left on the ground to decompose naturally.

Disadvantages:

- High cost for the digester, tubes, gas stove, and pots.
- It can increase women's workload; since it is them whose task would be running the digester. It can be a great physical burden to feed the digester, as, later on, removing the slurry and take it to the field.
- Elderly or sick people should have help with maintaining of the digester.
- Depending on material and location, installations have to be protected against theft and damages. Metal tubes are of special value and often prone to theft.
- Cultural rules might limit the acceptance of handling dung or faeces and their use as fuel for cooking.
- Cooking with biogas requires a change in cooking habits, which might prevent the adoption.
- Biogas is difficult to store and to transport.

3.4.6 Experience

Most of the studies focus more on biogas plants and production of the same than actual experience with its usage.

In a survey carried out in 2013 in Vietnam (EPRO Consulting JSC, 2014), more than half of interviewed users stated that the cooking environment has less dust, soot, and smoke, and three quarters were satisfied with the functionality of the biogas stove. Most of them mentioned the ignition switch with which they had difficulties. Additionally, repairing costs for the stove were very high. On further notice, it was shown that each biogas plant daily saves 4.5 kg of wood and 1.6 kg of agriculture residues from human food and animal feed preparation. Overall, that would mean that a household with biodigester saves around 1.2 million VND which equals around 40-50 Euros per year in fuel consumption.

4 Results and analysis

In this chapter, the solar cooker and the back-facility will be presented and how to implement them. The decision is made according to an extensive exploration of these units. The aim was to serve up to 100 visitors daily despite different weather conditions.

4.1 Solar cooker

Scheffler reflector is chosen to put as a primary solar cooking method.

The kitchen will utilize the Scheffler reflector 275 days annually. Having two Scheffler reflectors of the size 8m² will be able to provide six pots cooking simultaneously on a clear day.

Placement of the Scheffler reflector should be in the north facade, automatically rotating with the sun from east to west. Therefore, rotation space should be considered, and it should be placed in a measured distance not to be shaded from the building.

Due to the position of Nairobi, being close to the equator, the sun path during the year changes from north to south depending on the season. Therefore, it is important to adjust the inclination angle accordingly.

Accessibility for the Scheffler reflector is important to be able to adjust if needed.

Since there is a risk of having high concentrated beams from the sun, a protection fence is added to enclose the Scheffler reflector opening as shown in Tamera kitchen in figure 15.



Figure 15 - Tamera Scheffler reflector (Tamera, 2020)

4.2 Backup facility

The biogas was chosen as an alternative way of cooking as a backup, depending on the circumstances in the National Park. This method should provide fuel for rainy and cloudy days, which are estimated to be 90 days annually based on (Weather and climate, 2020). It is worth mentioning that there are more intense periods in the winter than summer, which can reach up to 15 rainy days a month.

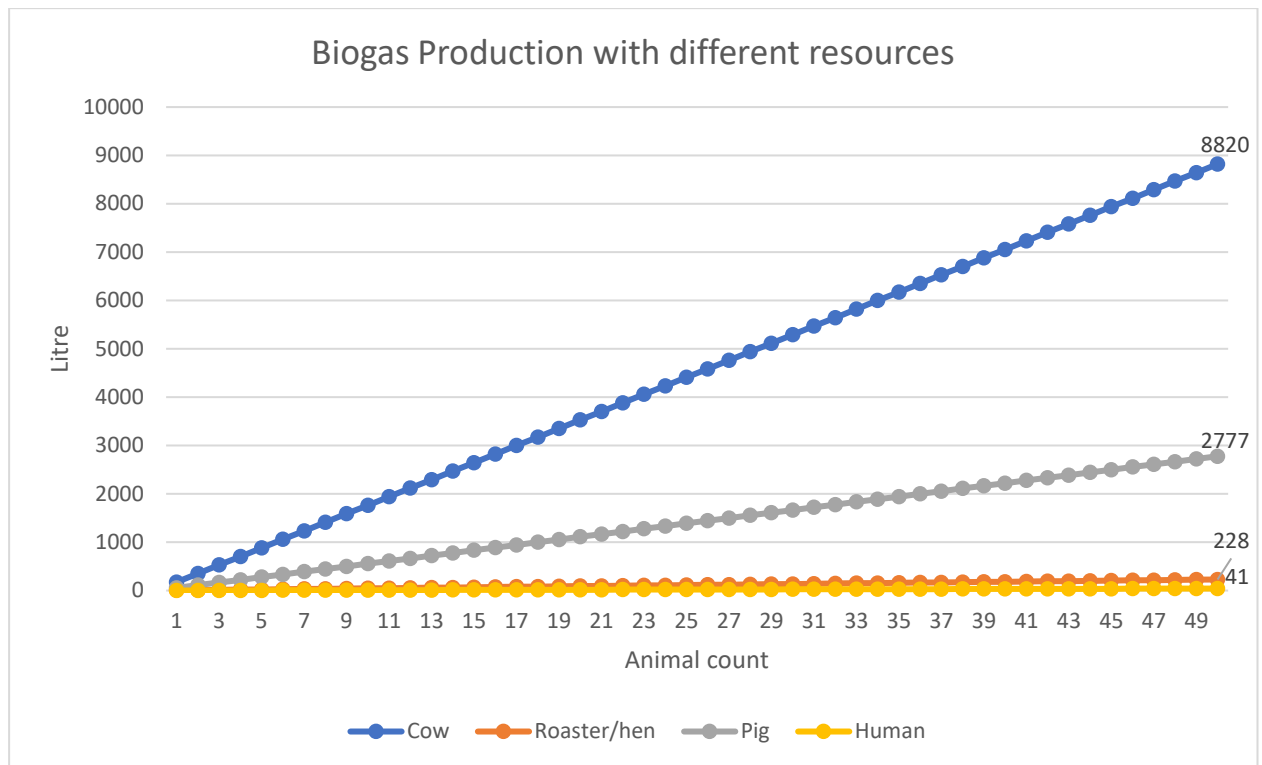
The size of the chamber needs to be determined on two major factors, the biogas amount needed for the restaurant and the feed-material that the restaurant is able to provide. According to Tamera (2020), they use food scraps as a main source of biomass to feed their 3000 litres digester. In addition to the food waste from the kitchen, Nairobi's National Park has a sanctuary which gives the possibility to make use of animal waste. That would also ensure a significant increase in the volume of biogas produced daily.

Due to the lack of information on safari animals' dung, the calculations have been based on farm animals such as cows, pigs, chickens, and even human faeces. Diagram 1 below shows daily production in litres. Table 5 shows how much animal farm produces daily, both dry matter and biogas, according to a study by Andriani, Wresta, Saepudin, and Prawara (2015).

Table 5 - Comparison of raw material and yielded biogas (Andriani et al., 2015)

| Source | Waste amount/day/kg | % Water | Dry matter | Biogas m ³ /kg dry waste |
|-------------|---------------------|---------|------------|-------------------------------------|
| Cow | 20-30 (28) | 80 | 20 | 0.023-0.040 |
| Dairy cow | 20-30 (28) | 80 | 20 | 0.023-0.040 |
| Buffalo | 30-40 (35) | 83 | 20 | 0.023-0.040 |
| Roaster/Hen | 0.15-0.20 (0.18) | 72 | 28 | 0.065-0.116 |
| Pig | 3.00-4.00 (3.40) | 67 | 9 | 0.04-0.059 |
| Human | 0.10-0.40 (0.15) | 77 | 23 | 0.02-0.028 |

Diagram 1 - Daily biogas production from farm animals.



The chamber size is going to be a rough estimation of the size of the biogas plant. The assumption is made based on the solar kitchen located in Tamera, Portugal. They use a 3000 litre biogas digester and they are able to feed up to 50 persons on daily basis (Tamera, 2018). Even though they have different circumstances considering the biogas needs, feed-materials provided daily and the weather conditions, there is a possibility to extend the retention time depending on the feed-material acquired daily to a certain limit (Macharia, & Musungu, 2018).

Since we need to provide food for a double amount of people, we require at least a chamber of 6000 litre. But to be able to have an idea of how big a plant could be and see if it is possible to put a bigger chamber beside the building. We are going to add the example provided by the manual (Macharia, & Musungu, 2018) that has 16000 litre chamber as shown in figure 16, which is much bigger than required but get a rough estimation of the size of the plant beside the building.

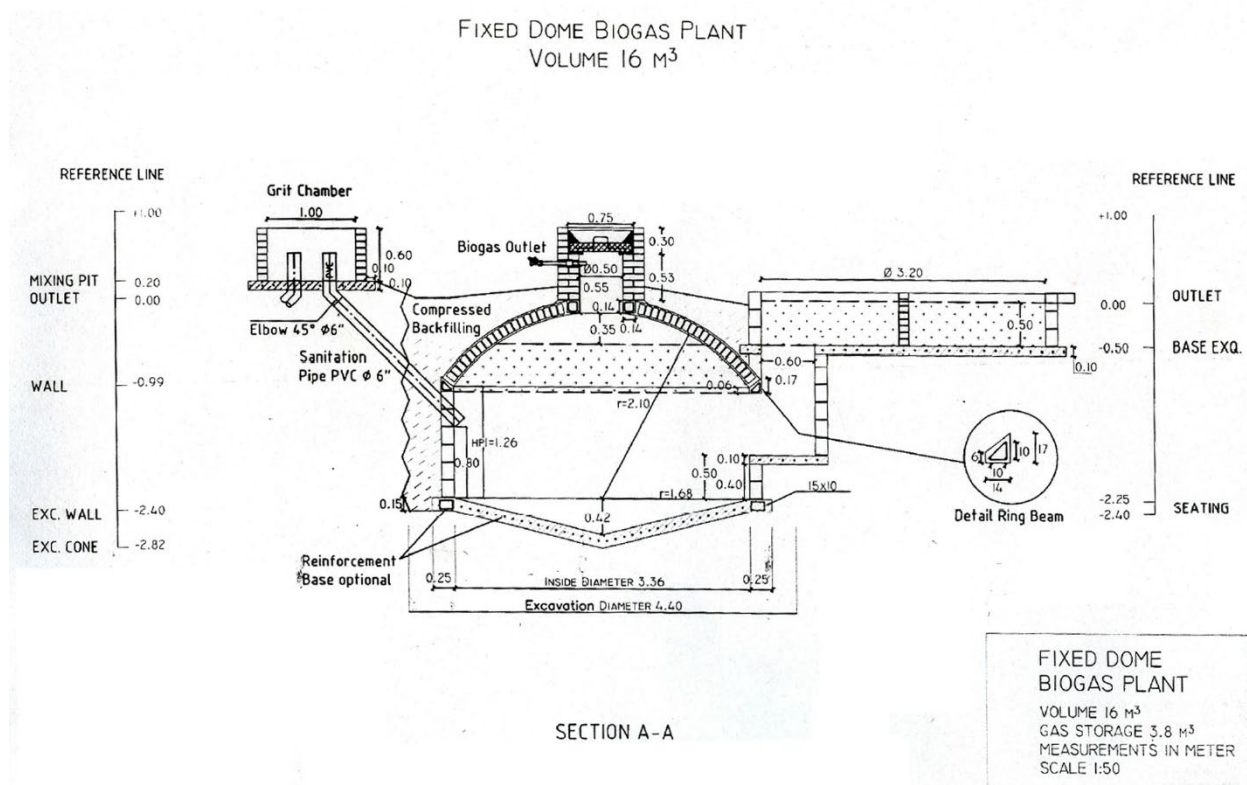


Figure 16 – A 16m³ biogas plant section (Macharia, & Musungu, 2018)

4.3 Design of the kitchen

This chapter will show the design factors and highlight adjustments added to ease the use of the kitchen and make it a functional restaurant. All the figures are adjusted in size and taken from the original documents that have been included in *Appendix B*.

The focus while designing the kitchen was the natural experience for the cook, regarding the fact that it uses a solar-powered cooking method. The placement of kitchen appliances has been taken into account, safety while using Scheffler reflector due to focus point inside of the kitchen, and the fact it needs to be adjusted every 3-4 days for proper functionality.

The restaurant layout has taken shape as shown in figure 17. The restaurant has two entrances, one from the south and the other one is from the east that goes through the dining room. The visitors are welcomed by the staff from the reception, which is also a bar. Beside the bar is the entrance door to the kitchen.



Figure 17 - Restaurant layout

The kitchen layout as shown in figure 18 consists of two solar cooking stoves and two biogas stoves. Spacious working area with 1200 mm passage which makes the workflow fluid. There are two water stations and a refrigerator area. A pantry room and an exit door to the backside of the restaurant, which grants easy access to the Scheffler reflector and the biogas plant.

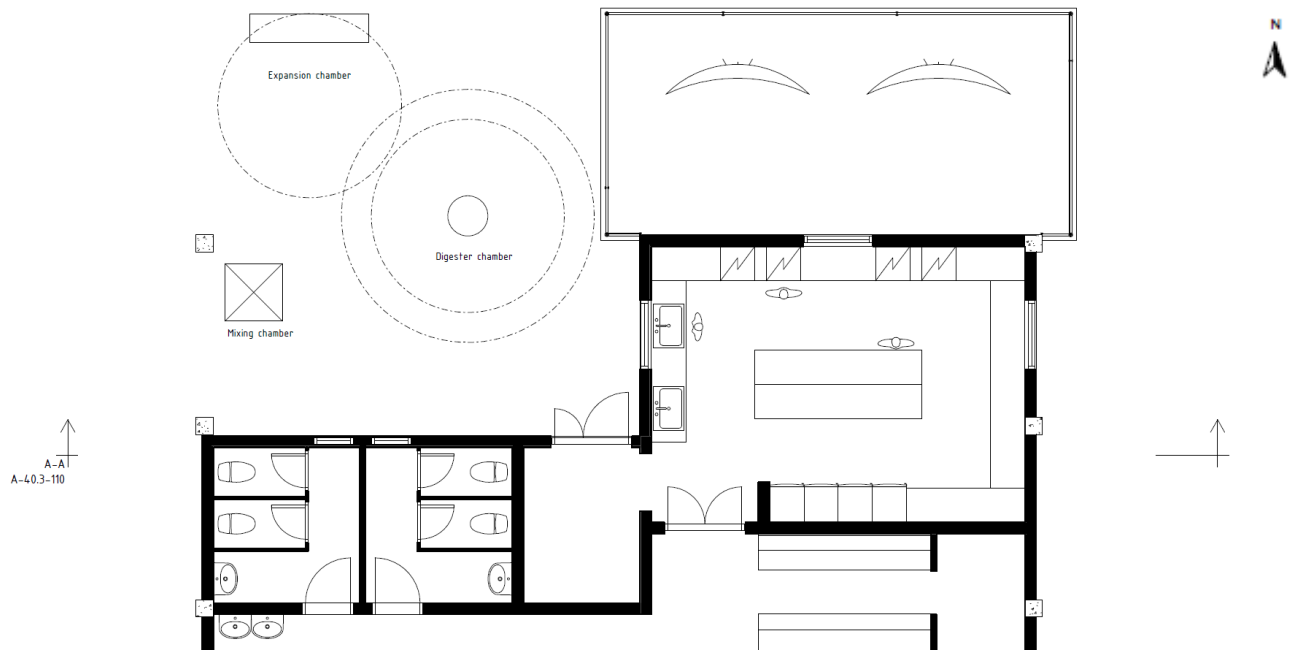


Figure 18 - Kitchen layout with Scheffler reflector and biogas plant.

Figure 18 also shows the approximate size of the biogas plant based on Macharia & Musungu (2008) with three chambers, a mixing chamber, a digester chamber, and an expansion chamber. The dotted line represents the chamber underground while the continuous line shows the parts above the ground.

Considering water installations in the kitchen, the bathroom has been placed close to the kitchen. That also gives the opportunity of using the roof for collecting water for usage in both, kitchen, and bathrooms, as well as sending wastewater into the biogas digester.

Construction materials locally used are bricks and concrete. With that in mind, different sketches regarding the exterior materials were made. The result is shown in figure 19 with the listed materials.

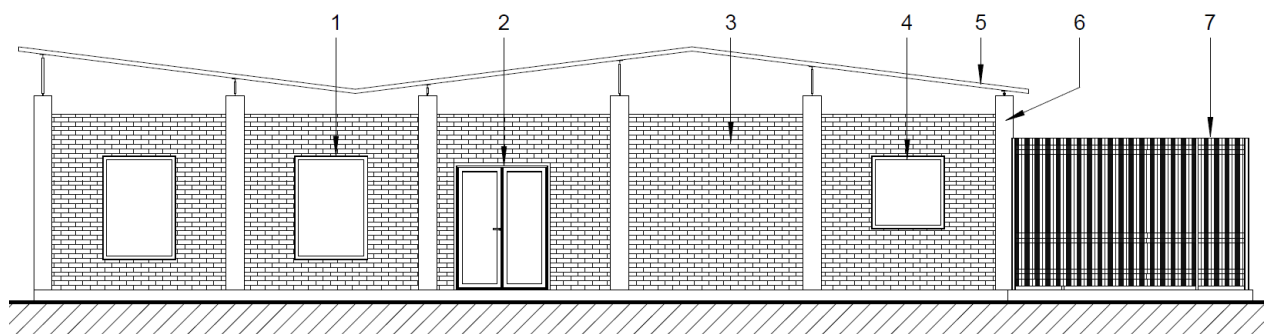


Figure 19 - East facade

1. Dining room window - dark brown frame.

2. Glass door - dark brown frame.
3. Bricks - tinted yellow.
4. Kitchen window - dark brown frame.
5. Metal plate – brown.
6. Concrete pillar.
7. Chain-linked fence.

The concrete pillars are there to connect bricks and make the building more robust and also to support the roof. The metal plate is used for roofing, it suites the weather conditions in Nairobi. Having big windows in the dining room adds a better airflow in the hot months and accommodate the view for the visitors outside. A simple view from the east north of the building is shown in figure 21.



Figure 20 – A simple rendering of the restaurant from the northeast.

Minor restrictions had to be considered with the usage of Scheffler reflector. The placement of the reflector must be towards the sun, which means its orientation is towards the south, while the kitchen's orientation is towards the north. The peculiarity of Nairobi is that, since it is so close to the equator, its sun comes half a year from the south, and other half from the north. That is also one of the reasons why Scheffler reflector was taken into account for designing this kitchen, because it has the ability to be tilted almost horizontally, and still receive the sun, even if it comes from the north, and send it into the focal point inside of the kitchen. To prove the claim, the next chapter called 4.3.1. *The solar study* deals with that issue.

Also, the height of the building had to be taken into account, so it does not block the sunlight when it comes from the south.

The roofing is inspired by KÉRÉ Foundation (2020). Due to high temperatures near the equator, buildings are built with a high secondary roof, ensuring the flow of the hot air and

exchange with cool air as shown in figure 21. Figure 22 shows the implementation of this concept in the kitchen area, section A-A.

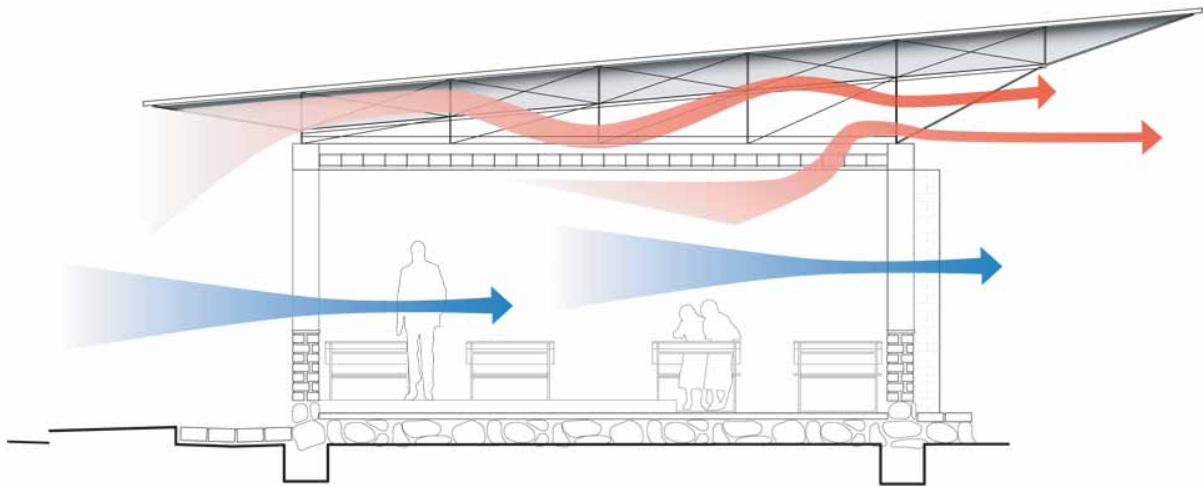


Figure 21 - Air circulation and cover from the sun on hot days. (KÉRÉ Foundation, 2020)

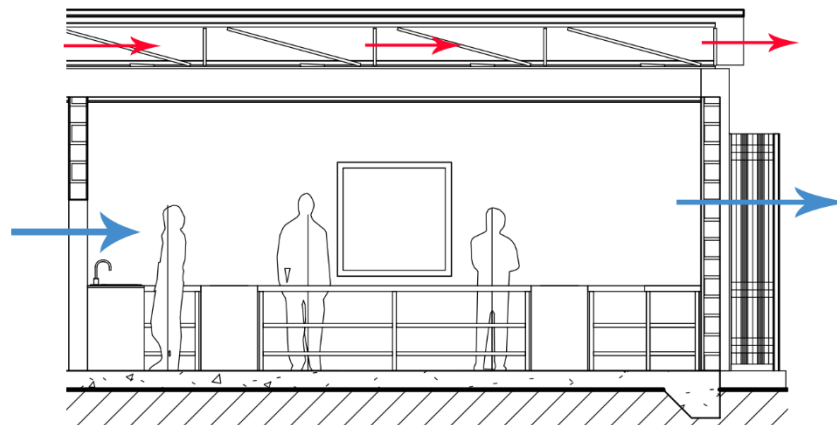


Figure 22 - Kitchen section explaining airflow.

4.3.1 Solar study

An important step of this thesis exploration is the solar study. Due to Nairobi's close placement to the equator, the sun coming from the south during summer, and from the north in winter, has to be taken into consideration. The solar study has been done using Revit to illustrate the shadow cast from the building during different yearly periods. Table 6 shows four different pictures for four different seasons of the year at 09:00, 12:00, 15:00, and 18:00.

Table 6 – Kitchen solar study for year 2020 in Nairobi using Revit.

| | |
|-----------------------------|--|
| 15 th of January | |
| 15 th of April | |
| 15 th of July | |
| 15 th of October | |

5 Discussion

5.1 Solar cooker

This master thesis work has reflected on different types of solar cooking products, as a step off into the possibilities of solar cooking. The main design concept of the kitchen was to make a commercial kitchen for the restaurant. That primarily meant the kitchen should be indoors, without disturbing the cook with high sun. Therefore, products like box ovens, panel ovens, Haines solar cooker 2.0, vacuum tube, and parabolic cooker where the cook is forced to stand in the sun whole day cooking were excluded. Scheffler reflector has shown itself as the optimum solution since it focuses the sunrays on a fixed focal point. As a result, cooking indoors was possible.

Downside to the Scheffler reflector is that it should be adjusted manually every second to third day. Another requirement is the education of the personal. Despite that, this is still the most optimum solution for the project. As an improvement and safety consideration, a more expensive option would be to make a steam system powered by Scheffler reflector. In that case heat, except for cooking, could also be distributed for heating water or the rooms during cold periods.

5.2 Backup facility

As a backup facility, biogas was chosen. It is based on its long lifetime, as well as self-sustainability. Since the restaurant is a part of the National Park and is expected to have visitors as well as animal sanctuaries, it has a lot of resources to sustain itself that way. The concern would be calculating the exact amount of produce required to produce biogas, in order to be equipped with the right size of the biogas digester. Other concerns with biogas facility is the high price in constructing it, as well as labour required regarding “feeding” it. An additional positive outcome of the biogas process is slurry, which could be used to make fruitful gardens.

5.3 Design

The solar kitchen design was solely based on the requirements of the Scheffler reflector. A solar kitchen based on a steam system would have made the design more flexible when it comes to the position of the kitchen or dining room. In that case, there would be a possibility of raising the entire construction one floor up to accommodate the view for the visitors.

6 Conclusion

In this chapter conclusions regarding the research questions will be drawn.

Leading concentrated solar beam into a building can be dangerous, how could this be tackled to achieve a safety-approved method?

To achieve safety approved method, an education course must be led to personal not to injure themselves working in the restaurant. Additionally, to prevent guests and personnel accidentally stepping into the biogas plant and Scheffler reflectors area, precautions signs and fences should be placed around.

While Scheffler reflector is not in use, to prevent burn accidents, a gate from the outside that scatters the focused light could be installed as shown in figure 15 in Tamera kitchen.

Investing in a new concept, there are risks that must be taken to apply these technologies. What are these risks and how can we tackle them?

One of the initial obstacles might be the high cost of both systems. From the previously mentioned example in Solare Brücke (2020), the first Scheffler reflector was still in use after 20 years in North-Kenya. This ensures that the cost of educating personnel and investing in Scheffler reflector would pay off in a reasonable amount of time. Regarding investing in the biogas plant, though the cost is high, the restaurant would be self-sustained, have a reliable source of energy, and produces less emissions since it is carbon negative which benefits the environment.

Another risk for the biogas system would be feeding. Feed-material needs to be provided in order for biogas to be created. A certain amount should be estimated before-hand in order to be able to decide the size of the chamber.

To be able to do so, it is best to interview cooks on the amount of food scraps they create during one working day. They should have common types of food they use, so they would be able to provide an estimate food scraps for the digester.

Additionally, the amount of human labour regarding maintenance and feeding the digester has to be considered. Education would be a solution for one of these issues while feeding digester with animal dung would be on restaurant personal to decide. Otherwise, a sufficient amount of food scraps would have to be provided.

7 Continued studies

Some options for continued studies would be designing a Scheffler reflector steam system and opening more possibilities in layout design.

Others would be designing a rain collector from the roof to have a usable water source apart from the borehole.

Another option can be specific biogas digester system, with accurate data of usable food waste and animal droppings. That way exact size of the chamber would be calculated, as well as slurry that can be used in gardening.

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Appendix A

1. How many people would it serve a day?

It depends on the size and maybe location. A rough estimate would be anywhere from 100 people.

2. What would they cook? Native food or more international type foods?

Again, depends on the location, but mostly local foods are done in national parks.

3. would the food be served on the go or served on tables? Would the restaurant require a dining hall?

Yes, food is served on tables mainly.

4. What type of building do they usually have? What are materials being used in construction?

Materials I have seen are the usual concrete/brick or concrete/stone combination. A few have open-air kitchen under a shed of iron sheets or thatched grass.

5. Would restaurant/park be close to town? Would it be connected to sewerage systems, water source, electricity or would it have it is own?

No, a majority are in remote areas, but they would have a water source (borehole water), connected to a sewerage system (constructed within the park), and electricity (from the grid, or from solar power). There is a safari park in the Kenya capital (called Nairobi National Park) which is 20 minutes from the city centre.

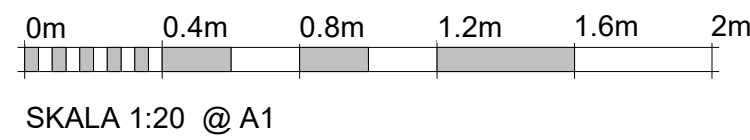
Appendix B

Detailed drawing done by Revit in this chapter.

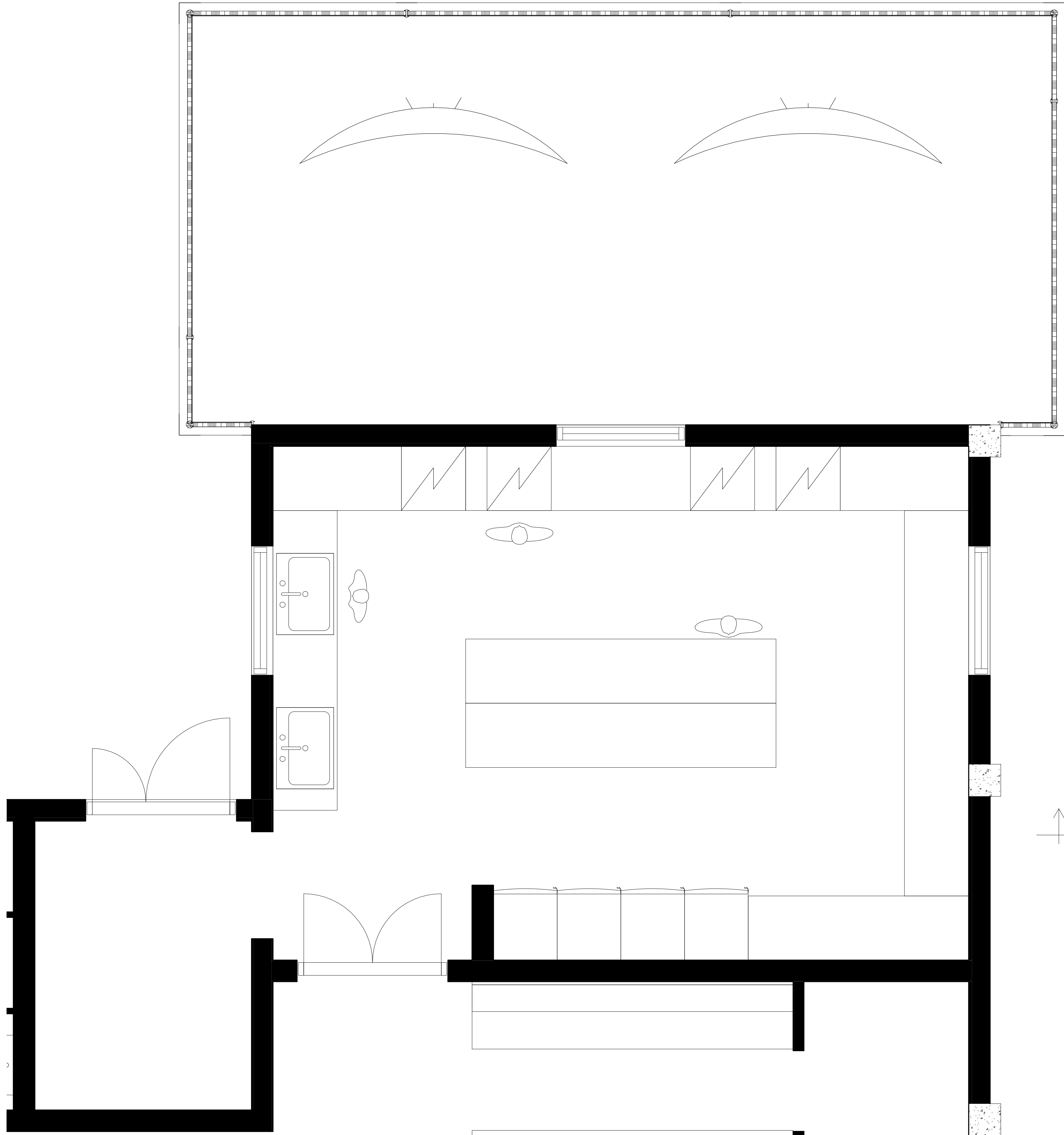
1. **A-40.1-110 – Restaurant**
2. **A-40.2-110 – Kitchen**
3. **A-40.2-111 – Kitchen with measurements**
4. **A-40.2-112 – Kitchen with biogas**
5. **A-40.3-110 – Façade**



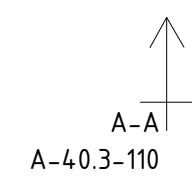
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| NAIROBI NATIONAL PARK RESTAURANT | | | | |
| SKALA A1 1:50 | | NUMMER A-40.1-110 | | BET |



A-A
A-40.3-110



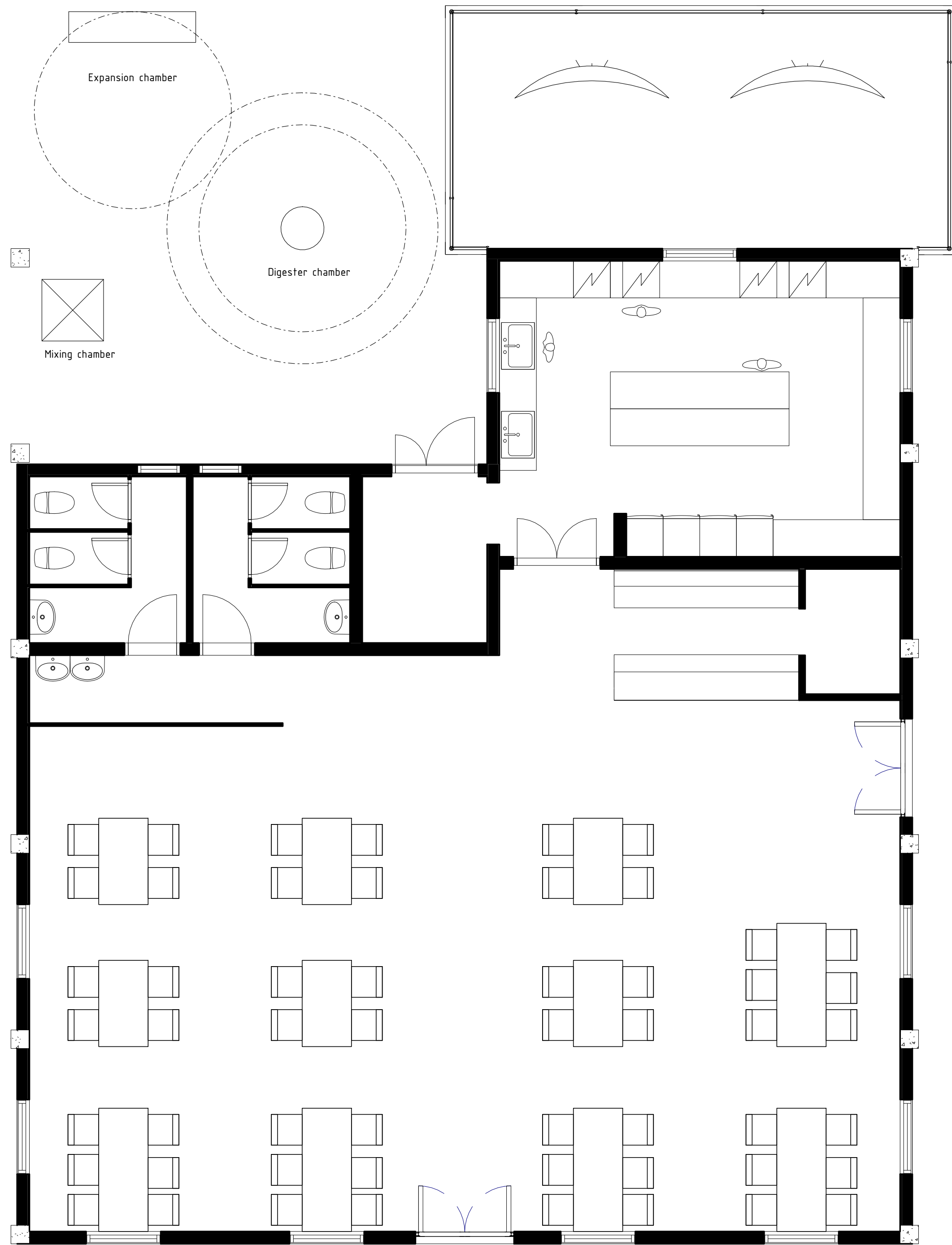
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| DATUM 10/09/20 | | ANSVARIG M.A. | | |
| NAIROBI NATIONAL PARK KITCHEN LAYOUT | | | | |
| SKALA | | NUMMER A-40.2-110 | | |
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| 03/20/07 | | M.A. | | |
| NAIROBI NATIONAL PARK KITCHEN WITH MEASUREMENT | | | | |
| SKALA | | NUMMER | BET | |
| A1 1:20 | | A-40.2-111 | | |

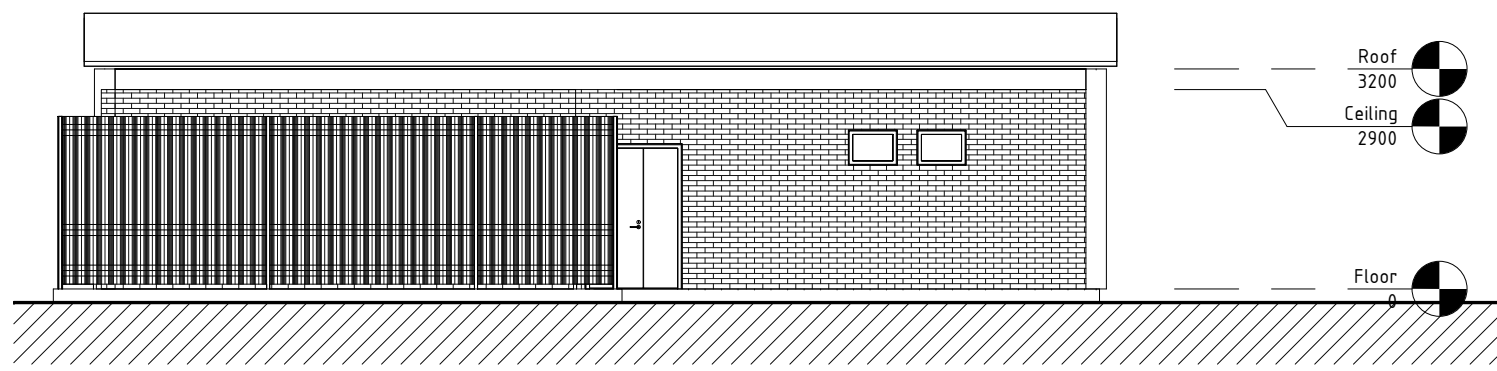


A-A
A-40.3-110

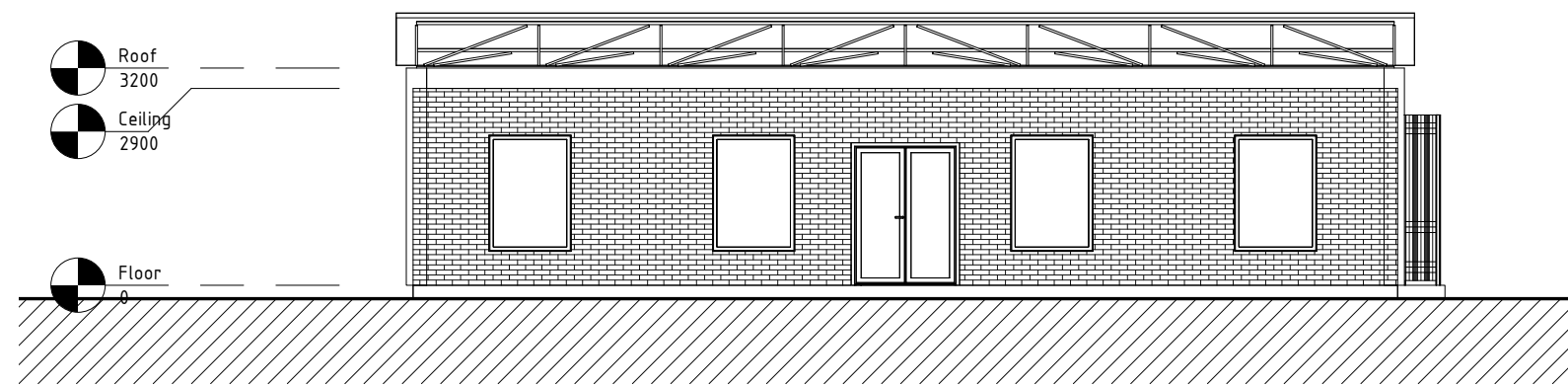


0m 1m 2m 3m 4m 5m
SKALA 1:50 @ A1

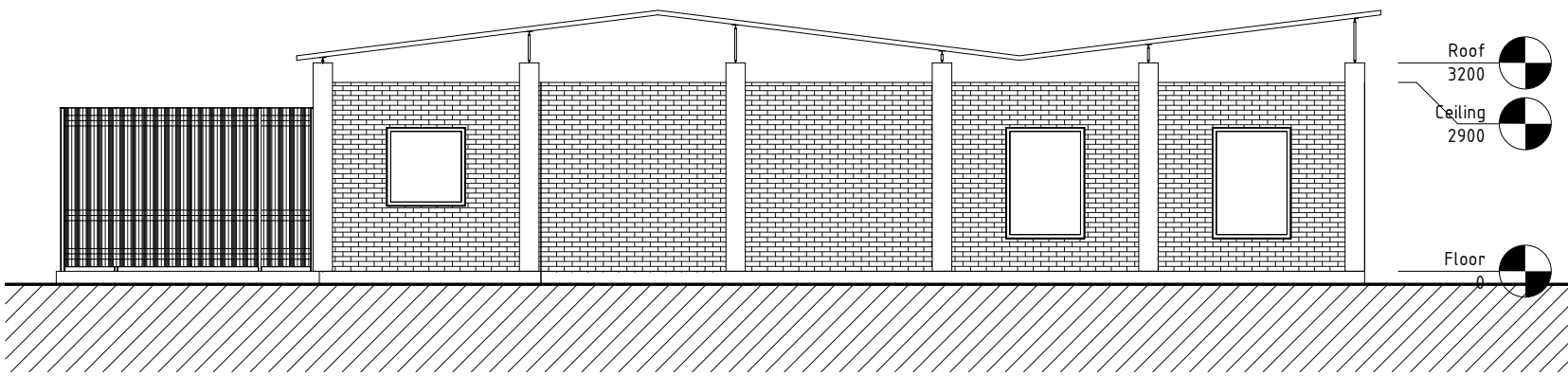
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| SOLAR KITCHEN DESIGN | | | | |
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| DATUM 10/13/20 | | ANSVARIG M.A. | | |
| NAIROBI NATIONAL PARK BIOGAS PLANT | | | | |
| SKALA | | NUMMER A-40.2-112 | | BET |



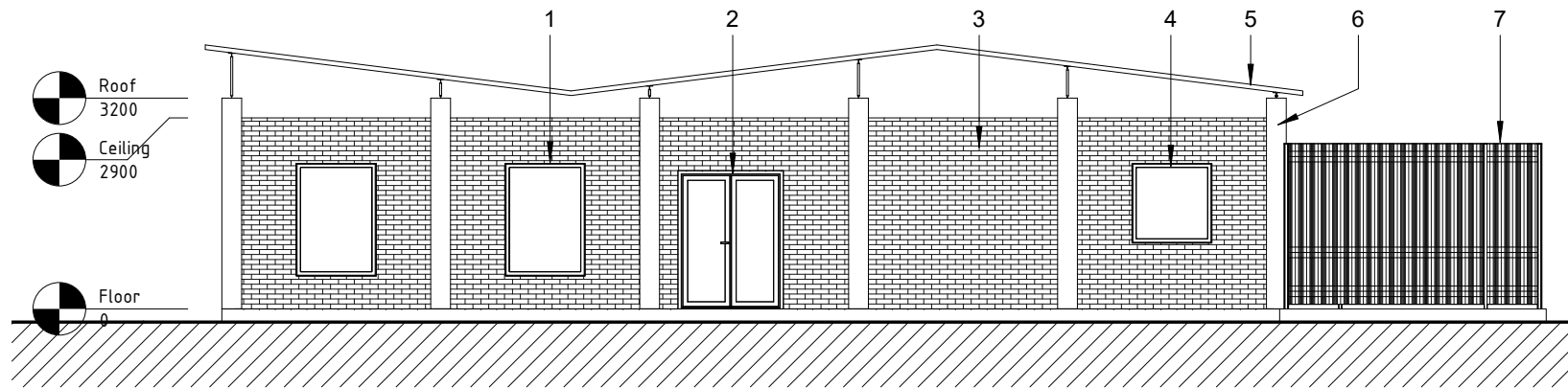
1 NORTH FACADE
1 : 100



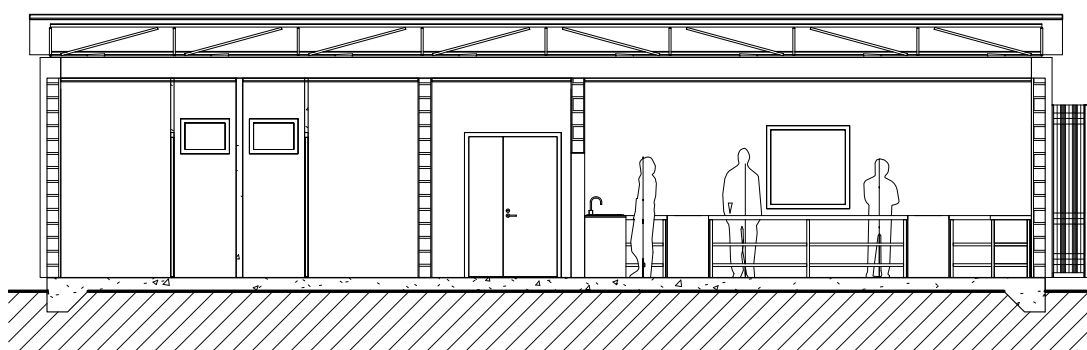
2 SOUTH FACADE
1 : 100



3 WEST FACADE
1 : 100



4 EAST FACADE
1 : 100



5 A-A
1 : 100

0m 2m 4m 6m 8m 10m
SKALA 1:100 @ A1

- 1 - Dining room Window - dark brown frame
- 2 - Glass door - dark brown frame
- 3 - Bricks - tinted yellow
- 4 - Kitchen Window - dark brown frame
- 5 - Metal plate - brown
- 6 - Concrete pillar
- 7 - Chain-linked fence

| | | | | |
|---|-----|--------------------------|------------|------|
| BET | ART | ÄNDRINGEN AVSEER | DATUM | SIGN |
| | | | | |
| SOLAR KITCHEN DESIGN | | | | |
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| UPPDRAG NR 001 | | RITAD/KONSTR. AV M.A. | HANDLAGARE | |
| DATUM 08/27/20 | | ANSVARIG M.A. | | |
| NAIROBI NATIONAL PARK FACADE AND SECTION | | | | |
| SKALA A1 1:100 | | NUMMER A-40.3-110 | | BET |