Burning the Woods and Flooding the Slums

Examining the Socio-economic and Environmental Burden of Wood Charcoal in Dar es Salaam, Tanzania

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LUCSUS
Lund University Centre for Sustainability Studies

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Supervisor: Sara Gabrielsson, LUCSUS, Lund University

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Dedication

I dedicate this work to Aisha, and all other women, who struggle to provide for their families every day. To Aisha, and all other women, who fight to save their homes from flooding every time it rains. To all the women who deserve a more just and sustainable reality; and to their children who deserve it too.

Figure 1. Walking in Tandale. Aisha and research assistant, Petro, walking down a street, post flooding, in Tandale, Dar es Salaam (Photo by author, Feb. 16, 2020)

Abstract [eng]

Wood charcoal is the main source of energy for cooking in urban Sub-Saharan Africa. It is widely known that charcoal production causes numerous environmental impacts, such as deforestation and environmental degradation. Interventions aimed at environmental improvements are common in Sub-Saharan Africa, however, there is limited focus on the trade-offs between the environmental and socio-economic implications across the entire wood charcoal supply chain. In this thesis, the socio-economic and environmental implications for people within the wood charcoal supply chain is examined through a case study of Dar es Salaam, Tanzania. Furthermore, the study assesses whether or not the identified socio-economic and environmental implications contribute to a sustainable urban energy system for cooking or not. The study utilizes systems-thinking and solution-orientation to understand the wood charcoal supply chain and aid interventions. Data was gathered through focus group discussions, semi-structured interviews, and observations. The data was analyzed through thematic coding guided by an energy justice framework. The main finding is that the wood charcoal supply chain has a range of environmental impacts that further exacerbate socio-economic challenges faced by people within the chain. The results show that charcoal production contribute to increased deforestation and rainfall. The consequence is found to be that wood charcoal producers and sellers struggle to secure wood charcoal availability and quality which result in increased prices for the end users. The results also indicate that producers and sellers can possibly turn to alternative livelihood activities, whilst users have no feasible alternative energy sources for cooking. Ultimately, the findings show that inter- and intragenerational equity and future sustainability is at stake because of current injustices and unsustainability of the wood charcoal supply chain. This study argues for a more just system that is robust, diversified, and equitable. To achieve such changes, stakeholder participation in decision-making needs to be established as well as alternative energy sources for cooking that meet the needs of current generations, without placing undue harm to the environment and to future generations.

IKISIRI [swa]

Mkaa ndio chanzo kikuu cha nishati ya kupikia katika ukanda wa jangwa la sahara ya Africa. Inafahamika kuwa mkaa unasababisha matatizo mengi ya kimazingira kama ukataji miti na uharibifu wa mazingira. Majaribio kadhaa yamefanywa na wafanya maamuzi pamoja na watafiti kubadilisha mnyororo wa mkaa kwa kuanzisha mikakati maalumu ndani ya taasisi zilizopo kwenye mnyororo mfano, kwa kubadilisha Teknolojia na njia za ukataji miti na uzalishaji. Pamoja na hayo, mkaa na madhara yake ya kimazingira bado yanaendelea kuwepo. Mapungufu katika kuboresha mnyororo wa uzalishaji mkaa, ni kujikita katika mahusiano baina ya madhara ya kimazingira na madhara ya kijamii na kiuchumi kwa watu wote waliopo katika mnyororo wa uzalishaji badala ya kujikita kwenye viwango vyake. Hivyo, nadharia hii inachunguza matokeo au hamasa ya mkaa katika jamii, uchumi na mazingira kwa kuangalia mnyororo mzima kwa eneo la utafiti ndani ya Dar es Salaam, Tanzania, na kujadili kama matokeo hayo yanamchango kwenye mfumo wa nishati endelevu ya kupikia au la. Kwa kutumia njia kama majadiliano ya kina, mahojiano madhubuti na uchunguzi wa kuona, mnyororo wa mkaa kwa Dar es Salaam unachunguzwa. Taarifa kutoka eneo la utafiti zilikusanywa na kuchambuliwa kwa kuzingatia nadharia ya haki ya Nishati ambayo inatengeneza sababu za urahisi wa upatikanaji, uwepo, ubora, unafuu wa gharama, uendelevu, na uongozi bora kama vitu muhimu kwa mfumo wa nishati. Matokeo ya utafiti huu yanaonesha kuwa uzalishaji wa mkaa unamadhara kadhaa ya kimazingira ambayo yana athiri shughuli za kijamii na uchumi kwa watu waliopo ndani ya mnyororo wa mkaa. Wakati ukataji miti na mvua vikiongezeka, upatikanaji wa mkaa unapungua, ubora unapungua na bei inapanda. Wakati wazalishaji na wauzaji wanauwezo wa kuhamia kwenye njia mbadala za uzalishaji, watumiaji hawana uwezekano wa kupata nishati mbadala madhubuti ya kupikia. Usawa wa ndani na wakimuingiliano na uhakika wa muendelezo wa mbeleni wa uzalishaji upo matatani kutokana na mwenendo wa sasa. Utafiti huu unashauri zaidi juu ya mfumo ambao ni mseto, wenye nguvu na usawa. Mabadiliko yatajumuisha uendelevu wa uzalishaji mkaa, lakini pia kuanzishwa kwa ushirika baina ya wadau na kusaidia nishati mbadala za kupikia, ambazo zainakidhi mahitaji ya watu waliopo katika mnyororo wa mkaa, bila kuleta madhara kwa mazingira na kizazi kijacho.

Key words: Cooking fuels, Energy Justice, Supply chains, Good Governance, Sub-Saharan Africa, Sustainability Science

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Last, but certainly not least, to my loving and supporting family and friends at home in Denmark. Thank you for always being there for me. Especially during my first weeks in Tanzania, when I doubted myself and the journey I had embarked on. I could not have done it without your unconditional support.

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List of Abbreviations

CPA	Charcoal Producer Association
CSC	Charcoal supply chain
DSM	Dar es Salaam (Tanzania)
EJF	Energy justice framework
FGD	Focus group discussion
GFW	The Global Forest Watch
KII	Key informant interview
MNRT	Ministry of Natural Resources and Tourism
NBS	National Burau of Statistics
PFM	Participatory forest management
SDC	Swiss Agency for Development and Cooperation
SDG	Sustainable development goal
SSI	Semi-structured interviews

TFCG	Tanzania Forest Conservation Group
TFS	Tanzania Forest Service Agency
TZS	Tanzanian shillings
USD	US Dollars
WB	World Bank
WCED	World Commission on Environment and Development

1 Introduction

Over 70% of the population in Sub-Saharan Africa (SSA) depend on wood fuel (charcoal and firewood) as their primary energy source for cooking (Sola et al., 2017). Although the use of wood as a cooking fuel is declining, an increase in the use of wood charcoal (charcoal), mainly in SSA, counterbalances this trend (IEA, IRENA, UNSD, WB & WHO, 2019). Tanzania stands out as one of the countries with the largest wood fuel usage in SSA. With wood fuel constituting just over 95% of the country's total cooking supply, it is much higher than the 60-90% average found in other SSA countries (World Bank (WB), 2010). More than 80% of the urban population in Tanzania consumes charcoal (Mwampamba, 2007). Without interventions, Tanzania's National Bureau of Statistics (NBS) (2017) projects that the number of urban consumers will double by 2030. Tanzania has 48.1 million ha of forest and woodland, but experiences the highest rate of deforestation at 1.16% in SSA (Lupala, Lusambo, & Ngaga, 2014). Charcoal has been estimated to cause 40% (Msuya, Masanja & Temu, 2011). Deforestation contributes to biodiversity loss and global warming (Msuya et al., 2011). Furthermore, charcoal smoke from cooking is harming both the environment and human health (Sola et al., 2017). Moreover, charcoal as a cooking fuel has connection to several sustainable development goals (SDGs), including SDG 3 (health), SDG 7 (affordable and clean energy), SDG 13 (climate action), and SDG 15 (life on land). Researchers and decision-makers have made several attempts to halt these environmental impacts of the charcoal supply chain (CSC), but as stated charcoal usage is expected to continue its growth.

Charcoal is argued to be a crucial source of livelihood for charcoal producers (Bailis 2005; Zulu & Richardson, 2013; Sola et al., 2017), as well as being cheap, accessible and affordable (Adenij, Zaccheaus, Ojo & Adedji, 2015; WB, 2010; Zulu & Richardson, 2013). Much research has therefore claimed that efforts to overcome environmental issues can be based on socio-economic changes, such as introducing improved production and cooking technologies to combat deforestation (Makame, 2007; Malimbwi & Zahabu, 2008; Sanga & Januzzi, 2005). Yet, a literature review by Sola et al. (2017) found that studies of charcoal in SSA predominantly focus on environmental impacts of the CSC and thus overlook or misattribute socio-economic implications. Additionally, most studies lack overall assessments of the entire CSC and linkages between actors within it. For example: "Environmental impacts focused more on wood fuel… whilst socioeconomic studies covered a wider range of… activities except for consumption" (Sola et al., 2017, p. 13). This is essential because policies targeting one part of the CSC may cause possibly negative and counterintuitive impacts on others parts (Sola et al., 2017). Thus, more research on the trade-offs between socio-economic and environmental implications across the entire CSC is needed to fully understand the system and aid interventions to the system (Sola et al., 2017).

Energy justice is a useful concept to assess both socio-economic and environmental impacts of energy systems (Sovacool & Dworkin, 2015). According to the framework; availability, accessibility, affordability, sustainability, and good governance, are essential to a just energy system (Sovacool & Dworkin, 2015). These concepts synthesize several aspects of an energy system, including temporal, economic, social, political, geographical, and technological. Moreover, energy justice can be utilized to examine energy systems across research fields and provide decision-makers with an ethical framework for planning in the energy sector (Heffron & McCauley, 2017). The concept can therefore be valuable to apply in order to get a broader understanding of the socio-economic and environmental impacts of charcoal energy systems.

This thesis examines trade-offs between socio-economic and environmental implications throughout the entire CSC by studying the case of Dar es Salaam, Tanzania (DSM) and deploying an energy justice perspective. Based on the case study, this research assesses whether the implications are contributing to or hindering energy justice. Additionally, sustainable pathways and alternatives for the future of the energy system in DSM are discussed. The research can contribute to scientific development and policy-making, while considering the needs of both society and nature to sustain energy services for current and future generations in DSM and in other similar settings.

1.1 Scope

This research originated as part of the Sustainable Sanitation in Theory and Action (SUSTAIN) research project with the aim of assessing the sustainability of charcoal and comparing it with fecal sludge derived charcoal (biochar). However, after conducting a literature review and identifying the above research gap, it was decided that more knowledge on charcoal in terms of the entire CSC and especially its socio-economic implications was needed. The thesis therefore moved slightly away from the initial aim; however, biochar is still taken into consideration when assessing future pathways for energy systems of cooking in DSM. Thus, the thesis sets out to explore a separate aim from the SUSTAIN project, but draws on knowledge, data, and people from the project.

1.2 Research objective

The purpose of this thesis is to examine the socio-economic and environmental implications for people within DSM's CSC and to assess the sustainability of this system through an energy justice perspective. The aim is to critique charcoal as an energy system for cooking in urban areas and to suggest sustainable pathways and alternatives for the system. The following research questions have been deployed in order to reach the purpose and fulfill the aim of this thesis:

1. *What are the socio-economic and environmental implications for people within the CSC in DSM?*
2. *How are the socio-economic and environmental implications of the CSC contributing to or hindering energy justice?*
3. *How can the energy system for cooking in DSM be developed sustainably for current and future generations?*

1.3 Relevance to sustainability science

The study is relevant to sustainability science in a number of ways. Firstly, due to its focus on interaction between nature and society and its relevance to the SDGs, the very subject of this thesis is within the realm of sustainability science (Kates et al., 2001). Secondly, the ambiguity of the study also showcases the uncertainties that dominate sustainability issues (Partelow & Boda, 2015). Moreover, it deals with certain anticipations about future conditions by discussing future pathways and alternatives for the energy system of cooking in DSM. Thus, it is also solution-oriented, which is a key component of sustainability science (Wiek, Withycombe & Redman, 2011; Cash et al., 2003). Thirdly, since the thesis examines the system of CSCs, the tradition of systems-thinking embedded in sustainability science is applied (Cash et al., 2003). Fourthly, transdisciplinarity, which is also key to sustainability science (Jerneck et al., 2011), is entrenched in the study through stakeholder participation during the data collection. The relevance to sustainability science is further elaborated in section 3, as it constitutes the conceptual framework of the study.

2 Background

2.1 Case study context: Dar es Salaam

Tanzania is the largest and most populated country in East Africa, with a population of just over 58 million (CIA, 2020) (Figure 2). Approximately six million people reside in DSM, making it the biggest city in Tanzania (Figure 3) (CIA, 2020). DSM is growing rapidly with a rate of 5.4% yearly, and the population is predicted to reach 10 million by 2050 (NBS, 2012; Rosen, 2019). The rapid growth combined with an absence of urban planning has resulted in around 80% of DSM's population living in unplanned settlements (NBS, 2017). Unplanned settlements entail that people lack access to infrastructure and services, such as running water and electricity, which are otherwise available within the city (Ramadhani, 2007).

Figure 2. Map of Tanzania in Africa (CIA, 2020).

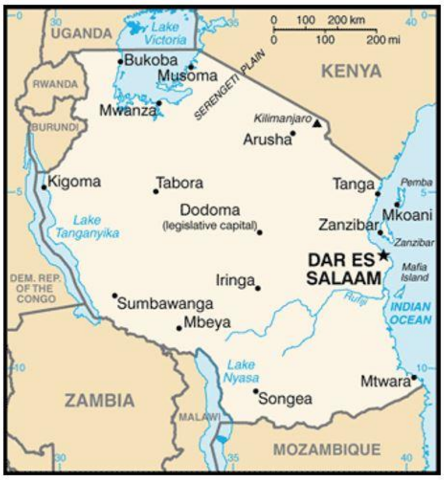

Figure 3. Map of Dar es Salaam in Tanzania (CIA, 2020).

2.2 Charcoal in Dar es Salaam

DSM consumes almost half of the charcoal produced in Tanzania (WB, 2010) with an annual consumption of 500,000-700,000 tons (Msuya et al., 2011; Sanga & Jannuzzi, 2005; WB, 2009). Charcoal production in Tanzania is estimated to cause 372,871 ha of forest loss annually, while production specifically for DSM is estimated to cause between 100,000-125,000 ha of forest loss annually (Msuya et al., 2011; TFS, 2015; WB, 2010). In addition, charcoal production for DSM has been attributed to causing immense impacts of forest degradation, soil degradation, and water runoff (Malimbwi & Zahabu, 2008.; Msuya et al., 2011 Mwampamba, 2007).

The charcoal industry provides income to several hundred thousand people and contributes 650 million dollars per year to people's livelihoods and the country's economy (WB, 2010). Charcoal producers usually reside to the north and west of DSM (Malimbwi & Zahabu, 2008). The land is either owned by the state, producers themselves, or family and friends. Producers are big or small-scale, with most people working in the industry being poorer households, who execute small-scale production (WB, 2010). Like the producers, sellers are either big or small-scale, and usually reside at markets or within the unplanned settlements of DSM. Big-scale sellers usually employ small-scale sellers and also maintain charcoal transport from production areas to DSM. Approximately 71% of households in DSM use charcoal as their first choice of cooking fuel (WB, 2010). And, charcoal is the preferred cooking fuel amongst all income-groups of people living in DSM (WB, 2010; Sander, Gros & Peter, 2013). In addition, charcoal provides a means of living for the many street cooks operating around DSM and particularly in the unplanned settlements. Figure 4 visualizes the linkages of actors and charcoal flow within DMS's CSC.

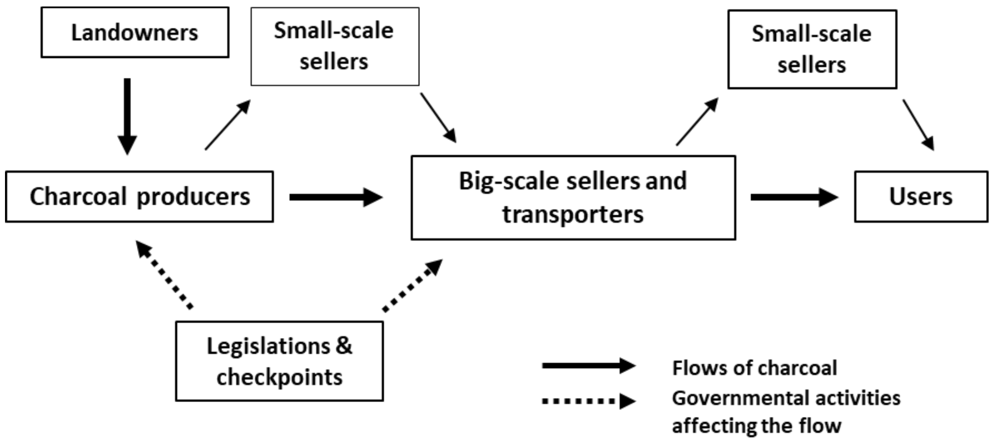

Figure 4. Actors and charcoal flow within Dar es Salaam's charcoal supply chain (Source: Author, 2020).

The CSC is a simplification of the system, as some actors, such as big-scale sellers, play more than one role, while others, such as small-scale sellers, may be bypassed at times. The complexity of the chain in DSM is not unique, as the flow of charcoal and actors within are similar to other CSCs, such as in Kenya (Bailis 2005). This thesis focuses mainly on the highly visible actors within the chain, namely: producers, big-scale sellers, users, and to some degree governmental institutions.

2.3 Charcoal policies and interventions in Dar es Salaam

Tanzania's charcoal legislation has been widely discussed in research (Ellegård, Chidumayo, Malimbwi, Pereira & Ing Voss 2002; Sander et al. 2013; WB, 2010). Most apparent is the government's attempt to limit supply and demand by putting a two week ban on charcoal production in 2006 (WB, 2010). The ban proved to be inefficient and the charcoal business continued almost undisturbed (WB, 2010). One reason for this inefficiency is the many governmental divisions executing the legislation: the national level, the sub-national level, the district level, the region level, and the village level (Ellegård et al., 2002; WB, 2010). Adding to this, the different sectors of the chain are governed separately by different entities (WB, 2010). The complexity of the system allows for illegal activities, such as side payments, bypassing of regulation, in addition to complicating implementation of policy reforms, which could make the industry more sustainable (Mwampamba, 2007; Sander et al., 2013; WB, 2010).

Several interventions by non-governmental institutions have been made. One of the most significant interventions one was introduced and facilitated by the Swiss Agency for Development and Cooperation (SDC) and Tanzania Forest Conservation Group (TFCG). The project began in 2012, with the goal of creating sustainable and well-governed supply chains in 30 villages to the west and north of DSM (SDC & TFCG, 2018). The achievements have been the production of 3,153 tons of sustainable charcoal in 13 of the villages and over 100,000 ha conserved woodland in 22 villages (SDC & TFCG, 2018). Furthermore, the incentive has generated an increase in collected taxes through sustainable charcoal production (SDC & TFCG, 2018). Although these outcomes all have positive aspects, a recurring problem is that the majority of initiatives are sector focused, predominantly on production, and thus oversee effects of the interventions on the remaining part of the CSC.

3 Conceptual and analytical frameworks

The following sections present the frameworks which guide a) the research strategy and design, and b) the data collection and analysis. The research strategy and design, is based on Wiek et al.'s (2011) sustainability science framework, which guides the research from creating the research questions to developing a fitting research design. Thus, this framework is the conceptual framework of the research. In order to answer the research questions, set out by the conceptual framework, Sovacool & Dworkin's (2015) concept of energy justice is utilized as an analytical framework to collect, analyze and discuss the empirical data. In the chapters below, the main concepts of the two frameworks are explained and it is justified why they are useful for this research.

3.1 Conceptual framework: sustainability science

Sustainability issues are complex and therefore demand complex research competences. Based on a literature review Wiek et al. (2011) have gathered the most essential competences needed when addressing sustainability problems, including: *systems-thinking*, *anticipatory*, *normative*, *strategic*, and *interpersonal competence*. This research addresses a complex sustainability issue and these competences help to organize and design the research (Table 1).

The *systems-thinking competence* includes the ability to analyze complex systems across different domains and scales (Wiek et al., 2011). In the case of this research, the CSC is analyzed at different domains by explaining both socio-economic and environmental implications of the chain. Additionally, it deploys a systems-thinking approach, by analyzing these domains across all levels of the CSC rather than examining just one level of it, i.e. by examining the domains of producers, sellers, and users rather than focusing solely on one of them. The analysis is finalized by deploying a systems-thinking approach across scales as local findings will be related to global scales through the SDGs.

The *anticipatory competence* evaluates or crafts a scenario of the future related to sustainability issues (Wiek et al., 2011). The goal is to avoid unintended harmful consequences and follow the imperative of intergenerational equity, which are key elements to the concept of sustainability (Wiek et al., 2011). In this research it is done by anticipating, what current trends of deforestation from wood charcoal production and consumption may look like in the future. By having an understanding of the system and how socio-economic and environmental implications relate to each other, it is possible to craft a picture of the future. The purpose is not to prove causations or quantitatively measure the effects, but rather to explain what the system looks like now and thus how it may look in the future if business as usual continues.

The *normative competence* is used to assess the (un)sustainability of current and future states of the system and develop sustainable visions for the future (Wiek et al., 2011). Hence, it holds an element of normativity, as it is unavoidably based on normative knowledge concerning: “justice, equity, ethics and socio-ecological integrity” (Wiek et al., 2011, p. 209). This competence is utilized in the research by assessing why the socio-economic and environmental implications of the CSC are unsustainable and what alternatives can bring in comparison. The assessment is based on Sovacool and Dworkin’s (2015) energy justice framework used for the analysis (cf. chapter 3.2).

The *strategic competence* is solution-oriented and links knowledge to action (Wiek et al., 2011). In practice, this means having an understanding of political agendas, logistical challenges, and using non-academic language whilst interacting with decision-makers (Wiek et al., 2011). This competence connects to the other competences in order to evaluate a transition from the present state of the system (in this case the CSC) to alternative states which consider existing path-dependencies (Wiek et al., 2011). This research addresses the strategic competence by linking together the various competences as defined by Wiek et al. (2011). Concurrently, the research is translated from knowledge to action within the SUSTAIN project, as stakeholder workshops with decision-makers, global institutions, and local stakeholders will be carried out at the end of the project.

Finally, the *interpersonal competence* is the ability to carry out collaborative sustainability research. A prerequisite, is the capability to: “understand, embrace and facilitate diversity across cultures, social groups, communities, and individuals” (Wiek et al., 2011, p. 211). Thus, epistemological pluralism is present to enable a comparison and understanding of different perspectives and preferences (Wiek et al., 2011). This is carried out in the research by stakeholder collaboration, both by partaking in the SUSTAIN project itself, where work is done across different cultures, but also during the data collection, where local stakeholders participate in the systems-thinking and the anticipatory thinking.

Table 1. Sustainability science competences utilized to guide the research strategy and design.

Competence	Recognition task	Research Objectives	Data and method
Systems-thinking; Interpersonal	Analyze the wood charcoal supply chain as a system	*What are the socio-economic and environmental implications for the people in the wood charcoal supply chain in DSM?*	Semi-structured interviews; Focus group discussions; Observations; Quantitative data
Anticipatory; Normative; Interpersonal	Anticipate and assess why the system is unsustainable	*How are the socio-economic and environmental implications of the supply chain contributing to or hindering energy justice?*	Analyzing the data utilizing Sovacool & Dworkin's (2015) energy justice framework
Strategic (linking together all competencies)	To discuss future pathways and alternatives	*How can the energy system for cooking in DSM be developed sustainably for current and future generations?*	Based on the results from the previous research questions and informed by additional literature

3.2 Analytical framework: energy justice

Emerging from the field of environmental justice, energy Justice is relatively new as a field of research (Munro, Horst & Healy, 2016). Environmental justice addresses the proposition, that distributions of environmental benefits and harms are interlinked with socio-economic processes (Munro, et al., 2016). Founded on this proposition, is Sovacool and Dworkin's (2015) pioneering definition of energy justice which provide direction when analyzing environmental and socio-economic impacts of energy systems and serves as a guideline for achieving sustainable and just energy systems. According to Sovacool and Dworkin's (2015) definition, a sustainable and just energy system is one: "that fairly disseminates benefits and costs of energy services" (p. 436). It is Sovacool & Dowrkin's definition that is utilized throughout the thesis, referred to as the energy justice framework (EJF).

The EJF identify a range of aspects utilized to assess the socio-economic and environmental implications of an energy system, the following aspects comprising the EJF apply: *resource availability, availability robustness, quality, affordability, accessibility, sustainability*, and *good governance*.

Availability is the most basic aspect of the EJF, as it encompasses the foundational need of distributing energy services amongst users. This is executed by utilizing a country's physical resources and a region's technical abilities (e.g. transport, distribution, storage) (Sovacool and Dworkin, 2015). Also implicitly assumed, is that energy resources need to be of high quality (Sovacool and Dworkin, 2015). Thus, within availability *resource* *availability*, *availability robustness*, and *quality* are applied when collecting and analyzing empirical data as well as discussing the socio-economic implications found.

Intragenerational equity is concerned with the right to access energy services fairly (Sovacool and Dworkin, 2015). It thereby entails that people have the right to enjoy basic needs and wellbeing such as food, shelter, unpolluted air, and energy (Sovacool & Dworkin, 2015). For simplification purposes, this aspect is defined as *accessibility* rather than intragenerational equity when applied to the data collection and discussion of the socio-economic implications.

Affordability entails stable and equitable prices (Sovacool & Dworkin, 2015). Meaning that lower-income households should not have to use a disproportionately large share, or more than 10 %, of their income on energy services (Sovacool and Dworkin, 2015). This definition was applied when collecting data and assessing the socio-economic implications.

Sustainability is the "duty of states of not depleting natural resources too quickly, and not causing undue harm to the environment" (Sovacool & Dworkin, 2015, p. 439). It also entails the Brundtland Report's idea of leaving future generations with the same resources as we have now (Sovacool & Dworkin, 2015). *Intergenerational equity* relates to the concept of *sustainability* in that future generations should enjoy a good life, undisturbed by the damage our energy system will inflict over time (Sovacool & Dworkin, 2015). Due to their interrelatedness, these two components are compiled and named *sustainability* throughout the data collection and discussion of trade-offs between the environmental and socio-economic implications.

Finally, the EJF entails three governmental aspects. Firstly, governmental *responsibility* entails that nations are responsible for protecting the natural environment and prevent any energy-related social and environmental externalities of the energy system (Sovacool & Dworkin, 2015). Secondly, *good governance* entails that the energy system is accountable in so that it thrives for democratic decision-making, and takes measures to reduce corruption (Sovacool & Dworkin, 2015). Thirdly, *due process* is to thrive for transparent processes and to ensure stakeholder involvement in energy policymaking (Sovacool & Dworkin, 2015). As all three components are intertwined, they are used in conjunction throughout the discussion under the term *good governance.*

4 Methodology

4.1 Research strategy and design

Prior to establishing the research strategy and design, a literature review was carried out. The purpose was to gather already existing knowledge on the subject and to get an overview of potential contradictions or inconsistencies within it (Bryman, 2012). The review was executed using Google Scholar's search engine, the Lund University Library databases, and inputs from PhD students at the SUSTAIN project. Search terms were applied individually, and in conjunction in several combinations, namely: charcoal, wood, cooking fuels, energy, supply chains, deforestation, Dar es Salaam, Tanzania, Sub-Saharan Africa.

The review helped identifying the research gap of systems-thinking. Wiek et al.'s (2011) sustainability science approach was thus deployed as a conceptual framework based on this identification. The knowledge from the review also established the foundation for the data collection and the use of the EJF. When utilizing both induction and deduction, empirical data is used to target theory, and theory is used to explain empirical data (Thualagant, 2016). Thus, empirical data was collected and used to gain insights into the implications of the CSC, whilst the EJF was used to assess and anticipate the consequences of the implications.

The research design is based on a case study of DSM. The purpose of using a case study can be manifold (Gerring, 2004), but is used in this research to extensively answer the research questions (Bryman, 2012). According to Flyvbjerg (2004) case studies are valuable to understand context-specific issues to provide context-specific knowledge, specifically involving people, as this study does. By using DSM as a case, the outcome of the study can provide situated knowledge that can feed into policies and initiatives for the future of cooking energy in DSM. Additionally, the purpose of case studies can be to transfer the results to other cases (Flyvbjerg, 2011). Although this is not the purpose of this study, DSM has similarities with other SSA cities (NBS, 2017), and the results can arguably be disseminated to similar cases and contribute to scientific development within them.

4.2 Research methods

The methodological approach is a mixed method case study in DSM. The analysis is divided in three parts. The first part of the analysis examines how actors within DMS experience the socio-economic and environmental implications of the CSC. In order to execute the analysis, the bulk of data was collected through focus group discussion (FGDs) and semi-structured interviews (SSIs) with the purpose of getting rich, complex, and potentially contradicting accounts (Kamberlis & Dimitriadis, 2011) of how actors experience the socio-economic and environmental implications of the CSC. To add to the FGDs and SSIs, participatory observations (observations) and visual ethnography were carried out to observe how actors engage with the CSC in their everyday lives. Key-informant interviews (KIIs) were conducted to understand the administration and legislation of charcoal. Quantitative data on forest cover in Tanzania is used in conjunction with the qualitative data to answer the first part of the analyses. The purpose is to add to peoples' accounts by explaining the physical consequences of the environmental implications that they experience and to anticipate future implications.

The second part analyses whether the identified implications are contributing to or hindering energy justice. It is based on the results of the first part, and the concepts of the EJF with the purpose of discussing the justice component of the identified implications.

The third part discusses sustainable future alternatives and pathways for cooking fuels in DSM, based on the previous results, as well as a literature review. The purpose is to discuss and compare trade-offs and synergies between the injustice of the CSC and future potential solutions and alternatives.

4.2.1 Case selection and sampling

Informal interviews were carried out prior to choosing a study site and sampling participants. The aim of these interviews was to get general and specific expert knowledge (Bryman, 2012) of the CSC in DSM. Furthermore, the purpose was to organize the data collection. Through the interviews, two key figures were acquired. Firstly, a research assistant, a SUSTAIN student, who functioned as a translator throughout the data collection. Secondly, an employee from the Ministry of Natural Resources and Tourism (MNRT), who functioned as a gatekeeper. A gatekeeper is useful to smooth access to groups of people and provide key information (Bryman, 2012).

The data collection took place in two different areas of DSM, Tandale and Kisarawe. Tandale is an unplanned settlement located in Kinondoni district in DSM, and Kisarawe is a charcoal production area located in the Pwani region 40 km southwest of DSM (see map over locations in Appendix A). Data collection through FGDs, SSIs, and observations took place in Tandale. Additional data collection through SSIs, KIIs, and observations took place in Kisarawe district.

The purpose of this thesis is to examine the socio-economic and environmental implications to the people within the DMS's CSC. The unit of analysis is therefore actors in the chain. Selection of participants was done through purposive sampling and convenience sampling. Purposive sampling is a method, where participants are stratified based on certain characteristics (Bryman, 2012), in this case based on their position in the CSC, i.e. user, seller, producer, and administrative actor. Recruitment was facilitated by the gatekeeper and local community leaders with knowledge of the local context and connections to participants, meaning that sampling was also based on convenience.

4.3 Data collection

Data was collected in DSM, Tandale, and Kisarawe between January 6, 2020 and February 17, 2020. The data collection process is visualized in Table 2.

4.3.1 Focus group discussions

The aim of the FGDs was to explore groups of users' experiences with charcoal. FGDs can provide large amounts of data on a single phenomenon in a short period of time (Bryman, 2012), which was useful as there is little knowledge on charcoal users (Sola et al., 2017). Two FGDs were conducted using the same interview guide (Apependix B) for both FGDs to ensure comparable and credible data (Bryman, 2012). The guide is semi-structured, based on themes from the EJF, but with open-ended questions. This was done to ensure insights beyond the analytical framework whilst at the same time addressing subjects from the framework (Kvale & Brinkman, 2009). The two FGDs were completed with ten people. Users in Tandale are predominantly female street cooks (cooking for business) and female domestic cooks (cooking at home). One FGD was carried out with six female domestic cooks and one with four female street cooks (see Appendix C for full description of participants). The groups were thus kept rather small compared to the standard eight person FGD group size (Bryman, 2012). This was done to allow for a thriving discussion, but at the same time make sure participants felt comfortable speaking (Bryman, 2012). During the FGDs, one person spoke at a time to allow for direct translations from Swahili[1] to English, enabling probing and follow-up questions from the author (Kvale & Brinkman, 2009). The FGDs took place on a quite rooftop in Tandale as seen in Figure 5.

Figure 5. Focus group discussions with users in Tandale. To the left: domestic cooks. To the right: street cooks (Photos by Sara Gabrielsson, Jan. 26, 2020).

[1] Official language in Tanzania.

4.3.2 Semi-structured interviews

The aim of the SSIs was to obtain an in-depth understanding of sellers' and producers' experiences with charcoal. During the SSIs, two semi-structured interview guides were used; one for sellers and one for producers (Appendix B). Similarly, to the FGDs, the interview guides follow the concepts from the EJF, with open-ended questions to allow for participants' insights beyond the themes of the framework (Kvale & Brinkman, 2009). Again, the research assistant translated word-by-word from Swahili to English during the interviews to allow for probing and follow-up questions. Two big-scale sellers were interviewed in Tandale, whilst they were working. This allowed for observations to be done simultaneously. Two small-scale producers were interviewed in Kisarawe on their farms (Figure 6). This was done in order to conduct observations and to make it easy for the producers to participate in the SSIs. See Appendix C for detailed description of the SSI participants.

Figure 6. Semi-structured interviews with producers in Kisarawe. To the left: small-scale producer being interviewed at his farm in Kisarawe. To the right: small-scale producer being interviewed at his farm in Tandale (Photos by Gatekeeper, Jan. 28, 2020).

4.3.3 Participatory observations

The main aim of the observations was to observe how local sellers, users, and producers engage with the CSC in their everyday lives. Additionally, it was to engage with actors who were not included in the SSIs, for example small-scale sellers. Observations were carried out in Tandale and Kisarawe. The observations were made whilst being with a local leader or the gatekeeper and were therefore evidently overt (Bryman, 2012). During the observations, questions were posed and field notes taken. Taking notes did not seem out of place, since the observations were overt. However, the notes were taken casually and discreetly to avoid people from feeling self-conscious (Bryman, 2012). Visual ethnography in the form of photographs were also taken to add to "what can be seen" as part of the lived experiences of people (Prosser, 2011). Users and sellers were observed in Tandale whilst cooking and selling during the daytime. Producers and production processes were observed in Kisarawe.

4.3.4 Key informant interviews

The main aim of the key informant interviews was to get general and specific knowledge on the administration and legislation of charcoal. Additionally, to get insights into big-scale producers and illegal activities that could not be accessed through SSIs. Two interviews were conducted with a Forest Officer in Kisarawe. The first interview was informal and unstructured and thus no interview guide was used. The second interview was structured using an interview guide (Appendix B). Both interviews were conducted in a mix of Swahili and English.

4.3.5 Quantitative data

Quantitative data on land use change in Kisarawe was to be obtained through the MNRT gatekeeper, with the purpose of contributing to an understanding of the CSC's environmental implications. However, due to ongoing difficulties with obtaining the data from the ministry, this understanding instead relies on secondary quantitative data of deforestation rates from other studies and data from the Global Forest Watch (GFW).

Table 2. Data collection in Dar es Salaam, Tandale, and Kisarawe Jan. 6 – Feb. 17, 2020.

When	What	Who	Where	Purpose
Jan. 6-24	Unplanned interviews; Observations	1 Gatekeeper MNRT 1 Research Assistant; Sellers and Users	DSM; Tandale	Get general insights to the CSC and arrange fieldwork
Jan. 26	Focus group discussion; Observations	10 users; 6 domestic cooks & 4 street cooks	Tandale	Examine charcoal users' experiences of the CSC
Jan. 28	Semi-structured interviews; Observations; Key informant interview	2 small-scale producers 1 Key informant; Forest officer	Kisarawe	Examine charcoal producers' experiences of the CSC; Supplemented with key informant knowledge
Jan. 31	Semi-structured interviews; Observations	2 big-scale Sellers	Tandale	Examine charcoal sellers' experiences of the CSC
Feb. 12	Follow-up Key informant interview (phone call)	1 Key informant; Forest officer	DSM	Follow-up on knowledge on legislations and administration regarding charcoal production
Feb 16	Follow-up observations; Photographing	Sellers and Users	Tandale	Follow-up observations on seller and users' experiences after heavy rainfall in Tandale
Feb 17 – May 1	Quantitative data analysis	Gatekeeper MNRT; GFW	DSM & Lund	Compliment actors' experiences of environmental implications

4.4 Data analysis

The analysis of the qualitative data was done through Kvale & Brinkman's (2009) steps: organizing the data through translation and transcribing, and then coding them through thematic coding. The translations and transcriptions were done by the research assistant in a word-by-word manner in order to allow for thorough reading and a comprehensive view of the interviews (Kvale & Brinkman, 2009). The second step was done through thematic coding (Bryman, 2012) with elements of theoretical reading (Kvale & Brinkman) utilizing the data management program Nvivo. The codes are based theoretically on the EJF, but in order to allow for new aspects, thematic sub-codes were generated based on the lived experiences of the informants. The framework codes were: accountability; accessibility; affordability; quality; sustainability; and good governance. The sub-codes came about based on repetition to identify patterns (Bryman, 2012). The sub-codes were: seasonality; deforestation; replanting; tree types; hardwood; softwood; flooding; expenses; and profit. The interviews were revisited several times during the process to encapsulate everything relevant (Bryman, 2012).

4.5 Reflexivity and research quality

Although the data collection generally went smoothly due to thorough preparations, it is always essential to reflect upon the research quality (Bryman, 2012). As this research is concerned with a complex sustainability issue, the chapters below address the trustworthiness of the research rather than its validity and reliability. Validity and reliability are concerned with confirming absolute truths, but sustainability issues are ambiguous (cf. chapter 1.3). The trustworthiness is assessed based on Guba and Lincoln's (1994) criterion of credibility, transferability and dependability.

Credibility entails carrying out research according to principles of good practice (Guba & Lincoln, 1994). Challenges arose in this regard, given that the research assistant was not familiar with some principles regarding qualitative method collection, translating and transcribing. However, these challenges were overcome by making the assistant aware of the issues and re-visiting the interview transcriptions together. Therefore, credibility of the findings, which was also enhanced by achieving triangulation through multiple research methods (Bryman, 2012), were not significantly affected by this.

Transferability of the findings can be ensured by providing thick accounts of the studied phenomena in order to enable others to judge whether or not it is transferable to another setting (Guba & Lincoln, 1994). The provision of direct quotes and photographs in the results fulfill this purpose, although the use of a translator may have limited the phronesis throughout the FGDs and SSIs (Kvale & Brinkman, 2009). Furthermore, the lack of insights to big-scale sellers reduces the account of their part in the CSC, although the interview with the Forest Officer expert provided some account of their position. The results are still valuable, especially given that most producers are indeed small-scale. Finally, primary quantitative data could provide recent insights to forest cover changes in Kisarawe, but the secondary data still suffice for the scope of the study.

Relevant to dependability of this study is Yardley's (2000) criteria of transparency, coherence, and reflexivity. Transparency and coherence were ensured by keeping records of the research process (Bryman, 2012) via fieldnotes, photos, sound files and written transcripts of the FGDs and SSIs. I practice reflexivity by considering the implications of my position as a European on my research. By utilizing a predominantly qualitative approach, I attempt to diminish my own bias by getting in-depth insights into the stakeholders' experiences (Bryman, 2012). I recognize that I will never be able to fully understand and represent the stakeholders' point of view, but I can try my best by giving thick accounts as previously described. As educational and cultural bias can complicate establishing trust to the interviewees (Kvale & Brinkman, 2009), I attempted to be knowledgeable about the cultural context and practiced Swahili throughout the data collection.

5. Results and discussion

5.1 Socio-economic and environmental implications

This section will introduce the socio-economic and environmental implications experienced by the people within the CSC. The implications are discussed according to the concepts of the EJF, as well as the empirical findings. In line with sustainability science, a systems perspective is utilized throughout the discussion, meaning that all highly visible actors within the chain are in focus. Furthermore, the discussion will end with an anticipatory assessment of what current trends of deforestation may implicate for future generations.

5.1.1 Resource availability: a prerequisite for charcoal availability

A country‘s resource endowment is a prerequisite to sustain energy services and it is therefore essential that this resource endowment is available and accessible (Sovacool & dworkin, 2015). In the case of charcoal, wood is a fundamental resource needed for production, and it is therefore crucial to understand whether or not wood is available and accessible to producers. This chapter is solely concerned with the socio-economic implications of current resource availability. Long-term implications and environmental consequences are to be discussed further in chapter 5.1.6.

Data show that forest coverage in close proximity to DSM has been reduced over the last decade (GFW, 2020). At the same time, areas of reserved forest have increased (Forest officer, Feb. 12, 2020). Permits for production in reserved areas are difficult to obtain making it hard for producers to access those trees (Producer 1, Jan. 26). However, since there is still available wood in other areas around DSM, producers reside according to the availability of trees. One seller has been in the charcoal business for over 20 years. He employs producers to provide charcoal for his business and has therefore observed these changes in availability over the years:

> We used to go to Morogoro as well but the trees are finished there. Then we came to Kisarawe, where you are talking of… we produced a lot there but the trees are finished in all the places where we used to harvest (Seller 1, Jan. 31, 2020)

Despite the changes, the same seller finds that “during the dry season charcoal is easily accessible as it is available almost everywhere” (Seller 1, Jan. 31, 2020). Additionally, he claims to have previously diverted his livelihood away from charcoal, but returned to it “because it is such good business” (Seller 1, Jan. 31, 2020). Thus, indicating that tee availability is not yet an issue for production.

Differences in tree maintenance amongst the producers in Kisarawe constitutes the most apparent concern of resource availability. Producer 1 cuts down parts of his trees, alternating logging to ensure continuous availability (Producer 1, Jan. 31, 2020). Producer 2, on the other hand, struggles with tree availability on his land, as he removes the entire tree trunk when logging trees for production. Producer 2 therefore walks long distances from his production site to access trees on the land of neighbors and friends (Producer 2, Jan 28, 2020). Although producer 2 complained about this, it did not seem to affect his production significantly: “I produce every month”. When asked about replanting trees he said: “I don’t reject it… if she gives us those trees, we will plant them here” (Producer 2 Jan. 28, 2020). Indicating that immediate financial concerns overweight tree availability and accessibility.

Lack of charcoal availability to users could also reflect a change in resource availability. Yet, users find that charcoal is generally both available and accessible as it is within walking distance in Tandale (All in FGD 1, Jan. 26, 2020). During observations it was also found that charcoal was abundant. Therefore, although resources for charcoal production are seemingly becoming less available and accessible close to DSM, it does not appear to affect charcoal availability. This trend is not surprising, as studies show that charcoal is the most readily available cooking fuel for people in SSA (Sanga & Januzzi, 2005; WB, 2010; Zulu & Richardson, 2013). As an example, in Nigeria: “for many urban poor, charcoal provides a…convenient and accessible source of energy for cooking” (Adeniji et al., 2015). However, availability in the EJF also entails a robust and reliable energy system, meaning that the energy service should be guaranteed at all times (Sovacool & Dworkin, 2015). Although availability is not overall deemed an issue, the results indicate that availability robustness is problematic during the rainy season in DSM.

5.1.2 Lack of availability robustness during the rainy season

Availability robustness is the system’s ability to withstand disruptions and guarantee reliable energy services (Sovacool & Dworkin, 2015). Earlier studies by the WB (2010) and Bailis (2005), deem charcoal as easily produced, transported, distributed, and stored. However, infrastructure and technology for production, transport, distribution and storage in DSM is vulnerable to disruptions. In SSA, charcoal is most commonly produced using traditional earth kilns (Malimbwi & Zahabu, 2008), which is also the case in Kisarawe (Figure 7). The kiln’s lack robustness during the rainy season as: ”the kiln might turn off if you don’t inspect it frequently, because the soil is wet, or, the kiln might be destroyed by rainwater” (Producer 1, Jan. 28, 2020).

Figure 7. Traditional earth kilns in Kisarawe. To the left: kiln prior to burning. To the right kiln whilst burning (Photo by author Jan. 28, 2020, Kisarawe).

Few producers therefore engage in production during the rainy season:

> I need charcoal money to run my life and agriculture as well (Producer 1, Jan 28, 2020).
>
> Listen, during the rainy season you [producer] are relaxed and they [sellers] are stressed busy searching for charcoal, they will pass here looking for us the bosses of charcoal, hahahaa! (Producer 2, Jan. 28, 2020).

The few, who produce during the rainy season, increase the price of the charcoal. As an example, producers sell one sack of charcoal at 10,000 Tanzanian shillings (TZS) (4.3 USD) during the rainy season, against 7,000-8,000 TZS (3-3.5 USD) during the dry season (Producer 1, Jan. 31, 2020). Thus, this indicate that the vulnerability of kilns leads to less availability and increased prices of charcoal.

Similar to producers, most small-scale sellers refrain from charcoal as a livelihood during the rainy season. (Field notes, 2020). The few sellers that manage to stay open are big-scale with capital and experience to overcome the hardships of reduced availability and increased prices for worse quality charcoal (Seller 1, Jan. 31, 2020). Adding to this is difficulties with transportation of the charcoal, which is most often executed by the sellers (Mwalambwi & Zahabu, 2008). As seen in Figure 8, transportation roads for charcoal, including Pugu Road leading from Kisarawe to Tandale, are prone to flooding (Anande & Luhunga, 2019). Flooding of roads combined with inadequate infrastructure result in trucks getting stuck in mud (seller 1, Jan. 31, 2020).

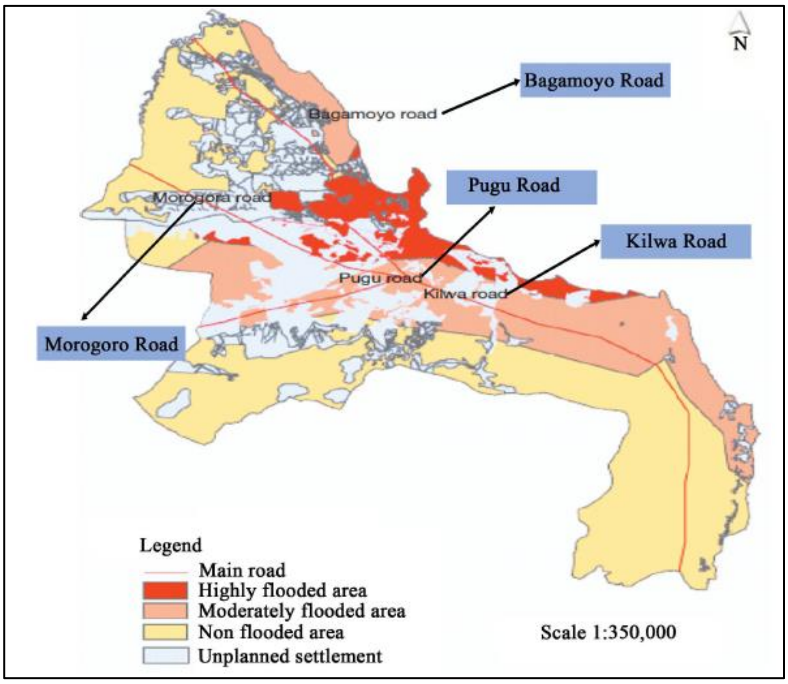

Figure 8. Flood hazard zone map overlain on unplanned settlements in DSM (Anande & Luhunga, 2019).

Figure 8 also illustrates how highly prone to flooding DSM's unplanned settlements are. Most people living in Tandale do not cook during the rainy season. This is because scooping out water from houses takes time away from cooking (Figure 9). Furthermore, charcoal and cooking stoves are often flushed away during erratic rainfall, as explained by the domestic cooks:

> The rainfall of two days ago, no one cooked, because water entered inside the houses and they flooded (Domestic cook 1, FGD 1, Jan 26, 2020).

> When flooding occurred two days ago, the whole charcoal sack was floating on water, upon opening the door, the whole of it went away with water, we had to put the kids on the roof, because the neighbors' houses were full of water as well (Domestic cook 4, FGD, Jan 26, 2020).

Figure 9. Flooding in Tandale. To the left: flooded houses in Tandale. To the right: flooded cooking areas within houses in Tandale (right) (Photos by author, Jan 19 & Feb 16, 2020).

Domestic cooks have no feasible alternative cooking fuel to turn to and therefore purchase food from street cooks instead of cooking or refrain from eating altogether (field notes, 2020). The street cooks thus experience an increase in profit during the rainy season, earning approximately 20,000 TZS (9USD) compared to 10,000 TSZ (4USD) per day during the dry season (all, FGD 2, Jan. 26, 2020). Owing to the fact that street cooks' stores are predominantly located upstream and therefore experience less flooding, most street cooks manage to prevent their businesses from getting flooded. In addition, they use special techniques of storing and drying charcoal: "There is a special place below the ceiling board to store it. The flood will flush the beds and mattresses but not the charcoal" (Street cook 3, FGD 2, Jan 26, 2020). Storage is possible for street cooks, but not domestic cooks, because street cooks use their increased profit to buy several sacks of charcoal instead of buckets or a single sack (Street cook 2, FGD 2, Jan. 26, 2020). Sacks lasts longer and a stash of charcoal can be stored securely under the ceiling. This, however, does not mean that street cooks do not experience distress because of the rainy season. The reality of street cooks having to prioritize charcoal over their remaining household essentials, such as beds and mattresses, show the importance of availability robustness and the value of charcoal as a means of livelihood to them. Ultimately, these results indicate that the CSC does not guarantee availability robustness of charcoal. Equally important, is that availability also entails energy services of high quality (Sovacool & Dworkin, 2015). In the case of DSM, high quality charcoal is, however, becoming less accessible and affordable.

5.1.3 Low accessibility and affordability of high-quality charcoal

The quality of charcoal is dependent on the type of wood used for production (All in FGD 1 & 2, Jan. 26, 2020) Producers, sellers and users categorize trees in two categories: wild trees and planted trees. The wood of a wild trees is hard whereas the wood of planted trees is soft. Charcoal made from hardwood burns for much longer than that of softwood (All in FGD 1 & 2, Jan 26, 2020). The issue of ensuring high-quality charcoal therefore relates to resource availability, as it depends on the tree availability and accessibility to the producers.

According to both FGDs (All in FGD 1 & 2, Jan 26th, 2020) charcoal made from Mpingo is preferred by users, as Mpingo is the hardest type of wood in Tanzania. However, Mpingo is almost exterminated due to charcoal production and additional activities, such as agriculture (Forest Officer, Jan 28, 2020). Remaining and replanted Mpgino is mostly reserved and therefore difficult to access for the producers (Producers 1 & 2, Jan. 28, 2020). Instead, Mkongowe and Muharaka are used for hardwood charcoal whereas fruit trees, such as mango and cashew, are used for softwood (Producer 1 & 2, Jan 28, 2020). Producer 1 prefers wild trees whereas producer 2 uses a mix of wild and planted trees. As previously explained, producer 1 leaves his trees to replant, yet producer 2 takes out the whole tree trunk, meaning that wild trees are mostly eradicated on his land. Producer 2 therefore struggles to access these trees, but, for economic reasons, have no intention of replanting them. Besides, there are no current regulations demanding producers to replant trees (Forest Officer, Jan. 28, 2020). Replanted trees are therefore mostly in form of fruit trees, due to their economic benefits:

> The natural trees, that was brought by God himself, are almost finished….there are some kind that we don't remove because they are needed, like Mango trees, the rest that are not useful, we cut them….These useless trees are useful for the government, but for us they are useless because they don't produce fruits or anything... The government says they produce quality air, but even Mango trees can do that and give fruits as well (Producer 2, Jan. 28, 2020).

For sellers, and thus also users, whether they can access high-quality charcoal therefore depends on the accessibility of wild trees to the producers but also on the attractiveness of replanting and maintaining them.

Interestingly, the interviewed sellers sell charcoal of differing quality. Seller 1 predominantly sell hardwood charcoal, whereas seller 2 solely sell softwood charcoal (field notes, 2020). Observations showed that seller 1 had significantly more customers than seller 2 (field notes, 2020). However, seller 2 still claims to be thriving: ”It is good for business, because people will be using and coming back frequently” (Seller 2, Jan 31, 2020). One reason seller 2 manages to sell worse quality charcoal is, according to himself, that users prefer bigger quantities over quality of charcoal. Yet, this is contradicting to user preferences which indicate that hardwood is preferred at all times (All in FGD 1 & 2, Jan 26, 2020). According to the users themselves, worse quality charcoal is rather bought due to time and money constraints:

> You can choose [quality], but you look at your time as well, if time allows you can move around to other sellers, but if you are late you have no option than taking the same charcoal, in order to start the business (Domestic cook 4, Jan. 26, 2020).

Besides being dependent on wood type, charcoal quality is also determined by the management of the kilns. Badly managed kilns may result in complete burning, leaving ash rather than charcoal, or poor burning leaving wood at the center of the charcoal (Producer 1, Jan. 28, 2020). The former results in less profit for producers, the latter in hardship for users (producer 1, Jan. 28, 2020). Quality therefore relates to availability robustness, as kilns are more difficult to manage during the rainy season thus resulting in lower quality charcoal being sold at an increased price.

Difference in charcoal quality depending on wood type and kiln management has previously been studied, however, with a heavier focus on the environmental implications over socio-economic (Malimbwi & Zahabu. 2008; Luoga, Witkowski & Balkwill, 2000, Adam, 2009). Meaning, that focus has been on discussing how turning to high-quality charcoal can reduce deforestation. In a socio-economic perspective, the results here argue that high-quality charcoal is still available, but less accessible and thus less affordable. Affordability is therefore also essential when assessing the implications of this.

5.1.5 The biggest household expense but the cheapest available cooking fuel

According to the EJF, energy services should be equitable priced with minimal volatility. Due to charcoal being the cheapest option available to users, it is often articulated as being affordable and stable in prices (WB, 2010; Sanga & Jannuzzi, 2005; Adeniji, et al., 2015). However, the following results indicate that charcoal is unaffordable and that prices fluctuate depending on the season.

The FGD participants (Jan. 26, 2020) explained that domestic cooks usually buy charcoal in 10-liter buckets and street cooks in 15-liter buckets which will last them a day. In Tandale a 10-liter bucket is sold at 2,000 TZS (0.86 USD) and a 15-liter bucket at 5,000 TZS (2 USD) (All in FGD 1 & 2, Jan. 26, 2020). Users have to spend significantly more during the rainy season as charcoal volume and bucket changes (Figure 10), leading to one bucket lasting them less than a day.

Figure 10. Charcoal buckets in Tandale. To the right: charcoal sold in 5-liter buckets after flooding in Tandale. To the left: charcoal sold in 10-liter buckets during the rainy season vs the dry season in Tandale (Photos by Amidu Mtalii, Feb 16, 2020).

Domestic cooks estimate that they use approximately 60,000 TZS (26 USD) per month on charcoal, whereas 25,000 to 40,000 TZS (11-17 USD) is spent on rent. In addition to that, water costs around 30,000 TZS (13 USD) per month, and households with access to electricity spend additional 10,000-20,000 TZS (4-9 USD) per month to pay for lighting, TV use, and mobile charging (Table 3).

Table 3. Monthly household expenses of domestic cooks in Tandale, 1 TZS = 0.0004 USD.

Monthly household expenses				
Expense type	Rent	Electricity	Water	Charcoal
Expense Amount	25-40,000 TZS	10-20,000 TZS	30,000 TZS	60,000 TZS

Other aspects, such as food, could arguably be essential household expenses as well, but the four expenses mentioned here were picked out and estimated by the domestic cooks themselves during FGD 1 (Jan. 26, 2020). Based on this, charcoal constitutes 40% of the most essential monthly household expenses. Tanzania's GDP per capita is 1,061 USD (WB, 2018a). To compare, Nigeria's GDP per capita, where charcoal is also the main cooking fuel (Adeniji et al., 2015), is 2,028 USD (WB, 2018b). In practice, using 26 USD a month on charcoal is a significant portion of people's overall livelihood expenses. The street cooks similarly use a disproportionate large part of their business expenses on charcoal: "probably even more than half of my profit is on charcoal" (Street Cook 5, Jan. 26, 2020). All of the cooks earn between 10,000-20,000 TZS (4-9 USD) a day depending on the season. Of that, they use 5,000 TZS (2 USD) on charcoal every day. Charcoal therefore constitutes between 25-50 % of the money earned.

The WB (2010) came to similar conclusions: "The consumer's ability to pay for charcoal seems already stretched to the maximum" (p. 36). Also, Sanga & Januzzi (2005) estimated that the lowest income quartile in DSM used up to 40% of their income on charcoal. In 2010, a sack of charcoal was sold at 37,000 TZS (16 USD) (WB, 2010), today, the users buy it for 50,000 TZS (30 USD) during the dry season and around 70,000 TZS (30 USD) during the rainy season. The fact that the price of charcoal has almost doubled since the WB´s conclusion ten years ago is worrying, given that charcoal is still the cheapest available energy source for cooking (All in FGD 1 & 2, Jan 26, 2020). As an example, a readily available cooking fuel would be natural gas, but most people cannot afford gas (Sanga & Jannuzzi, 2005). The street cooks even make a loss if they use it: "I make a profit by using charcoal, but I would make a loss if I used gas" (Street cook 4, FGD, Jan. 26, 2020). The domestic cooks support the notion that charcoal is the cheapest energy source available to them: "Even for us, it is not as if we like using charcoal, if we get an alternative, which is as cheap as charcoal, we will dump charcoal" (Domestic cook 5, FGD Jan. 26, 2020). Yet, as this study indicates charcoal is still the cheapest option available, but it is not necessarily affordable.

5.1.6 Unsustainable deforestation trends and intergenerational inequity

Since the previous results show that charcoal is the cheapest available cooking fuel in DSM, it is relevant to consider the environmental implications of this high demand. *Sustainability* argues for maintaining resources in a way that can sustain future energy demands (Sovacool & Dworkin, 2015), it is therefore also relevant to consider what the implications entail for future generations. Furthermore, the trade-offs between the environmental and socio-economic implications will be considered.

Calculation of deforestation from charcoal production is dependent on several factors, for example, land use change, consumption rates, population growth rates of, kiln efficiencies, and wood type (Msuya et al., 2011). It is therefore also questioned how much charcoal production attribute to deforestation. In line with this, SDC and TFCG (2017) argue that charcoal production is far from the biggest contributor to deforestation, and that it should rather be attributed to clearing land for agriculture (SDC & TFCG, 2017). However, the previously described results indicate that charcoal and agriculture function as livelihood in conjunction, or that agriculture is a side-income to charcoal production. Mwampamba (2007) supports this notion and claims that efforts against deforestation in Tanzania are failing because charcoal is not recognized as a singular industry contributing to deforestation. In line with this, studies estimate that charcoal production lead to 40% of deforestation in Tanzania annually (Msuya et al., 2011). Thus, this indicates that the charcoal industry has a significant impact on the forest cover in Tanzania.

Mwampanba (2007) has constructed eight scenarios for the future of forest in Tanzania. While scanty data prevent attribution of the likelihood of one scenario over another, seven out of eight scenarios predict that more than 1 million ha of forest will be lost annually due to charcoal production in Tanzania from 2007 through 2100 (Mwampamba, 2007). Msuya et al. (2011) predict that forest losses will increase from 105,303 ha in 2009 up to 2.8 million ha total forest lost by 2030 due to charcoal production for DSM alone. Current data on the forest loss from charcoal production is not public available, but national numbers of forest loss in Tanzania have been increasing from 2001 through 2018 (GFW, 2020). Assessing the future implications of this, holds some anticipation as it is based on these scenarios rather than absolutes. Yet, the above scenarios, combined with the prediction that charcoal consumption is increasing (WB, 2010), indicate that the system is not able to sustain the energy needs of future generations. The CSC is therefore contributing to intergenerational inequity as the needs of present generations compromises the ability of future generations to meet their own needs and thus hinder sustainable development as defined by the World Commission on Environment and Development (WCED, 1987).

Additionally, the high rates of forest loss can be linked to current generations' hardship during the rainy season. This linkage can be made, because deforestation leads to global warming through the loss of carbon (CO_2) and other greenhouse gasses (GHG), which would have been otherwise stored in the forests (Fisher et. al., 2011; Lupala et al., 2014; Okoko et. al., 2017). It is estimated that the total CO_2 loss from charcoal supply to DSM will be 49.7 million tons from 2011-2030 in addition to 9,830,000 and 12,478,009 tons of N2O and CH_4 respectively (Msuya et al., 2011). A warmer atmosphere can hold more moisture resulting in increased water vapor and hence increased rainfall (Burch & Harris, 2014). It is predicted that heavy rainfall will increase but be shorter and more severe, which leads to longer dry spells and increased risks of flooding (Burch & Harris, 2014)). Furthermore, deforestation leads to less capacity for water infiltration to soils, thus increasing surface run-off and leading to flooding (Msuya, et al., 2011; Burch & Harris, 2014). It is relevant to note though, that deforestation from charcoal cannot solely be attributed as the cause of climate change and increased rainfall, as multiple other industries cause far higher GHG emissions. However, charcoal production is still a contributor.

5.1.7 Non-transparent and corrupt governmental institutions in the charcoal supply chain

Both the socio-economic and environmental implications of the CSC can be partly attributed to governmental activities, as they can, for example, influence replanting of trees as well as taxing and pricing of charcoal (Malimbwi & Zahabu, 2008). Furthermore, the EJF argues that it is the duty of the state to ensure sustainable resource use. It is therefore relevant to consider the influence that governmental institutions have on the socio-economic and environmental implications.

As was touched upon in section 2, SDC and TFCG's has initiated an initiative to reduce deforestation of wild trees. In Kisarawe, producer 2 (Jan. 28, 2020) encountered the initiative as workshops and free seeds were given to the producers. However, obtaining the seeds is strenuous: "The wild tree seeds are available for free at the district office but the protocol for accessing them is what makes people use the fruit trees" (Producer 2, Jan. 28, 2020). As mentioned in section 2, institutions involved in charcoal initiatives are manifold. When visiting the producers, this complexity was observed as it was necessary to go through four administrative levels. Even as a researcher investigating the institutions in detail, these different levels are a jungle to navigate and show the lack of transparency that the stakeholder inclusion entails.

Furthermore, the government has introduced a "Harvesting Plan" to monitor logging activities (Forest Officer, Jan. 28, 2020). Currently the plan comprises 17 out 79 villages in Kisarawe (Field notes, 2020). Included in the plan are initiatives of replanting and preserving wild trees (Forest Officer, Feb 12, 2020). Producers can obtain permits to log in reserved areas, but the process is yet again strenuous and producers turn to illegal logging or using fruits trees instead (field notes, 2020). As a response to these illegal activities, it was observed that TFS inspects charcoal trucks and confiscates charcoal illegally logged and produced from wild trees (Figure 11). TFS stated that confiscated items are resold on auction to people working within the administrative levels (Field Notes, 2020). Although it was not said out loud, the gatekeeper insinuated that the auctions are corrupt, as TFS profits and the charcoal is sold disproportionately cheaper. Governmental corruption allows for loopholes in regulations and discourages complying to the regulations (Mwampamba, 2007). As an, example, Producer 1 (Jan. 28, 2020) has not paid his taxes since 2018. All in all, non-transparent and corrupt governmental institutions counteract otherwise positive efforts to halt deforestation and therefore adds to the likelihood of forest loss having negative consequences for future generations.

Figure 11. Charcoal checkpoint and confiscation at Tanzania Forest Service Agency in Kisarawe. To the left: charcoal checkpoint. In the middle: confiscated Mpingo. To the right: confiscated charcoal sacks (Photos by author, Jan. 28, 2020).

5.2 Energy injustices in Dar es Salaam caused by the unsustainability of the charcoal supply chain

The previous sections examined people's experiences of socio-economic and environmental implications within the CSC as well as an anticipation of what these implications entail to future generations. Based on these experiences and the anticipation, the following section will discuss whether the identified implications are contributing to or hindering energy justice. Here, the normative competence of sustainability science is applied as the sustainability of the system is assessed based on the EJF.

Resource a*vailability* comes down to the abundance of a region's physical resources needed to sustain the energy service (Sovacool & Dworkin, 2015). Close to DSM, resources for charcoal production are still available, although increasingly less accessible to producers. Charcoal is therefore currently available to sellers and users. However, the results insinuate that wild trees, used for *high quality* charcoal, are becoming less accessible and attractive to replant to producers. Essentially, this leads to less availability of high-quality charcoal for sellers and thereby also users, which goes against energy justice (Sovacool & Dworkin, 2015). Additionally, availability insinuates *robustness* and reliability of the energy service. The system must be able to produce, transport, distribute, and store energy services regardless of unforeseen and foreseen disturbances (Sovacool and Dworkin, 2015). Yet, kilns are difficult to manage when it rains and producers therefore produce less, engage in supplementary livelihood activities, and increase charcoal prices during the rainy season. Lower charcoal availability from producers and difficulties with transport means that sellers correspondingly turn to other activities and increase charcoal prices. Thus, users have difficulties accessing and paying for charcoal during the rainy season.

Despite what has been claimed otherwise, the results indicate that charcoal is not affordable. Sovacool and Dworkin's (2015) define *affordability* as "all people, including the poor, should pay no more than 10 percent of their income for energy services" (p. 440). The results show that charcoal constitutes 40 % of household expenses for domestic cooks and up to 50 % of street cooks' income. Affordability is therefore not fulfilled and is only worsened during the rainy season, meaning that prices are not stable which also contradicts *affordability* (Sovacool & Dworkin, 2015). Charcoal is evidently the cheapest energy source available for cooking in DSM, however, it is not affordable. Linking to this, is lack a of diversification of the energy system. Diversification has not been explicitly articulated during this discussion, but is embedded within EJF as having a diversified energy supply chain as part of *availability* (Sovacool & Dworkin, 2015). The results illustrate lack of diversification of the energy system in DSM because alternative energy sources for cooking are not available and affordable to users.

The results additionally indicate that, according to the EJF definition, the current energy system in DSM is unsustainable. Embedded in *sustainability*, natural resources should not be depleted too rapidly, not cause any undue social and environmental harm, and that future generations can enjoy a good life regardless of the damages caused by current energy systems (Sovacool and Dworkin, 2015). Although trees are still available close to DSM, predictions indicate that the current activities will lead to significant forest loss if production is continued in the future. The consequences are undue harm to the environment and increased rainfall which reduces charcoal affordability and availability, both to current and future generations. Exacerbating this, is the lack of democratic decision-making and transparency, otherwise stated as *good governance* in the EJF (Sovacool and Dworkin, 2015). Various non-transparent institutions which are difficult to navigate, as well as corrupt governance processes hinder efforts of reforesting and illuminating illegal activities in DSMs CSC.

All in all, the socio-economic and environmental implications are complexly intertwined and are hindering energy justice more than they are contributing to it. The environmental implications of the CSC, in the form of deforestation, can be claimed to impact the availability, accessibility, quality, and affordability of charcoal.

Paradoxically, rates of deforestation are negatively affected by the very same socio-economic activities, as continued unsustainable production, distribution, and demand for charcoal will increase forest loss, and then again contribute to the socio-economic implications. Thus, if business as usual continues, this unsustainable system will persist, and become worse, increasing the hardships for current and future generations.

5.3 The future of cooking in Dar es Salaam – sustainable pathways and alternatives

While the findings thus far have indicated many negative socio-economic and environmental implications of the current CSC, there exists potential for improving the system and contributing to more sustainable pathways. In the following, these potentials are discussed through the strategic competence of sustainability science, by considering path-dependencies and potential transitions from one state to another. The analysis focuses on a number of on-going and newly introduced solutions in the form of technological improvements, participatory forest management (PFM)[2], certifications, and alternative cooking fuels.

Many efforts have been done to introduce improved and more robust technology, especially focusing on improved kilns for charcoal production in order to secure availability of charcoal and reduce its environmental impacts. Improved kilns have mainly been researched with the aim of reducing emissions and input of trees needed for kilns (Adam, 2009; Felix & Gheewala, 2011; Malimbwi & Zahabu, 2008). These improvements are positive in terms of the environmental implications, but does not necessarily take into account the socio-economic needs of the people within the CSC. Improved kiln technologies are often expensive for producers to invest in and do not consider the dynamic nature of charcoal production which entails different production sizes dependent on change in wood availability (Malimbwi & Zahabu, 2008). Furthermore, as concluded by Malimbwi & Zahabu kiln efficiency boils down to the type of trees used for the production, as differing hardness of the wood ultimately determines the quality of the charcoal. Part of the technology issue therefore comes down to availability of tree species and thus relates to the environmental sustainability and governance of the CSC.

In terms of improved and more robust technology, which take users into consideration, cooking stoves have been created, tested, and implemented (cf. chapter 1). However, often the stoves are either not adopted by a significant number of users or users end up abandoning them (Makame, 2007; Mwemezi, 2009). Most studies show that this is due to lack of engagement of users in the design and implementation of the stoves. The result is that the stoves do not fit pots and pans owned by users and a lack of trust in the stove robustness (Makame, 2007; Mwemezi, 2009). For these reasons, one study concludes that the improved cooking stoves

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should be seen as alternatives to the existing stoves, rather than an improvement to them (Mwemezi, 2009). The stoves should be produced with consideration of readily available resources in the specific areas (Mwemezi, 2009). Or, that readily available resources should be introduced as energy sources for cooking that fit existing cooking stoves (Mwemezi, 2009; WB, 2010). This speaks for diversification of the energy system; just as Sovacool and Dworkin (2015) and the results of this thesis argue for.

As touched upon earlier, government attempts to include stakeholders have failed. This is despite the fact that PFM is otherwise wide-spread in Tanzania (Lupala, et al., 2014; Mkhai Nawe & Manda., 2018). Mkhai et al. (2018) argue that the biggest problem, when managing forests in Tanzania, is an anthropogenic lack of concern for the forest itself. This lack of concern is also reflected in the interviewed producers' attitude towards wild trees as non-beneficial. Such perspectives need to be taken into account in forest management, but failure to connect with producers hinders successful PFM in Tanzania (Mkhai et al., 2018). In Kenya, PFM has, to some degree, been successful through Charcoal Producer Associations (CPA), which link the government and producers with each other (Wanjiru & Omedo, 2016). Thus, CPA's may be a way to simplify the communication between the administrative levels and the producers in the CSC, to make it easier for producers to express their concerns and in turn for the government to carry out initiatives.

In addition to CPAs, charcoal certification has been established in Kenya. The certificates establish standards for charcoal production and hence secures its quality (Wanjiru & Omedo, 2016). However, certifications run the risk of raising the price for users. The WB (2009) suggests, that standards for charcoal production will integrate the sector better in Tanzania's tax system, yet result in: "the end price to consumers is expected to rise" (p.11). Based on the results of this thesis, charcoal already constitutes a disproportionately large part of users' expenses. Meaning, that although setting standards is promising for reducing environmental impacts and securing high-quality charcoal, it may affect the already lacking affordability of charcoal. Thus, issues of certification showcase that sector focused initiatives risk overseeing effects of the interventions on the remaining part of the CSC.

One solution, which could distribute benefits for people across the entire CSC and diversify the cooking energy system, is biochar, derived from human fecal sludge (sludge) (Diener et al., 2014). In unplanned settlements, like Tandale, there exists a lack of infrastructure for managing sludge which in turn pollutes and spreads diseases (Diener et al., 2014). However, sludge can be turned into bio briquettes using simple, on-site technologies. Fecal sludge is therefore a readily available resource that can be turned into energy (Diener et al., 2014). In Rwanda, Pivot Works is collecting sludge and turning it into biochar pellets for use as energy fuel (Gabrielsson, Myers & Ramasar, 2020). Not only is biochar from Pivot Works cheaper than other biomass fuels (including charcoal), it is also renewable, reliable regardless of the season, and can be produced locally (Gabrielsson et al., 2020). Thus far, Pivot Works has mainly targeted industrial sectors, but other initiatives have successfully implemented biochar intended for domestic cooking (Gabrielsson et al., 2020). In Kenya, Sanivation, a social enterprise, is working with local companies to install container toilets in people's homes, to collect the sludge and turn it into biochar (Sanivation, n.d.). Correspondingly, Slamson Ghana Ltd uses simple technologies to turn sludge into briquettes (Slamson Ghana, n.d.). Users in Ghana's unplanned settlements responded positively to Slamson's briquettes (BBC, 2015). Mainly because they are highly affordable and do not require any cooking stove changes (BBC, 2015). Tests from the SUSTAIN project in DSM also show positive responses from users based on biochar's quality and most importantly because it can be produced at a cost ten times lower than the price of wood charcoal (Peienterprises, n.d.). However, calculations show that to substitute biochar completely for wood charcoal is not feasible (Peienterprises, n.d.). Additionally, biochar development is only in its infancy in Tanzania and much more research and efforts must be made to increase production and use. But biochar still holds promising features as an alternative to charcoal, because of its available robustness, quality and affordability. Furthermore, when promoting alternatives to charcoal it is necessary that initiatives be supported by international institutions, national governmental institutions and/or be introduced in close collaboration with local enterprises, to ensure stakeholder inclusion across the entire CSC. In doing so it could also contribute to a more diversified energy system as sought after in the energy justice discourse.

6 Conclusion

It is engrained in the system that charcoal is dominating the energy system for cooking in SSA and its usage is predicted to increase in urban areas. It is also well-known that charcoal production and usage lead to numerous environmental impacts, such as deforestation and environmental degradation; however, little knowledge exists on its trade-offs to socio-economic implications throughout the supply chain. To fully understand the charcoal system, and thus aid interventions, a systems perspective which considers these trade-offs was needed. This thesis examined and discussed the socio-economic and environmental implications experienced by the people within the CSC of DSM, by utilizing qualitative data collected through interpersonal competences in line with sustainability science. The data was additionally discussed to be deploying the sustainability science competences.

Through systems-thinking it was found that actors experience various implications of the CSC, including: i) producers face reduced *access* to wild trees and thus users struggle with accessing and affording *high-quality* charcoal, ii) producers and sellers struggle with charcoal distribution during the rainy season, thus reducing *availability robustness* to the users, and iii) whilst providing a livelihood for producers and sellers, users use a disproportionately large part of their expenses on charcoal deeming it *unaffordable*. Unlike producers, sellers, and street cooks, who can possibly turn to alternative livelihoods or increase their income in times of hardship, users have no alternative cooking fuels to turn to. Thus, the CSC is not robust nor *diversified*.

It can be anticipated that trade-offs between socio-economic and environmental implications are leading to an unsustainable energy system. Lower availability of wild trees reduces availability of high-quality charcoal to current generations and lead to a deficiency of resources needed to sustain the energy service for future generations. Furthermore, forest loss leads to water runoff and periods of erratic rainfall, thus contributing to the hardships of the rainy season. In turn, as long as the energy system is not diversified, socio-economic activities will continue to increase the environmental implications. From a normative perspective, this means that if business as usual continues, current deforestation trends will result in intergenerational inequity as future generations will suffer from current CSC activities. Moreover, current implications of the CSC constitute an unsustainable system which is neither robust nor diversified and puts intra- and intergenerational equity at risk.

The future of cooking energy for CSC can be assessed by utilizing normative and strategic competences. Numerous promising recommendations exist for the future of cooking in DSM; however, most have proven unsuccessful. Sector-focused solutions such as improved kilns and cooking stoves or implementing PFM are such examples. Instead, diversifying and rethinking the production could have many synergies to the SDGs.

Biochar can, for instance, provide a source of livelihood for producers, sellers and street cooks, as well as being a cheaper alternative to wood charcoal. At the same time, biochar combats forest loss caused by charcoal production and contributes to a more sustainable sanitation supply chain. Thus, it contributes to SDG 6 (clean water and sanitation), SDG 8 (decent work and economic growth), and SDG 13 (climate action). Yet, although biochar can diversify the energy system and provide an affordable and robust alternative to wood charcoal, it should be implemented through inclusive decision-making. Part of the implications happening throughout the CSC can be attributed to the corrupt and non-transparent management and legislation by the different governmental institutions. Therefore, stakeholder-inclusion across the entire CSC is essential to create sustainable energy systems. All efforts are needed to reduce the burning of the woods and preventing the flooding of the slums.

7 References

Adam, J. C. (2009). Improved and more environmentally friendly charcoal production system using a low-cost retort–kiln (Eco-charcoal). Renewable Energy, 34, 1923-1925. doi: 10.1016/j.renene.2008.12.009

Adeniji, O. A., Zaccheaus, O. S., Ojo, B. S., Adedeji, A. S. (2015). Charcoal Production and Producers' Tree Species Preference in Borgu Local Government Area of Niger State, Nigeria. *Journal of Energy Technologies and Policy, 5*(11). Retrieved from https://www.iiste.org/Journals/index.php/JETP/article/view/27191

Anande, D. M & Luhunga, P. M. (2019). Assessment of Socio-Economic Impacts of the December 2011 Flood Event in Dar es Salaam, Tanzania. *Atmospheric and Climate Sciences 9,* 421-437. https://doi.org/10.4236/acs.2019.93029

Bailis, R. (2005). *Fuel from the Savanna: the social and environmental implications of the charcoal trade in sub-Saharan Africa.* [Doctoral Dissertation, University of California, Berkley]. Retrieved from https://www.researchgate.net/publication/35398066_Fuel_from_the_Savanna_the_social_and_environmental_implications_of_the_charcoal_trade_in_sub-Saharan_Africa

BBC (2015, December 1st). COP21: Ghana's green energy gamble on 'poo-power. Retrieved May 6, 2020 from https://www.bbc.com/news/av/world-africa-34802143/cop21-ghana-s-green-energy-gamble-on-poo-power

Bryman, A. (2012). *Social research methods* (4th ed) [Adobe Digital version]. Oxford, UK: Oxford University Press. Retrieved from https://www.researchgate.net/profile/Yousef_Shahwan4/post/What_is_the_best_and_the_most_recent_book_in_medical_research_methodology/attachment/59d6525179197b80779aa90f/AS%3A511717807321088%401499014441133/download/Social+Research+Methods.pdf

Burch S. L & Harris, S. E (2014). *Understanding Climate Change: Science, Policy, and Practice*. Toronto: University of Toronto Press

Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., Jäger, J., & Mitchell, R. B. (2003). Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences, 100*(14), 8086–8091. https://doi.org/10.1073/pnas.1231332100

CIA (2020, March 16). The World Factbook – Africa: Tanzania. Retrieved May , 2020 from https://www.cia.gov/library/publications/the-world-factbook/geos/tz.html

Diener, F., Semiyaga, S. Niwagaba, C., B., Muspratt, A., M., Gning, J. B., Mbéguéré, M., … Strande, L. (2014). A value proposition: Resource recovery from faecal sludge—Can it be the driver for improved sanitation? *Resources, Conservation and Recycling, 88*, 32-38. http://dx.doi.org/10.1016/j.resconrec.2014.04.005

Ellegård, E., Chidumayo, E., Malimbwi, R., Pereira, C. & Ing. Voss, A (2002). *Charcoal Potential in Southern Africa, CHAPOSA* [Final Summary Report, Tanzania.] Retrieved from http://coastalforests.tfcg.org/pubs/Char_Southern_Africa_CHAPOSA.pdf

Felix, M. & Gheewala, H. S. (2011). A Review of Biomass Energy Dependency in Tanzania. *Energy Procedia, 9,* 338-343. https://doi.org/10.1016/j.egypro.2011.09.036

Fisher, B., Lewis, S. L, Burgess N. D., Malimbwi R. E., Munishi P. K., Swetnam, R. D., …Balmford, A. (2011). Implementation and opportunity costs of reducing deforestation and forest degradation in Tanzania. *Nature Climate Change, 1*. DOI: 10.1038/NCLIMATE1119

Flyvbjerg, B. (2004). Five misunderstandings about case-study research. In C. Seale, G. Gobo, J. F. Gubrium, & D. Silverman (Eds.), *Qualitative Research Practice* (pp. 390-404). Thousand Oaks, CA: SAGE Publications.

Flyvbjerg, B. (2011). Case Study. In K. N. Denzin & S. Y. Lincoln (Eds.), *The Sage Handbook of Qualitative Research* (pp. 301-317). Thousand Oaks, CA: SAGE Publications.

Gabrielsson, S., Myers, S. & Ramsar, V. (2020). Linking the Water-Energy-Food Nexus to Sanitation: Will it Save and Improve Lives? In Grover, V. I., & Alfarra, A. (eds.), *Water, Sustainable Development and the Nexus: Response to Climate Change* (pp. 114-133). NW: Taylor & Francis Group

Gerring, J. (2004). What is a case study and what is it good for? *American Political Science Review, 98*(2): 341-354. https://doi.org/10.1017/S0003055404001182

Global Forest Watch (GFB) (2020). Tanzania. Forest Change. Retrieved May 6, 2020 from https://www.globalforestwatch.org/dashboards/country/TZA

Guba, E. G., and Lincoln, Y. S. (1994). Competing Paradigms in Qualitative Research, in N. K. Denzin and Y. S. Lincoln (eds), *Handbook of Qualitative Research* (pp. 105-117). Thousand Oaks, CA: SAGE Publications

Heffron, J., R. & McCauley, D. (2017). The concept of energy justice across the disciplines. *Energy Policy, 105*, 658–667. http://dx.doi.org/10.1016/j.enpol.2017.03.018

IEA, IRENA, UNSD, WB, WHO (2019). *Tracking SDG 7: The Energy Progress Report 2019.* World Bank Publications. Retrieved from https://www.irena.org/publications/2019/May/Tracking-SDG7-The-Energy-Progress-Report-2019

Jerneck, A., Olsson, L., Ness, B., Anderberg, S., Baier, M., Clark, E., …Persson, J. (2011). Structuring Sustainability Science. *Sustainability Science, 6*(1), 69-82. DOI 10.1007/s11625-010-0117-x

Kamberelis, G. & Dimitriadis, G. (2011). Focus Groups: Contingent Articulations of Pedagogy, Politics, and Inquiry. In K. N. Denzin & S. Y. Lincoln (Eds.), *The Sage Handbook of Qualitative Research* (pp. 545-563). Thousand Oaks, CA: SAGE Publications.

Kates, R. W., Clark, W. C, Corell, R., Hall, M. J., Carlo C. C., Lowe, I., … Svedin, U. (2001). Sustainability Science. *Science, 292.* Retrieved May 6, 2020: https://science.sciencemag.org/content/292/5517/641?casa_token=oX9XI7aQyH8AAAAA:Wv-BQt_PZNEC-MXO3w2j8lNf2NnqZQciite3LxDK_TaB8H45LRklIN688HY6wE_qnj_cSwVbweS0lxI

Kvale S. & Brinkman S. (2009). *Interview. Learning the Craft of Qualitative Research Interviewing* (2nd ed). Thousand Oaks, CA: SAGE Publications

Luoga, E. J., Witkowski, E. T. F & Balkwill, K. (2000). Subsistence use of wood products and shifting cultivation within a miombo woodland of eastern Tanzania, with some notes on commercial uses. *South African Journal of Botany, 66*(1), 72-85. https://doi.org/10.1016/S0254-6299(15)31053-X

Lupala, Z. J., Lusambo, L. P., & Ngaga, Y. M. (2014). Management, Growth, and Carbon Storage in Miombo Woodlands of Tanzania. *International Journal of Forestry Research*, 1–11. https://doi.org/10.1155/2014/629317

Makame, O. M. (2007). Adoption of Improved Stoves and Deforestation in Zanzibar. *Management of Environmental Quality: An International Journal 18*, (3), 353–365. https://doi.org/10.1108/14777830710731798

Malimbwi, R. E. & Zahabu, E. M. (2008). *Woodlands and the charcoal trade: The case of Dar es Salaam City*. (Working Papers of the Finnish Forest Research Institute 98: 93–114). Retrieved May 6th, 2020: http://www.metla.fi/julkaisut/workingpapers/2008/mwp098-12.pdf

Mkhai, E. M., Naw, J. & Manda, P. A. (2018). Use of Participatory Forest Management as a Strategy for Sustainability of Kazimzumbwi and Pugu Forest Reserves, Tanzania. *University of Dar es Salaam Library Journal*, *12* (1). Retrieved from https://www.ajol.info/index.php/udslj/article/view/164193

Msuya, N., Masanja, E., & Temu, A. K. (2011). Environmental Burden of Charcoal Production and Use in Dar es Salaam, Tanzania. *Journal of Environmental Protection, 2,* 1364-1369. doi:10.4236/jep.2011.210158

Munro, P., Horst, G. & Healy, S. (2017). Energy Justice for All? Rethinking Sustainable Development Goal 7 through Struggles over Traditional Energy Practices in Sierra Leone. *Energy Policy, 105*, 635–641. https://doi.org/10.1016/j.enpol.2017.01.038

Mwampamba, T. H. (2007). Has the woodfuel crisis returned? Urban charcoal consumption in Tanzania and its implications to present and future forest availability. *Energy Policy*, *35*(8), 4221–4234. https://doi.org/10.1016/j.enpol.2007.02.010

Mwemezi, R. (2009). *Innovations and Sustainability: The Case of Improved Biomass Stoves' Adoption and Use in Tanzania.* [Master's Thesis, LUMES, Lund University, Sweden]. Retrieved from https://www.researchgate.net/publication/323605188_Innovations_and_Sustainability_The_Case_of_Improved_Biomass_Stoves'_Adoption_and_Use_in_Tanzania

National Bureau of Statistics, Tanzania (NBS) (2012). *2012 POPULATION AND HOUSING CENSUS. Population Distribution by Administrative Areas*. Retrieved from http://www.tzdpg.or.tz/fileadmin/documents/dpg_internal/dpg_working_groups_clusters/cluster_2/water/WSDP/Background_information/2012_Census_General_Report.pdf

National Bureau of Statistics, Tanzania (NBS) (2017). *National Environment Statistics Report, 2017 Tanzania Mainland*. Retrieved from https://unstats.un.org/unsd/environment/Compendia/United%20Republic%20of%20Tanzania,%20National%20Environment%20Statistics%20Report,%202017.pdf

Okoko A., Reinhard, J. Wymann, D. S., Zah, R., Kiteme, B., Owuor S. & Ehrensperger, A. (2017). The carbon footprints of alternative value chains for biomass energy for cooking in Kenya and Tanzania. *Sustainable Energy Technologies and Assessments 22,* 124–133. http://dx.doi.org/10.1016/j.seta.2017.02.017

Partelow, S., & Boda, C. (2015). A modified diagnostic social-ecological system framework for lobster fisheries: Case implementation and sustainability assessment in Southern California. *Ocean & Coastal Management 114*, 204-217. http://dx.doi.org/10.1016/j.ocecoaman.2015.06.022

Peienterprises (n.d.). Faecal Sludge Management in Dar es Salaam, Tanzania (FSM-DT). Retrieved from http://www.peienterprises.co.tz/project/1

Prosser, J. (2011). Visual Methodology: Towards a More Seeing Research. In K. N. Denzin & S. Y. Lincoln (Eds.), *The Sage Handbook of Qualitative Research* (pp. 479-497). Thousand Oaks, CA: SAGE Publications.

Ramadhani, S. H. (2007). *Effect of Tenure Regularization Programme on Building Investment in Manzese Ward in Dar es Salaam, Tanzania.* [Master's Thesis, International Institute for Geo-information Science and Earth Observation Enschede, The Netherlands]. Retrieved from https://webapps.itc.utwente.nl/librarywww/papers_2007/msc/upla/ramadhani.pdf

Rosen, J. W. (2019). This Tanzania City may soon be one of the world's most populous. Is it ready? *National Geographic*. Retrieved May 6, 2020 from https://www.nationalgeographic.com/environment/2019/04/tanzanian-city-may-soon-be-one-of-the-worlds-most-populous/

Sander, K., Gros, C. & Peter, C. (2013). Enabling reforms: Analyzing the political economy of the charcoal sector in Tanzania. *Energy for Sustainable Development, 17,* 116-126. http://dx.doi.org/10.1016/j.esd.2012.11.005

Sanga, G. A. & Januzzi, G. D. M., (2005). *Impacts of efficient stoves and cooking fuel substitution in family expenditures of urban households in Dar es Salaam, Tanzania*. (Campinas, SP: Energy Discussion Paper2.59.1 (05)). DOI: 10.13140/RG.2.2.12979.12320

Sanivation (n.d.). Sanitation as a service. Retrieved May 6, 2020 from https://www.sanivation.com/

Slamson Ghana (n.d.). Resource Recovery. Retrieved May 6, 2020 from https://www.slamsonghana.com/resource-recovery

Sola, P., Cerutti, P. O., Zhou, W., Gautier, D., Iiyama, M., Schure, J., Chenevoy, A., Yila, J., Dufe, V., Nasi, R., Petrokofsky, G., & Shepherd, G. (2017). The environmental, socioeconomic, and health impacts of woodfuel value chains in Sub-Saharan Africa: A systematic map. *Environmental Evidence*, *6*(1), 4. https://doi.org/10.1186/s13750-017-0082-2

Sovacool, B. K., & Dworkin, M. H. (2015). Energy justice: Conceptual insights and practical applications. *Applied Energy*, *142*, 435–444. https://doi.org/10.1016/j.apenergy.2015.01.002

Swiss Agency for Development and Cooperation (SDC) & Tanzania Forest Conservation Group (TFCG) (2018). *Transforming Tanzania's Charcoal Sector.* [Brochure]. Retrieved from http://www.tfcg.org/wp-content/uploads/2018/06/TTCSLeaflet2018FINALEnglish.pdf

Swiss Agency for Development and Cooportation (SDC) & Tanzania Forest Conservations Group (TFCG) (2017). *Reducing Deforestation: 5 Recommendations for the National Forest Policy*. [Information Note]. Retrieved from http://www.tfcg.org/wp-content/uploads/2018/06/TTCSReducingDeforestationRecommendations2017.pdf

Tanzania Forest Services Agency (TFS) (2015). *NFORMA National Forest Resource Monitoring and Assessment of Tanzania Mainland. Main Results. The United Republic of Tanzania*. Retrieved from http://www.fao.org/forestry/43612-09cf2f02c20b55c1c00569e679197dcde.pdf

Thualagant, N. (2016). Kontekstualiserede casestudier [Contextualized case studies]. In C. J. Kristensen & Hussain, A., M. (Eds), *Metoder i Samfundsvidenskab* [Methods in Social Science] (pp.317-329). Frederiksberg, Samfundslitteratur

Wanjiru, H. & Odera, G. (2016). *How Kenya can transform the charcoal sector and create new opportunities for low-carbon rural development.* Swedish Environmental Institute [SEI] & United Nations Development Programme [UNDP]. Retrieved from https://www.sei.org/publications/kenya-charcoal-sector/

Wiek, A., Withycombe, L., & Redman, C. L. (2011). Key competencies in sustainability: A reference framework for academic program development. *Sustainability Science*, *6*(2), 203–218. https://doi.org/10.1007/s11625-011-0132-6

World Bank (2018b). Nigeria. Retrieved May 6, 2020 from https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=NG

World Bank (WB) (2009). *Environmental Crisis or Sustainable Development Opportunity? Transforming the charcoal sector in Tanzania*. Retrieved from http://documents.worldbank.org/curated/en/610491468122077612/pdf/502070WP0Polic1BOx0342042B01PUBLIC1.pdf

World Bank (WB) (2010). *Enabling Reforms: A Stakeholder-Based Analysis of the Political Economy of Tanzania's Charcoal Sector and the Poverty and Social Impacts of Proposed Reforms.* Retrieved from http://documents.worldbank.org/curated/en/998871468246037505/pdf/551400ESW0P1201PE1Charcoal1TZ1FINAL.pdf

World Bank (WB) (2018a). Tanzania. Retrieved May 6, 2020 from https://data.worldbank.org/country/tanzania

World Commission on Environment and Development (WCED) (1987) *Our common* future*.* Retrieved from https://www.are.admin.ch/are/en/home/sustainable-development/international-cooperation/2030agenda/un-_-milestones-in-sustainable-development/1987--brundtland-report.html

Yardley, L. (2000). Dilemmas in Qualitative Health Research*. Psychology and Health, 15*(2), 215 –28. DOI: 10.1080/08870440008400302

Zulu, L., & Richardson, R. (2013). Charcoal, livelihoods, and poverty reduction: Evidence from sub-Saharan Africa. *Energy for Sustainable Development*, *17*, 127–137. https://doi.org/10.1016/j.esd.2012.07.007

8 Appendices

8.1 Appendix A. Case study areas

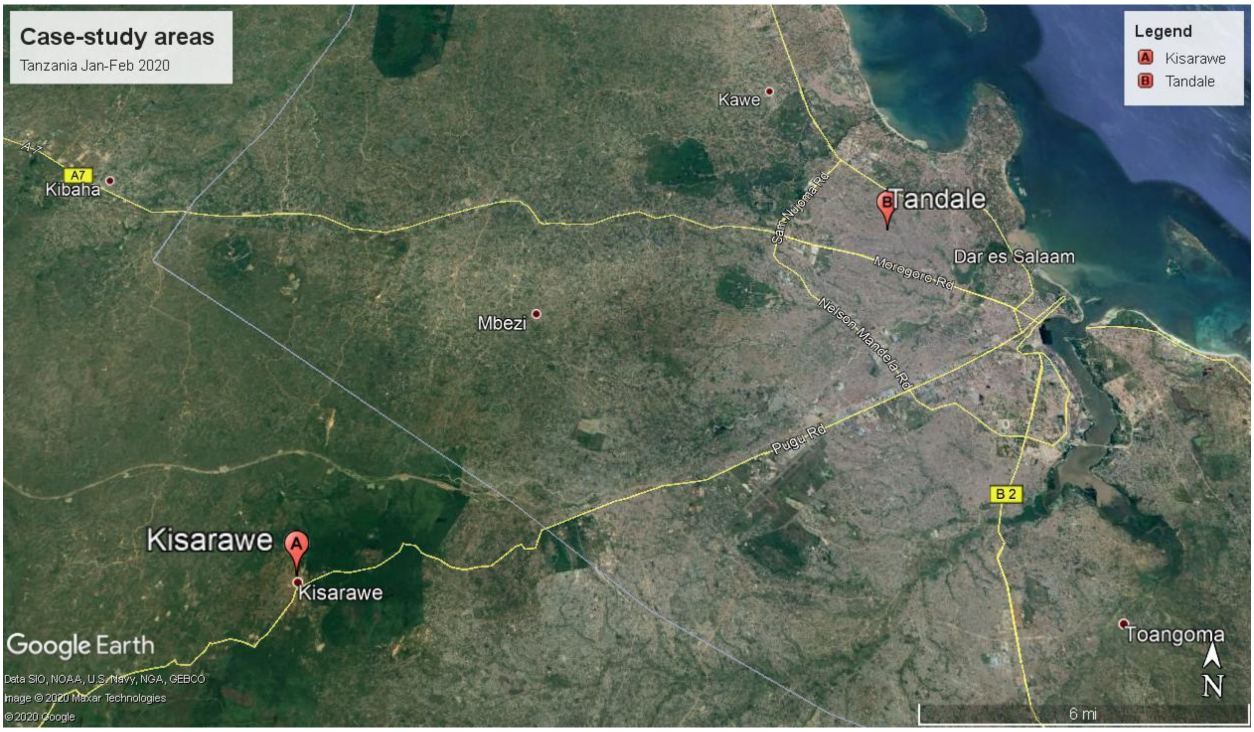

Figure A1. Case study areas: A) Charcoal production area, Kisarawe district in the Pwani region 40 km southwest of Dar es Salaam and B) Unplanned settlement, Tandale ward in Kinodoni district in Dar es Salaam region.

8.2 Appendix B. Interview guides

Table B1. Interview guide FGDs: domestic cooks and street cooks in Tandale

interview guide FGDs	
Introduction	Hello, I'm Laura and this is Petro and Sara. Petro will translate for me and Sara is here to observe, but may add question. We are currently working on a project that assess wood charcoal and its alternative energy sources. This session will therefore focus on how all of you experience wood charcoal use in terms of a range of factors as well as your own inputs. Everyone should feel free and comfortable to speak, but it is important to try and only speak one at a time. The session is recorded in order to remember what has been said. Everything will be translated into English and written down. We will ensure anonymity, i.e. no names will be mentioned, and the sound files will not be used for anything but translating. Do you have any questions before we begin?
Opening questions	*Is wood charcoal your main source of energy used for cooking?* *(depending on how the discussion goes - Why/why not?)*
Quality	*Are there different types of charcoal to choose from?* - *What kind of wood charcoal do you prefer? And why?*
Affordability	*What do you think about the price of wood charcoal?* - *How much charcoal do you buy at a time?* - *How long will that last you?* - *How much do you pay for it?* - *How much do you use on charcoal compared to other monthly expenses? /How much of your business' profit is used on the charcoal?*
	Does the price ever change - If yes: - *When* - *Why* - *How much?*
Availability	*Is wood charcoal always available to you?* *(depending on how the discussion goes - If no, when not? And what do you do then?)*
Accessibility	*How easy is it for you to access wood charcoal?* - *Is it available within your street?* - *Do you have to pay anything to access it?*

Round up	*Do you have anything else to add?* Alright, thank you so much for your participation!

Table B2. Interview guide SSIs with sellers in Tandale

interview guide Sellers	
Introduction	Hello, I'm Laura and this is Petro. I am a Danish student working together with students from the University of Dar es Salaam. Petro is one of them, and he will be translating for me today. We are currently working on a project that assess wood charcoal and its alternative energy sources. This session will therefore focus on how you experience wood charcoal use in terms of a range of factors as well as your own inputs. The session is recorded in order to remember what has been said. Everything will be translated into English and written down. We will ensure anonymity, i.e. no names will ever be mentioned, and the sound files will not be used for anything but translating. Do you have any questions before we begin?
Opening questions To ease in the conversation and get a bit of background knowledge	*How did you start working as seller?* *For how many years have you worked as a seller?*
Socioeconomic Affordability, availability, accessibility	*Is this your main source of income?* - *If no, what else do you do?*
	How many sacks/buckets of charcoal do you typically sell per day? - *How much profit do you get per sacks/bucket?* - *Do prices change?* - *If yes, for what reason* - *If yes, how much?*
	Where do you get your charcoal from? - *Why?* - *Do prices differ depending on where you get it from?* - *How often do you get it?* *Do you transport the charcoal yourself?* - *If no, who does?* - *If yes, how?*
	Who are your costumers usually?

	Do you face any challenges, in the charcoal business?
Environmental Quality & sustainability	*Do you sell different kinds of charcoal?* - *If yes, what types?* - *What types are preferred by your customers?* - *Do you change price depending on the type?*
	Is charcoal always available? - *If no, when not? And what do you do* - *Do you have to pay more in the rainy season?* - *If yes, how do you tackle that?*

Table B3. Interview guide SSIs with producers in Kisarawe

Interview guide Producers	
Introduction	Hello, I'm Laura and this is Petro. I am a Danish student working together with students from the University of Dar es Salaam. Petro is one of them, and he will be translating for me today. We are currently working on a project that assess wood charcoal and its alternative energy sources. This session will therefore focus on how you experience wood charcoal use in terms of a range of factors as well as your own inputs. The session is recorded in order to remember what has been said. Everything will be translated into English and written down. We will ensure anonymity, i.e. no names will ever be mentioned, and the sound files will not be used for anything but translating. Do you have any questions before we begin?
Opening questions To ease in the conversation and get a bit of background knowledge	*How did you get into working with charcoal in the first place?* *For how many years have you done it?*
Socioeconomic (affordability)	*Is this your main source of income?* - *If no, what else do you do?*
	How many bags do you produce per week? - *What is the cost of producing one sack?* - *How much profit do you get from it?* - *What do you make per week/month?*
	Do prices change?

	- *If yes, for what reason* - *If yes, how much?*
	How is charcoal transported? - *Who pays for the cost?* - *If you do, how much do you typically pay?* - *Do prices change? And why?*
	Are there any female charcoal producers? - *Why/why not?*
Environmental and technical Tree type (quality, availability and accessibility) related to demands	*What types of tree do you usually use?* - *Why?* - *Are there differences in demand depending on buyers?* - *Do you change price depending on the type?*
	Does the type of tree affect the production of the charcoal? - *E.g. does the charcoal take longer or shorter time to produce depending on the tree type?*
	How do you process your charcoal? - *Are there challenges with production?* - *If yes, what are they?*

	Do you cut down the trees for your charcoal yourself?
	- *Where do you get trees from?*
	    o *Is it a wild forest? Or a "man-made" forest?*
	- *What happens after you take down the trees?*
	    o *Do you replant them?*
	    o *If no, does someone else?*
	    o *If yes, what kind of trees are replanted? The same kind?*
	    o *Why/why not?*

	Do you produce charcoal throughout the year? - *If not, what do you do when you do not produce charcoal?* - *Do you move depending on the availability of trees?*

Table B4. Interview guide KII with the Forest Officer of Kisarawe

<table>
<tr><th colspan="2">Interview guide Forest Officer</th></tr>
<tr><td>Introduction</td><td>So, we just want to know a bit more about some specific things concerning regulations and producers who are producing illegally, since we mostly talked about the ones who are in it and since we cannot go and talk with them ourselves.</td></tr>
<tr><td>General on producers
To clarify a few things</td><td>What is the average size of producers – would you say most produce at the same level as the ones we interviewed?
- Are those the most common type of producers?
o If not, what type is?</td></tr>
<tr><td rowspan="3">On Illegal activities
How are they tackled? How do they attempt to be included? (Good Governance)</td><td>How many illegal producers do you estimate that there is?
- Where do you frequently find illegally produce of charcoal?
- Are these areas within the TFS regulated areas?</td></tr>
<tr><td>Do you have any monitoring on them, in terms of how much tree they cut, plant and sell?
- Which types?</td></tr>
<tr><td>Are you currently trying to make them become part of legal production initiatives?
- What incentives are there for the producers to become part of them?</td></tr>
<tr><td>On governmental activities
(Good Governance)</td><td>Last time we talked you mentioned that the revenue from charcoal production is around 2-3 billion TZS. Who gets that revenue? How?</td></tr>
</table>

8.3 Appendix C. Participant characteristics FGDs and SSIs

Table C1. Overview of FGD participants in group 1: domestic cooks.

Interview ID	Location	Cooking fuel used	Household size	Gender
Domestic cook 1	Tandale	Charcoal and gas	1	Female
Domestic cook 2	Tandale	Charcoal	2, no children	Female
Domestic cook 3	Tandale	Charcoal	Family with 3 or more children	Female
Domestic cook 4	Tandale	Charcoal	Family with 3 or more children	Female
Domestic cook 5	Tandale	Charcoal	2, no children	Female
Domestic cook 6	Tandale	Charcoal	Family with 3 or more children	Female

Table C2. Overview of FGD participants in group 2: street cooks.

Interview ID	Location	Cooking fuel used	Years of experience	Gender
Street cook 1	Tandale	Charcoal	5 years	Female
Street cook 2	Tandale	Charcoal	3 years	Female
Street cook 3	Tandale	Charcoal	3 years	Female
Street cook 4	Tandale	Charcoal	10 years	Female

Table C3. Overview of SSI participants: sellers and producers

Interview ID	Location	Business type	Gender
Producer 1	Kisarawe	Small-scale family business. Produces with his wife and has no employees.	Male
Producer 2	Kisarawe	Small-scale family business. Produces with his wife and has no employees.	Male
Seller 1	Tandale	Big-scale family business. Two major stores run by him and his wife as well as several minor stores run by employees	Male
Seller 2	Tandale	Big-scale business. One major store and several minor stores run by employees	Male