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Production, utilization and implementation of coconut charcoal in rural Mozambique

As a clean cooking fuel and a way to improve economic empowerment of women in Linga Linga

Ina Johnsson

Thesis for the dregree of Master of Science in Engineering

Division of Environmental and Energy System Studies
Department of Energy Sciences
Faculty of Engineering | Lunds University

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By: Ina Johnsson

in8163jo@student.lu.se

Thesis for the degree of Master of Science

Thesis advisors: Marcus Lundgren

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This degree project for the degree of Master of Science in Engineering has been conducted at the Department of Energy Sciences, Faculty of Engineering, Lund University.

Supervisor at the Department of Energy Sciences was Marcus Lundgren marcus.lundgren@energy.lth.se.
Examinator for the thesis was Öivind Andersson oivind.andersson@energy.lth.se

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Department of Energy Sciences
Faculty of Engineering, Lund University
Box 118, 221 00 Lund
Sweden
www.energy.lth.se

Abstract

Air pollution is a global health problem and in Mozambique, indoor air pollution is primarily caused by cooking over an open fire. This study examines the potential of coconut charcoal as a cleaner cooking fuel and as a possible source of income for women in the village of Linga Linga, Mozambique. Previous research conducted in the village identified a need to investigate the willingness of the community to adopt a different cooking method. Hence, this thesis focuses on the implementation of a solution. The study was conducted through a literature and case study in Linga Linga, which included field trials of different charcoal production methods, interviews, observations, and a workshop. The findings proved that coconut is a suitable material for charcoal production and that there are several methods of producing it in the village, none of which is superior to the others in terms of implementation rate. The so-called "pit method" was preferred for its low smoke production. Women in the village expressed interest in producing and selling charcoal, but for cooking a fungão (a type of grill) was needed and the high cost made the charcoal unsuitable as a primary cooking fuel. However, charcoal could be used as a complementary fuel to wood and small-scale sales could benefit the women. The study concludes that a successful implementation requires consideration of factors beyond the technical aspects. Two different approaches were suggested: first, recognizing the differences between the engineer and user lifeworlds and attempting to understand them. Second, avoiding the imposition of labels that could lead to a distinction between the participants and contribute to a postcolonial structure. The study also acknowledges the challenges as well as the necessity of interdisciplinary research. These findings may be valuable for future studies in Linga Linga, as well as studies aimed at improving life quality for people in other contexts.

Key words: Mozambique, health, charcoal, coconut, cooking fuel, implementation, lifeworld, colonialism

Resumo

A poluição do ar é um problema global de saúde e, em Moçambique, a poluição do ar em ambientes internos é principalmente causada pela culinária em fogo aberto. Este estudo examina o potencial do carvão de coco como combustível de cozinha mais limpo e como possível fonte de renda para mulheres na aldeia de Linga Linga, Moçambique. Pesquisas anteriores realizadas na aldeia identificaram a necessidade de investigar a disposição da comunidade em adotar um método de culinária diferente. Esta tese, portanto, concentra-se na implementação de uma solução. O estudo foi conduzido por meio de uma revisão de literatura e um estudo de caso em Linga Linga, que incluiu testes de campo de diferentes métodos de produção de carvão, entrevistas, observações e um workshop. Os resultados mostraram que o coco é um material adequado para a produção de carvão e que existem vários métodos de produzi-lo na aldeia, sendo que nenhum é superior aos outros em termos de taxa de implementação. O chamado "método de cova" foi preferido por sua baixa produção de fumaça. As mulheres da comunidade manifestaram interesse em produzir e vender carvão, mas o custo de um fungão o tornou inadequado para uso como combustível de culinária principal. No entanto, o carvão poderia ser usado como combustível complementar à madeira e vendas em pequena escala poderiam beneficiar as mulheres. O estudo conclui que a implementação bem-sucedida requer consideração de fatores além dos aspectos técnicos. Foram sugeridas duas abordagens diferentes: primeiro, reconhecer as diferenças entre os mundos de vida do engenheiro e do usuário e tentar entendê-los e, segundo, evitar a imposição de rótulos que contribuiriam para uma distinção entre os participantes e contribuiriam para uma estrutura pós-colonial. O estudo também reconhece os desafios, mas a necessidade de pesquisa interdisciplinar. Essas descobertas podem ser valiosas para estudos futuros em Linga Linga, bem como estudos com o objetivo de melhorar a qualidade de vida das pessoas em outros contextos.

Translated by Pedro Timane

Sammanfattning

Luftförorening är ett globalt hälsoproblem och i Moçambique orsakas inomhusluftförorening främst av matlagning över öppen eld. Denna studie undersöker potentialen hos kokosnötskol som en renare bränslekälla för matlagning och som en möjlig inkomstkälla för kvinnor i byn Linga Linga, Moçambique. En tidigare studie i byn identifierade ett behov av att undersöka hushållens vilja att anta en annan matlagningsmetod, därför fokuserar denna avhandling på implentation av en lösning. Studien genomfördes genom en litteraturstudie och en fallstudie i Linga Linga, vilket inkluderade fältförsökt av olika produktionsmetoder av kol, intervjuer, observationer och en workshop. Resultaten visade att kokosnötter är ett lämpligt material för koltillverkning och att det finns flera metoder för att producera det i byn. Ingen av metoderna var överlägsen de andra när det kommer till grad av implemtation. Den så kallade ”gropmetoden” var fördelaktig baserat på dess låga rökproduktion. Kvinnorna i samhället visade intresse för att producera och sälja kol, men kostnaden för en fungao (en typ av grill) som var nödvändig vid använding av kolen, gjorde kolen olämplig som primärt bränsle för matlagning. Kol kan dock användas som ett komplement till trä och småskalig försäljning skulle kunde gynna kvinnorna. Studien trycker på att ett framgångsrikt genomförande kräver hänsyn till faktorer bortom de tekniska aspekterna. Två olika tillvägagångssätt föreslås: först att vidkänna skillnader mellan ingenjörens och användarens livsvärldar och försöka förstå dem. Vidare, att undvika införandet av benämningar som kan bidra till en distinktion mellan deltagarna och bidra till en postkolonial struktur. Studien lyfter också utmaningarna men nödvändigheten av tvärvetenskaplig forskning. Dessa resultat kan vara värdefulla för framtida studier i Linga Linga, liksom studier som syftar till att förbättra livskvaliteten för människor i andra sammanhang.

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Secondly, I would like to thank the Swedish people who supported me with the project in Linga Linga. Michel, the head of Project Vita, for initiating the project, enabling me to follow through with it, and for your hospitality and insights. Sara, who served as the coordinator for Project Vita, for all the assistance in planning the project and for all the support on-site. Rickard, for all the good laughs, and Pedro, for believing in me. Thank you all for welcoming me into your worlds.

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Ina Johnsson
May 2023

Contents

1 Introduction

Everywhere in the world, humans, animals and the environment are affected by anthropological pollution. Air pollution was in 2012 named one of the world's single largest environmental health risks by the World Health Organization (WHO), linked to around seven million premature deaths annually, which is nearly one of eight (The Guardian 2014). Air pollution is defined as any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere and, 99% of the world's population breathes air that exceeds the WHO's guideline limits for levels of pollutants. There is a difference between ambient outdoor air pollution and household indoor pollution (WHO 2022a). The former is caused, for example, by industries, transportation, pesticides usage and energy usage and production (WHO 2022b). Household indoor pollution is mostly caused by the use of inefficient and polluting fuels and technologies within the home (WHO 2022c). Low and middle income countries are the most affected by both indoor and outdoor pollution (WHO 2022a). In figure 1 and 2 the number of death by risk factor can be seen in Sweden, a high income country, and Mozambique, a low income country (World Bank Data 2021). In Sweden, the number of death by risk factor due to air pollution was 758 cases in 2019, with indoor air pollution accounted for three out of these, circa 0.4 %. In Mozambique, there were 26,921 cases and indoor pollution accounting for 25,017 of theses, which is approximately 93% (Our World in Data 2019).

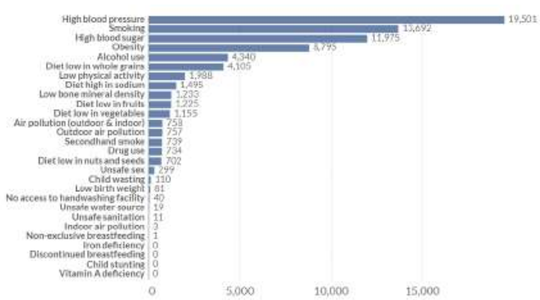

Figure 1: The number of death by risk factor in Sweden (Our World in Data 2019)

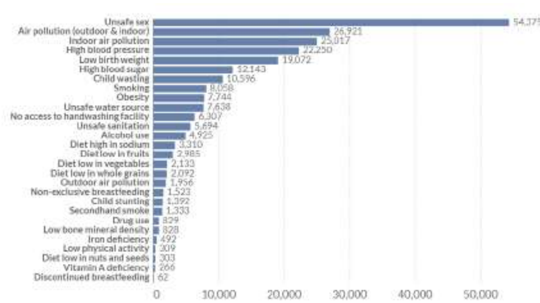

Figure 2: The number of death by risk factor i Mozambique (Our World in Data 2019)

Around 2.4 billion people worldwide cook using an open fire, and is one of the major causes for indoor pollution (WHO 2022c). In sub-Saharan Africa, 18% of the population have access to so called "clean fuels and technologies for cooking". In overall Mozambique 5% have access (World Bank Data 2020a) and in rural areas around 0.2% (World Bank Data 2020b).

In 2018, a study was done in a rural village in southern Mozambique by two students at Royal Institute of Technology in Sweden, Eriksson and Johansson Gunnarsson. The aim of the study was to investigate problems that people in the village experienced, and find technical solutions for the problems. One finding, was the experience of health problems due to indoor pollution while cooking (Eriksson and Gunnarsson 2018, pp. 1–5).

In 2019, Ebrahim and Lilja, also students at Royal Institute of Technology in Sweden, made a case study in the same village, with the aim to investigate the possibility of producing and utilizing bio energy from available local resources (Ebrahim and Lilja 2019, p. 2). The study proved it possible to use a so called micro gasifier cook stove for cooking instead of an open fire, and that coconut husk and shells were in surplus in the village and could be used in the gasifier cook stove. The gasifier could also produce coconut charcoal. The study concluded that the technique could be valuable for the households in the village, but that it could be hard to implement the technique since the concept differed from the current cooking practice.

It was suggested to investigate the willingness of the locals to use the gasifier cook stove. Furthermore, it was suggested an evaluation of the charcoal quality produced in the gasifier and if it could compare to wood as a cooking fuel, as well as investigating other ways to use biomass for cooking in the village (Ebrahim and Lilja 2019, p. 29).

According to the founder of the organization *Project Vita*, Michel Olofsson, operating in the village, the current method of cooking over an open fire, the so called *three-stone-method* is the most used method and have been used for ages. The women in the village are mostly responsible for cooking and are hence more exposed to the pollution. According to Michel, using charcoal is not common and there is no production of charcoal in the village. On the other hand, there could be a possibility to economically empower women by small-scale sales of charcoal locally (Olofsson 2022).

Moving forward with the findings of Ebrahim and Lilja, this thesis is focused on production and use of coconut charcoal, incorporated with the current cooking practice, the three-stone-method in Linga Linga. The thesis investigates the improvements on indoor pollution and the possibility of economical empowerment of women as a result of utilizing coconut charcoal. Further, it investigates and discusses conditions for a successful implementation of a technique like this based on more than the teqnical aspects, created in one part of the word, aiming to improve the life quality in another.

1.1 Aim

The aim with this thesis is to investigate the possibility of producing and utilizing coconut charcoal in Linga Linga, Mozambique, to be used as a clean cooking fuel and as a way to economically empower women. This to improve the life quality of the user group.

1.2 Research Questions

1. Are coconut shells and husk a good material for making charcoal?
2. What ways are there to produce charcoal from coconut shells in Linga Linga, Mozambique?
3. How much smoke is produced when cooking with coconut charcoal in comparison to coconut shells?
4. Which methods of producing charcoal is better, with respect to a successful implementation and smoke production in Linga Linga?
5. Are the techniques suitable for households in Linga Linga, both with respect to technical and social aspects?
6. What factors beyond the technical aspects are important for the technique to be implemented to benefit the user group and used long term in the village?

1.3 Methodology

To achieve the objective and answer the research questions both a literature study and a field study was conducted. The literature study was conducted as secondary research, while the field study was conducted as primary research. Both studies was conducted with a interdisciplinary approach, combining technical and anthropological disciplines. The literature study was divided into three parts, where the first two focusing on technical aspects and the last used sources from the field of anthropology. The sources are described in specific in chapter 2.1.

The case study included several different events. Field trials was done with different charcoal production methods, including evaluation of implementation rate and smoke exposure. Ethnographic research was done in the form of interviews and observations to draw conclusions about implementation and suitability. An workshop was also done to evaluate the methods together with the user group. Within the case study, there were different parameters to be decided, these were based on both the ethnographic research and technical limitations. The detailed methodology for the case study will be described in the chapter 3.

Further, both studies aimed to integrate a hermeneutic and a positivist mindset. While the positivist model emphasizes knowledge, the hermeneutic model focuses on meaning and interpretation. The literature study tried to integrate the two mindsets using different sources with different focus on knowledge and interpretation. The case study integrated the different mindsets during the field tries and the observations and interviews. For example, whiles the positivist model was used when evaluating the smoke exposure, the hermeneutic mindset was used when spending time with women in the village and defining implementation parameters.

2 Literature Study

This section presents the literature study and outlines the specific methodology employed in the study. The study is divided into three parts, each focusing on distinct topics that are connected to either production, utilization or implementation of coconut charcoal in the context of Linga Linga, Mozambique.

2.1 Methodology

The first part of the study used several different sources, found mostly in the library of Lund University.

The second part was done a more qualitative way, based on the study done by Ebrahim and Lilja and the study done by Eriksson and Gunnarsson conducted in Linga Linga Mozambique.

The third part was based on the book *Medicine as Culture: Illness, Disease and the Body* by Lupton. The book was used in the class *Cultural Perspectives on Health, Lifestyle and Medicine* given at the Department of Arts and Cultural Sciences at Lund Universily. The second source used was a book by Loomba, an Indian literary scholar and professor at the University of Pennsylvania, titled *Colonialism/Postcolonialism*. The third source *Reflecting on Economic Question* is a summary of the Inaugural Conference of the Institute from Social and Economic Studies in Mozambique 2007, partly founded by the Swedish International Development Agency (SIDA). Two texts were used from this book. First, *Heterodox Reflections About Development and Globalization in Africa* by Pimenta, a professor in Economics and Central Africa Studies at Oporo University, Portugal. Second, *Transport, Trade and Economic Development in Mozambique: An Agenda for Change* by Dibben a Senior Lecturer in Employment Relations at the University of Sheffield, UK.

Part One

The first part of the literature study covers the energy supply and demand in Mozambique as well as in the European Union, thermochemical conversions, the content and constituents of biomass, different charcoal production methods, emissions of combustion and the value chain of charcoal in Africa.

2.2 Energy Supply and Demand

The energy demand and supply is very uneven across the globe. For example, the World Bank estimated in 2020 that 100 % of the population of European Union had access to electricity (World Bank Data 2020c). In contrast, in sub-Saharan Africa 48 % had access to electricity at the same time. For Mozambique, that figure was 30 % (World Bank Data 2020d).

According to the *Biomass Energy Strategy (BEST) Mozambique*, a collaboration between EU Energy Initiative Partnership Dialogue Facility and the Ministry of Energy Mozambique, 80% of the energy used in Mozambique 2012 was in the form of traditional biomass, almost exclusively wood fuel and used for cooking (Energy for Development 2013).

In the European Union, 2020, the energy sources were mainly made up by five categories; petroleum products 35%, natural gas 24%, renewable energy 17%, nuclear energy 13% and solid fossil fuels 12% (European Union 2018). Within the renewables, biomass accounted for circa 60% (European Union 2019).

According to BEST, the development of alternative energy sources for cooking and heating, electricity and gas, requires large investments and will take time. The dependency on wood fuels is hence not expected to decrease in the near future. The development of a sustainable wood fuel supply chain is the most promising option for Mozambique to ensure availability of sustainable and affordable energy (Energy for Development 2013).

2.3 Biomass

Biomass is a non-fossilized and biodegradable organic material originating from plants, animals and micro-organisms. Biomass is considered a sustainable and renewable energy source, since it is constantly being created by the interaction of carbon dioxide (CO_2), air, water, soil, and sunlight. However, the carbon balance is of great value when considering a resource sustainable. Deforestation can lead to more CO_2 being released than being absorbed in photosynthesis, which can disturb the carbon balance. This distortion leads to global warming and deforestation threatens the world's biodiversity. Forests are home to a great numbers of animal and plant species and deforestation can drive these species into extinction (National Geographic 2023).

A major part of biomass is lignocellulose, witch is the non-starch, fibrous part of a plant. It's three major constituents are cellulose, hemicellulose, and lignin. Unlike carbohydrate or starch, lignocellulose is not easily digestible by humans. Therefore, lignocellulosic biomass is not a part of the human food chain, and does not threaten the world's food supply.

There are two types of lignocellulosic plants, herbaceous and non-herbaceous. A herbaceous plant is one where leaves and stems die annually at the end of the growing season. Non-herbaceous plants live year-round. A non-herbaceous plant can hence provide wood fuel all year, witch makes the production more predictable (Basu 2013).

2.4 Thermochemical Conversion

In a thermochemical conversion, bonds between molecules are broken down. This releases the chemical energy that was stored during the process of photosynthesis (Ram and Mondal 2022). Thermochemical conversion pathways can look different. Combustion is one pathway where the energy is directly used as heat. Pyrolysis, liquefaction and gasification are pathways where the energy is stored for further use, as a solid, liquid or gas respectively (Nunes et al. 2018).

Biomass as a renewable energy carrier can be used for different purposes via different thermochemical conversions. However, for all processes to be successful, the biomass needs to be dry (Roth 2014, p. 13).

2.4.1 Combustion

Combustion is one of the oldest technologies used by mankind, and today about 90% of the world's energy support (for traffic, power generation, and heating) is provided by combustion (Warnatz et al. 2006, p. 1). Combustion is a exothermic reaction in which a fuel is oxidized. The most used oxidizer is air, which contains oxygen. The most common fuels contains hydrogen and carbon, and are called hydrocarbons. The hydrocarbons react with oxygen to produce CO_2 and H_2O (Mandø 2013, p. 64). Fuels can be in all three phases, gas, liquids and solid. The combustion process depends on the state of the fuel. For gases, combustion occurs due to the difference in potential energy between the reactants and the products. Due to the conservation of energy, the enthalpy (a form of potential energy) is converted into thermal energy and radiation during the chemical reaction (Roth 2014, p. 13).

Exothermic reactions can occur at different temperatures, but the reaction rate is very slow at low temperature. Above a certain temperature, heat generation of the reaction matches or exceeds the rate of heat loss to the surroundings, and the process becomes self-sustaining. This minimum temperature is known as the ignition temperature, and it varies for different fuels in atmospheric air (Basu 2013, p. 72). For a gaseous fuel, the reaction occurs when the reactants have reached their ignition temperature. However, for solid material, the process is much more complex, with several simultaneous reactions happening (Emmons and Atreya 1982, p. 259).

2.4.2 Combustion of Biomass

The basic combustion route of a solid fuel is shown in 3. When the particle is exposed to heat, the moisture in the particle will first evaporate. During devolatilization, the volatile hydrocarbons (often called volatile matter or VM) which are in solid state, separate from each other as the temperature increases and enter a gaseous state. This gas is commonly referred to as wood gas, or pyrolysis gas. This process of VM entering the gas phase happens on the wood surface and is a form of pyrolysis leaving a char layer on the surface of the wood. At the same time, the wood gases react with oxygen in the atmosphere, creating the visible flame and heat of a fire. The produced wood gases diffuse through the layer of the char, creating more fire. The heat form the fire is conducted though the char layer and pyrolyse more virgin wood. (Emmons and Atreya 1982, pp. 260–261). The solid char needs more energy to be separated and enter a gaseous phase. When it does, it burns and leaves behind inert species, known as ashes (Mandø 2013, pp. 65–66).

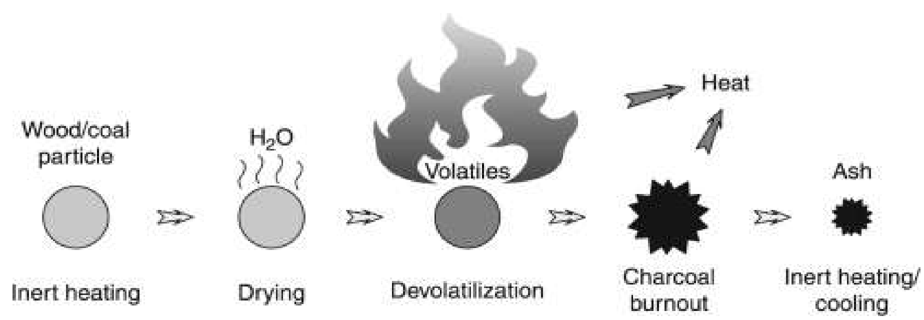

Figure 3: Particle combustion route (Mandø 2013, p. 65).

It should be mentioned that this explanation does not reflect the true nature of combustion. Even the combustion of the simplest hydrocarbon, methane, has 277 elementary steps with 49 species according to the most recent models. A complete description of all mechanisms involved in biomass combustion still remains to be fully explored (Mandø 2013, p. 66).

2.4.3 Pyrolysis of Biomass

Pyrolysis is as part of the combustion process, but if the oxygen is limited, it can act as a thermochemical conversion alone, with the aim to produce charcoal. As seen in table 1 there are different types of pyrolysis: slow pyrolysis or carbonization, fast pyrolysis and torrefaction. Slow pyrolysis yields around 35% charcoal, and the process occurs over days, compared to fast pyrolysis which happens in seconds and yields mostly bio-oil. Torrefaction yields around 80% charcoal, and the process is regulated with certain time and temperature and the process is industrial. This yield in table 1 is for wood (Ronsse et al. 2015, pp. 293–295).

Table 1: Thermochemical conversion process (Ronsse et al. 2015, p. 294)

	Fast pyrolysis	Carbonization	Gasification	Torrefaction
Temperature	~500°C	>400°C	600-1800°C	<300°C
Heating rate	Fast, up to 1000°C/min	<80°C/min	–	–
Reaction time	Few seconds	Hours~days	–	<2 h
Pressure	Atmospheric (and vacuum)	Atmospheric (or elevated up to 1 MPa)	Atmospheric, pressurized up to8 MPa	Atmospheric
Medium	Oxygen-free	Oxygen-free or oxygen-limited	Oxygen-limited (air or steam/oxygen)	Oxygen-free
Liquids (bio-oil)	75%	30%	5%	5%
Noncondensable gases	13%	35%	85%	15%
Char/solids	12%	35%	10%	80%

2.5 Content and Constitutes of Biomass

For a successful production of charcoal, the composition of the biomass is important. The composition of biomass varies depending on factors such as geographical location, climate, soil type and part of the plant. The composition of the biomass can be determined by a so-called proximate analysis where moisture, volatile matter, ash content and fixed carbon content are determined. By ultimate analysis the carbon, hydrogen, nitrogen and oxygen content of the biomass can be determined.

There is a positive relationship between the fixed carbon in biomass and charcoal yield, volatile matter and ash content are negatively related to the yield. With higher biomass volatile matter content, gas production is increased instead of the solid charcoal (Nunes et al. 2018, pp. 6–7). Also, the ignition temperature is lower for fuels with higher volatile matter. In table 2 the proximate and ultimate analysis of several biomasses and coal can be seen. This analysis was conduced in the study of Rabi Kabir Ahmad et al, titled *Exploring the potential of coconut shell biomass for charcoal production.*

Table 2: Chemical and physical characteristics of some biomass material done by proximate - and ultimate analysis (Kabir Ahmad et al. 2022, p. 6).

Biomass	Proximate Analysis %				Ultimate analysis %					Ref.
	MC	VM	FC	Ash	C	H	N	S	O	
Lignite	2.28	9.09	72.06	16.57	74.5	2.66	1.39	0.48	2.12	[47]
Coal	9.34	25.68	31.59	33.39	72.15	7.19	1.55	0.89	18.21	[48]
Coconut shell	5.56	70.82	21.80	1.80	40.08	5.22	0.22	0.17	54.31	Current Study
Rice husk	8.40	65.33	10.04	24.63	31.60	5.20	0.70	0.09	37.79	[45]
Palm kernel shell	4.00	58.00	43.00	4.00	51.00	7.00	3.00	0.48	39.00	[43]
Sugarcane Bagasse	5.25	82.55	8.30	3.90	46.60	5.92	0.14	43.35	0.09	[23]
Hardwood	7.80	72.30	25.00	2.70	48.60	6.20	0.40	–	41.10	[49]

In table 3 some of the parameters shown in figure 2 can be seen, with some variance in values. It also shows the higher- and lower heating value. The higher heating value is the lower heating value with the addition of the heat of vaporization of the water content in the fuel. It describes the total energy produced in the form of heat when the substance is combusted completely with air under standard conditions (Promdee et al. 2017, p. 1176).

Table 3: Chemical and physical characteristics of some biomass material, with addition of heating value (Promdee et al. 2017, p. 1176)

Proximate analysis and Heating value	Moisture (%)	Ash (%)	Volatile Matter (%)	Carbon (%)	Heating Value (KJ/kg)	Lower Heating Value (KJ/kg)
Rice Husk	12.00	12.65	56.46	18.88	14.75	13.51
Rice Straw	10.00	10.39	60.70	18.90	13.65	12.33
Bagasse	50.73	1.43	41.98	5.86	9.24	7.37
Cane Trash	9.20	6.10	67.80	16.90	16.79	15.47
Palm Fiber	38.50	4.42	42.68	14.39	13.13	11.40
Corncob	40.00	0.90	45.42	13.68	11.29	9.62
Tapioca Rhizome	59.40	1.50	31.00	8.10	7.45	5.49
Eucalyptus Bark	60.00	2.44	28.00	9.56	6.81	4.91
Coconut Shell	12.56	5.85	62.96	18.63	16.87	10.08

2.6 Charcoal Production and Usage

The major use of charcoal today is for outdoor cooking. The second largest use is in industrial applications, for example in iron production. It can also be used in filtration and purification of water, cosmetic and as activated charcoal in medicine (Utley 2005).

Charcoal can be produced both in industrial and non-industrial ways. In both cases, the biomass in ignited by external means. For the non-industrial production, volatile matter such as straws and husk can be used to supply the biomass with enough heat for the biomass to catch fire. Further, the biomass is insulated and shield from oxygen for it to pyrolyze and produce charcoal. The process needs to be regulated in a way that the biomass is not combusted into ashes nor not carbonized at all. When produced industrially, the process can be better controlled in for example oxygen input, compared to a non-industrial method, which affect the conversion. (FAO 1983a).

2.6.1 Earth Pit and Mound

The oldest technique for carbonization is to use earth to shield from oxygen and insulate the biomass. According to Food and Agriculture Organization of the United Nations (FAO) it is the most used technique for shielding. It is of low cost and available wherever biomass and earth are found. There are two distinct ways to use earth as a barrier, first is to use a pit, where the biomass is placed in the pit, and then the pit is somehow covered. The other is to cover up a pile/mound of biomass on the ground with earth. The earth forms a insulating barrier for the carbonization to take place preventing a leakage of air, that would cause the biomass to burn to ashes. Both methods, if skilfully carried out, can produce good charcoal within their technological limitations.

There are several limitations for both methods. The pit is wasteful in resource since it is very difficult to control the circulation of gases in the pit. Much of the wood is burned to ashes due to an excess of air, and another portion of the biomass is only partly carbonized because it was never properly heated and dried out (FAO 1983b).

The mound method is also used in many countries. Essentially, the process is the same as for the pit method. The earth mound is preferred over the pit where the soil is rocky, hard or shallow, or where the water table is close to the surface. The pit is better where the soil is well-drained, deep and loamy. The mound is more practical in agricultural areas where fuelwood may be scattered.

A mound site can be used over and over again, whereas pits tend to be used only a few times before new holes are dug. It is more practical to gather fuelwood in a pile than in a pit for drying purposes. Gathering over a period of time fits well within the lifestyle of a small farmer. In addition to being utilized on the farm, the charcoal can be a source of small cash income which requires no initial cash outlay.

The main factors limiting the mound method is the challenges of sealing it against air during the entire carbonization and maintaining good air circulation (FAO 1983c).

In figure 4 and 5 a large-scale pit and mounds can depicted.

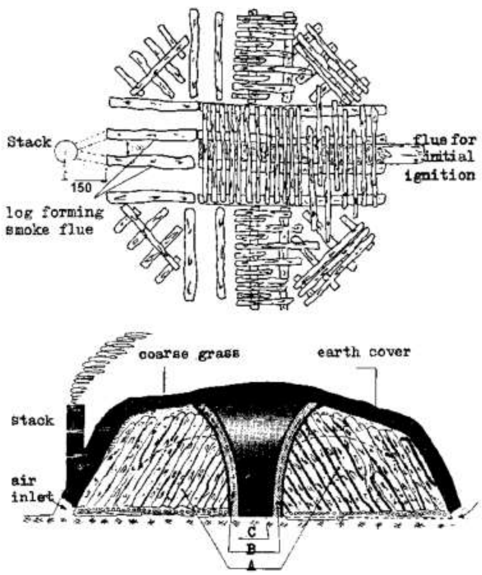

Figure 4: A large-scale mound (FAO 1983c).

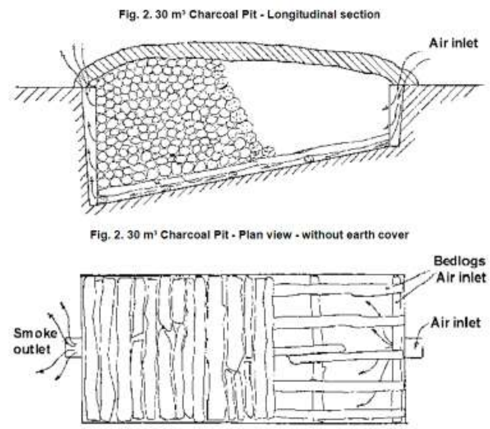

Figure 5: A large-scale pit (FAO 1983b).

2.6.2 Metal/Brick Kiln and Micro Gasifier Cook Stove

Charcoal can also be produced using brick or metal kilns, not using earth for shielding and insulating. Although these methods are more expensive and not always available where the biomass is located, they can provide better sealing than earth-based methods. Well-constructed and properly operated brick kilns are among the most effective ways of producing charcoal. They are cost-effective and can yield high-quality charcoal. Brick kilns come in many different designs around the world, but they all must be relatively unaffected by thermal stress and rain (FAO 1983d).

Charcoal can be produced in kilns made from oil drums. This method successfully operated using fast-burning raw materials like coconut shells and scrub wood. Compared to methods using earth, the conversion efficiency obtained in oil drum kilns are relatively high. However, a disadvantage of using oil drums is that it can be difficult and expensive to obtain them. Moreover, the drums tend to worn out rather quickly due to the thin metal and have to be replaced frequently (FAO 1983e).

When producing charcoal in metal kilns, the wood gases produced can also be used as a cooking fuel. In small-scale operations, this is known as a micro gasifier cook stove. According to Roth 2014, gasifier can function as miniature charcoal kilns and produce charcoal as a by-product of cooking. In figure 6 and 7 a large-scale metal kiln and a micro gasifier cook stove is depicted.

Figure 6: A large-scale metal kiln (FAO 1983e).

Figure 7: A micro gasifier cook stove made in the study by Ebrahim and Lilja 2019, p. 22.

2.7 Emissions and Health

As mentioned in chapter 1, pollutants can enter the environment though various means. It is helpful to classify pollutants as either primary, which are directly emitted into the environment, or secondary, which are formed from primary pollutants reacting in the environment, when examining their impact on human health (WHO 2023).

Major primary pollutants formed during biomass combustion include carbon monoxide (CO), other hydrocarbons, nitrogen oxides (NO_x), sulfur oxides (SO_x) and particulate matter (PM). A secondary pollutant is for example ground-level ozone. These pollutants have different effects on human health (Mandø 2013, p. 69).

PM refers to a mixture of solid particles and liquid droplets that can be found in the air and in different sizes. PM10 includes coarse particles between 2.5 and 10 micrometers in diameter, and PM2.5 refers to particles with a diameter less tan 2.5 micrometer. Black carbon or soot is a major component of PM2.5, caused by incomplete combustion (WHO 2023). Smoke can contain hundreds of different compounds, but visible smoke is mostly soot, tar, oils, ash and water vapor. Each particle is too small to been seen alone, but when come together, they become visible as smoke

(University of Waikato 2019).

Both short- and long-term exposure to smoke, and especially black carbon has been associated with cardiovascular health problems and premature mortality. Exposure to both NO_x and SO_x are linked to asthma and other respiratory diseases. CO diffuses into the bloodstream and inhibits the cells to bind oxygen which damages the tissues and cells. Exposure to CO can cause breathing difficulties, exhaustion and dizziness. If exposed to high levels, CO can be deadly (WHO 2023).

Traditional charcoal industry is considered to be both inefficient and polluting, emitting harmful gases containing methane, CO and PM. While emissions from modern industrialized processes has been well investigated, such technology is beyond reach for rural areas in Africa, and emissions from traditional kilns has not been particularly investigated.

According to Sparrevik et al., few studies have actually measured emissions of improved system in situ. The lack of documentation is likely due to the difficulties of conducting such measurements, as many production sites are located in remote areas. The difficulties of obtaining measurements are compounded by a limited number of operating units on site, making it difficult to perform comparative studies (Sparrevik et al. 2015, p. 66).

2.8 Value Chain of Charcoal in Africa

Around ninety percent of the harvested wood in Africa is used for energy, and charcoal consumption increases more than ordinary fuelwood and is becoming a huge business due to the population growth and urbanisation. Charcoal is more energy dense than fuelwood, making it is better suited for distribution to cities. However, the growing demand for charcoal and other woodfuels in Africa has wide-ranging consequences for biodiversity (SWEDEV 2021).

The Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF) calls for participants in the value chain to develop strategies to ensure policy coordination and enforcement. The lack of alignment between governments and official policies leaves small-scale traders, particularly women, vulnerable to exploitation. Jolien Schure, a CIFOR-ICRAF associate, argues that there is a need to develop a roadmap for sustainable charcoal production and trade, both domestically and across the boarders. Currently, regulation across Africa regarding woodfuel are mostly focused on bans and restrictions targeting both export and import, and many governments have outlawed commercial exportation of charcoal. This has catalysed the informal economy of charcoal with small-scale traders and sellers and most activities take place after dark. The trade is likely to increase, with Africa's population expected to be the double in 2050 (Biggar 2022).

Part 2

This part will summarize the study by Ebrahim and Lilja, *The feasibility of producing and utilizing bioenergy in Linga Linga, Mozambique.* The site will be described according to the authors, and key findings of the study will be presented. Furthermore, key findings from the study by Eriksson and Gunnarsson *En sammanställning av problem i hushåll i Linga Linga, Moçambique*, regarding cooking and smoke, will be described.

Linga Linga is located in the province of Inhambane in the southeastern part of Mozambique. The nearest town is Morrumbene, approximately 35 kilometers away. There are around 400 households in Linga Linga with a population of around 1200. The population is young, and increasing. Most houses in Linga Linga are of simple construction, made by reed straws or palm leaves and wood from coconut trees. The people of Linga Linga speak the local language Gitonga and many also understands Portuguese, which is the official language of the country. The main occupations in the village are fishery and handcraft, some also work with cultivation or at local hotels. There is a school in Linga Linga for grade 1 to 7, and the pupils can continue to $12^t h$ grade in Morrumbene. The long distance from Linga Linga to Morrumbene affects school attendance, and many children leave school after $7^t h$ grade (Ebrahim and Lilja 2019, pp. 15–16).

There is a lot of solid biomass in the village. The most common biomass on the peninsula is coconut tree. All parts of the coconut tree can be used for different purposes. The coconut tree is a non-herbaceous plant grown in tropical climates around the world, with Mozambique being one such place. Coconut is used in various ways, such as coconut water, oil, milk for both humans and animals. For bioenergy, both the trunk, branches, leaves, husk and shell can be used. Around the village, and in people's homes, one could find vast of coconut shells and husk laying around.

Furthermore, the most common way of cooking in the households is the three-stone-fire method. A pot is placed on three stones, and wood (or other biomass) is used to create a fire between the stones. In figure 8 the husks (in front) and the shells (in the back) of the coconut can be seen. In figure 9 water is boiling on a three-stone-fire (Ebrahim and Lilja 2019, pp. 16–18).

Figure 8: Coconut husk and shells piling in a backyard of a household (Ebrahim and Lilja 2019, p. 17).

Figure 9: The three-stone-method is used, but with a metal rack instead of stones (Ebrahim and Lilja 2019, p. 18).

The two different ways considered for producing and utilizing bioenergy were a gasifier cook stove and anaerobic digester (Ebrahim and Lilja 2019, p. 3). The gasifier cook stove was considered more suitable for the households in Linga Linga (Ebrahim and Lilja 2019, p. 18).

The study showed that the general perception was that charcoal was not commonly used for cooking, but existed for this purpose. However, a few households had used charcoal at some occasions and preferred it over firewood because of the energy efficiency and the reduction of smoke. The charcoal could be used directly in the three-stone-fire. By using the charcoal made out of coconut husk for cooking, the time spent on collecting fuel could be reduced, as it was shown to be a time-consuming practice. By reducing the time spent collecting fuel, women could devote their time to entrepreneurship, such as selling their produced charcoal to gain additional income. It was also concluded that households needed to find an advantage in using a gasifier cook stove compared to the three-stone-fire method and understand the benefits of producing charcoal (Ebrahim and Lilja 2019, pp. 21–25).

According to Eriksson and Gunnarsson, smoke from cooking was identified as a major problem for the people interviewed in Linga Linga. Many reported irritation in their eyes and lungs due to smoke exposure. The interviewees did not experience any other problems with cooking. The authors expected a desire for a more effective cooking method, but none was expressed by the respondents(Eriksson and Gunnarsson 2018, pp. 6–7).

Part 3

This part will describe several topics related to the human experience of implementation. First, the relationship between cultural and health will be described from the author Deborah Lupton perspective in the book *Medicine as Culture: Illness, Disease and the Body.* Further, colonialism and postcolonialism will be described from the perspective of Aina Loomba in her book *Colonialism/Postcolonialism.* Inter-disciplinarity and colonial language will be described form Carlos Pimenta's perspective in *Heterodox Reflections About Development and Globalization in Africa.* Furthermore, a short description of the colonial history of Mozambique will be described by Pauline Dibben in her paper *Transport, Trade and Economic Development in Mozambique: An Agenda for Change.*

2.9 Sociocultural Perspective on Heath

In her book, Lupton highlights that Western scientific medicine is a product of social and cultural processes, just as much as the medical knowledge and practices developed in non-Western societies are. The term "culture" frequently appears in the medical literature, but is typically used to denote non-Western cultures. Lupton argues culture in the context of heath, should be understood as the "conglomeration of meanings, discourses, technologies and practices that accumulate around medicine within Western societies as well as outside them" (Lupton 2012b, p. 3).

Lupton continues that in all societies, issues of embodiment, health, illness, disease and death are inextricably interlinked with social and cultural processes. The biological dimensions and medical understandings of these phenomena cannot be extricated from the social and cultural settings in which they are known and experienced.

Furthermore, she describes the concept of "lifeworld", which is used by anthropologists and sociologists to describe the everyday sociocultural context in which meaning is created. The concept of lifeworld was introduced by Edmund Husserl as part of the hermeneutic research approach.

Within healthcare, this term encompasses the understandings, concepts and beliefs people bring to the medical encounter, which are shaped by personal experiences, interactions with others, mass media and the internet, as well as membership in social class, gender or generational, racial or ethnic groups. Lupton highlights the importance of recognizing that doctors and healthcare professionals bring their own cultural beliefs to the medical encounter, which are generated not only by their scientific training but also by other aspects of their lifeworlds.

By incorporating elements of both meaning systems, doctor and patient negotiate authority over meaning in the medical encounter. Rather than standing apart from and observing their patients' lifeworlds, doctors can actively contribute to and possibly transform the lifeworlds through their efforts to translate medical knowledge (Lupton 2012b, p. 4).

Lupton continues that by exposing the bases of medicine, health care and illness and show that they are not necessarily given or 'true' but are subject to change, one can create the opportunity for alternative ways of thinking and speaking. She gives an example of menopausal women, and how if they can successfully argue that the ceasing of menstruation is a new, liberating dimension of womanhood rather than the death of femininity, the bodily experiences around the process can be transformed (Lupton 2012a, p. 3).

According to Lupton, medical anthropologists have to a great extent recognized that the culture of a patient influences the experience of illness. However, the connection between researchers in the field to biomedical practice, and the need to maintain institutional usefulness, has led to a reluctance to adopt a social criticism perspective, out of fear of losing access to the health arena. Consequently, non-western culture's medical beliefs have sometimes been viewed as superstition, and anthropologists have promoted compliance of these cultures with biomedical practices (Lupton 2012c, p. 14).

2.10 Colonialism and Mozambique

According to the *Oxford English Dictionary* (OED), a colony is a settlement in a new country where a group of people settle down and form a society that is either submitted or jointly governed by the mother country. This society consists of the original settlers and their descendants and exists as long as the union with the mother country is sustained. The people who lived at the place of settlement before the arrival of the colonists are not mentioned in this definition (Loomba 2005, p. 17). In many cases the indigenous people were viewed as mysterious, superstitious, uncivilized and developmentally disabled by the colonists (Loomba 2005, p. 24).

Colonization has taken place thoughout all human history, where colonists have taken over the control of other peoples' land and assets. However, modern European colonialism changed the world in a way earlier colonists did not. One theory explaining the massive influence of the modern European colonialism is that it coincided with the rise of capitalism in Western Europe, whereas previously colonialism was not as strongly linked to capitalism. The modern colonialism restructured the economy of the settlement and created a complex dependence between the settlement region and the mother country, including human and natural resources trading. The resources went in both directions, but the profits always ended up in the settlers' hands. This economic imbalance created the necessary conditions for European capitalism and industrialization to rise (Loomba 2005, p. 19).

When speaking of postcolonialism, a complex term intended to describe remaining effects of the modern European colonialism, many critics argue that the persistence of inequality and dependency in formerly colonized countries raises the question about the therm "postcolonial" to describe the situation. A country can be postcolonial, that is officially independent, and neocolonial, that is economical and/or cultural dependent. Even if a country is officially decolonized, there is still a global division between the "first" and "third" world (Loomba 2005, p. 23). Postcolonialism is not simply a historical period after colonialism, but rather a critical framework for examining the ongoing effects and legacies of colonialism (Loomba 2005, p. 26).

Vasco de Gama arrived in Mozambique in 1498, and marked the arrival of the Portuguese. They gradually colonized and settled the country and ruled for over four centuries. After a ten-year long liberation war Mozambique gained independence in 1975 and became the People's Republic of Mozambique. After the independence, a 16 year long civil war followed, with the destruction of much of the country's infrastructure, the displacement of over three million people and over one million deaths (Dibben 2007, p. 198).

2.11 Interdisciplinarity

According to Pimenta, it is today well-known that breaking down the whole into parts and studying them in details is not the most simple nor most appropriate method for the scientist or philosopher to understand the whole. This because the whole is more then the sum its parts, and is is also the relationship involving differences and similarities between the parts and the irreversibility of the process. The author argues that for a better understanding of the whole, there is a strong need for interdisciplinarity, within the field of research. However, the author also recognize the difficulties and the complexity of interdisciplinary research. One of the difficulties arise from the fact that all perceive reality through interpretive models that are familiar to us. An example of this is the lexicon of the discipline. In a interdisciplinary team, there could be huge knowledge gap between the members since the disciplines do not share lexicon (Pimenta 2007, pp. 20–22).

Further in his paper, Pimenta argues that the use of the term "underdevelopment" to describe Africa implies that it is an inevitable and "natural" phenomenon, when it rather is imposed from the outside by colonialism and neocolonialism. He contends that the idea of development being an act of "developed" helping the "underdeveloped" is a continuation of colonist thinking. Instead, underdevelopment should be understood in the context of the unique circumstances of each society, rather then solely on external comparisons, which holds true for any society (Pimenta 2007, pp. 40–42).

3 Case Study: Methodology

In this section the methodology of the case study conducted in Linga Linga, Inhambane province, Mozambique from September to November 2022 will be presented. All the pictures presented in this section were taken during this period.

The case study employed various research methods that complemented each other. Four sets of events formed the backbone of the field study: Interviews with 15 women in the village, observations made in the village, field trials of charcoal production methods and a charcoal production workshop. The interviews, observations and fields trials were conducted sporadically during the period, and the workshop took place at the end.

The section covers the selection of production methods, the setup of the field trials, the selection of implementation parameters, and the chosen ways of evaluation.

3.1 Selection of Production Methods

Firstly, a selection of four charcoal production methods were investigated. These four were described in *Simple technologies for charcoal making* written by Food and Agriculture Organization of the United Nations in 1987 described in chapter 2.6. The gasifier, described in chapter 2.6.2 was not tested since that was done in the study by Ebrahim and Lilja.

Furthermore, two basic parameters were established: Material availability and setup time. These parameters were used to determine which methods would be further investigated. Material availability was deemed necessary, as the test could not be conducted without the required material. The setup parameter was chosen due to the scope of the project, in order ensure that the method was not too time-consuming.

3.2 Setup of Field Trials

The field trials were conducted in collaboration with Branquimho Agosto, a charcoal production expert who also participated in the study by Ebrahim and Lilja. The first step for all production methods was to collect coconut shells and dry them. The field trials were all done on sandy ground, in Branquimho's or Michel's home and all the methods were tested repeatedly.

3.2.1 Earth Pit

For the pit method, a hole was dug in the ground and the coconut shells were placed within the hole, leaving enough space for air to flow between the shells to allow even heat distribution. A fire was started above the coconut shells with other materials, such as the husk of the coconut, branches and straws, then ignited with matches. Once the fire was burning fiercely, an aluminium plate was placed on top of the fire.

3.2.2 Earth Mound

For the mound method, a grid of sticks was created on the ground, and the coconut shells were stacked on top of the grid in a pile. The pile was covered with branches that had many leaves and later with mud made of sand and water. The front of the pile was not covered, and the ignition took place there with husk and straws. The pile was later covered when the fire had created enough heat.

3.2.3 Metal Kiln

The kiln method was done in a metal can. The shells were placed in the can and ventilation holes were made. The lid was later placed on top and sealed with sand.

3.3 Selection of Implementation Parameters

In order to evaluate the different on-site methods of producing charcoal with respect to implementation factors, it was necessary to determine these factors. The implementation parameters were based on common answers from the interviews and frequently observed observations.

3.4 Interviews

The interviews were conducted with 15 women in their homes. The interpreter, Elton de Rosa, selected the women based on their location, availability and willingness to participate in the study. It was important that the participants had time and understood the context of the study and its benefits. The interviews were conducted sporadically during the field study period, but all of them were completed before the workshop. The interview questions were first formulated in Swedish and then translated to English. The questions were then translated into either Portuguese or Gitonga by the Elton and asked to the women. Then Elton translated their answers once again to English.

3.5 Observations

The observation took on various forms. First, the function, social constructions, traditions and customs were observed in Linga Linga, as well as in other parts of the country visited during the field period. Second, there were many observations of people cooking and preparing food. Third, observations were conducted in the household of one woman, Sonia Erculano. During the interview, Elton was present, other times of observation, the communication was done through gesturing and very basic Portuguese.

Observations were also conducted during the field trials together with Branquimho. The communication was also done though gesturing and basic Portuguese.

3.6 Workshop

The workshop included Branquimho, Elton and Sonia with around 15 other women and children. All the interviewed women were invited. Since transportation in the village took place by foot, a location close to the women's home was chosen, this being a garden belonging to one of the families.

At the workshop, Branquimho displayed the different charcoal production methods, while an explanation of the stages was translated by Elton to the women. All participants helped preparing and monitoring the processes. Afterwards, the women were asked which of the methods they preferred and why. The workshop ended with a shared meal of traditional coconut buns made by Sonia in the local way.

3.7 Evaluation

First, the three methods were evaluated based on the three implementation parameters during both the field trials and the workshop.

Second, the methods were evaluated in terms of smoke exposure. Observations were conducted during the field trials to identify events involving prolonged smoke exposure time, which served as the basis for the smoke exposure evaluation.

The suitability of any of the techniques for the households were partly evaluated based on the implementation parameters and smoke exposure. It was further evaluated based on the interviews and observations in the village. The same approach was used to investigate the difference in smoke between burning coconut shells and coconut charcoal.

4 Case Study: Results

In this section, the results of the case study will be presented.

4.1 Material Availability and Setup Difficulty

Table 4: Availability of materials, setup time and decision to move forward with the methods.

	Earth Mound	Earth Pit	Brick Kiln	Metal Kiln
Material needed	Earth, Leaves and Water	Earth and Aluminium Plate	Bricks	Metal Can
Material available in the area	Yes	Yes	Yes	Yes
Setup time within a day	Yes	Yes	No	Yes
Method further tested	Yes	Yes	No	Yes

In table 4, four production methods are presented and evaluated based on material availability and setup time. The earth mound, earth pit and metal kiln methods were chosen for further investigation. The brick kiln was not selected due to its long setup time.

4.2 Implementation Parameters Selection

Most of the interviewees did not know how to make charcoal. Some of them had seen it, but did not know how to do it.

According to several women, the reason why they did not use charcoal for cooking was because of the price. One woman, who had a gas stove, did not use it much since it was too expensive. Most of the women had full days of work. They did the laundry, gathered or bought and prepared food, collected wood, cooked, took care of the house and children and worked making hats and baskets out of a material called pajla. Sonia was up by dawn and did her daily tasks. There was some time for leisure, but there were many task to complete every day. When she did her handcraft, she usually did it together with other women of the family, such as sisters-in-law or friends, and she said that in this way, the work was much more pleasant. Since there was little access to electricity in the village, many people, including Sonia, went to bed at dusk and therefore, needed to finish their daily tasks during the daylight hours.

All the women who were interviewed wanted to participate in the workshop and learn, but not all of them were able to attend. Some of the interviewees showed up, and because of a strong word-of-mouth, other women and their children came as well. In the end, there were more women present who were not interviewed than those who were.

During one interview, a women asked what was in it for her and how the coconut charcoal could benefit her. Another woman, who occasionally cooked with charcoal, stated that it was better than wood since it produced less smoke and did not darken her pots. Almost all of the interviewed women expressed a desire to sell the finished charcoal.

Many of the questions were not well understood, and the women asked several times for the translator to reframe the questions. At one point, one woman asked for a new phone. A couple of moments later she said that she could not afford some tomato for cooking. At the end of the workshop, when asked if there were any further questions, one women asked if she could be provided with a bed.

This recurring information was used to establish three implementation parameters:

1. Technical difficulty: Refers to the level of skill and expertise required to implement the method.
2. Cost and time consumption: Refers to the resources needed to implement the method, both in terms of time and money.
3. Understanding of value for user: Refers to the perceived benefits of the method by the end user.

4.3 Events of Smoke Exposure

The following three events were observed to affect the smoke exposure time while producing charcoal.

1. Time required for a self-sustaining fire.
2. Time needed to cover up the fire for pyrolysis to start.
3. Requirement of reignition for the pit/mound/kiln later in the process.

4.4 Earth Pit

The final version of the earth pit is shown in 10 and 11.

Figure 10: A fire burning above the pit with coconut shells.

Figure 11: The aluminium plate covering the hole, with an air ventilation hole on the front side. The back side had the opposite holes open to allow the air to flow.

When it came to technical difficulties, the pit was easy to make. No tools were needed, since the hole could be dug with a coconut shell. The fire on top of the hole was easy to follow, and could burn fiercely with excess of oxygen. After a few trials, it was pretty easy to understand when the aluminium plate should be put on the fire to pyrolyze the shells. However, since the fire burned heavily, much of the upper shells was converted to ashes and the yield of charcoal was affected. The inlet and outlet holes for air was also easy achieved with the uneven surface of the plate, allowing the air flow through. It could easily be observed if the pyrolysis was still ongoing by the smoke from the ventilation holes. When it was time to collect the charcoal, it was a little problematic when the charcoal pieces were small to gather them from the sand.

Regarding cost and time consumption, setting up the pit took approximately 20 minutes (not including collecting the shells) if the aluminium plate was available on site. The duration of the pyrolysis varied depending on the pit size, but for around 30 coconuts, the pit was ignited in the afternoon and had cooled off by next morning. The cost of the aluminum plate was 200 MZN, equivalent to the minimum daily wage in Mozambique.

During the workshop, one particularly enthusiastic woman expressed that the pit was the best option for making charcoal, citing its ease of setup and suitability for her. She appeared to have more material wealth than most of the other participants, suggesting that cost was less of a obstacle for her. She expressed a desire to work with the pit if given the opportunity. However, no other women at the workshop expressed a preference for the pit method.

In terms of smoke exposure, the pit burned with an excess of oxygen during the ignition period. Covering the pit using the plate was easily done, so the exposure to smoke during this stage was in the matter of minutes. The fire did not need to be reignited during any of the attempts with the method.

4.5 Earth Mound

Figure 12 to 15 depict the final setup for the earth mound.

Figure 12: A grid of sticks, enabling better airflow.

Figure 13: Coconut shells in a pile, staked above the grid.

Figure 14: The pile covered with branches for the mud to later be stabilized.

Figure 15: The pile covered in mud, set on fire from the end where the smoke emerges.

The mound method had some technical difficulties, requiring several steps and many alterations from the first try to the last. For example it was tried with the ignition-hole on top of the mound instead of the side. This alteration was discharged since it did not simplify the ignition of the mound. Another example was the use of clay in the initial attempts, which was replaced with mud since the clay dried and created a shell that allowed too much air into the process.

Furthermore, it was difficult to determine when the fire had generated sufficient heat for the pyrolysis to occur and the ignition hole could be enclosed. It was also challenging to determine the size of the ventilation holes, as there was no previous experience to guide this decision. However when successful, charcoal yield was very good, and it was easy to collect because the shape of the shells was well preserved.

The mound did not have any costs, all materials were collected in the village. The preparation time for the mound was around one hour (excluding the time of gathering coconut shells). The process was started in morning and finished the morning after.

At the workshop, about half of the women who answered which method they liked the most picked the mound. The majority of these women where over the age of 40 and were familiar with the process of making wood charcoal but had not been a part of making it themselves. Since they recognized the method, they thought it was the best and easiest one.

In terms of smoke exposure, the mound method was easily ignited, but it took some time to get the fire self-sustaining. This prolonged the smoke exposure time. Additionally, it was time-consuming to cover the ignition hole with both branches and mud, further prolonging the exposure time. For several of the trials, the mound needed to be reignited after some time since it was not warm enough to pyrolize the shells, which also extended the exposure time. In figure 16, the smoke from the ignition phase can be seen while making the mound in the workshop.

Figure 16: The mound being tested on the workshop, generating smoke while ignited.

4.6 Metal Kiln

In figure 17 the final metal kiln is demonstrated, one of the kilns is burning with fire on top, and the other one is covered with a lid and sand.

Figure 17: A metal kiln burning, and one covered with sand.

In the metal kiln, about five coconut shells could be fitted when cut in pieces. Since it contained little biomass, it was difficult to get the fire going on top of the can. Taking glowing char from a already burning fire and adding it to the top of the can, solved the problem. Collecting the finished charcoal was easy, as it was sealed inside the can. There were several trials with different types of cans, for example: cans stacked on top of each other with a smaller can as a cover. This setup did not fit five coconut shells and was neglected.

Since the batch was small, the process started in the morning and was finished by the afternoon. The cans were not found in an abundance in the village, the ones used in the field trials were given for free. The setup time for the kiln was around 30 minutes.

At the workshop, younger women expressed their preference for the kiln method, stating it looked easy to use and they appreciated the quick process. One woman even mentioned that she would try the method in her backyard. Branquimho also expressed his preference for the kiln method during the workshop.

Regarding smoke exposure, if the fire was started on the can, the exposure time was quite long. However, if the fire was started with glowing char, there was hardly any exposure at all at this stage. The covering of the can was also quick and easy: the lid was put on and sand was added on top to seal it. Out of all the trials, only one required reignition.

The metal kiln had a special smell during use, and it was impossible to remove all the oil or varnish from the can before use.

4.7 Finished Charcoal

The finished charcoal can be seen in figure 18 and 19. The size of the charcoal pieces varied depending on the method and circumstances, as described previously.

Figure 18: Collected charcoal from all different method, and different trials.

Figure 19: Some charcoal taken out from a mound.

4.8 Cooking and Charcoal

The coconut consists of an outer shell, in Portuguese known as *casca de coco*, and an inner shell, in Portuguese *caforo*. Inside there is water or milk, depending on the maturity of the coconut. The casca de coco was easy to ignite, while the caforo was harder to set on fire. Branquimho stated that charcoal made from caforo was a better material for making charcoal as it burnt more slowly, whereas charcoal made from casca de coco was consumed very quickly.

Many households used a combination of wood, branches and coconut shells and husk to make fire for cooking. Wood was preferred by many because it could be placed between the three stones, and when part of the log burned out, it could be further pushed into the fire. This required little work, and no need to stand directly in the smoke while pushing the logs. This setup can be seen in figure 20 and 21. The three-stone-method, in Portuguese known as *chaleira*, was used in all the interviewed households. The setup was slightly different in every home and in figure 20 to 23 some examples are shown. Some were outside, some were inside and some were in between.

Figure 20: The chaleira, made with three stones inside at Sonia's place.

Figure 21: A chaleira located under a shelter, but with one open side.

Figure 22: A chaleira made outside, starting the fire with casca de coco.

Figure 23: A different setup, at Branquimho's home. Placed under a roof but with open walls for ventilation, but covered from rain. He used both wood and charcoal in this setup.

The women who sometimes used charcoal used a so-called *fungão*, a type of grill. According to some women, a fungão was necessary to cook with charcoal, while one woman expressed that charcoal could also be used in the chaleira. The fungão was expensive, according to all women, and the three women who had one shared it with their extended family. One woman stated that she liked to use the fungão for some purposes, such as cooking meat or fish, but preferred the chaleira when cooking for example rice. Four women who did not own a fungão, but had all used it on several occasions liked it because it did not produce as much smoke as the chaleira. One woman put it, "When using the fungão, I do not have to suffer". When asked if she experienced any health issues when cooking using the chaleira, she said that after a long day in the sun, cooking over the hot fire is hard. Another woman mentioned that her pots did not darken when using the fungão. Branquimho preferred using charcoal over wood but declared it was too expensive to use charcoal all the time. In figure 24 and 25, a fungão is depicted. The first with pots on top and the other in the middle of grilling a chicken.

Figure 24: A fungão with to pots on top, ready to be started.

Figure 25: Branquimho making chicken on a fungão fuel by coconut charcoal. The fire is burning without much visible smoke.

During the interviews, one woman reported that smoke from cooking caused health problems for her, including coughing and eye pain. However, the other women reported no health problem due to the smoke exposure. Several women commented that charcoal was preferred when the wood was wet. When talking to a man named Antonio in the village, he expressed his love for the natural way of cooking with the chaleira. He cooked at a small bar called Calito's, where he had access to a fungão, but he preferred using the chaleira. Another man in the village, also named Antonio, also preferred the chaleira. He had access to both a gas stove and a fungão at his work. According to him, the gas stove did not get hot enough to cook the way he wanted, whereas the chaleira provided a better taste. One woman mentioned that during a period heavy rainfall, her family used an old varnish can and put caforo in it for cooking. When asked why they stopped using it, she answered "the rain stopped".

When asked "what is important to you when you cook?" the women responded with a variety of answers, mostly centered around the taste of the food, whether it be a special ingredients or simply that it tasted good. When asked if they face any practical problems when cooking, most women responded with a no, while some did not understand the question and replied with ”I don’t know”. One woman answered with ”Matapa”, which is Mozambique’s national dish. In response to ”have you always cooked and prepared food in the same way?” most women answered yes, although some clarified that they do not cook the same dish every day.

4.9 Trade and Charcoal

The most common way for the interviewed women to provide for their families was to engaged in handcrafts, traded in Morrumbene or in Maxixe, a larger city around one hour away. Many explained that their products were collected by someone who sold them in Morrumbene, Maxixe, and even as far as the capital Maputo. In all three places, the handcraft could be found and at one market in Maputo, the saleswoman declared that the hats were from Linga Linga.

When asked about challenges of obtaining charcoal in Morrumbene, the women of Linga Linga expressed that it was expensive and that purchasing it from the local bar Carlito’ in the village would be even more costly. They mentioned that wood was available for free. The village had a main road where various sales stands and bars, including as Carlito’s, were located. The road served as a central gathering place for villagers to socialize and exchange information.

Charcoal sales were more prevalent along the roads closer to the cities, as seen in figure 26, a road close to Maputo and figure 27 near the main road in Linga Linga. Brick kilns for producing brick were also present along the roads to Maputo.

Figure 26: Charcoal sales outsides of Carlito’s.

Figure 27: Charcoal sales along the road close to Maputo.

5 Discussion

When deciding upon the direction to move forward from previous work done in Linga Linga, many factors were taken into consideration. One of the pillars became health and emission, another the production of charcoal for later use rather than as a combined cooking technique as in the case of Ebrahim and Lilja. The reason for this shift, was due to an intention to be more considerate to the users wants and needs. The study by Ebrahim and Lilja implied that the combined technique could be of value for the households but could be hard to implement due to the difference compared to the current practice. It was concluded that the households need to understand the advantages and benefits of the new technique. This study thus became more focused on how a user group, in this case women, could benefit form a different technique and if it could be easier implemented if it did not differ from their current practice but stood alone as something new. The focus on emission and health came naturally since Eriksson and Gunnarsson had defined smoke from cooking a major problem for the people of Linga Linga. This discussion aims to connect technical aspects of coconut charcoal production methods, workable in the context of Linga Linga, and the human experience of implementation.

5.1 Viability of Coconut as a Material for Charcoal Production

The coconut plant is non-herbaceous and can provide woodfuel year around. The husk, casca de coco, is not suitable for charcoal production due to its high content of volatile matter according to Branquimho. The coconut shell, caforo, on the other hand, are more suitable for conversion as it has a higher fixed carbon content, which leads to a better charcoal yield. An approximate analysis done by Kabir Ahmad et al. showed that the coconut shells consist of 71% volatile matter which seems like a high number. However, when compared to hardwood, which had a volatile matter content of 72% in the reference study, coconut shells are just as good for charcoal production based on this factor. Palm kernel shell, which have an fixed carbon content of 43%, would be a better option based on this parameter. However, all palm trees observed in the village were coconut palm trees and not palm kernel tree, ruling out the possibility of making charcoal out of palm kernel shells.

Additionally, coconut shells have a low ash content (1.8%) which is good for the charcoal yield, and a low moisture content (5.6%) compared to for example hardwood with 7.8%. The other study by Promdee et al. showed slightly different numbers, but coconut shells are still within a good range compared to other biomass. It should be mentioned that the composition of the biomass depends on the geographic location. The coconut also has a good heating value in comparison to other biomasses, such as Eucalyptus bark. Therefore, it can be concluded that coconut shells are a good material for charcoal production based on their physical and chemical properties.

Coconut shells have a low content of both nitrogen and sulfur according to both Kabir Ahmad et al. and Promdee et al., which results in low formation of the pollutants NO_x and SO_x when combusted, making them a favorable fuel option from an emission stand point. However, it cannot be conclusively stated that producing charcoal from the shells is more beneficial than burning them directly based solely on this factor.

During the field trials, it was demonstrated that coconut shells could be converted into charcoal, with the yield depending on various factors such as the circumstances and production method. One significant advantage of using coconut for charcoal production is the surplus of the material and the limited use of it at present. This was revealed in the study conducted by Ebrahim and Lilja and confirmed by this study.

5.2 Production Pathways and General Limitations

There are several ways to produce charcoal, both industrial and non-industrial, and the basic process is similar: heating, drying, and an exothermic reaction with limited oxygen followed by a cooling stage. The most common traditional methods use earth to shield the fuel from oxygen, bricks or metal can also be used. In this study it was concluded that an earth mound, earth pit and a metal kiln should be further investigated for producing coconut charcoal in Linga Linga. While the FAO recommends the use of brick kilns due to their cost and yield efficiency, there was not enough time to make bricks and test this method. When traveling around the county, it was observed that large brick kilns were used to make bricks in certain places along the roads. Therefore, the brick method could be a good option and it may be worth investigating how bricks are made to see if a similar method could be used for producing charcoal.

The intention was to observe a large-scale charcoal production with wood. The women selling charcoal along the roads said that the charcoal was made far into the woods and after several attempts to find a charcoal production site, it had to be deprioritized due to the challenges of getting there. It would have been of great value to observe a large-scale charcoal production.

Biomass pyrolysis can produce charcoal in different ways, each yielding different results based on factors such as temperature, heating rate, reaction time and pressure. Fast pyrolysis was not considered for on-site experimentation due to its need for industrial regulation, and its tendency to produce more bio-oil than charcoal. Torrefaction, on the other hand, has a high yield of charcoal, around 80%, but is also an industrial process. Slow pyrolysis was used for all three different methods in the field trials.

Carbonization or slow pyrolysis have a charcoal yield of around 35%. The result of this study is believed to be less, since the methods were only tested a couple of times and with limited knowledge about the biomass being converted. Regulating oxygen during the process was challenging and require considerable experience to obtain satisfactory results. Similarly, controlling the temperature and ignition temperature of the coforo was difficult, and other materials had to be used to make the fire self-sustaining.

5.3 Evaluation of Emissions

It is inevitable that more compounds than CO_2 and H_2O are formed during combustion and pyrolysis. However, the amount of emission can greatly vary in both thermochemical processes.

All three carbonization processes that were tested created visible smoke, both dark and white. The smoke probably contained soot when it was dark and mostly water vapor when it was white. With this assumption, knowing the soot contains PM, it could be concluded that PM in various sizes was present during the production of charcoal.

After several days of trying different production methods, both dizziness and headaches were experienced. This could be caused by high levels of CO, which can lead to dizziness when exposed to it. Since it was hard to control the oxygen flow, there may have been incomplete combustion in the pyrolysis process, resulting in the formation of CO. This would not be the case when using the coconut shells directly for cooking. As mentioned by Sparrevik et al. 2015, traditional charcoal production is very inefficient and polluting, and modern industrial investigations of CO and PM are not available in rural Africa. This thesis does not argue that charcoal production cannot be done without industrial control, but it argues that during uncontrolled small-scale production exposure to soot can be as severe as cooking with woodfuel and the expose to CO can be higher.

Since the coconut shells do not contain much sulfur nor nitrogen, it can be assumed that NO_x and SO_x were not highly present during the combustion or production of charcoal.

According to Sparrevik et al. 2015, few studies have been conducted on emission measurements due to difficulties of conducting such measurement in rural areas. This study had the opportunity to conduct on-site measurement comparing soot from coconuts shells with coconut charcoal. The measurement could have been done with some kind of fabric put above the burning shells and burning charcoal for the particles to stick and color the fabric. It was yet decided to not preform measurement on-site, since staying close to the fire to control the fabric not catching on fire increased time spent in the smoke. Instead the smoke was observed from a distance to minimize the exposure. When cooking with coconut charcoal, there was very little smoke, whereas more smoke was observed when cooking with the shells directly, which was mostly white smoke indicating the presence of water vapor. These results were supported by the responses from the interviews conducted, where several women reported that charcoal emitted less smoke than firewood. Similar results were reported by Ebrahim and Lilja, where households who had used charcoal, preferred it over firewood due to its energy efficiency and reduced smoke. One woman mentioned that her pots were less dark when using charcoal, which could be an indicator of lower smoke production. Thus, observing the pots after use could be a potential method for measuring the amount of smoke and hence the amount of soot.

In order to draw conclusions about the different levels of smoke for the conversion methods, the exposure time was determined for the three methods. Since the pit did not needed to be reignited and was easy to ignite, it had the least exposure time. The mound had the longest exposure time, both while covering up and starting. However, this could change with experience and practice. The metal kiln gave off a smell in some of the trials, possibly due to chemical reactions from residues of oil or varnish in the can. This could potentially be a sources of PM, worth taking into consideration. When the kiln was ignited with glowing char, it had no exposure time, but if there was not already a fire burning, the exposure time was high.

5.4 Evaluation of Implementation Rate of the Methods

To be able to evaluate the chosen methods with regards to a successful implementation, parameters were established to find the most important factors in this context. These parameters were based on recurring answers from the interviews and observations during the field period. Frequency of events was used as the foundation for these parameters, although they could have been chosen differently based on other factors. It should be stressed that the interviews were challenging due to the language barrier and poorly formulated questions, which may have influenced some of the frequent answers.

For the first parameter: technical difficulties, the mound was the most difficult to make for someone who had never done it before. However, since some of the women knew this method existed, they did not find it as difficult to perform as the other methods. About half of the women in the workshop liked this method the most. However, it was tried the most times since it was difficult to get it going. The pit was easy to make and understand when it was warm enough to cover up, which was not the case with the mound, but only one woman preferred this method. In the case of both the mound and pit, it was hard to collect the charcoal in the sand. The kiln was easy to make and understand when it was hot enough and the younger women liked this method the most.

The mound was the cheapest method, with no cost but it was the most time-consuming. The metal kiln was less time-consuming, but it was done on a smaller scale. To be able to make a bigger batch, an oil drum would be needed, which was not readily available in the village. The metal kiln was suitable for small batches, but more for the use of biochar than cooking, as the pieces were quite small. The pit was not too time-consuming, but it was expensive if the plate was used, which was confirmed when no one liked the method at the workshop.

According to the FAO in *Simple Technique of Producing Charcoal* a disadvantage of using oil drums is that they can be difficult and expensive to obtain. This also applies to the small cans used in this study. Additionally, drums tend to need frequent replacement, and the same is likely true for the cans, as it was observed that they became deformed after only a few uses.

For the parameter of understanding the value for the user, all three methods performed similarly. It was evident from both the interviews and the workshop that the benefits and value of the charcoal production were not well communicated. An example of this was a woman who asked for a new bed when asked if she had any questions about charcoal. However, since the attendance was high, there was some interest among the women, and hopefully, they gained some understanding of the value. One such example was with the kiln when a woman expressed interest in having it in her backyard.

In summary, none of the methods were superior to the other in regard to the implementation parameters; all could be performed by different women depending on their preference and what parameter was of most importance to them.

Other factors to take into consideration when evaluating the different methods are yield, soil type, and efficiency. According to the FAO, the pit method is wasteful in resources because of the difficulty to control the gases in the pit. This was also demonstrated in the field trials, with high variation in the quality of charcoal. Many of the shells were burned to ashes, while some shells were barely carbonized.

According to FAO, the earth mound is preferred over the pit where the soil is rocky, hard or shallow, or the water table is close to the surface. The pit is better where the soil is well drained, deep and loamy. For this purpose the pit would be better since the soil was sandy in Linga Linga.

The mound method, however, is considered more practical in agricultural areas where fuelwood

may be scattered. This is also true for Linga Linga since heavy rainfall sometimes makes it difficult to gather the shells in a pit, which would not allow them to dry properly. However, it is still possible to save the shells in a pile and then transfer them to a pit on a sunny day. Regardless of the method used, the shells must be arranged properly, so one would probably need to redo the pile.
The main factors limiting the mound is according to FAO, the problem of sealing against air during the entire burn period and keeping good circulation, which the field trials also showed being a problem, making it less efficient.

Taking these factors into consideration, it appears that the pit is less effective and provides the least yield compared to the kiln and mound, which makes the latter two preferred options. However, it is important to note that neither yield nor efficiency were mentioned as important factors by the women, and were not considered as critical for implementation in this case. This does not rule out the possibility that they could of importance at another stage, for example if the coconut charcoal is made and trade by the women.

5.5 Suitability of Small-Scale Charcoal Production for Household Use

The milk and fat from the coconut is part of the human food chain in Linga Linga. The shells and husk are made of mostly lignocellulose, which makes it a suitable for bio-energy since it does not threaten the food supply.

With an increased energy demand and a population growth in sub-Saharan Africa, both Energy for Development and SWEDEV expect the usage of fuelwood and charcoal to increase in the nearest future and both argue for a sustainable value chain as the best way forward. According to SWEDEV charcoal is expected to increase more than fuelwood and a charcoal made of a biomass not leading to deforestation would be of great value, such as coconut shells. Nevertheless, the value chain of the charcoal would preferably be sustainable in all dimensions, economically, environmentally and socially. As of today the informal economy is not enhancing a sustainable market. In this aspect, it is not as easy as to say that a small-scale production of coconut charcoal could economically empower women.

However, all the women interviewed were involved in handcrafts such as making bags and hats, and were familiar with the production, collection, and selling process in a different locations. It was demonstrated that this route was well-established and that handcrafts were reaching Maputo. It is possible for small-scale sales of coconut charcoal to follow a similar route and be a suitable source of income for women. The sales of wood charcoal were also observed to be well-established outside of Linga Linga, and it is conceivable that coconut charcoal could enter the same market.

The workshop, which had around 15 participants, indicated a interest in the topic. All women who were asked expressed a desire to participate, with many expressing interest in selling coconut charcoal. Based on this response, it can be assumed that producing coconut charcoal in Linga Linga could be suitable.

All households in Linga Linga predominantly use the chaleira for cooking, as observed in this study and confirmed by Ebrahim and Lilja. Although Ebrahim and Lilja suggested that charcoal produced in a gasifier could be directly used in the chaleira, several women in this study expressed that charcoal was not suitable for the chaleira and should instead be used in a fungão. This presents an implementation gap for the techniques tested in this study. Even if small-scale charcoal production is a viable option, there is currently no suitable way to use the charcoal for cooking, rendering the technique unsuitable.

Observations of different versions of the chaleira revealed that Branquimho's setup, which had walls to keep the charcoal contained, was more suitable for charcoal than other chaleiras where logs were pushed into the fire. Using logs proved to be a more effective way to sustain the fire and expose less smoke to the household. Although several women witnessed that the fungão produced less smoke than the chaleira, it was noted that the fungão was expensive to buy. Further research could be conducted to develop a cheap and practical fungão. With charcoal made of coconut shells and a cheap fungão the smoke exposure during cooking could be lessened to a low cost.

The chaleira was very popular in the village, and there were no practical problems experienced with it. Some thought it was much better than to use both gas and charcoal, and several preferred the taste when using the chaleira. Furthermore, the variations of chaleira setups suggest the possibility of adapting the technique for different fuels, such as using charcoal as a complement to wood. Several women mentioned that charcoal was preferred during rainy periods, and that a can was used to cook in during one of these periods. However, when the rain stopped, wood was preferred in the chaleira. Hence, in this context, the thesis advocates the use of charcoal as a supplementary fuel to wood rather than a replacement.

5.6 Navigating Differences in Lifeworlds and Colonial Structures for a Successful Implementation

In *Medicine as Culture: Illness, Disease and the Body*, Lupton argues that the experience of health, illness, and death is intertwined with social and cultural processes. Merely considering the biological dimensions is not enough to understand these phenomenons. This argument can be extended to other aspects of life, such as energy use and pollution.

In the EU, renewables accounted for about 17% of the energy use, while petroleum and natural gas accounted for 59% in 2019. In contrast, in Mozambique, 80% of the energy use came from biomass, a renewable energy source. In terms of numbers, Mozambique is further along in the process of achieving a carbon-neutral energy sector. However, the use of wood fuel causes deforestation and indoor pollution.

When Lupton speaks of lifeworlds in the context of the doctor-patient relationship, she refers to the understanding of each other's lifeworlds in the encounter to find a common solution to a problem. This concept is also relevant in the relationship between an engineer and a user of a technique. For instance, a European engineer operating in EU with 100% electricity availability does not share the same lifeworld as a user of a chaleira in rural Mozambique, who uses fuelwood and has no access to electricity, and their definition of renewable energy will differ.

In biological terms, both short- and long-term exposure to smoke, particularly black carbon, have been associated with health problems and premature mortality. Smoke from cooking was identified as a major problem in the study by Eriksson and Gunnarsson, and it was assumed that people in Linga Linga would prefer a different cooking method. However, when asked in this study, only one out of fifteen women reported experiencing health problems due to smoke, and all of them liked using the chaleira. For instance, one woman stated, "I do not need to suffer when using the fungão", and the health problem she experienced was merely dizziness from the heat while cooking on a hot day. The connection between a problem and its impact on one's health is also defined within our lifeworld. In this case, the woman interviewed did not make a direct connection between a problem and a health problem. This does not imply that her health was not affected according to the definition of health in this thesis, nor does it imply that her health was affected according to her own definition of health. As argued by Lupton, Western scientific medicine is a product of social and cultural processes, just as much as medical knowledge and practices in non-western societies are, affecting our definition of health.

One further example of an difference in lifeworlds in this study was when the question "do you experience any heath problem while cooking?" was asked and the answer was no. The question implied that there should be a health problem when cooking. If one has no idea of the effects of smoke, how could one consider it a problem? If one is standing in the smoke, and a person across the street knows it is cancerous, he/she would be confused by why the person is standing in the smoke, and the other person would be equally confused by the question "why are you standing there?".

Another example from this study, when the question "do you face any practical problems when you cook?" was answered with "matapa", it can be assumed that either the original meaning of got lost in translation, or that question is apprehended differently depending of our lifeworlds. By acknowledge and respecting the difference in lifeworld the parties in a project like this can better understand each other and create techniques that can be implemented and benefiting for the user group.

Lupton argues, if the problem is to be understood in the same way, and a common solution is wanted, the lifeworld of the two involved need to make sense to each other. One can contribute to the others lifeworld with their knowledge and vice versa. She explains; by incorporating elements of both meaning systems, doctor and patient negotiate authority over meaning. This would also be true for a engineer and a user.

During the field trials, it was fascinating to witness the contrast between the complex physics of combustion and pyrolysis on one end, and the local knowledge of how to make a fire on the other end. Despite the language barrier, the two worlds were communicated through gestures and basic Portuguese. While some knowledge was exchanged, other aspects remained elusive.

In her work, Lupton argues that health and illness states are not necessarily objective truths, using the example of menopausal women to advocate for a liberating dimension of womanhood instead of seeing it as the death of femininity. Similarly, the exposure to cooking smoke be as a source of anthropogenic pollution according to some, while others view it as a natural way of preparing food.

Another example: when Ebrahim and Lilja described the houses in Linga Linga as being of "simple construction", it reflects an outsider's perspective. To someone familiar with machines, industrials and trucks, a house made of straw might seem uncomplicated. However, for whom who build the house by hand, it might not be so simple. This leads to the next important factor for a successful implementation, our knowledge and understanding of colonialism and its effects today.

Mozambique have a long history of colonization, by different powers, most recently by Portugal from the beginning of 1500 to 1975. The Portuguese changed the political, economical and cultural landscape of the country, which is still visible today. While settling in a country physically is different from traveling to a distant country to establish knowledge, this thesis argues that a cautious approach is necessary when trying to implement any sort of technique. As Pimenta argues, underdevelopment is not a natural phenomenon, but imposed by colonialism, and spreading this view is a way to strengthen neocolonialism. Looma also refers to the global division of "first" and "third" world as part of postcolonialism.

A part of modern European colonialism have been to undermine groups of people, and as Lupton argues, some medical anthropologists still promote the adoption of Western practices over cultural beliefs perceived as "superstitions". In the case of this study, it is strongly demonstrated that the definition of health varies depending on lifeworlds. Therefore, this thesis emphasizes the importance of avoiding any imposition of a developed-versus-underdeveloped status or similar division onto any aspects of the project. Instead, the exchange of knowledge and lifeworlds should be viewed as means to improve the lives of all parties involved. This mindset would improve the chances of an successful implementation.

The methodology for the case study was somewhat irregular, as it was based on the common knowledge of the participants and could only be conducted in collaboration. While the methodology could have been different, leading to different conclusions, it was important to avoid setting specific parameters or making hypotheses beforehand.

Pimenta advocates for interdisciplinary research as a necessary means of achieving a comprehensive understanding of complex issues, and this study has sought to work in this way by connecting different fields of knowledge to better understand and improve a situation. Given the differences in lexicon between fields such as technology and anthropology, it has been challenging to explain concepts in a shared context.

Defining a problem in one part of the world to be solved in another is a complex undertaking, and success in both arenas requires a careful approach. As pointed out by Lupton, adopting a social criticism perspective to a subject without losing access to the research arena, such as technology, can be challenging. Nonetheless, this thesis argues that interdisciplinary approaches are necessary for an implementation that would improve the lives of people in any contexts.

5.7 Future Work

A suggestion for future work within Linga Linga would be to investigate the possibility to produce coconut charcoal from already existing charcoal production sites, currently producing wood charcoal. An overall suggestion, in line with the conclusion of this study, would be to work interdisciplinary, combining technical and anthropological aspects and positivist and hermeneutics approaches.

6 Conclusions

In conclusion, coconut shells, rather than the husk, are a suitable material for charcoal production due to their chemical and physical properties, as well as their abundance in the village of Linga Linga. Additionally, there are various methods of producing charcoal. In the case of Linga Linga, three methods were found to be workable within the time frame: an earth pit, an earth mound and a metal kiln, all using slow pyrolysis. These methods were evaluated based on three implementation parameters: *Technical difficulties* and refers to the level of skill and expertise required to implement the method. *Cost and time consumption*, which refers to the resources needed to implement the method, both in terms of time and money and *Understanding of value for the user*, which refers to the perceived benefits of the method by the end user. Each method had their pros and cons, and none was significantly better than the others in terms of these three parameters.

In terms of smoke production, the earth pit method is preferred over the earth mound method, which had a longer exposure time, and the metal kiln, which emitted fumes from the can used. However, even if charcoal produced less smoke than firewood when used for cooking, the smoke generated during charcoal production could add up over time. Therefore, it is not possible to conclude whether exposure to total smoke is reduced by using charcoal instead of woodfuel.

If charcoal is to be used, a fungão (type of grill) was deemed necessary. Since the fungão was found to be expensive, it is concluded that there is an implementation gap if charcoal is produced but cannot be used with the current cooking method (the three-stone-method or chaleira). The chaleira setup varied in design within the village, potentially it could be modified to accommodate the use of charcoal. The coconut charcoal is in this context of cooking considered more of a complement to woodfuel rather than a complete alternative. The topic of charcoal production sparked interest among most women interviewed, many of whom already engage in small-scale sales of handcrafts. The production and sale of coconut charcoal on a small-scale level could economically empower women in the village.

In order to achieve a successful implementation of a new technique that is beneficial for the user and sustainable in the long run, it is suggested to use two approaches. First, it is essential to acknowledge that the engineer and the user of the technique may have different lifeworlds, and efforts should be made to understand these differences through interactions. Secondly, it is important not to impose any labels on the participants of the study in terms of developed or underdeveloped, or any other similar labels that could contribute to a division between the parties. Such labels could inhibit the success of the project and contribute to a postcolonial structure.

Lastly, it is important to acknowledge that working in an interdisciplinary manner is not always easy, and it can impact the validity of the results. However, this study concludes that if the aim is to improve the quality of life for people, interdisciplinarity is necessary.

7 Appendix

7.1 Appendix 1

This section of the appendix is presenting the interview questions divided up in sections.

Cooking

- Have you in your household always cooked and prepared food in the same way?
- What factors are important to you when you cook?
- Do you think there is any practical problems when you cook?
- Do you think there is any health problems when you cook?

Charcoal

- Have you used charcoal when you cook? If yes, what was your experience?
- Do you know how to make charcoal?
- Do you want to learn how to do it?
- Do you know were to buy charcoal?

Breadwinning

- How is your family supported today?

If there is any type of sale/trade:

- Who is buying your goods?
- Would you be interested in selling charcoal?
- Have your family always been supported in the same way?

Implementation

- If there is charcoal available to buy in Morrumbene, what do you see as a problem with using the charcoal then?
- If there is charcoal available to buy at Carlito's, what to you see as a problem them with using charcoal?

References

Basu, Prabir (2013). "Chapter 3 - Biomass Characteristics". In: *Biomass Gasification, Pyrolysis and Torrefaction (Second Edition)*. Ed. by Prabir Basu. Second Edition. Boston: Academic Press, pp. 47–86. ISBN: 978-0-12-396488-5. DOI: https://doi.org/10.1016/B978-0-12-396488-5.00003-4. URL: https://www.sciencedirect.com/science/article/pii/B9780123964885000034.

Biggar, Hugh (2022). "Informal trade in charcoal and firewood in Africa creates need for sustainable approach". In: *Forest News*. [Accessed 23 Mars 2023]. URL: https://forestsnews.cifor.org/78304/informal-trade-in-charcoal-and-firewood-in-africa-creates-need-for-sustainable-approach?fnl=en.

Dibben, Pauline (2007). "Transport, Trade and Economic Development in Mozambique: An Agenda for Change". In: *Reflecting on Economic Question: Papers presented at the Inaugural Conference if The Institute for Social and Economic Studies*. Maputo: IESE, pp. 196–214. ISBN: 978-989-96147-1-0.

Ebrahim, Mila and Fanny Lilja (2019). "The feasibility of producing and utilizing bioenergy in Linga Linga, Mozambique". MA thesis. Royal Institute of Technology, Stockholm, pp. 1–33.

Emmons, Howard and Arvind Atreya (Dec. 1982). "The science of wood combustion". In: *Proceedings of the Indian Academy of Sciences Section C: Engineering Sciences* 5, pp. 259–268. DOI: 10.1007/BF02904581.

Energy for Development (2013). *Biomass Energy Strategy (BEST) Mozambique*. [Accessed 2 February 2023]. URL: https://www.aler-renovaveis.org/contents/lerpublication/EUEI_2013_FEB_Biomass_Energy_Strategy_Mozambique_FactSheet.pdf.

Eriksson, Erica and Sofia Johansson Gunnarsson (2018). "En sammanställning av problem i hushåll i Linga Linga, Moçambique". MA thesis. Royal Institute of Technology, Stockholm, pp. 1–31.

European Union (2018). *2.1 Where does our energy come from?* [Accessed 2 February 2023]. URL: https://ec.europa.eu/eurostat/cache/infographs/energy_2020/bloc-2a.html.

— (2019). *Biomass*. [Accessed 2 February 2023]. URL: https://energy.ec.europa.eu/topics/renewable-energy/bioenergy/biomass_en.

FAO (1983a). "Chapter 4 - Carbonisation processes". In: *Simple Technologies for Charcoal Making*. [Accessed 1 May 2023]. Food and Agriculture Organization of the United Nations. URL:

https://www.fao.org/3/X5328e/x5328e05.htm#chapter%204%20%20%20carbonisation%20processes.

FAO (1983b). "Chapter 5 - Earth pits for charcoal making". In: *Simple Technologies for Charcoal Making*. [Accessed 1 May 2023]. Food and Agriculture Organization of the United Nations. URL: https://www.fao.org/3/X5328e/x5328e06.htm#chapter%205%20%20%20earth%20pits%20for%20charcoal%20making.

— (1983c). "Chapter 6 - Making charcoal in earth mounds". In: *Simple Technologies for Charcoal Making*. [Accessed 1 May 2023]. Food and Agriculture Organization of the United Nations. URL: https://www.fao.org/3/X5328e/x5328e07.htm#chapter%206%20%20%20making%20charcoal%20in%20earth%20mounds.

— (1983d). "Chapter 7 - Brick kilns". In: *Simple Technologies for Charcoal Making*. [Accessed 1 May 2023]. Food and Agriculture Organization of the United Nations. URL: https://www.fao.org/3/X5328e/x5328e08.htm#chapter%207%20%20%20brick%20kilns.

— (1983e). "Chapter 8 - Metal kilns". In: *Simple Technologies for Charcoal Making*. [Accessed 1 May 2023]. Food and Agriculture Organization of the United Nations. URL: https://www.fao.org/3/X5328e/x5328e09.htm#chapter%208%20%20%20metal%20kilns.

Kabir Ahmad, Rabi et al. (2022). "Exploring the potential of coconut shell biomass for charcoal production". In: *Ain Shams Engineering Journal* 13.1, p. 101499. ISSN: 2090-4479. DOI: https://doi.org/10.1016/j.asej.2021.05.013. URL: https://www.sciencedirect.com/science/article/pii/S2090447921002355.

Loomba, A. (2005). *Kolonialism/postkolonialism*. The new critical idiom. TankeKraft Förlag, pp. 1–303. URL: https://books.google.se/books?id=odj07EwUA-0C.

Lupton, Deborah (2012a). "Conclusions". In: *Medicine as Culture: Illness, Disease and the Body*. Third Edition. [Accessed 27 April 2023]. London: SAGE, pp. 1–3. ISBN: 9781446254530. DOI: :https://doi.org/10.4135/9781446254530. URL: https://sk.sagepub.com/books/medicine-as-culture-3e.

— (2012b). "Introduction". In: *Medicine as Culture: Illness, Disease and the Body*. Third Edition. [Accessed 27 April 2023]. London: SAGE, pp. 1–7. ISBN: 9781446254530. DOI: https://doi.org/10.4135/9781446254530. URL: https://sk.sagepub.com/books/medicine-as-culture-3e.

— (2012c). "Theoretical Perspectives on Medicine and Society". In: *Medicine as Culture: Illness, Disease and the Body*. Third Edition. [Accessed 28 April 2023]. London: SAGE, pp. 1–23. ISBN:

9781446254530. DOI: : https://doi.org/10.4135/9781446254530. URL: https://sk.sagepub.com/books/medicine-as-culture-3e.

Mandø, M. (2013). "4 - Direct combustion of biomass". In: *Biomass Combustion Science, Technology and Engineering*. Ed. by Lasse Rosendahl. Woodhead Publishing Series in Energy. Woodhead Publishing, pp. 61–83. ISBN: 978-0-85709-131-4. DOI: https://doi.org/10.1533/9780857097439.2.61. URL: https://www.sciencedirect.com/science/article/pii/B9780857091314500042.

National Geographic (2023). *Deforestation*. [Accessed 2 February 2023]. URL: https://education.nationalgeographic.org/resource/deforestation/.

Nunes, Leonel Jorge Ribeiro et al. (2018). "Chapter 1 - Introduction". In: *Torrefaction of Biomass for Energy Applications*. Ed. by Leonel Jorge Ribeiro Nunes et al. Academic Press, pp. 1–43. ISBN: 978-0-12-809462-4. DOI: https://doi.org/10.1016/B978-0-12-809462-4.00001-8. URL: https://www.sciencedirect.com/science/article/pii/B9780128094624000018.

Olofsson, Michel (Apr. 2022). *Meeting about MFS*. Interview. Interviewed by Ina Johnsson. Skype.

Our World in Data (2019). *Indoor Air Pollution*. [Accessed 4 April 2023]. URL: https://ourworldindata.org/indoor-air-pollution.

Pimenta, Carlos (2007). "Heterodox Reflections About Development and Globalization in Africa". In: *Reflecting on Economic Question: Papers presented at the Inaugural Conference if The Institute for Social and Economic Studies*. Maputo: IESE, pp. 1–23. ISBN: 978-989-96147-1-0.

Promdee, Kittiphop et al. (2017). "Characterization of carbon materials and differences from activated carbon particle (ACP) and coal briquettes product (CBP) derived from coconut shell via rotary kiln". In: *Renewable and Sustainable Energy Reviews* 75, pp. 1175–1186. ISSN: 1364-0321. DOI: https://doi.org/10.1016/j.rser.2016.11.099. URL: https://www.sciencedirect.com/science/article/pii/S1364032116308632.

Ram, Mahendra and Monoj Kumar Mondal (2022). "Chapter 13 - Biomass gasification: a step toward cleaner fuel and chemicals". In: *Biofuels and Bioenergy*. Ed. by Baskar Gurunathan et al. Elsevier, pp. 253–276. ISBN: 978-0-323-85269-2. DOI: https://doi.org/10.1016/B978-0-323-85269-2.00008-3. URL: https://www.sciencedirect.com/science/article/pii/B9780323852692000083.

Ronsse, Frederik et al. (2015). "Chapter 11 - Carbonization of Biomass". In: *Recent Advances in Thermo-Chemical Conversion of Biomass*. Ed. by Ashok Pandey et al. Boston: Elsevier, pp. 293–

324. ISBN: 978-0-444-63289-0. DOI: https://doi.org/10.1016/B978-0-444-63289-0.00011-9. URL: https://www.sciencedirect.com/science/article/pii/B9780444632890000119.

Roth, Christa (2014). "Cooking on wood-gas from dry biomass – how it works". In: *Micro-gasification:cooking with gas from dry biomass*. Ed. by Heike Volkmer. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, pp. 1–156. ISBN: 978-0-12-809462-4.

Sparrevik, Magnus et al. (2015). "Emissions of gases and particles from charcoal/biochar production in rural areas using medium-sized traditional and improved "retort" kilns". In: *Biomass and Bioenergy* 72, pp. 65–73. ISSN: 0961-9534. DOI: https://doi.org/10.1016/j.biombioe.2014.11.016. URL: https://www.sciencedirect.com/science/article/pii/S0961953414005170.

SWEDEV (2021). *Charcoal value chains in Africa and their role for sustainable development.* [Accessed 23 April 2023]. URL: https://www.swedev.dev/charcoal-value-chains-in-africa-and-their-role-for-sustainable-development/.

The Guardian (2014). *WHO: air pollution is single biggest environmental health risk.* [Accessed 4 April 2023]. URL: https://www.theguardian.com/environment/2014/mar/25/air-pollution-single-biggest-environmental-health-risk-who.

University of Waikato (2019). "What is smoke?" In: *Science Learning Hub*. [Accessed 24 April 2023]. URL: https://www.sciencelearn.org.nz/resources/748-what-is-smoke.

Utley, William S. (2005). "Charcoal". In: *Encyclopedia of Toxicology (Second Edition)*. Ed. by Philip Wexler. Second Edition. New York: Elsevier, p. 505. ISBN: 978-0-12-369400-3. DOI: https://doi.org/10.1016/B0-12-369400-0/00202-7. URL: https://www.sciencedirect.com/science/article/pii/B0123694000002027.

Warnatz, Jürgen. et al. (2006). *Combustion.* 4th Edition. Berlin, Heidelberg : Springer-Verlag Berlin Heidelberg, pp. 1–389. URL: http://dx.doi.org/10.1007/978-3-540-45363-5.

WHO (2022a). *Air pollution.* [Accessed 4 April 2023]. URL: https://www.who.int/health-topics/air-pollution#tab=tab_1.

— (2022b). *Ambient (outdoor) air pollution.* [Accessed 4 April 2023]. URL: https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health.

— (2022c). *Household air pollution.* [Accessed 4 April 2023]. URL: https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health.

WHO (2023). *Air quality and health*. [Accessed 23 April 2023]. URL: https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/health-impacts/types-of-pollutants.

World Bank Data (2020a). *Access to clean fuels and technologies for cooking (% of population) - Sub-Saharan Africa*. [Accessed 4 April 2023]. URL: https://data.worldbank.org/indicator/EG.CFT.ACCS.ZS?locations=ZG.

— (2020b). *Access to clean fuels and technologies for cooking, rural (% of rural population) - Sub-Saharan Africa*. [Accessed 4 April 2023]. URL: https://data.worldbank.org/indicator/EG.CFT.ACCS.RU.ZS?locations=ZG.

— (2020c). *Access to electricity (% of population) - European Union*. [Accessed 2 February 2023]. URL: https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=EU.

— (2020d). *Access to electricity (% of population) - SUb-Saharan Africa*. [Accessed 2 February 2023]. URL: https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=ZG.

— (2021). *Data for Low income, Mozambique, Sweden, High income*. [Accessed 4 April 2023]. URL: https://data.worldbank.org/?locations=XM-MZ-SE-XD.