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Urban Improved Cookstove Adoption

A study in Tanzanian urban areas

Master's Thesis in Sustainable Energy Systems

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Gothenburg, Sweden, 2015

MASTER'S THESIS 2015

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ABSTRACT

Cooking with biomass on inefficient cookstoves is done by 96% of the households in Tanzania. This implies a waste of resource due to the very low energy conversion efficiency of cooking with the traditional cookstoves, and has negative impacts on the human health and the environment. To reduce these negative impacts and increase the efficiency of cooking, *improved cookstoves* (ICS) have been promoted during the last decades. ICS use less fuel and emit less smoke for the cooking of a certain amount of food compared to traditional cookstoves. Unfortunately, past projects and programmes promoting ICS adoption have had limited success.

The main purpose of this study is to identify and investigate key drivers and barriers for ICS adoption in urban areas in Tanzania. The study is based on interviews with stakeholders and households conducted during an 8-week field study in the two Tanzanian cities Dar es Salaam and Moshi. The study also includes a comparison of the perceived drivers and barriers between households and stakeholders. The second purpose of the study is to perform a market survey to collect data about the stoves and the fuel prices on the Tanzanian market. With this data a compilation of the stove models could be made and also a comparison between the models different financial performance.

From the interviews it was found that the financial performance of the cookstoves is very important for the consumers in their choice of cookstove. The *decreased fuel consumption* and thereby the reduced cost of fuel is one of the key drivers for ICS adoption, while *high investment cost* is one of the key barriers. The two other key drivers found in the study are *time-savings* and *less smoke* (improved health). Another major finding from the interviews is that most households complain about the poor quality of ICS, forming one barrier for ICS adoption. The barrier *poor quality* becomes especially critical because most households refer to low quality ICS when they think of ICS in general, and are not aware of the existence of several ICS models and the difference between them.

One way to reduce or eliminate the barriers is to introduce a system with standards which would help to improve the quality of the ICS models and also facilitate the consumers' choice of cookstove. Another way is to strengthen the role of the government in the development of the market for ICS.

Keywords: improved cookstove, charcoal, adoption, driver, barrier

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SAMMANFATTNING

Matlagning på ineffektiva spisar med biomassa som bränsle används av 96% av hushållen i Tanzania. Det utgör ett slöseri med resurser på grund av den låga verkningsgraden av att laga mat på det här sättet, och har dessutom en negativ inverkan på människors hälsa och på miljön. För att minska den negativa inverkan på hälsa och miljö har effektiva spisar (ICS) promotats under de senaste decennierna för att öka effektiviteten av matlagning. De effektivare spisarna använder mindre bränsle och avger mindre rök jämfört med de traditionella spisarna. Tyvärr har de tidigare projekten och programmen som genomförts med syfte att öka användandet av ICS haft begränsad framgång.

Huvudsyftet syftet med studien är att identifiera och undersöka drivkrafter och barriärer för att öka användandet av effektivare spisar i stadsmiljö i Tanzania. Studien baseras på intervjuer med aktörer och hushåll genomförda under en 8-veckors fältstudie i de två tanzaniska städerna Dar es Salaam och Moshi. Studien innehåller även en jämförelse av de upplevda drivkrafterna och barriärena mellan hushåll och aktörer. Det andra syftet med studien är att utföra en marknadsundersökning för att samla in uppgifter om spisarna och bräsnlepriser på den tanzanianska marknaden. Med de uppgifterna kunde en sammanställning göras av spisarna och också en jämförelse av skillnaderna för de olika modellernas kostnadseffektivitet.

Från intervjuerna konstaterades det att den ekonomiska prestandan av spisarna är mycket viktig för konsumenterna i deras val av spis. Den *minskade bränsleåtgången* och därmed den reducerade kostnaden för bränsle utgör en viktig drivkraft för ökad användning av effektivare spisar, medan den *höga investeringskostnaden* utgör en barriär. De två andra viktiga drivkrafterna som identifierades i studien är *tidsbesparing* och *mindre rök* (förbättrad hälsa). En annan viktig slutsats från intervjuerna är att de flesta hushåll klagar på den låga kvaliteten på de effektivare spisarna, vilket utgör ytterligare en barriär för ökad användning av effektivare spisar. Barriären med *låg kvalitet* blir extra stor på grund av att de flesta hushållen refererar till effektivare spisar av låg kvalitet när de tänker på effektivare spisar, och är inte medvetna om att det finns flera olika modeller av effektivare spisar samt skillnaderna emellan dem.

Ett sätt att reducera eller eliminera barriärerna är att introducera ett system med standarder vilket skulle hjälpa till att öka kvaliteten på de effektivare spisarna och att underlätta konsumenternas val av spis. Ett annat sätt är att stärka myndighetens roll i utvecklingen av marknaden för effektivare spisar.

Nyckelord: effektiva spisar, träkol, drivkraft, barriär

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We want to send a great thanks to all people who have helped us during this thesis; without you it would not been easy to conduct this project. Great thanks also to the Swedish Council for Higher Education for the financial support, through the MFS-scholarship, which made it possible for us to perform the field study. We want to thank our examiner Erik Ahlgren for his patient support and guidance throughout the thesis, and Lennart Bångens for his support and expertise during the field study in Tanzania as well as in the preparatory work. Thanks also to Niklas Vahlne for information about the cookstoves and the issues related to them. Further, we want to thank all participants in the interviews and questionnaires during the fieldwork for their willingness to answer our questions, Sylvester Kwiyega and Alex Matei for their help during the start-up in Tanzania, and Prakseda, Yona Mshana and Linus Mtenga who helped us interpret.

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Christoffer Johnsson
Louise Lund

June 2015, Gothenburg

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ACRONYMS

BC	Black Carbon
GHG	Greenhouse Gas
IAP	Indoor Air Pollution
ICS	Improved Cookstove
ISO	International Organization for Standardization
IWA	International Workshop Agreements
KCJ	Kenya Ceramic Jiko
KPT	Kitchen Performance Test
LPG	Liquefied Petroleum Gas
MDG	Millennium Development Goal
NGO	Non-Governmental Organization
PM	Particular Matter
TSF	Three-stone Fire
WBT	Water Boiling Test

The exchange rate used in the report is $1\text{USD} = 1800$ TSh (February 6, 2015).

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1. INTRODUCTION

Biomass fuels used for cooking on inefficient cookstoves are still the most common way of cooking in developing countries. In this case study Tanzania will be used as reference, where the percentage of the population using biomass fuels for cooking is 96% (Global Alliance for Clean Cookstoves, 2014a). The main used fuels are firewood (77.6%), charcoal (19%) and kerosene (2.3%), and only a minor part of the fuels (1.1%) comes from gas, electricity and other solid fuels. Cooking with biofuels stands for 68.22% of the total energy consumption in Tanzania (International Energy Agency [IEA], 2012). The wide use of biofuels for cooking, along with the very low energy conversion efficiency of cooking with inefficient cookstoves, implies that a lot of resources could potentially be saved by increasing the overall efficiency.

The low energy conversion efficiency related to cooking with inefficient cookstoves directly correlates with the high Indoor Air Pollution (IAP) occurring in developing countries, which leads to severe health impacts. IAP is the fifth biggest health risk in the developing world (Global Alliance for Clean Cookstoves, 2014b) and contributes to premature death for over 4 million people a year (Lambe et al., 2014) (Global Alliance for Clean Cookstoves, 2014b) (World Health Organization [WHO], 2014). Among these are 12% due to pneumonia, 34% from stroke, 26% from ischemic heart disease, 22% from chronic obstructive pulmonary disease (COPD) and 6% from lung cancer (WHO, 2014). Further, the links between household air pollution and tuberculosis, cataract, nasopharyngeal, laryngeal cancers, low birth weight and the amount of stillbirths (Pope et al., 2010) have been proved and evidences are found. All these health effects are affecting women and small children to a larger extent compared to men and children attending school or work, due to the time they are exposed to the smoke (Martin et al., 2013).

In rural areas, the use of biofuels for cooking with inefficient cookstoves requires a lot of time for gathering fuel. This forces especially women and children to household related work instead of education or working with activities that provide income (Sommer et al., 2014) (Lewis & Pattanayak, 2012). The fuel gathering is also a risk for women's personal safety as they have to walk long distances to reach areas where fuel can be gathered (Global Alliance for Clean Cookstoves, 2013), and thus exposing themselves for the potential risk of assault, rape etc. This problem is not that big in urban areas, where the majority of the population uses charcoal which they buy close to their home.

The wide use of biofuels for cooking and the low energy conversion efficiency of cooking over open fire and inefficient stoves contribute to negative effects on the local and global environment. The local effects are degradation of forests (Hofstad et al., 2009) (Köhlin et al., 2011), damaging for ecosystems (wildlife), deforestation (Geist & Lambin, 2001) and erosion (United Nations Framework Convention on Climate Change [UNFCCC], 2011), while the global environmental effects are all those caused by the increased level of greenhouse gas (GHG) emissions in the atmosphere (Sagar & Kartha, 2007).

The negative aspects of woodfuel based cooking show that there are areas where improvements are possible. Increasing the energy conversion efficiency of the cookstove leads to: decreased IAP, decreased deforestation, time-savings and increased gender equality, which all are included

in the Millennium Development Goals (MDGs) (WHO, 2014). Using clean household energy supports MDG 7: *ensure environmental sustainability*. In particular does the work with clean household energy help to achieve MDG 4: *reduce child mortality*, and MDG 5: *improved maternal health.* Further, it will contribute to *gender equality* (MDG 3) and *eradicate extreme poverty and hunger* (MDG 1) due to that less time is needed for fuel gathering and women can instead spend time to activities generating income.

In order to work towards the MDGs through better stoves, improved cookstoves (ICS) have been promoted during the last decades (Martin et al., 2013). The ICS have, compared to the traditional cookstoves, an improved combustion process in terms of higher conversion efficiency and reduced emissions, as well as a higher level of safety regarding burn injuries (Amosy et al., 2010). There are a number of very different ICS; from some very simple designs providing only moderate improvements of both conversion efficiency and emissions to advance designs based on fuel gasification. ICS designs that reduce the fuel consumption by 50-60%, compared to the three-stone fire (TSF) used in most of Tanzania's households today, are common (Sommer et al., 2014) (Swedish Energy Agency, 2014). However, some ICS are claimed to reduce the fuel consumption with up to 80% (ARTI Energy, 2014). The emissions and time for cooking can be reduced by up to 80-90% and 50% compared to the TSF respectively (ARTI Energy, 2014).

Various programs have been implemented in several developing countries to increase the adoption rates of ICS. In the past, ICS have mainly been promoted and distributed in poor rural areas. The success of the programmes as well as the success of commercial markets has been very limited, and often ICS that were distributed for free have been abandoned. In Tanzania, only 1% of the population use an ICS (Global Alliance for Clean Cookstoves, 2014a). One probable reason to the low deployment success in rural areas is the lack of monetary gains since the fuel is gathered for free. There is of course also a relation between design and price. For rural applications, since price is an important factor, simple designs have often been chosen.

In urban areas of Tanzania, the fuel is normally bought and the stove utilization therefore leads to direct monetary gains. This can make the promotion of the ICS in urban areas more effective, although most people do not seem aware of these gains. Recently, due to increasing charcoal prices, it seems like ICS adoption rates in urban areas (primarily Dar es Salaam) are sharply increasing. New market actors have shown interest in entering into the market. Thus, it is an opportune time for studies of market development, drivers and barriers for ICS adoption, and of factors that determines the choice of cookstove.

1.1 Aim of study

The study comprises two objectives. The purpose of the first is to identify and address key drivers and barriers for ICS adoption in urban areas in Tanzania, and investigate how these influence the adoption rate.

To achieve the goal of the main objective, the following questions are investigated:

What are the consumers' and stakeholders' views of drivers and barriers for ICS adoption in urban areas compared to using the traditional cookstoves they already have? How are the different drivers and barriers weighted, and how coherent are they between households and stakeholders?

The second objective is to perform a market survey to collect data about the stoves and fuel prices on the Tanzanian market.

1.2 Expected results

It is easy to think that adaption of a new technology mainly depends on its costs and economic benefits/drawbacks. But since there have been several projects where ICSs have been distributed freely without any success in adoption rate, it is expected that there are other drivers/barriers than the economy that are crucial for the adoption. Such drivers can be improved health, time-savings and better safety, while possible barriers are culture, availability, knowledge, learning and missed functions.

1.3 Limitation of study

The study will focus on urban areas in Tanzania, primarily Dar es Salaam and Moshi. The limited time for the study will not enable collection of enough material to make the analysis statistically significant. The study will focus on ICS using firewood and charcoal as fuel. More advanced cookstoves driven by gas or electricity are rarely used and therefore not included in the study.

1.4 Disposition of thesis

The method for the study is described in Chapter 2 *Method*. To better understand the context of the study, Chapter 3 *Background* provides basic information relevant for the study. In Chapter 4 *Literature study of drivers and barriers,* drivers and barriers found in previous projects for ICS adoption are described. Chapter 5 *Cookstoves* presents the collected data for the different models included in the study and the issue of standardization. In Chapter 6 *Result*, the major findings from the field study regarding ICS adoption are presented. The analysis of the collected material is presented Chapter 7 *Analysis*. Some strengths and weaknesses with this thesis, as well as the thesis relevance in relation to previous studies and for future studies are discussed in Chapter 8 *Discussion*. The following chapter, *Conclusion*, present a short summary of the main results.

2. METHOD

The study is based on literature and interviews/questionnaires with stakeholders and with various types of households (both who have and have not yet adopted ICS). The literature study were performed to obtain knowledge about the subject and to identify a potential area for research, which became the comparison between households and stakeholders and the market survey as a knowledge gap existed there. It was also performed in order to plan the data collection and enable a comparison with our findings. The reasons to include both stakeholders and households are to get a broader view of the subject and to see how and on what arguments information from different perspectives is consistent or differ.

The study is carried out using Tanzania as a reference country and the field study is conducted in the two Tanzanian cities Dar es Salaam and Moshi. Tanzania was chosen because of the good collaboration between SIDA (Swedish International Development Cooperation Agency), Chalmers and Tanzania which provided valuable contacts for the study. Also, Tanzania represent one of the developing countries where the problems with inefficient cookstoves are large and where the work with ICS adoption has been going on for several decades without successful dissemination of ICS. Dar es Salaam was chosen because most of the key stakeholders' head offices are located there and also because it represents a large city, while Moshi was chosen because of its smaller size and thereby enable to see if the data is consistent between a larger and a smaller city.

2.1 Method for collection of data

To collect data for the study, interviews with key stakeholders and households were done during February-April 2015. The respondents of key stakeholders include governmental organizations, NGOs (Non-Governmental Organizations), producers, retailers and sellers. Contact information for some of the stakeholders were provided by personal contacts, while the rest of the stakeholder contacts were found through internet research, reading reports and articles, and by attending meetings during the field study in Tanzania. The household respondents were found through visiting selected areas where most people had a low-medium income. In each area, about 5-6 households were interviewed.

Most of the interviews with stakeholders were held in English. Three interviews were held in Swahili; one with a retailer of ARTI Energy selling Envirofit cookstoves, one with the workshop for TaTEDO selling Jiko Bora and one with a seller on Makumbusho market in Dar es Salaam selling locally made counterfeit Jiko Bora of low quality (for more information about the retailers see Appendix I). For the interviews hold in Swahili, an interpreter translated the interviews between English and Swahili. All of the interviews with households were hold in Swahili and also for these interviews an interpreter translated into English.

For the interviews with stakeholders a set of prepared open-ended questions were used (see *Table 1* below), i.e. the interviews were semi-structured. The questions were designed to be open-ended in order to both gain understanding about the current situation in Tanzania and to have an open discussion about their perceived drivers and barriers. For some interviews, the questions were modified to suit the respondent. Even though the questions were prepared before the beginning of the field study, the questions were allowed to change during the field study in order to enable improvements as we learnt more about the subject. The key point in the

interviews with the stakeholders was to find which drivers and barriers for ICS adoption the stakeholders see. The stakeholders were also given questions about their work with ICS (past and ongoing projects), their thoughts about future development and what they think are important for the consumers. For the stakeholders who produce and/or sell ICS, also questions about the particular model were asked (model, price, efficiency, lifespan, fuel savings etc), as well as questions about positive and negative feedback given by the consumers, market competitors and what factors determine the consumers choice of cookstove model.

Table 1 ***Interview questions for the stakeholders.*** The table presents the questions given to the stakeholders. The first part of the table presents the interview questions given to all the stakeholders, whilst the second part presents the additional questions given to stakeholders who produces and/or sells cookstoves.

Interview questions for the stakeholders
How does the organization/company work with ICS adoption and development?
Does the organization/company have any ongoing projects?
What seems to be the main drivers for ICS adoption?
What seems to be the main factors causing a barrier for ICS adoption?
What do you think about the market in the near future, and in the long term development? (A time-perspective of 5 and 10 years respectively were given)
Is the market for ICS increasing, decreasing or unchanged?
What are the most important factors to bear in mind when conducting a program for ICS adoption?
What seems to be important for the consumers when they buy a cookstove?
What are the consumers concerned about regarding the use and purchase of cookstoves?
Additional questions for stakeholders producing and/or selling cookstoves
Which model are you selling?
What is the price for your cookstove?
How high is the efficiency of the cookstove?
How high is the fuel consumption?
How long does the cookstove last? Do you give any warranty or provide repair?
What feedback (positive and negative) have you got from the consumers regarding ICS?
Are there other competing technologies on the market today? Which?
What factors determine the consumers' choice of cookstove model?

The structure for the interviews with households included one introducing part in which the respondent answered a questionnaire and a second part in which the respondent answered a set of prepared, open-ended questions. Both parts were designed while having knowledge gained only through literature study.

For the questionnaire, the document differed between households using an ICS and households not using an ICS. This was to better suit the respondent. Both versions of the questionnaire are found in appendix where Appendix II presents the questionnaire used for the interviews with households using an ICS, and Appendix III presents the questionnaire used for the interviews with households not using an ICS. In the questionnaire there was a focus on what type of cookstoves the households have, what fuels they use, for what type of food they do and do not

use each stove, and what would make them buy an ICS or use their current ICS more. The questions were designed to touch as many drivers and barriers as possible while still not being leading. Both open-ended questions and questions with statements for which the respondents could tick boxes according to the relevance of each statement were used. In the end of the questionnaire, the respondents were asked to state advantages and disadvantages they see with ICS. To avoid misunderstandings because of lacking language skills, the questionnaires were given in Swahili. In the second part of the interviews with households, the respondents were given the opportunity to more in-depth explaining their answers in the questionnaire. The questions for the second part of the interviews with households are presented in *Table 2*.

Table 2 ***Interview questions for the households.*** The table presents the questions for the second part of the interviews with households.

Interview questions for the households
Are there any dishes that are harder or easier to cook with the ICS compared to a traditional cookstove? Which? Why?
How many cookstoves have you bought during the last couple of years? Why have you bought new ones?
What factors are important when you will buy a cookstove?
How much did you pay for your cookstove?
Do you know if the type of cookstove you have exists in better quality?
What do you think about the availability of ICS?
Do you feel like people in general are aware of ICS and its advantages? How?
Do you think men and women prioritise differently when it comes to spending money on the household? If “Yes”, how?
If there is any fuel left after you have finished cooking the food, what do you use it for?

The data collected regarding the cookstoves and fuel prices were collected through the literature study to the extent that data existed. The rest were collected through interviews with stakeholders except durability and price of the counterfeit Jiko Bora which were collected through interviews with households.

Some data or information for the study were collected through own observations during the field study. This type of data is related to how the stoves are sold and where they are sold. When this data are used in the report, it is clearly stated that the data are from own observations.

2.2 Method for analysis

The data from the interviews consists of quantitative data. To be able to draw conclusions on which factors that form key drivers and barriers, and how these are weighted, the data have been divided into categories.

When collecting the most central data about drivers and barriers from stakeholders and households, the respondents were given the task to state drivers/advantages and barriers/disadvantages they see with ICS without any given statements or categories. The categories have been formed afterwards and the answers have then been divided into the categories. The formulation in the questions differed between stakeholders and households; drivers and barriers were used in the interviews with stakeholders, while advantages and disadvantages were used in the household interviews. The reason is that the households may not see which factors forming drivers and barriers for ICS adoption, but they can more easily explain advantages and disadvantages they see with purchasing and using ICS. The same formulations have been used when presenting the result.

The design of the interviews with stakeholders as well as the second part of the interviews with households, consisting of open-ended questions, resulted in different phrasings of the same subject for several questions. Also these answers have been categorized for which the categories were chosen afterwards and with the literature study in mind.

The answers from the questionnaire to the questions with statements for which the respondents could tick boxes according to the relevance of each statement are presented in tables. These are used in the analysis to compare the answers from the questionnaire with the answers from the second part of the interviews with households and with the answers from the interviews with stakeholders.

In order to see where the data from the stakeholders and the households differ and where it is consistent, the data from the stakeholders and the households are presented separately. For the households, some parts have been further broken down to enable a comparison between households who use ICS and households who do not use ICS.

Data of the stoves regarding investment cost, fuel price, lifespan, critical parts and reparability were collected during both the interviews with stakeholders and with households. For the data on investment cost, fuel price and lifespan, an average of the values have been calculated and used in the report. These values are used because no existing data on the current values of these factors were found in the literature or on the web. The mean values were required in order to make a comparison between the stoves and to calculate the cumulative cost of the stoves.

The most prominent drivers and barriers from the results were chosen for further analysis. The following categories are used for the analysis: Financial performance, Quality, Awareness, Availability and Smoke. For the *financial performance*, data is presented about the cumulative cost for purchasing and using a stove during 15 months. The calculations of the cumulative cost are done using following equation:

$$C_{Cumulative} = C_{Inv} * D + C_{Fuel} * t * F_{Fuel\ saving}$$

where $C_{Cumulativ}$ is the cumulative cost in USD and C_{Inv} is the investment cost of the stove in USD. The durability, D, is dependent on the expected lifetime of the stove because each time the stove breaks a new investment has to be made. The value for the durability starts at 1 and increases with 1 each time the expected lifetime has been reached. C_{Fuel} is the monthly fuel cost for a traditional metal stove in USD/month, t is the time in months and $F_{Fuel\ saving}$ is the fuel savings of a stove compared to the fuel savings of a traditional metal stove with a value between 0 and 1.

3. BACKGROUND

This chapter is aimed to provide the reader with background information relevant for the understanding of the study. The chapter includes information about Tanzania, Dar es Salaam and Moshi, as well as information about cooking habits, fuel prices and environmental impacts of cooking.

3.1 Tanzania

Tanzania is located in East Africa and is a large country with a population of about 45 million people (Clough, 2012) (Embassy of Sweden, 2015) and an area of 945 087 km^2 (Mercer, 2013) (Embassy of Sweden, 2015). The percentage of residents living in rural areas is 74%, with an urbanization rate of 4.7% (Clough, 2012). The average household size is 4.8 persons/household (Mercer, 2013) and the life expectancy is 57 years (Mercer, 2013) (Embassy of Sweden, 2015).

The country is governed as a republic (Embassy of Sweden, 2015) and the residents are composed of different religious, ethnic and linguistic groups. Swahili and English are the two official languages, and the two larger religions are Christianity (45%) and Islam (33%) (Mercer, 2013). Even though there are religious and cultural differences within the country, Tanzania is a peaceful state where people have a friendly and welcoming nature (Global Alliance for Clean Cookstoves and IDEO.org, 2012).

The percentage of the population below the international poverty line is 68% (Clough, 2012). Food, rent and fuel are the largest economical expenses for most Tanzanians (Global Alliance for Clean Cookstoves and IDEO.org, 2012) (Shemdoe, 2015). The gross domestic product (GDP) in 2013 was estimated to 33.23 billion USD (695 USD per capita) (The World Bank, 2013) and a large share of the national budget (30%) comes from international aid (Embassy of Sweden, 2015).

The rate of students attending primary school is 98% whilst the rate for secondary school is 20% (Mercer, 2013). Agriculture represents 80% (Clough, 2012) of the employment and 85% (Mercer, 2013) of the export. Industrial mining (especially gold) forms parts of the employment and the revenues, while the oil reserves might have potential for future revenues.

3.1.1 Dar es Salaam

Dar es Salaam is located at the coastline in east Tanzania and is Tanzania's largest city. It was the capital city until 1970s when the government was moved officially to Dodoma (Ziljma, 2015). Even though Dodoma is the official capital city today, Dar es Salaam is still the commercial capital city where most of the institutions are based and most of the financial-businesses take place.

The population in Dar es Salaam is increasing at a growth rate of 4.4 percent per year (assumed growth rate between 2006 and 2020) (City Mayors Foundation, 2014) and are now at an amount of over 4.3 million residents. About 38% has completed primary education (National Bureau of Statistics [NBS], 2010) and the employment rate of women and men are 68% and 82.4% respectively. The annual average salary in Dar es Salaam is 600 USD (The DAR Project, 2012)

and as the Gini coefficient[1] is quite low, 10.7 (NBS, 2010), the median income will be approximated to the same amount.

While Tanzania's total economy is considered an agrarian economy, this differs in Dar es Salaam where only 3.6% is involved in agricultural work (NBS, 2010). The main occupational backgrounds in Dar es Salaam are unskilled manual labour, domestic services, skilled manual labour and sales and services.

3.1.2 Moshi

Moshi is located in the north-eastern Tanzania, just south of Kilimanjaro in the region named the Kilimanjaro region. The city was established as a military camp in the late 19th century, but has since then become dependent on the agriculture surrounding the city, unskilled manual labour and on tourism (mainly tourists climbing the mountain).

The past years decreased price for coffee beans and thereby the profitability with growing coffee is driving the urbanisation into Moshi. The population growth is 2.8% per year (Moshi Municipial Council, 2013). Still, many people live outside the city but goes into town for work, putting the population at an estimated figure of 185 190 during night and 555 570 during the day.

About 36% of the population have completed primary education and the unemployment rate in Moshi is about 28% for both women and men (NBS, 2010). Most common occupation is agricultural work, after this come unskilled manual labour for women and skilled manual labour for men.

3.2 Cooking habits

Cooking with biomass is used by 96% of the households in Tanzania, while 2.3% of the cooking is done with kerosene and only 1.1% by using gas, electricity and other solid fuels (Global Alliance for Clean Cookstoves, 2014a). It is common to have several stoves in the household (Global Alliance for Clean Cookstoves and IDEO.org, 2012). Different stoves and fuels are used for different purposes, and for some dishes or sizes of dishes it is required to use more than one stove at the same time. Firewood and charcoal is preferred to use for food that takes long time to cook, for example rice and beans. Kerosene can reach high temperature very fast, but is more expensive than charcoal (Amosy et al., 2010). This makes kerosene the preferred choice for small amounts of food and when you want to prepare something quickly, for example morning tea (Amosy et al., 2010) (Global Alliance for Clean Cookstoves and IDEO.org, 2012). Half gas/half electrical stoves and electrical stoves are available in the upper-end appliance stores, but because of the electricity shortage they are seldom used (Global Alliance for Clean Cookstoves and IDEO.org, 2012).

[1] A coefficient indicating how the wealth is distributed in an area, ranges between 0-100

In *Figure 1* the fuel ladder is shown. It illustrates the usual step-ups in fuels (only taking into account the cost of the fuel) that a household can take when money is available.

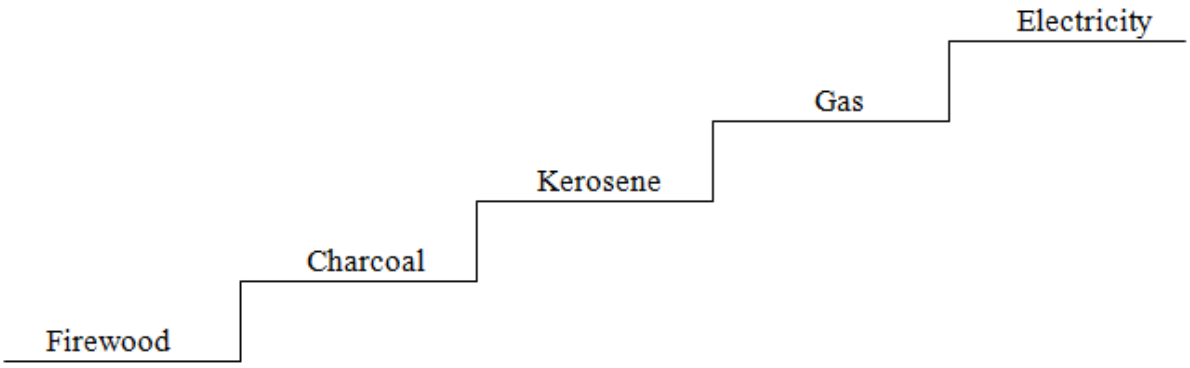

Figure 1 ***Fuel ladder for cooking in developing countries.*** The ladder considers the cost of fuels and how a household could move up in more expensive fuels when money is available (Global Alliance for Clean Cookstoves and IDEO.org, 2012).

In urban areas the access to firewood is limited, making people buy and use charcoal. The percentage of the urban population using charcoal is over 80% (Sawe, 2009). Since firewood is cheaper than charcoal, this is used also in urban areas when charcoal is hard to afford. The use of gas is rare due to its expensiveness.

Lately, some alternative fuels have entered the market: briquettes and pellets. Briquettes and pellets are both efficient fuels with a low cost, but they are not yet widely available (Global Alliance for Clean Cookstoves and IDEO.org, 2012). Increased production, distribution, and marketing can help these fuels take larger share of the market of cookstove fuels. Important for the marketing is to compare cooking times and cost with charcoal, helping people distinguish between charcoal and alternative fuels.

Comparing urban and rural areas, the fuel use differs a lot. Whilst charcoal is the main fuel in urban areas, firewood is the most used fuel in rural areas (Riedijk, 2011). The reason to the high use of firewood in rural areas is the low cost due to the possibility to gather firewood.

3.3 Fuel prices

There are many factors that can affect the current fuel prices on the market, especially for solid fuels where location, increase/decrease in demand, dry/wet season, regulations (e.g. increased protection of forests) and taxes are influencing factors. For liquid fuels such as LPG (Liquefied Petroleum Gas), the price is almost only dependent on the current price on the world market.

As can be seen in *Figure 2* the price for propane (which is a LPG) dropped severely after the financial crisis of 2008 and has not been able to stabilise since then, i.e. the price has been fluctuating since then and therefore making the future price of LPG uncertain. Prognosis made in the last 10 years also points at that the price were expected to be much higher than it is now;

many of the prognoses predicted a price more than double of the current price (Thomson Reuters, 2015).

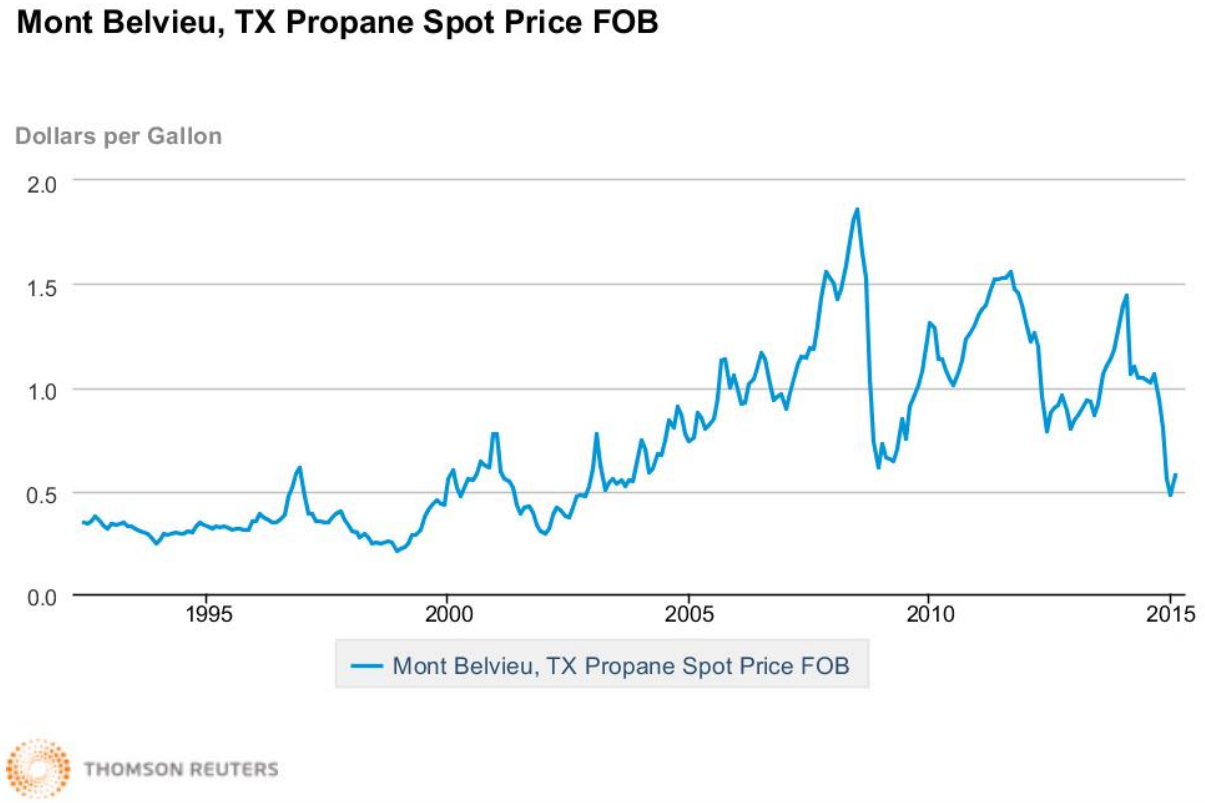

Figure 2 ***Spot price for propane between the years 1992-2015***. The price is in USD per Gallon (Thomson Reuters, 2015).

The price for charcoal seems to be mostly affected by location, where the demand has a certain role. Dar es Salaam has a large population and scarcity of nearby forest, making the demand for charcoal higher than the supply, which does not occur in rural areas and smaller cities like Moshi. This is reflected in the price, as one bag of charcoal (28kg) in Dar es Salaam costs about double as much as in Moshi and rural areas (Laustsen, 2015) (Lesiriam, 2015) (Shemdoe, 2015) (Nindie & Wilson, 2015).

Figure 3 shows the price trend of charcoal in Dar es Salaam between the years 2003 – 2015. Data for the years 2003-2008 is taken from literature (Peter & Sander, 2009), while data for 2015 is taken from interviewed stakeholders (Shemdoe, 2015) (Nindie & Wilson, 2015) (TaTEDO, 2015). The price presented is the average value per bag, where one bag is defined as 28 kg (Peter & Sander, 2009). In reality, the weight of a bag can vary and be as high as 120 kg and the price varies between dry and wet season with several USD. From the figure, an average price increase of 2.7 USD/year can be seen. The figure also shows the current average price of charcoal in Dar es Salaam: 33.3 USD/28$kg_{charcoal}$ (1.19 USD/$kg_{charcoal}$). This can be compared to the price of charcoal in Moshi, which is about 13.9-16-6 USD/28$kg_{charcoal}$ (0.56-0.66 USD/$kg_{charcoal}$) (Laustsen, 2015) (Lesiriam, 2015).

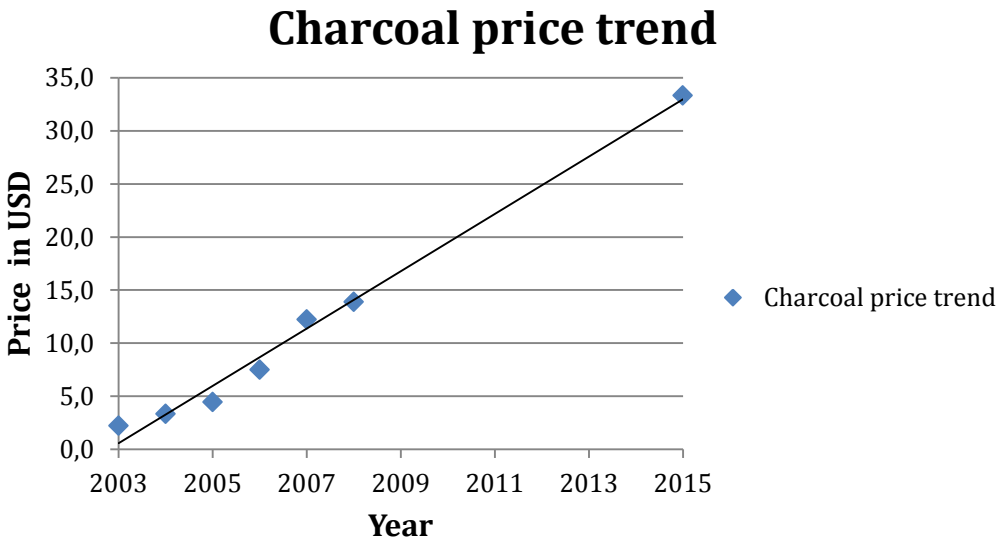

Figure 3 ***The yearly average price of charcoal in Dar es Salaam between the years 2003-2015.*** The price is per one bag of charcoal, where one bag is defined as 28 kg (Peter & Sander, 2009). From the figure a price increase of 2.7 USD/year is found, and the current price is 33.3USD//28kg$_{charcoal}$. Data for the years 2003-2008 is taken from literature (Peter & Sander, 2009), while data for 2015 is taken from interviewed stakeholders (Shemdoe, 2015) (Nindie & Wilson, 2015) (TaTEDO, 2015).

There are also other alternatives to the traditional charcoal entering the market: briquettes and pellets. Charcoal briquettes made from dry biomass or agricultural waste has been developed in order to reduce the price for fuel and to preserve forest. These briquettes have a bit less in power compared to charcoal, but the power output is quite constant. On the negative side is that these briquettes also produce more ashes, probably because they contain more sand (Rajabu, 2015). The price for these briquettes in Dar es Salaam is almost 14 USD for 25 kg (TaTEDO, 2015). Another fuel produced in Moshi is briquettes made from waste materials, such as saw dust and rice husks. The price is 5.55 USD for 25 kg of briquettes, less than half the price of a bag of charcoal although taxes are enforced on briquettes but not on charcoal (Laustsen, 2015) (Peter & Sander, 2009).

3.4 Environmental impacts of cooking

The combination of a wide use of biofuels for cooking and the very low energy conversion efficiency of cooking with inefficient cookstoves leads to several negative effects on the environment. Locally, the environment is affected in terms of forest degradation (Hofstad et al., 2009) (Köhlin et al., 2011) (Miles et al., 2009), damaging of ecosystem, deforestation (Geist & Lambin, 2001) (Miles et al., 2009) (Ruiz-Mercado et al., 2011) (Swedish Energy Agency, 2014) (Krögerström, 2014) and erosion (UNFCCC, 2011). Globally, increased level of GHG emission in the atmosphere causes impacts on the environment (Sagar & Kartha, 2007) (Miles et al., 2009). The way of cooking in the developing world is also one of the primary sources of black carbon (BC) emissions, causing negative impact on both the environment and human health (C2ES, 2010).

3.4.1 Deforestation

Deforestation is a large problem in Tanzania (Riedijk, 2011). The forest cover is almost 40% of the total land area (Clough et al., 2012), and much of the forests are very environmentally valuable due to its high level of biodiversity and the several endemic species living there. Between the years 1990 and 2010 Tanzania's forest area decreased with 19.4% (slightly above 8 million hectares) and the deforestation is continuing with a rate of over 1% annually. One problematic implication of deforestation is the impact on the carbon cycle (Bradford, 2015), which represents the second largest, human-caused source of carbon dioxide to the atmosphere. Another implication from deforestation is the decreased vapour flows from land causing disruption on natural weather patterns, changing the current climate models.

The deforestation also causes significant impacts on watersheds, soil and vegetation (Riedijk, 2011), affects the water cycle negatively (Bradford, 2015) and contributes to the loss of important species. In turn, loss of species implies negative consequences for local population relying on the plants and animals living in the forest as well as for medical research. For the soil, tree roots anchor the soil and prevent it from washing or blowing away. Without this anchoring, problem for the growth of vegetation occurs. Erosion of soil can lead to decreased local water quality because silt can, if the soil erodes, enter the lakes, streams and other water sources. Poor human health by the population living in the affected areas is one of the consequences.

The opinions on the cause of the deforestation differ. Some sources (Riedijk, 2011) (Nyamo-Hanga, 2015) claim that the charcoal production is the main cause of the deforestation, while other argues that charcoal production does not affect deforestation at all (Mwampamba et al., 2013). According to Mwampamba (2013), the use of charcoal and wood is not a contributing factor for deforestation in developing countries, although the wood that comes from deforested areas is often used as fuel directly or to produce charcoal. Instead the main cause of deforestation in Tanzania is said to be the increased need for agricultural land (Globalis, 2013). Another estimation shows that about 70% (Clough et al., 2012) of the deforestation in Tanzania is caused by fuel wood harvest (directly or indirectly), and the remaining about 30% is due to agriculture. However, the charcoal production increases the monetary benefit of continued deforestation.

Due to the high economic value of forest and forest services to Tanzania's economy (20.1% of GDP based on prices from 2006) (Ministry of Natural Resources and Tourism, 2008) (Kaale et al., 2012) and the high total annual revenue from the charcoal sector (350 million USD only in Dar es Salaam in 2006, which had increased with 300% by 2014), the rapid depletion of biomass resources also causing economic and social impacts (Clough et al., 2012). However, there is an informal gap about the contribution of the forest sector to the national economy due to the high informality in trade on timber and non-timber products which makes an uncertainty in the estimations (Kaale et al., 2012).

3.4.2 Black carbon

Black carbon (BC) is a component in particular matter ($PM_{2.5}$) which is formed by incomplete combustion of biomass, biofuels and fossil fuels (United States Environmental Protection Agency [EPA], 2012) (C2ES, 2010). Emissions of BC have negative impacts on human health and ecosystems, reduce the agricultural production in some parts of the world and causes damage of materials. Premature death as well as respiratory and cardiovascular effects has been linked to emissions of BC, and the climate is influenced through BC's direct absorption of light, reduced

reflectivity of ice and snow and interaction with clouds. The direct absorption of light together with the reduced reflectivity of ice and snow cause a net warming. The interaction with clouds is not well quantified and may have a net warming or cooling effect.

The global BC emissions are estimated to be about 8.4 million tons (in 2000) (EPA, 2012). A large part of the emissions take place in the developing world. Asia, parts of Africa and parts of Latin America are among the largest emitters of BC. The sources and trends of BC emission vary significantly between regions and countries. Diesel engines, cookstoves, forest fires and wood burning are among the primary sources (C2ES, 2010). One quarter of the global BC emissions comes from cooking with inefficient cookstoves (Lambe et al., 2014).

The atmospheric lifetime of BC is short, days to weeks, which means that strategies to reduce the BC emission can give positive health and environmental effects within the next coming decades (EPA, 2012) (C2ES, 2010). To do this, a specific focus on reducing direct $PM_{2.5}$-emissions is required. Residential cooking is a large source of BC emissions globally and mitigation within this sector represents the largest potential for public health benefits.

4. LITERATURE STUDY OF DRIVERS AND BARRIERS

Many international organizations see the importance of improving the way of cooking in many of the developing countries and believe that dramatically reduced fuel consumption can enable improved livelihood, improved health, empower women and reduce the impact on climate change (Global Alliance for Clean Cookstoves, 2013) (Sommer et al., 2014). During the past decades, several projects have therefore been running to increase the adoption rate of ICS. Still, the dissemination of ICS is lower than expected. In order to increase the adoption rate it is important to understand the drivers and barriers connected to the technology. In this chapter, drivers and barriers that commonly have been observed in previous ICS adoption projects will be explained. A compilation of the drivers and barriers are presented in *Table 3* and *Table 4* respectively.

4.1 Drivers

Several articles points to the many advantages with ICS, which can work as drivers for ICS adoption. Savings of money and time are two important advantages (Riedijk, 2011) (Kshirsagar & Kalamkar, 2013). Reduced exposure to smoke and thus improved health is another (Global Alliance for Clean Cookstoves, 2013). Also status-seeking can work as a driver for ICS adoption (Shankar et al., 2014). Protection of the environment may not work as a driver from the consumers' perspective, but can be a driver from a policy perspective to increase the promotion of new cookstoves (Lambe et al., 2014).

One of the most mentioned drivers for ICS adoption in previous projects is the possibility to save money. The possibility to save money comes directly from the decreased fuel consumption which is attributed to ICS (Kshirsagar & Kalamkar, 2013). With reduced fuel consumption a smaller amount of fuel is needed each day and thus less money has to be spent on fuel (Riedijk, 2011). Further, this should enable households to save money for a later purchase and thus making it possible to buy fuel in larger quantities instead of on a day-to-day basis which is common in Tanzanian households today. If the households succeed with saving the money and buy fuel in larger quantities, the price per kilogram of fuel is lower and the money-savings becomes even higher (The World Bank, 2009). But there is risk for a rebound effect (i.e. more fuel is used) which occur if the ICS is used for new tasks such as heating water for bathing or if larger amount of food is cooked (Mwampamba et al., 2013). According to EnDev (Energising Development, 2012) the additional money due to reduced fuel cost is usually used to invest in food and other domestic use, but also for paying school fees and other costs related to education for their children.

For the advantage in time-savings, the strength of the driver mostly depends on the location. This is because the way of getting fuel differs between rural and urban areas. In rural areas the fuel is usually gathered and long walks are required to collect the fuel. With ICS, the fuel consumption is reduced and fewer long walks are required, leading to the possibility of essential time savings in these areas. In urban areas, the fuel is usually purchased at the markets or from sellers who are standing beside the street, implying that this way of time-savings is not as significant as in rural areas. However, the ICS reduces the cooking time (Kshirsagar & Kalamkar, 2013) (Ruiz-Mercado et al., 2011) and thereby saves time for households in both rural and urban areas, which has been found to be an important driver for households (Mobarak et al., 2012). The reduced cooking time comes both from reduced ignition time and from the high concentration of the heat

which reduces the time to heat the meal. It has also been found that the saved time can lead to increased income generation through more time spent at work (García-Frapolli et al., 2010)

The two previous mentioned advantages (savings of money and time) come partly from the low fuel consumption. The low fuel consumption also reduces the exposure to smoke, which improves health and can in the long run save lives (Grieshop et al., 2011) (Global Alliance for Clean Cookstoves, 2013). But even though people in the industrialized countries see the high importance of improved health and highly weigh this advantage, some articles (Ruiz-Mercado et al., 2011) (Shankar et al., 2014) point on the fact that households in developing countries seldom respond to the smoke or pollution issues with ICS. Instead fuel savings, convenience, intra-household gender dynamics and time-savings seems to be more important in these countries. This is confirmed also on a study performed in Bangladesh (Arif et al., 2011), showing that those who bought an ICS chose a portable one in front of one with chimney even though the IAP was essentially more reduced with the cookstove with chimney compared to the portable cookstove. The reason to not choose the one with chimney was said to be that this model did not reduce the fuel consumption to such a large extent as the portable one, implying that economics comes before health in Bangladesh. This is also confirmed by a study in rural Mexico which found that only about 40% of the respondents were concerned about health impacts caused by the smoke (Troncoso et al., 2007).

Another possible driver for ICS adoption is status-seeking, since owning an ICS sometimes work as a symbol for well-being (Shankar et al., 2014) (Ruiz-Mercado et al., 2011). This driver can be of high importance in some areas and within some groups of people. Status-seeking could be fuelled by if decision makers or other important persons use ICS (Shankar et al., 2014) and if the adoption rate were driven by status-seeking it is possible that the cheapest option of ICS would not be chosen. This effect has been seen in high-income countries. *Table 3* below presents a compilation of the drivers for ICS adoption found in the literature.

Many projects for ICS adoption have had a very low success rate. This can be explained with that these projects had rural areas as target and these areas have no monetary benefits from ICS adoption (Vahlne & Ahlgren, 2014). Another thought is that in order to increase the willingness to pay for ICS, the ICS models should be designed with features valued more highly by men since it is often the men who have the money to invest (Shankar et al., 2014) (Beltramo et al., 2014). Important is to not risk depreciating the features valued by women, since it is often women who cook and it is important that they want to use the ICS consistently.

Table 3 ***Drivers for ICS adoption from the literature.*** The table presents drivers for ICS adoption observed in previous projects

Drivers for ICS adoption observed in previous projects
Possibility to save money/decreased cost of fuel
Time-savings through reduced time spent on gathering fuel and cooking
Reduced exposure to smoke/improved health
Status-seeking

4.2 Barriers

Articles from previous ICS adoption projects also state several factors causing a barrier for ICS adoption. One such factor is the lacking knowledge about the existence of ICS and its advantages, especially in areas where adoption projects have not been carried out (Riedijk, 2011) (Winrock International, E+Co & Practical Action Consulting East Africa, 2012). The most reliable and important source for spreading the information about ICS is a consumer that is already using an ICS (Mwampamba et al., 2013). The importance of seeing the technology is shown in a study in India (Shankar et al., 2014) where the most effective driver for ICS adoption was product demonstration. Other ways that have seemed helpful are to have women as salespersons and to perform follow up visits in areas where adoption projects have been performed. The follow up visits appears to be very important as an ICS should not be considered adopted when it have been bought, but when it has created a shift from the traditional stove through correct and consistent use. Researchers in previous projects have also noted the importance of including the participation of women and their opportunities of income generation which ICS adoption could lead to (Malhotra et al., 2004).

It is also necessary to increase the quality and to work with standards and quality control/assurance (Bailis et al., 2009). Today, some ICS models are of poor quality, they break easily and it can therefore be hard to make people satisfied with the ICS (Riedijk, 2011). Another aspect of standards is explained by Gifford (Gifford, 2011), where ICS users complain about that the stove is too small to fit all pots, as stove producers fail to produce stoves which fit to the local pots.

Intra-household gender dynamics has been identified as an important barrier as it is the wife in the household that uses the stove while the husband decides if they are to buy an ICS or not. The husband's priorities might not be the same as the wife's (Shankar et al., 2014). To create a demand for the stoves, the marketing of the technology has to function and be based on the key properties requested by the consumers. It has been suggested that adding functions to the ICS that appeals to the husband (such as possibility to charge the mobile phone) can reduce this barrier, but also functions that appeals to the wife can increase the adoption rate.

Other possible barriers are culture and conservatism, as changing habits seldom is easily accepted (Arif et al., 2011) (Lambe et al., 2014). In this case the issue is mainly how to cook the food and how it tastes. Many consumers believe the food tastes better if it is cooked on their traditional cookstove and do not want to try another way of cooking. But according to a study in Bangladesh (Arif et al., 2011), the majority of those who have eaten food cooked with an ICS said it tasted the same or even better than food cooked on a traditional cookstove. However, the issue of culture and habits make it important for stoves developers and adoption projects to include a social consideration in order to ensure a long-term adoption (Kshirsagar & Kalamkar, 2013). Another problem is that even though an ICS is used, traditional cooking practices might not achieve the highest efficiency of the ICS (Hanna et al., 2012). Also the issue of religion is important to keep in mind. A study by Shankar (Shankar et al., 2014) found a religious barrier related to the smoke. In this study, the consumers saw the smoke from the cookstove as a connection to the Gods, and therefore they did not want to adopt a cookstove with less smoke.

The last barrier explained will be the financial one, as even though it is becoming profitable with an ICS in urban areas it can not be taken for granted that the first investment to buy an ICS can be made. Previous projects have shown that higher income levels in rural areas increases the adoption rate of ICS, which then is also likely true for urban areas (Kshirsagar & Kalamkar, 2013). To reduce this barrier, some sort of financial aid or micro-loans might be needed. However, in 2007 it was found out that about 30% of those using charcoal in Dar es Salaam had a matching income of those using LPG, while the prevalent thought among many charcoal consumers is that charcoal is their only affordable option (Palmula & Beaudin, 2007).

Table 4 ***Barriers for ICS adoption from the literature.*** The table presents barriers for ICS adoption observed in previous projects.

Barriers for ICS adoption observed in previous projects
Lacking knowledge about ICS and its advantages
Poor quality of some ICS models
Financing
Intra-household gender dynamics
Culture
Conservationism
Religion

5. COOKSTOVES

For cooking with biomass fuels, there are two categories of cookstoves: *traditional cookstoves* (i.e. TSF and traditional metal stove) and *improved cookstoves*. A cookstove that uses less fuel to cook a certain amount of food compared to cooking with a traditional cookstove is called an ICS (Riedijk, 2011). The lower fuel consumption also leads to less smoke. The problem with low energy conversion efficiencies with the traditional cookstoves is due to large heat losses and partially burned fuel. The ICS are developed to minimize the heat loss to the surroundings and to maximize the heat transfer through complete combustion. Today, there are no exact international criteria for cookstoves to be classified *improved cookstove*.

Below follows a description of the cookstove models included in the study and presents the data collected during the field study. The section with cookstove models is followed by a section describing the issue of standardization, where the Water Boiling Test (WBT) and the Biomass Stove Safety Protocol are briefly described.

5.1 Models

On the markets in urban Tanzania, mostly cheap cookstoves are provided (Global Alliance for Clean Cookstoves and IDEO.org, 2012). It is often possible to choose between a metal stove and a clay-lined stove. The latter are considered improved because the clay-line increases the thermal efficiency of the stove, but the quality can still be poor. Through own observations during the field study it was found that the more advanced cookstoves are rare at the markets, but several models in different price range are sold by national and international companies in their small shops or at their production sites. Another observation during the field study was that the most common models in urban Tanzania are counterfeit models of Jiko Bora, followed by the traditional metal stove.

The selection of models to include in the study is based on the models found through the literature study. Knowledge about one model, the Jiko Makini (see chapter 4.1.7 *Jiko Makini*), was gained through interviews with different stakeholders. Some models exist in several sizes. In the study a size that fits a family of 4-5 persons is used, which is in most cases the smaller model.

5.1.1 Traditional metal stove

This stove usually has a cylindrical design, but other shapes do exist. A picture of a traditional metal stove with the cylindrical design can be seen in *Figure 4*. It does not have the ceramic liner to decrease the heat losses to the surroundings as some of the ICS models have, instead it only has a thin perforated grate to hold the charcoal. The thermal efficiency is about 15-20 % (United Nations Center for Human Settlements [UNCHS], 1993) and the average price is 3.6 USD (6400 TSh) (Clough et al., 2012). According to the interviews with households performed during the field study, the lifespan is about 15 months (mean value).

Figure 4 ***Traditional metal stove.*** A picture of a traditional metal stove (BioEnergy Discussion Lists).

5.1.2 Jiko Bora

Jiko Bora[2] is a charcoal ICS similar to the Kenya Ceramic Jiko (KCJ) which has been disseminated successfully in Kenya (Sawe, 2015). The Jiko Bora was adapted and adopted from Kenya's KCJ in a pilot project launched in 1988 by the Ministry of Energy and Minerals in Tanzania under the Renewable Energy Development Project Unit (REDPU). Since the last couple of decades, the NGO TaTEDO (see Appendix I) works with the production and dissemination of Jiko Bora.

Jiko Bora is locally produced and exists in different models (Sawe, 2015). It is produced in two sizes (small and large) and with a cylindrical or hourglass design. Both designs have a ceramic liner that increases the thermal efficiency compared to the traditional metal stove. The hourglass design can be seen in *Figure 5*. The model preferred by the consumers is the cylindrical, smaller model, which is the model Jiko Bora is referred to in this study. All stoves are produced at the production site in Dar es Salaam, but about 60% are transported to and sold in other cities. The price for Jiko Bora is 6.7 USD (12 000 TSh).

Figure 5 ***Jiko Bora.*** A picture of a Jiko Bora (TaTEDO).

Since Jiko Bora is developed to suit urban households in Tanzania, it is good in meeting local needs (Sawe, 2015). The durability is 3-5 years. The ceramic liner is the critical part and the part that breaks first. If the ceramic liner breaks it is possible to get a new one from the workshop. The thermal efficiency is 35% and the fuel savings is about 50% compared to a traditional metal stove (Riedijk, 2011) (Sawe, 2015).

[2] Jiko is the Swahili word for stove and Bora means excellent

5.1.3 Counterfeit models of Jiko Bora

On the market there are several producers of ICS with similar design as the original Jiko Bora, but with poorer quality. The quality of the different models of Jiko Bora on the market differs depending on the quality of the material and the production method used (Sawe, 2015). The most critical part is the ceramic liner. For a good ceramic liner the clay is dried in the sun and then burned in an oven, while for lower quality ceramic liners the clay is just dried in the sun. The thermal efficiency and the fuel savings of a counterfeit Jiko Bora is about the same as for the original Jiko Bora, i.e. 35% and 50% (Rajabu, 2015) respectively, but the durability differs. According to the interviews with households performed during the field study, the stove usually breaks after about 8 months (mean value). The household interviews also gave that the price for one of these stoves ranges from 1-3 USD (2000 – 5000 TSh). The price span partly depends on the quality of the material used. A picture of the counterfeit Jiko Bora taken during the field study can be seen in *Figure 6*.

Figure 6 ***Counterfeit Jiko Bora.*** Picture of a counterfeit Jiko Bora taken during the field study.

5.1.4 Kuute stove

Costech (see Appendix I) has made improvements to the Jiko Bora and the new version is called Kuute stove, an ICS running on either charcoal or briquettes (Shemdoe, 2015). Kuute stove has a thermal efficiency of 42% (Riedijk, 2011) and the fuel consumption is 50% lower compared to Jiko Bora (Shemdoe, 2015) (Riedijk, 2011). The lower fuel consumption is mainly because the fire is enclosed by the stove which increases the efficiency (Shemdoe, 2015). A small pipe works as a chimney to let the exhaust gases out, the pipe can be seen at the far end of the stove in *Figure 7*. The enclosure of the fire created a limitation in the possibility to use different size of pots and a changeable ring on the top has therefore been developed in order to give a more flexible size. The design and composition of materials on the Kuute stove is basically the same as for a Jiko Bora. Also the lifespan is the same, i.e. 3-5 years (Rajabu, 2015). The time it takes to cook with Kuute stove is essentially longer compared to Jiko Bora, for example boiling 5 litres of water takes 45 minutes with Kuute stove while only 15 minutes with Jiko Bora. The price for Costech's Kuute stove is 5.6 USD (10 000 TSh).

Figure 7 ***Kuute stove.*** Picture of a Kuute stove developed by Costech (Riedijk, 2011).

Today, the research institute CAMARTEC in Arusha is working with the development and dissemination of Kuute stoves. CAMARTEC has developed a model with better quality compared to the original one. This model is produced in two sizes, small (4-5 persons) and large, which are sold to a price of 33.3 USD (60 000 TSh) and 61.1 USD (110 000 TSh) respectively. The performance between Costech's and CAMARTEC's model is about the same, but the quality of CAMARTEC's model is better (longer durability).

5.1.5 Envirofit

Envirofit is an enterprise who designs, produces and sells ICS of high quality (Envirofit, 2015). The materials are manufactured in China and the stoves are sold with carbon finance and introduction discount (Riedijk, 2011). In Tanzania, the company ARTI Energy (see Appendix I) sells Envirofit. They provide different models of both firewood and charcoal stoves, for both households and institutions (Tarimo & Thonus, 2015). One of the charcoal stoves, Envirofit CH-5200, can be seen in *Figure 8*. Four of their household stoves and one institutional stove are being sold in Tanzania. The efficiency of these models is 36% (Engines and Energy Conversion Lab, 2012) and the fuel savings is 60% compared to an un-improved metal KCJ type stove, i.e. a traditional metal stove from Kenya (Riedijk, 2011) (Engines and Energy Conversion Lab, 2012). The lifespan of the stove is above 5 years (Riedijk, 2011) and the price for a household stove for 4-5 persons is 27.8 USD (50 000 TSh).

Figure 8 ***Envirofit CH-5200.*** A picture of an Envirofit taken during the field study in Dar es Salaam.

5.1.6 Jikokoa

Jikokoa is a charcoal ICS developed by the company Burn Design Lab (see Appendix I), a picture of the Jikokoa is shown in *Figure 9*. The stove is designed to suit urban areas and entered the market in Tanzania only 4-5 months ago (Nyer, 2015). The production takes place in Kenya where it has been sold for about 1.5 years. The stove has been tested in lab which resulted in a 45% higher efficiency compared to the KCJ, i.e. 44% thermal efficiency, but in field the performance is even better. The durability is said to be two years and the company gives a warranty of one year. After one year it is still possible to come back to the shop to get the stove repaired, but you have to pay. Fuel savings is about 60% compared to Jiko Bora (Burn Design Lab, 2015). The price for Jikokoa is 41.7 USD (75 000 TSh) (Nyer, 2015).

Figure 9 ***Jikokoa.*** Picture of the Jikokoa stove (Burn Design Lab, 2013).

5.1.7 Jiko Makini

Jiko Makini is the only gasification stove on the Tanzanian market (Laustsen, 2015). Instead of using charcoal or firewood it gasifies briquettes made from agricultural waste such as sawdust and rice husks (Laustsen, 2015) (Lesiriam, 2015). It consists of two segments: the bottom assembly where the fuel is supplied and ignited so that the gasification process can begin and the top assembly where the gas is mixed with additional air so that the gas ignites. In *Figure 10* the Jiko Makini is shown when the two segments are assembled.

Figure 10 ***Jiko Makini.*** A picture of the gasification stove Jiko Makini (Narayan, 2012).

According to the water boiling test (WBT) performed on the stove the efficiency is 30% (Rajabu, 2015). The developer of the stove (Laustsen, 2015) argues that the efficiency in field should be a bit higher, around 35%. The difference between the test and in field is because the water boiling test requires the stove to run on full power during the test, while in the field the stove is supposed to be operated at a bit less than full power and thus the efficiency becomes higher.

The price for a Jiko Makini is 25 USD (45 000 TSh) (Lesiriam, 2015).

5.1.8 Compilation of the models

In *Table 5*, a compilation of the presented models are shown. Fuel type, thermal efficiency, fuel savings, price and lifespan are specified.

Table 5 ***Compilation of the cookstove models.*** Compilation of the models described in the chapter. Fuel type, thermal efficiency, fuel savings, price and lifespan is shown for each model. For the fuel savings, the fuel consumption for the traditional metal stove is used as reference value.

	Fuel type	**Thermal Efficiency**	**Fuel savings**	**Price (USD)**	**Lifespan**
Traditional metal stove	Charcoal	15-20%	Reference value	3.6	~ 15 months
Jiko Bora	Charcoal	35%	~ 50%	6.7	3-5 years
Counterfeit Jiko Bora	Charcoal	35%	~ 50%	1-3	~ 8 months
Kuute stove	Charcoal Briquettes	42%	~ 75%	5.6[3]	3-5 years
Envirofit	Charcoal Firewood	36%	~ 60%	27.8	Above 5 years
Jikokoa	Charcoal	44%	~ 80%	41.7	2 years
Jiko Makini	Briquettes	30%[4]	See note[5]	25	Above 2 years

5.2 Standardization

Since 2012 a temporary international standardisation has existed under the name *IWA 11:2012 Guidelines for evaluating cookstove performance*. IWA stands for *International Workshop Agreements* and is an ISO (International Organization for Standardization) document produced by market players and other stakeholders during international workshops (International Organization for Standardization, n.d.). An IWA can be developed rapidly to address public policy requirements or emerging market needs, and does not have to go through the national delegation. The reason why the IWA is temporary is because it is reviewed after three years by an ISO board, who decides if it can continue, should be revised or withdrawn.

The *Guidelines for evaluating cookstove performance*, which was coordinated by the Global Alliance for clean cookstoves, consists of four indicators: Efficiency/Fuel use, Total emissions, Indoor emissions and Safety (International Organization for Standardization, n.d.). The indicators are all independently rated along 5 Tiers; Tier 0 to Tier 4 (where Tier 0 is lowest

[3] 5.6 USD for the model from COSTECH. CAMARTEC sells Kuute stove for 33.3 USD.
[4] The efficiency measured in the water boiling test. In field the performance is higher and should be about 35%.
[5] No comparable data exists. Although Kiwia & Laustsen Ltd (Laustsen, 2015) says you can save 16.6 – 22.2 USD/month (30 000 – 40 000 TSh)

performing and Tier 4 is highest performing). The three first indicators are tested through a Water Boiling Test version 4.2.3 (see Chapter 4.2.1) and the fourth indicator is ranked through Biomass Stove Safety Protocol version 1.1 (see Chapter 4.2.2). In *Figure 11* an illustrative view of the indicators, Tiers and for which test that is used for each indicator is shown. The purpose of the guidelines is to set goals for development, communicate progress of development, make decisions easier for governments, retailers and costumers, and to make it possible for organizations and countries to make specific priorities after local needs.

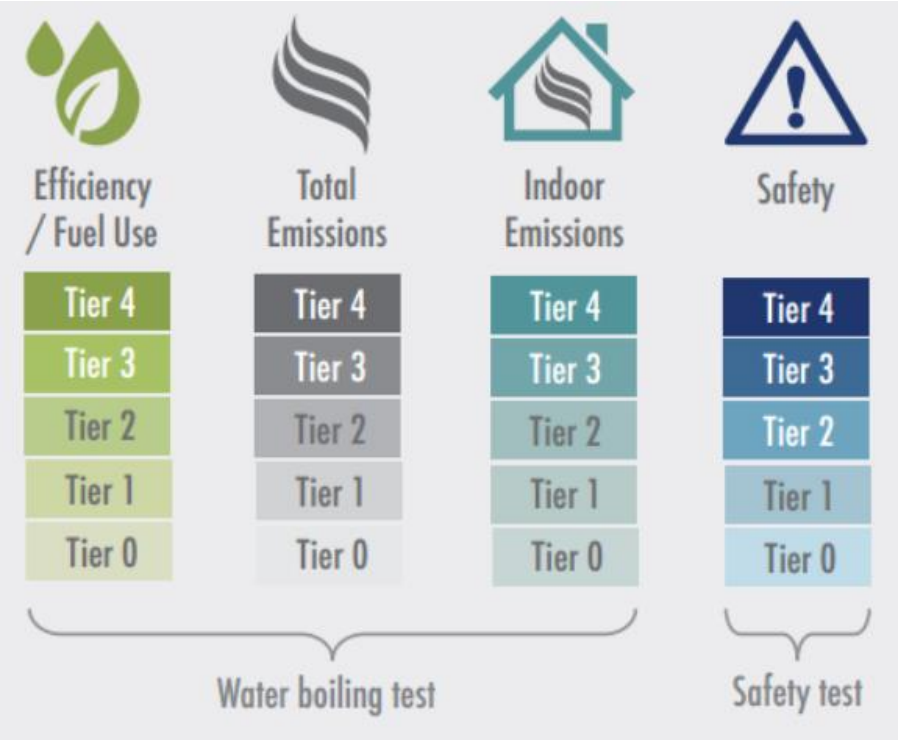

Figure 11 ***The different indicators and Tiers from the IWA Tiers of performance*** (Global Alliance for Clean Cookstoves, u.d:a).

5.2.1 Water Boiling Test

The Water Boiling Test (WBT) is a way to test the performance of cookstoves in a controlled laboratory environment where the tests can be reproduced (Bailis et al., 2007). The test can be seen as a simplified simulation of cooking where the measurements are performed while bringing water to a boil. The WBT tests the following:

1. Stove efficiency
2. Average burning rate (fuel consumed per unit of time while bringing water to a boil)
3. Specific fuel consumption (fuel required to produce a unit of output)
4. Average stove power
5. Time to boil
6. Turn down ratio (to what degree the power output can be controlled)

When the test was developed its purpose was only to test fuel efficiency. Because of the increased awareness of health and environmental impacts, the Global Alliance for Clean Cookstove has now incorporated instructions in their manual for the WBT on how to include

measurements of emissions (e.g. Carbon Monoxide, Nitrogen Oxides and particular matter) while performing the WBT (Global Alliance for Clean Cookstoves, 2014c).

As the WBT takes place in laboratory environment the results can differ from how the stoves perform in field. The difference can be either positive or negative. To see how the stove performs in a real life situation, a *Kitchen Performance Test* (KPT) can be used (Rajabu, 2015). For the KPT, stoves and fuel are distributed to households, and measurements of the daily fuel consumption are done. After 2 weeks, a protocol test is done about cooking habits and the users feeling about the stove.

5.2.2 Biomass Stove Safety Protocol

The Biomass Stove Safety Protocol includes guidelines for ten safety evaluation procedures that can be made on stoves in order to assure the safety level (Global Alliance for Clean Cookstoves, u.d:b). The tests are:

1. Sharp edges and points (entangled cloths can tip the stove over)
2. Cookstove tipping (testing the stoves stability)
3. Containment of fuel
4. Obstructions near cooking surface (ensures that there is nothing that a hot pot can collide with when being moved)
5. Surface temperature
6. Heat transfer to the environment
7. Handle temperature
8. Chimney shielding
9. Flames surrounding cook pot
10. Flames exiting fuel chamber, canister or pipes

6. RESULT

During the field study 55 interviews were done, whereof 8 were with organizations, 8 with companies and 39 with households. Of the interviews with households, 15 were with households who do not use ICS and 24 with households using some kind of ICS. In the following sections the important findings from the interviews will be presented.

6.1 Stakeholders

In total 16 stakeholders were interviewed; 8 organizations and 8 company representatives. Costech, GVEP, REA, SIDO, SNV, TaTEDO, TIRDO and Dr. Hassan Rajabu from the University of Dar es Salaam represent the 8 organizations interviewed, while ARTI Energy (both one representative from the head office and one store employee), Burn Design Lab, Envotec, Fivestar Hardware Ltd, TaTEDO (one store employee from their workshop), Kiwia & Laustsen Ltd and one seller at Makumbusho market place represents the 8 interviews conducted with company representatives. For more information about the stakeholders, see Appendix I.

The interviews focused on the stakeholders past and present projects with ICS adoption, what drivers and barriers they have observed in their work and see in future work, as well as thoughts about the future regarding the development and use of cookstoves and fuels. The results are presented in the sections below.

6.1.1 Drivers in the view of the stakeholders

In *Figure 12* drivers for ICS adoption in the view of the organizations and the companies are shown respectively and together. The presented drivers refer to drivers observed in the stakeholders' past projects and their view of drivers of today's and future market development. The bars show how many of the stakeholders who see each category as a driver for ICS adoption. The category *decreased fuel consumption* relates to decreased running cost i.e. possibility to save money through reduced fuel cost. Also *durability* relates to cost savings; the durability of ICS are (if not including the counterfeit Jiko Bora) longer compared to the traditional metal stove and the consumer does not need to buy a new cookstove as often as required with the traditional metal stove. *Higher safety* refers to burn injuries, and *attractive* relates to status-seeking since owning and using an ICS entails status in some areas and within some groups of people.

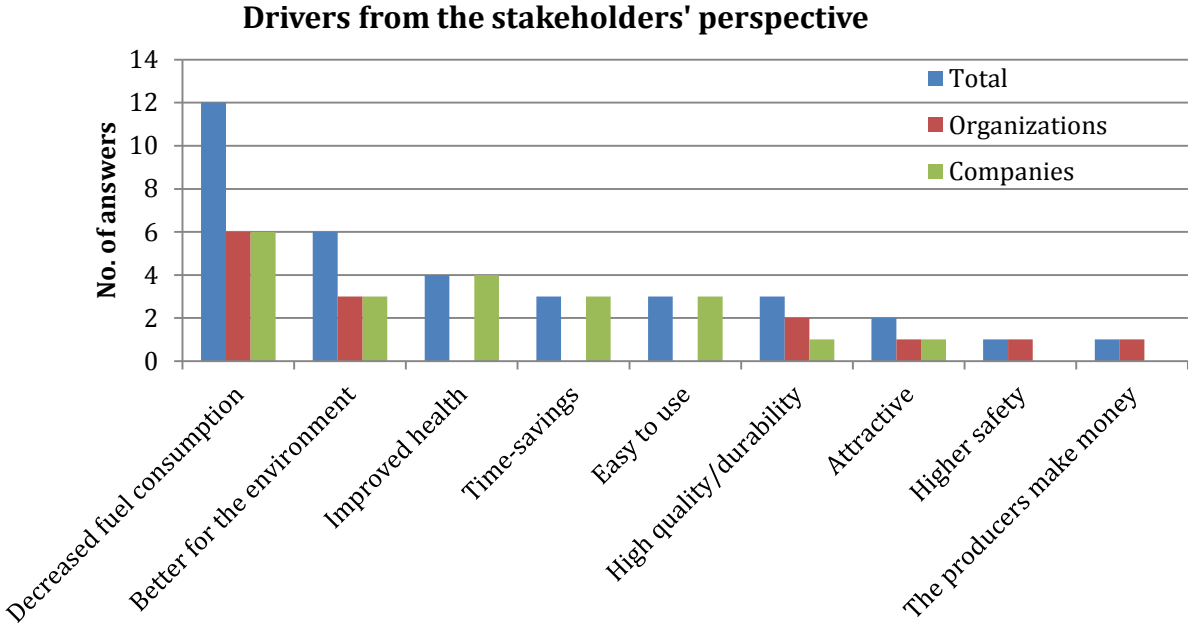

Figure 12 ***Drivers for ICS adoption in the view of the stakeholders.*** The drivers in the figure regards to the stakeholders perceived drivers, both from past projects and their view of drivers of today's and future market development. The bars show how many of the stakeholders who see each category as a driver for ICS adoption. The left bars show the total number of stakeholders who see each category as a driver for ICS adoption; the middle bars represent the answer from the organizations and the right bars represent the answers from the companies.

The figure shows that the decreased fuel consumption and thus the possibility to save money through decreased fuel cost is the most frequently observed driver among the stakeholders, mentioned by 12 stakeholders (6 organizations and 6 companies). Protection of the environment, with a focus on decreased deforestation, is the second most mentioned driver for ICS adoption. REA (Nyamo-Hanga, 2015) states that we might have to start a technology shift towards something that does not hurt the environment. According to Burn Design Lab (Nyer, 2015) a new type of "green charcoal" made from agricultural waste is coming. This fuel is better for the environment compared to charcoal and will maybe slow down the technology shift. TaTEDO (Sawe, 2015) pushes on the fact that not only the stoves have to become better and have to have increased dissemination, also the charcoal production has to increase its efficiency.

Some companies believe improved health, time-savings and usability are drivers for ICS adoption, while none of the organizations mentioned these as possible drivers during the interviews. Few respondents also mentioned high quality, attractive, higher safety and profitability for stakeholders as drivers for ICS adoption.

6.1.2 Barriers in the view of the stakeholders

In *Figure 13* barriers for ICS adoption in the view of the organizations and the companies are shown respectively and together. The bars show how many of the stakeholders who see each category as a barrier for ICS adoption. The barriers presented regards to barriers observed in the stakeholders' past projects and their view of barriers of today's and future market development. The bars show how many of the stakeholders who see each category as a barrier for ICS adoption. *Awareness* refers to the lacking knowledge among the consumers about different models of ICS and their benefits. The resistance to adopt a new technology and the difficulty to get a new technology accepted is presented as *Technology diffusion. Gender inequalities* refers to the fact that the women do the cooking while men decide about the money, which is the normal situation in Tanzanian households. Also, different areas in Tanzania have different cooking habits leading to different requirements on the cookstove. Today, few companies adjust the design of the stove to fulfil the different requirement. Instead one design is sold to all areas. This problem is presented as *Design* in the figure. *Priorities* refers to that buying a new cookstove is not of highest priority when the household have a tight budget.

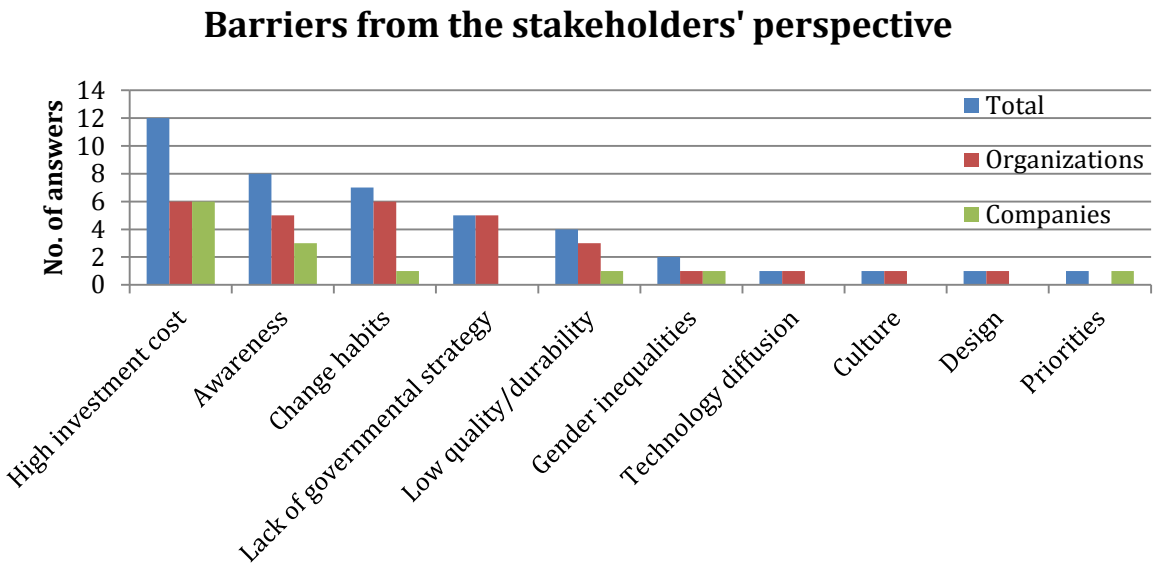

Figure 13 ***Barriers for ICS adoption in the view of the stakeholders.*** The barriers in the figure regards to the stakeholders perceived barriers, both from past projects and their view of barriers of today's and future market development. The bars show how many of the stakeholders who see each category as a barrier for ICS adoption. The left bars show the total number of stakeholders who see each category as a barrier for ICS adoption; the middle bars represent the answer from the organizations and the right bars represent the answers from the companies.

Financing

From the figure, *high investment cost* is the most frequent answer among both the organizations and the companies regarding barriers for ICS adoption. Out of the 16 interviews with stakeholders, 12 stakeholders said this is a barrier (6 organization and 6 company representatives). Looking at the 3 companies selling the more expensive cookstoves[6], the 2 companies Burn Design Lab (Nyer, 2015) and Envotec (Mwambije, 2015a) said the consumers have complained about the high price for ICS and see the high investment cost as a reason why people have not bought the ICS. But ARTI Energy (Tarimo & Thonus, 2015) said there are people who got the money to buy an ICS.

Awareness

Even though the awareness of the benefits with ICS (such as reduced environmental and health impacts compared to cooking on inefficient cookstoves) starts to get higher, awareness is still a large barrier for ICS adoption. This is confirmed by 8 of the stakeholders interviewed. Only one stakeholder, TIRDO (Nindie & Wilson, 2015), said the awareness is good in urban areas.

According to Burn Design Lab (Nyer, 2015) the most common way to get awareness is from neighbours who use an ICS and talk about it. In this way, new households want to try and the dissemination starts. Burn Design Lab thinks the marketing should and can be improved. TIRDO (Nindie & Wilson, 2015) said the market should be able to provide the consumers with information. Dr Rajabu (Rajabu, 2015) said that there should be demonstrations to increase the awareness, a method supported by ARTI Energy (Tarimo & Thonus, 2015) who said "seeing is believing" and believes the consumers have to see the advantages with ICS and that cooking with ICS does work.

Tradition, culture and gender dynamics

One barrier mentioned by 7 stakeholders is conservationism, as using an ICS requires a new way of cooking; people have to learn how to feed the stove with fuel, get the right heat etc. With the old stove they know when to put in more fuel, get the heat they want and they can do other things while cooking as for example washing (Rajabu, 2015). SIDO (Benedicto, 2015), TaTEDO (Sawe, 2015), ARTI Energy (Tarimo & Thonus, 2015), Kiwia & Laustsen Ltd (Laustsen, 2015) and Dr Rajabu (Rajabu, 2015) said conservative people want to use the same technology and/or fuel they have done before. REA (Nyamo-Hanga, 2015), Kiwia & Laustsen Ltd (Laustsen, 2015) and Dr. Rajabu (Rajabu, 2015) said it is a common thought that the food tastes differently if it is cooked with another technology/fuel and that the ICS have to cook staple food better than TSF to be accepted.

TaTEDO (Sawe, 2015) said it is important to understand the socioeconomic situation of the targeted population; what food they are cooking, their preferences, habits etc. According to Burn Design Lab (Nyer, 2015) the socioeconomic situation might differ between different areas/cities, for example in Morogoro the stove is used for both cooking and heating water for bath while in Dar es Salaam the stove is only used for cooking. Also, different areas have different access to fuel. SIDO (Benedicto, 2015) point that the decision of what fuel to use partly depends on what fuels that are available around the area you live. In areas with good access to firewood, the households prefer firewood stoves.

[6] ARTI Energy, Envotec and Burn Design Lab are selling the more expensive ICS models

Another issue within the subject of tradition and culture mentioned by Kiwia & Laustsen Ltd (Laustsen, 2015) and Fivestar Hardware Ltd (Lesiriam, 2015) is that traditionally, the men have the money to invest in a new cookstove while women cook the food. Kiwia & Laustsen Ltd (Laustsen, 2015) pointed that since the man does not do the cooking he does not know how much work it takes to cook and does not see the reason to spend money on a stove. Fivestar Hardware (Lesiriam, 2015) explained the today's situation in which the seller tells and demonstrates for the buyer (usually the man) how to use the stove, but when the buyer brings it home no explanation is given to the person who will cook (usually the woman). This makes the problem with improper using, leading to unnecessary high fuel consumption and low durability.

Governmental strategy

The organizations Costech (Shemdoe, 2015), REA (Nyamo-Hanga, 2015), TaTEDO (Sawe, 2015) and TIRDO (Nindie & Wilson, 2015) highlighted the importance of a governmental strategy. According to TaTEDO (Sawe, 2015), the government in Tanzania has not recognized the importance of charcoal, which is estimated to be worth over 1 billion USD. This is confirmed by the fact that less than 3% of the national financing goes to ICS. TIRDO (Nindie & Wilson, 2015) says the government shows willingness but the implementations are limited. Policies are not enforced. There are no strong statements from the government that says "We should have ICS in all institutions", and no long-term plan with clear landmarks as: "yy% increase in adoption by the year xxxx". Recently, TaTEDO (Sawe, 2015) has seen a reaction from the government since they do not like imported products.

Costech (Shemdoe, 2015), REA (Nyamo-Hanga, 2015), TaTEDO (Sawe, 2015) and TIRDO (Nindie & Wilson, 2015) were all clear about what great influence the government has on the market development and their possibility to increase the adoption rate through regulations or some other governmental strategy. According to TaTEDO (Sawe, 2015), a good governmental strategy could make the institutions working with ICS adoption much stronger and larger, which would facilitate their work considerably and increase the adoption rate of ICS.

Poor quality

According to the store manager at TaTEDO's workshop (TaTEDO, 2015), Kiwia & Laustsen Ltd (Laustsen, 2015) and REA (Nyamo-Hanga, 2015), the durability is an important factor for the consumers when they buy a cookstove. The lifetime of the stoves is often several years, but critical parts (the ceramic liner and the plate the fuel rest on) have low durability and breaks after few months. TIRDO (Nindie & Wilson, 2015), TaTEDO (Sawe, 2015) and REA (Nyamo-Hanga, 2015) said there is a need for specifications and standards in order to improve the quality of ICS. Before these are enforced and the quality is improved, it is important to provide spare parts (Tarimo & Thonus, 2015) (Sawe, 2015) (Laustsen, 2015) (Rajabu, 2015). TaTEDO (Sawe, 2015) see the importance of improving the quality of their stoves and said if the quality cannot be assured other competing stoves will take over.

Imported products

On the market for ICS in Tanzania, there are many international companies selling imported products. Kiwia & Laustsen Ltd (Laustsen, 2015) believes the international competition will be even larger in the future. According to Burn Design Lab (Nyer, 2015), Envotec (Mwambije, 2015a) and Kiwia & Laustsen Ltd (Laustsen, 2015) it is hard for national companies to compete

on the market for household ICS because some imported cookstoves are sold to a subsidized price (carbon subsidy). The carbon subsidies can also be used by national companies but as it is a cumbersome process to get it no one does. The market for household cookstove is especially hard to compete on as there are more companies working towards those consumers. TaTEDO (Sawe, 2015), Burn Design Lab (Nyer, 2015) and Envotec (Mwambije, 2015a) said Envirofit (sold by ARTI Energy) is a large competitor on the market for charcoal ICS. According to TaTEDO (Sawe, 2015), Envirofit suits medium to high-income households and Burn Design Lab (Nyer, 2015) said Envirofit is sold to half its original price due to the subsidies. The market for institutional cookstoves is easier because fewer international companies work with these stoves.

Some stakeholders (Nyer, 2015) (Mwambije, 2015a) (Sawe, 2015) said the imported cookstoves have essential disadvantages. Envotec see a disadvantage for the companies selling imported stoves in that they only sell stoves in one design, which has to fit all households. Since there are different requirements for different households (size, habits etc.), Envotec said there are better national companies on the market selling stoves with different designs for different requirements. Another disadvantage which was explained by Burn Design Lab (Nyer, 2015) and TaTEDO (Sawe, 2015) is the uncertainty in the carbon market which some imported cookstoves rely on. Neither Burn Design Lab nor TaTEDO believe in building the ICS market on the carbon market because if the carbon price goes up or down, the price for the cookstoves is affected as well as the possible profit for the companies.

6.1.3 Thoughts about future fuel use

All of the interviewed stakeholders believe that charcoal has many years left on the market, even though TaTEDO (Sawe, 2015) and Kiwia & Laustsen Ltd (Laustsen, 2015) predicts the price of charcoal to continue to go up during the next coming years. Costech (Shemdoe, 2015), REA (Nyamo-Hanga, 2015), SIDO (Benedicto, 2015), TaTEDO (Sawe, 2015) and ARTI Energy (Tarimo & Thonus, 2015) said the availability of firewood is limited in urban areas and electricity is too expensive and not available. Of the alternatives (firewood, LPG, electricity and briquettes/pellets) LPG is the fuel for which the demand is predicted to increase most according to the stakeholders.

Envotec (Mwambije, 2015a) said the demand for LPG started 3 years ago and TaTEDO (Sawe, 2015), Kiwia & Laustsen Ltd (Laustsen, 2015), Burn Design Lab (Nyer, 2015) and TIRDO (Nindie & Wilson, 2015) think there will be a switch towards LPG in about 10-20 years. According to REA (Nyamo-Hanga, 2015), Envotec (Mwambije, 2015a) and SIDO (Benedicto, 2015) the problem with LPG today is its high price, while TaTEDO (Sawe, 2015) said one essential disadvantage with LPG is the inability to buy gas in such small amounts as for one day consumption which is preferred by many Tanzanians. TaTEDO (Sawe, 2015) predicts that today's relatively low price for LPG will continue to go down the next coming years and also that the people are becoming wealthier, which strengthen the thought about a fuel switch towards LPG. TIRDO (Nindie & Wilson, 2015) believes that within 5 years, the government has enforced policies and standards which will make it economically beneficial to use LPG for cooking. Looking 10 years from now TIRDO thinks these enforcements have made most of the high and medium income households use LPG and also that biogas projects are running at this time.

There are also some new technologies entering the market. Burn Design Lab (Nyer, 2015), Costech (Shemdoe, 2015), FIVESTAR Ltd (Lesiriam, 2015) and SIDO (Benedicto, 2015) mentioned a new initiative with briquettes made of waste and believe this technology can be more used in the future. FIVESTAR Ltd (Lesiriam, 2015) believes the market will be dominated by this technology 10 years from now, mainly due to the restrictions on firewood and charcoal they think the government will set in the near future (i.e. within 5 years from now). Burn Design Lab (Nyer, 2015) and ARTI (Tarimo & Thonus, 2015) said that the "green charcoal" made of agriculture waste is entering the market. ARTI is producing and selling this "green charcoal" and said it is cheaper, last longer and are better for the environment compared to charcoal. Both technologies are new in Tanzania and require some years before they can compete on the market. Burn Design Lab (Nyer, 2015) do not think these technologies will take over the market, but looking 10 years from now, Burn Design Lab (Nyer, 2015) think these technologies will be more widely used.

6.2 Households

In the areas: Kigogo, Kijitonyama, Kinondoni, Kurasini and Mburahati in Dar es Salaam, 25 interviews were conducted with different households, with about 5 interviews in each area. In Moshi, 14 households distributed over different areas of the city were interviewed. Of the total 39 households interviewed, 24 used an ICS. The percentage of interviews with ICS users was higher in Dar es Salaam compared to Moshi (76% in Dar es Salaam, 36% in Moshi).

The overall impression of ICS is good; both among users and non-users (only one respondent had a negative attitude to ICS). Regarding the usability, most respondent said that there are no dishes that are harder to cook with the ICS (23 of 32 answers), but some (7 of 32 answers) said large dishes are harder or impossible to cook with the ICS due to the limitation in size of pot to use on the cookstove. Also, few respondents said the ICS is too unsteady and not suitable for dishes where stirring the pot is important (as for cooking the local dish ugali[7]).

All of the respondents said the awareness and the availability of ICS is good, but out of 37 answers only 6 of the households answered that they had become aware of ICS and its advantages through advertisement. The rest said that the information had come to them through other sources, such as their friends and relatives but also through their own experience.

Regarding the financing, all respondents answered that they bought their cookstove with saved money. This answer was given regardless which type of stove the respondent had.

Of the 24 users of ICS, 50% (12 users) also had a kerosene stove which was used for preparing food/water quickly, while another 29% (7 households) had some other kind of stove i.e. traditional metal stove or 3 stone-fire. In households without ICS, only one used another complementary stove. *Figure 14* demonstrates the percentage distribution of how ICS users and non-users also use other types of stoves.

[7] Ugali is a maize porridge which is staple food in many East African households.

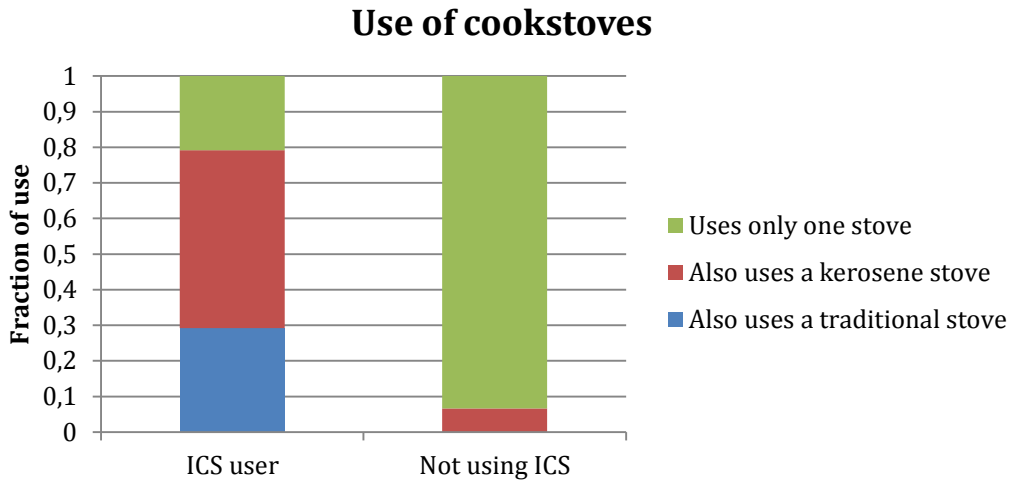

Figure 14 ***Use of different models of cookstoves*****.** The figure shows the percentage distribution of how users and non-users of ICS also use other types of stoves.

Regarding the design, it was both observed and confirmed by the questionnaire results that all the respondents had cookstove models that were movable (the TSF might be considered semi-movable because of the weight of the stones). The majority of the respondents said that if they are buying a new stove they make sure it is easy to move.

6.2.1 Advantages

The respondents' thoughts about the most important advantages with ICS are shown in *Figure 15* below. The figure shows that three advantages are significantly more seen by the respondents, these are: *Time-savings*, *Less smoke* and *Decreased fuel consumption*. Here, *time-saving* includes both saving in time due to less time spent on cooking and less time are required for purchasing or gathering fuel. *Less smoke* leads to improved health and *decreased fuel consumption* means decreased running cost due to that less money is spent on fuel.

Advantages mentioned by less than 15% of the respondents are: *ICS can cook all type of food*, *Food tastes better*, *Access to fuel*, *Safer*, *Better for the environment*, *Easy to use* and *Good quality*. The category *Safer* refers to burn injuries.

The figure also shows that the answers from the households using ICS and the households which do not use ICS today are coherent. As most they differ with 15%. For the category *Less smoke* the answers differed among the non-users depending on location; in Dar es Salaam this advantage was rarely mentioned by the households while in Moshi it was mentioned as an advantage by two thirds of the non-users. Among the users of ICS, the answers were coherent between the two cities.

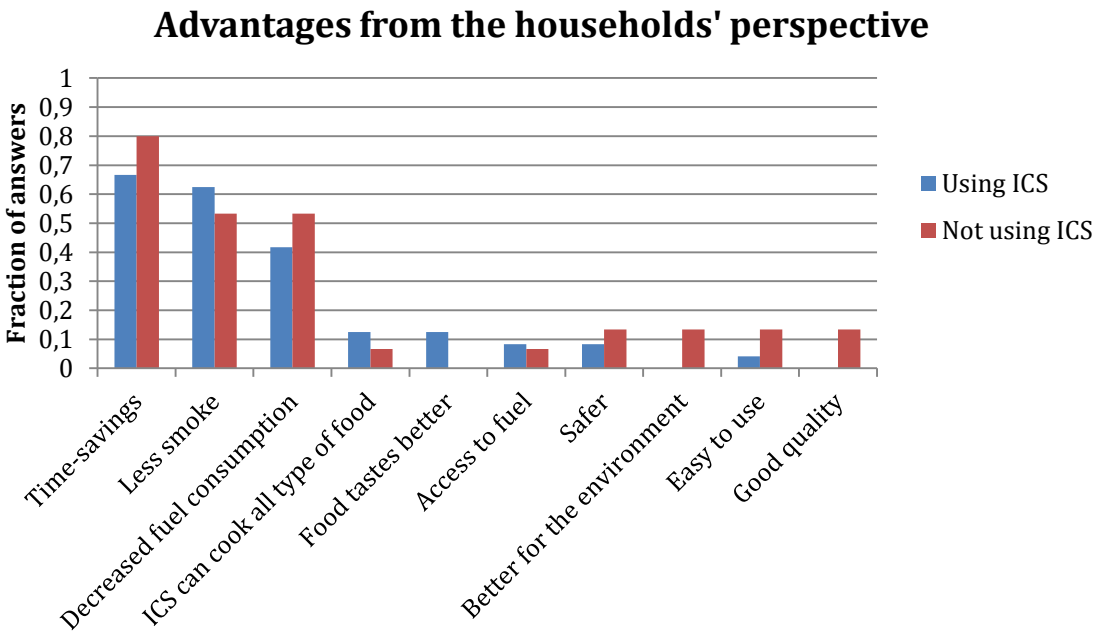

Figure 15 ***The respondents' thoughts about the advantages with an ICS.*** The left bars represent the answers from respondents using ICS, while the right bars represents the answers from respondents not using ICS. The x-axis is scaled from 0 to 1 and shows the fraction of respondents within each category (user/non user) mentioned each specific advantage when they got the task to enumerate advantages with ICS.

6.2.2 Disadvantages

Almost all respondents complained about the poor quality of the ICS. This is confirmed in *Figure 16* showing the answers from the respondents when they got the task to enumerate disadvantages with ICS. Two respondents (one user and one non-user) said there are no disadvantages with ICS. The answers within the categories *Emits smoke* and *Easy to get burned* indicates that the respondents sometime refers to more advanced stoves (i.e. gas or electrical stoves) while answering the questionnaire. Comparing ICS with a traditional stove, the traditional stoves always have a higher amount of uncombusted particles in the smoke.

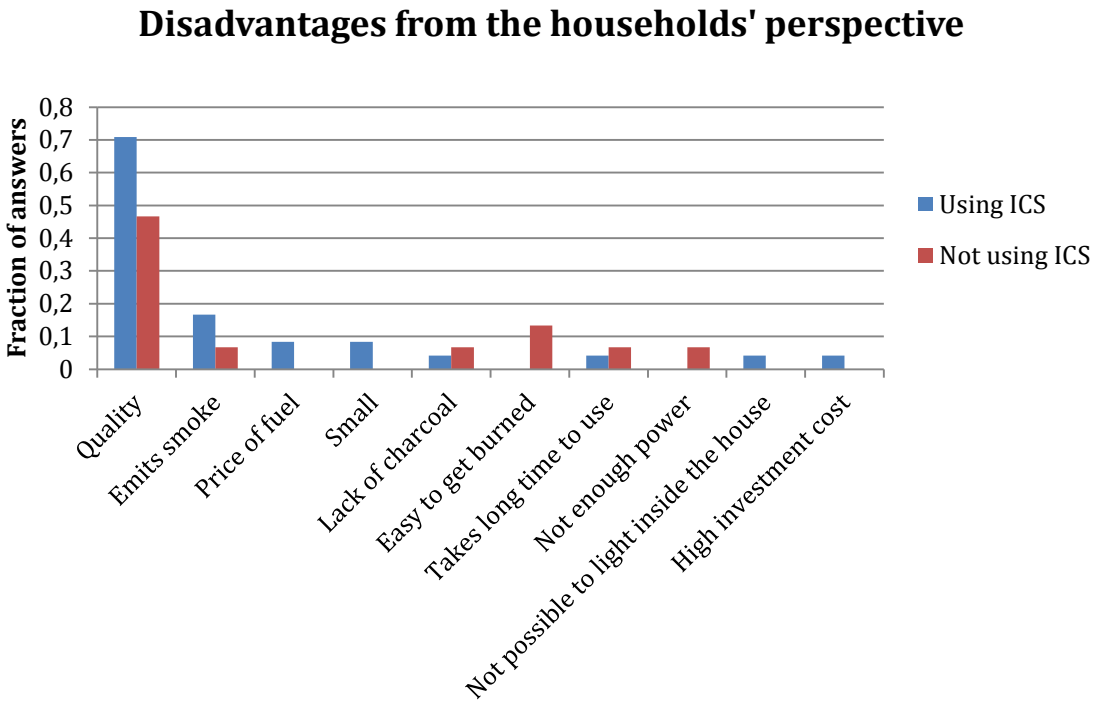

Figure 16 ***The respondents' thoughts about the disadvantages with ICS.*** The left bars represent the answers from respondents using ICS, while the right bars represents the answers from respondents not using ICS. The x-axis is scaled from 0 to 1 and shows the fraction of respondents within each category (user/non user) mentioned each specific disadvantage when they got the task to enumerate disadvantages with ICS.

Most households who intend to buy an ICS go to the market and buy a cheap model with low quality. This model looks like the original Jiko Bora and most of the consumers do not know they have not bought the original one. After about 8 months the stove breaks and they complain about the poor quality. These cheap cookstoves cost on average 2.1 USD (3800 TSh), while stoves of the same model and efficiency but with better quality costs about three times as much (6.7 USD) and last for 3-5 years. From the questionnaires it is also clear that it is more common by the households who do not use ICS to check for quality when purchasing a new stove (7 of 15 of the non-users answered this, while 3 of 24 of the ICS users answered that they checked for quality when purchasing a new stove).

6.2.3 Reason to use an ICS

Most people are aware of the possibility to save fuel with ICS, which are confirmed in their choice of cookstove for different kind of dishes. During the interviews the respondents were asked for what kind of food they use and not use the ICS, and also why. The pervading answer were that ICS is used for food that takes long time to cook (for example rice and beans), because for these dishes the possibility to save fuel is larger due to the long cooking time. This can also be seen in *Table 6* which shows that out of the 24 respondents using an ICS, 11 said that they use the ICS because it is cheaper to cook with it. That the household only has one stove (an ICS) and that the food tastes better if it is cooked with the ICS are two more reasons for using the ICS, answered by 4 respondents each.

Table 6 ***Reasons to use the ICS for certain types of food.*** The respondents' answers to reasons for using the ICS for certain types of food.

Reasons to use ICS for certain food	
It is cheaper to cook with the ICS	11
Has only one stove (an ICS)	4
The food tastes better if it is cooked with the ICS	4
Easier to cook with the ICS	1
The ICS does not emit smoke	1

The main factor that would make the ICS users use the stove even more is if the market price for the fuel would increase. This means that they would use their traditional stove less, as the ICS uses less fuel but also that if the price for kerosene would increase they would instead use their ICS more. Out of the 24 respondents, 14 said that this was relevant while 8 said that it was not relevant, which can be seen in *Table 7*. A majority responded that an increased knowledge of how to cook with the ICS was not relevant in order to get them to use it more, indicating that most people does not see a difference in the cooking practice compared to a traditional stove or that they feel that even though there are a difference it is still not a barrier. Not included in the table is that one woman answered that a decreased access to firewood would make her use the ICS more.

Table 7 ***Reasons to use the ICS more.*** The respondents' answers to what factors that would make their household use the ICS more.

What would make your household use the ICS more?	Relevant	Neutral	Not relevant
Increased market price for fuel	14	2	8
Better knowledge in how to cook with the ICS	3	7	14

The most important thing that would make those that do not have an ICS buy one is financial help, after that comes decreased market price and slightly after that increased knowledge in how to cook with an ICS. The results from this question are illustrated in *Table 8*.

Table 8 ***Factors which would enable a purchase of ICS.*** The respondents' answers to the question "What would make your household buy an ICS?"

What would make your household buy an ICS?	Relevant	Neutral	Not relevant
Decreased market price	9	2	4
Financial help	13	0	2
Increased knowledge how to cook with an ICS	6	3	6

The respondents that still did not own an ICS were asked about which reasons that would make them buy one. The two most common answers were time-savings and the higher safety (in terms of burn injuries and the risk of causing a fire) an ICS leads to. These were closely followed by a decreased demand for fuel. However, all alternatives in the questionnaire were seen as relevant by the respondents, which can be seen in *Table 9*. For all multiple choice questions in the questionnaire there was an option for an open answer as "Other". Two of the respondents added that an ICS is more attractive than the traditional stoves which then could be another reason to buy an ICS.

Table 9 ***Reasons to invest in an ICS.*** The answers from the respondents who do not have an ICS on a question about what reasons that could make them buy an ICS.

Reason to buy an ICS	Relevant	Neutral	Not relevant
Decreased fuel demand/cheaper	12	0	3
Improved health/less smoke	10	2	3
Enables cooking of larger amount of food	8	2	5
Better for the environment	10	2	3
Time-savings	13	1	1
Higher safety	13	2	0

6.2.4 Reasons to not use an ICS

When the non-users answered the question "Why does your household not use an improved cookstove?" the majority felt that the main issue is the high investment cost, while the rest of the options were not seen as a problem by most of the respondents (see *Table 10*). The problem with the high investment cost becomes even larger due to the gender inequalities existing in Tanzania. In most households it is the women who cook while the men have the money to invest. During the interviews the women said they would prefer to buy an ICS if they had the money, while the men preferred to buy other things like alcohol and entertainment. Besides the options given in the questionnaire for the above question, four persons added that they do not have an ICS because they think the quality of the stove is too low compared to a traditional metal stove.

Table 10 ***Reasons to not use an ICS.*** The respondents answers to the question "Why does your household not use an Improved cookstove?"

Why does your household not use an Improved cookstove?	Relevant	Neutral	Not relevant
High investment cost	9	3	2
Do not need one	2	11	2
Availability	0	12	3
Difficult to cook some dishes	1	10	4
Lack of functions	0	8	7

The ICS users where asked why they do not use the ICS for all cooking. The answers on that question can be seen in *Table 11*, showing that other cookstoves are preferred for cooking that goes fast (for example tea) or are too large to cook on the ICS. The TSF is used when it is hard to

afford charcoal. During the interviews most consumers said the size of pot that fits the cookstove is a very important factor when they buy a new cookstove. One existing barrier is therefore the non-existing standards of size for both pot and stove manufacturers, or that most cookstoves are produced without possibility to fit together with different sizes of pots (like the Kuute does).

Table 11 ***Reasons to not use the ICS for certain food*****.** The respondents' answers to reasons to not use the ICS for certain food.

Reasons to not use ICS for certain food	
Other alternatives (mainly kerosene) are faster	13
The ICS is too small - the pot does not fit	3
Firewood is faster and easier	1
Can not afford using charcoal	1

7. ANALYSIS

In this chapter, the parameters *financial performance*, *quality*, *awareness*, *availability* and *smoke* are analyzed. These parameters are chosen because of how they stood out as the most mentioned factors for ICS adoption in the results, both for stakeholders and for household respondents. A consideration had to be done regarding the relevance of some of the households answers; this is however discussed in Chapter 7 *Discussion*. From the results, the *financial performance* and the *quality* seem to be the most important factors for the consumers. *Awareness* is interesting because it seems to differ between the stakeholders' and the households' perspectives and the *availability* are fundamental for a viable market. The parameter *Smoke* has been widely discussed and is in focus in many conducted and ongoing projects for ICS adoption, both regarding health and environmental impacts.

7.1 Financial performance

One of the most promoted advantages with ICS is the cost savings due to the low fuel consumption, promoted by both the organizations and the companies. According to the stakeholders, the low fuel consumption and thereby the low running cost makes the ICS models economically beneficial in the long run even though the investment cost is higher compared to the investment cost for a traditional stove (i.e. a traditional metal stove or a TSF).

The results found about drivers and barriers regarding financial performance are coherent with what Kshirsagar & Kalamkar (2013) say about decreased fuel consumption and high investment cost. No relation was however found to what Mwampamba (2013) states about a possible rebound effect, although this was not investigated to any extent. What was found from the interviews that was not found in the literature are to what extent the decreased fuel consumption leads to direct monetary benefits, an estimation on how much that can be saved in a given time and how short the payback time is for even the most expensive stoves.

The cost savings may only be valid in urban areas since people pay for fuel in these areas whilst most people usually gather fuel in rural areas. But even in urban areas, some consumers do not see the cost advantage with ICS. Costech (Shemdoe, 2015), REA (Nyamo-Hanga, 2015), ARTI Energy (Tarimo & Thonus, 2015) and Kiwia & Laustsen Ltd (Laustsen, 2015) said this problem appears because people tend to not look at the life cycle cost; instead they are only focusing on the investment cost. The high focus on the investment cost among the consumers are confirmed in the questionnaire in which most of the households that do not have an ICS answered it is because of the high investment cost. The fact that all respondents who use ICS said they bought the ICS with saved money strengthens the problem with the investment cost even further, especially when none of the companies (except Burn Design Lab in Kenya) support any option of financial aid or loan which the consumers could use.

By looking at the life cycle cost it is possible to see which stoves that is most economically beneficial. However, the economic output depends on many factors whereof the most significant is the fuel cost, which depends on where in the country you live and also on the amount of fuel you purchase. The price of fuel is higher in urban areas compared to peri-urban and rural areas, and is also higher in large cities compared to small cities. Many Tanzanians prefer to buy fuel on one-day basis, which results in a small amount of fuel purchased several times per week. From

an economic perspective, this is not preferable since the price per kilogram fuel is higher for these small bags compared to the larger bags of ~25-30 kg lasting for about 1-2 months.

The two figures below shows the cumulative cost for the models described in chapter 4. *Figure 17* refers to the situation in Dar es Salaam were the charcoal price is ~30 USD for a 25 kg bag, and *Figure 18* refers to the situation in Moshi were the charcoal price is ~14 USD for a 25 kg bag. Important to bear in mind is that fuel costs in the figures are based on the price per kilogram of a 25 kg bag. Many Tanzanians do, as stated above, buy their fuel in smaller amounts to a higher price per kilogram, making the fuel costs have a larger impact than the figures shows. This makes the break points become shorter for when it is economically beneficial to invest in a cookstove with higher investment cost and lower fuel consumption compared to those in the figures.

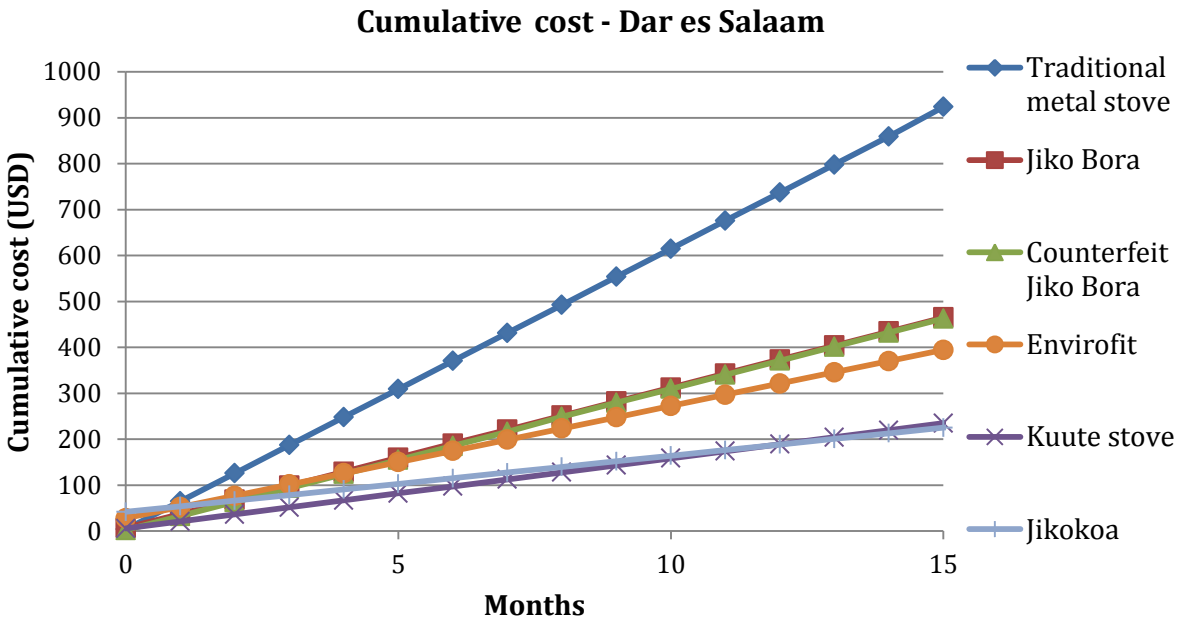

Figure 17 ***The lifecycle cost of the different models of cookstoves in Dar es Salaam.*** In the figure Jiko Makini is not included because this model is not sold in Dar es Salaam.

Figure 17 shows that all ICS models are economically beneficial compared to the traditional metal stove, and all stoves have their break-even point within a month. Comparing the counterfeit Jiko Bora with the original Jiko Bora, *Figure 17* shows that it is not possible to save any substantial amount of money by investing in the original one. However, investing in the original Jiko Bora becomes economically beneficial after 24 months use. The figure also shows that despite the high investment cost of Envirofit (almost 4 times the investment cost compared to the original Jiko Bora), the breakpoint for when Envirofit becomes more economically beneficial than the original Jiko Bora appears after only 4 months. Looking at the model with highest investment cost, Jikokoa, the figure shows that this model perform even better than Envirofit. Jikokoa has lower cumulative cost than the original Jiko Bora already after 2 months. This is due to the lower fuel consumption with Jikokoa. Kuute stove has slightly lower

investment cost compared to Jiko Bora and is the stove with lowest cumulative cost up to 12 months. After 12 months is Jikokoa the model with lowest cumulative cost.

Even though the figure shows that the financial performance of the original Jiko Bora is lower compared to the counterfeit model, this should be taken lightly. The reason is that the data collected in the study did not include for how long the stove had been broken before a new was purchased. It could be that the stove broke after 6 months and it was still used for another 2 month before a new was purchased. A broken stove could have a lower thermal efficiency and thereby increase the actual fuel consumption. With increased fuel consumption also the cumulative cost of the stove becomes higher and thereby making the counterfeit Jiko Bora less favourable.

In the figure showing the cumulative cost for the stoves in Moshi (*Figure 18*) a couple of things differ compared to the figure for Dar es Salaam. First of all the price for charcoal is about the half, which means that the running cost has a lower effect on the overall cost. In addition to this the ICS model Jiko Makini has been included as it is sold and marketed in the Kilimanjaro region but not in Dar es Salaam. The Jiko Makini uses briquettes as fuel and, according to Kiwia & Laustsen Ltd (Laustsen, 2015), the monthly cost is 11.1 USD (20 000 TSh), which can be compared to the monthly cost for feeding the traditional metal stove with charcoal of 28 USD (50 000 TSh).

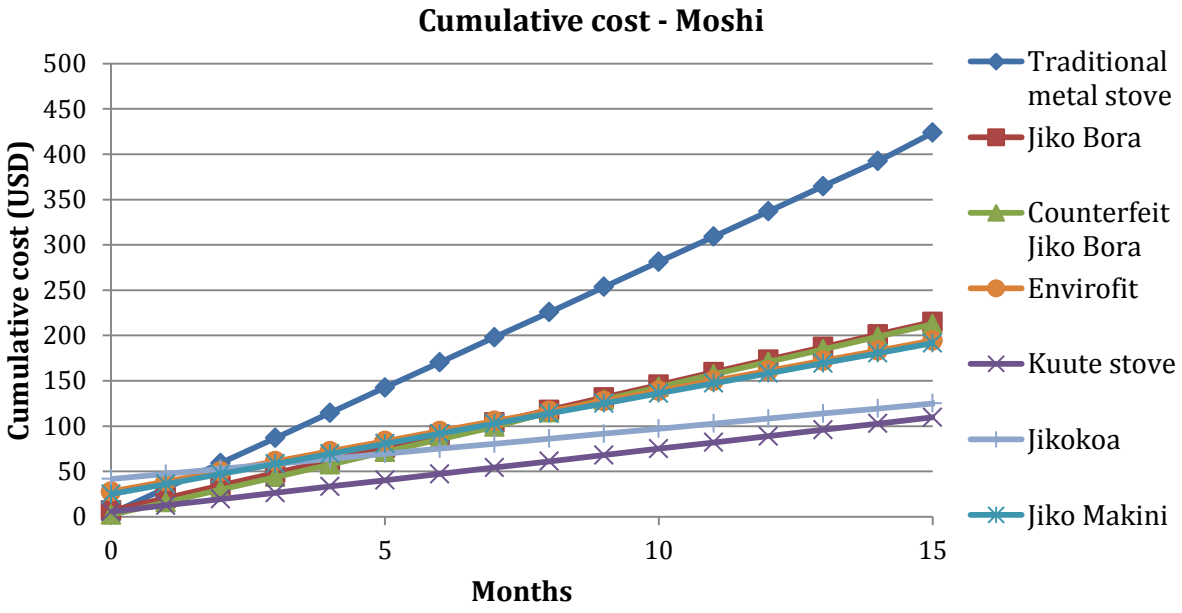

Figure 18 ***The lifecycle cost of the different models of cookstoves in Moshi***.

Due to the lower charcoal price in Moshi the break-even point for the stoves differs as from the case in Dar es Salaam. In Moshi, the break-even point for Envirofit, Jikokoa and Jiko Makini occur after between one and two months. Also due to the lower charcoal price in Moshi, the Jiko Makini is not really able to compete with the other high-end models. Jiko Makini surpasses the Jiko Bora after 7 months, but would have become more economically beneficial in an area with

higher price of charcoal as in Dar es Salaam (if the availability of briquettes were sufficient). If the two figures are compared it is possible to get an insight in how much impact the fuel price has on the cumulative cost. Envirofit becomes more economically beneficial than Jiko Bora after 8 months in the case of Moshi, while after 4 months in Dar es Salaam. For Jikokoa, the same comparison results in 5 months in Moshi, while only 2 months in Dar es Salaam. The ICS model with lowest cumulative cost in Moshi is the Kuute stove, which is never surpassed by any model as in Dar es Salaam where the Jikokoa surpasses after 12 months.

From Chapter 3.1.1 *Dar es Salaam*, it is given that the median income is approximated to 600 USD per person and year. Hence, a family in Dar es Salaam or Moshi could save more than 366 USD per year or 161 USD per year respectively by investing in a Jiko Bora (counterfeit or original). This would mean a 28% saving of the yearly income for a family in Dar es Salaam. Moving to an even more efficient stove, for example the Jikokoa, would result in a saving of 182 USD per year compared to the Jiko Bora (548 USD per year compared to the traditional metal stove).

Since one of the problems today is the low awareness of the different alternatives on the market and their specifications (efficiency, fuel consumption, durability etc.), more effort could be made on compiling and marketing data. Before this is done, it is hard for the consumers to make a good and conscious choice. More about the issue of awareness is covered later in the analysis in the subchapter *Awareness*.

Another important fact not to forget is that even if a household invest in an efficient cookstove with low fuel consumption, this does not necessarily lead to savings of fuel (Mwampamba et al., 2013). If the household decide to cook more or use the stove for tasks they did not do before (for example boiling water), the rebound-effect occur and the fuel consumption can remain the same or even increase.

7.2 Quality

The most prominent disadvantage with ICS according to the households is the poor quality of the stoves, while only 3 of the organizations and 2 of the companies see this as a problem. This is again a part of the problem with poor awareness, this time both among the consumers and the stakeholders. The consumers are not aware of the different models available on the market and their specifications and the stakeholders are not aware of the consumers' thoughts about the quality. Increased awareness among the companies about the consumers' thoughts would enable more effective marketing.

In the literature, Bailis et al. (2009) states the importance of working with standards to improve the quality of ICS, which was also found through the interviews with households and to some extent with the stakeholders. What is new is however that most of the ICS are of higher quality but it is not those that are dominating the market. The market consists almost only of counterfeit models for which the quality need to be improved, but that would instead bring them up to the standard of the original models and thus also the same price level.

In one observed case, one ICS user went back to a traditional metal stove after use of several counterfeit Jiko Bora because they kept breaking. The new traditional metal stove that they

bought was of high quality and cost more than the original Jiko Bora, i.e. the household had the money to buy an original Jiko Bora. It is possible that cases like this is spreading a bad reputation about both low and high quality models of ICS, constituting a resistance to buy ICS and thereby decreases the adoption rate.

REA (Nyamo-Hanga, 2015), TaTEDO (Sawe, 2015) and TIRDO (Nindie & Wilson, 2015) believe in building a system with standards to increase the quality of ICS. This would also facilitate the consumers' choice of cookstove since it will become easier for the consumers to get information about each stoves' specification (e.g. efficiency, fuel consumption, durability). If the quality is increased, the long durability can be a driver for ICS adoption since the quality is already something the consumers look at when they buy a new stove.

The fact is that a process for this has already been created through the Tiers (see chapter 3.2 Standardization), which can give the consumers a better insight in the stoves before they purchase them. A way to further increase the effect of this could be with stickers, a method SNV (Sebastian, 2015) have helped producers with. The stickers can include information about which Tiers the stove has achieved and contact information for the producer, as well as act as a kind of insurance that the stove is not a fake. By using such stickers it would help create awareness among the households of which producers who are to prefer and thereby making the market fairer.

Another complementary solution of the problem with low quality is to provide spare parts for the critical parts of the cookstoves. Examples of such solutions are to offer discount on repairs and replacement of broken parts, selling parts for replacement or to attach several spare parts already when the cookstove is originally bought.

7.3 Awareness

It is important to remember that there are two different areas of awareness when it comes to ICS adoption: awareness of the benefits with using ICS and awareness of the existing models and their respective specifications. Regarding the awareness of the several benefits that comes from using an ICS, subjects as economy, health, environmental and time-saving are among the most promoted. The households have proven to be aware of all of these through the survey, although most of the focus is directed at the monetary benefits. Still, the awareness can become higher.

From the literature on the subject of awareness it was found that the most reliable source for spreading the information about ICS is a consumer that is already using an ICS (Mwampamba et al., 2013), which also have been stated by stakeholders in this study and found through how the households gained awareness about ICS. The literature (Shankar et al., 2014) also confirms the findings from the interviews with stakeholders about how important demonstrations and follow up visits are. What was found from the interviews but not in the literature is that most households are aware of the benefits that ICS brings, but they are not aware of the different stove models that exist on the market and thus not how these stoves differ and in most cases are better.

Kiwia & Laustsen Ltd (Laustsen, 2015), SNV (Sebastian, 2015) and ARTI Energy (Tarimo & Thonus, 2015) believe both health and environmental issues can work as drivers for ICS adoption, while in contrast to this Burn Design Lab (Nyer, 2015) said the environment is only a

vision for the consumers. In order to make those workable drivers, almost all stakeholders said it is important to work with increasing the awareness of the benefits with using ICS. But as the urban population seems to be aware of the fundamental benefits of ICS their focus could make a bigger difference if it was directed at the second area; the awareness of the different ICS models.

From the interviews with households it was confirmed that most of the ICS users use a counterfeit Jiko Bora, but they are not aware that they are not using the original Jiko Bora nor that other models exists. The reason for this can be explained with what Burn Design Lab (Nyer, 2015) said; that the most common way to get awareness is from neighbours and that the dissemination starts that way. This could indicate that the channel of information through advertisement is too low and that could cause problems as the information could be misrepresented and some parts could be lost. The low awareness of the existing models and the difference between them is one such problem, contributing to a low ICS adoption rate.

7.4 Availability

Almost all of the stakeholders mentioned availability of the stoves as a barrier for ICS adoption, but most of the companies said they are trying to expand and reach new markets. Even though all but one household stated that the availability of ICS is good, it is clear that they only had the counterfeit Jiko Bora in mind. This is clear because only 13% of those who have an ICS were aware they do not have the original Jiko Bora, while the rest did not know that there exist models of higher quality. Additionally, when showing a pamphlet from ARTI Energy about the Envirofit no one had seen those stoves before, implying a lacking availability or marketing.

No literature was found on the subject of the availability of stoves on the market. What was found during the field study was that the counterfeit stoves are highly available in urban areas while, as the stakeholders state, the more expensive models have to increase their availability.

The only company that mentioned availability as a barrier was Fivestar Hardware Ltd (Lesiriam, 2015). The availability of their stoves are affected both because they are quite new and therefore have not been able to expand much yet, but also because they are dependent on another type of fuel of which they are almost the sole producer. In order to begin sales in a new area they also have to assure a consistent supply of briquettes.

7.5 Smoke

Smoke is connected to several subjects whereof health, environmental impact and cleanliness are the most relevant for the ICS sector. Many projects have been conducted and are running to solve these problems. Most (or all) of them are focusing on the development and dissemination of ICS, which means a focus on the demand-end (Mwampamba et al., 2013). None or few projects have been conducted to look at the supply-end, focusing on developing a more efficient production of charcoal. Today, the kiln efficiency for charcoal production is very low. It would be possible to increase today's efficiency of 16.6% (Riedijk, 2011) towards 30% according to another source (FAO, 1987). By putting resources on this as a supplement to trying to increase the adoption rate of ICS it is possible to decrease deforestation and erosion while making charcoal cheaper, both by requiring less wood in the kiln but also by decreasing costs of transportation to and from the charcoal production sites.

Regarding the urban population's thoughts about the smoke and its health impacts, the ones who have an ICS see improved health as a great advantage over the traditional stoves. For the non-users, the answers differ depending on location. In Dar es Salaam, the households using traditional cookstoves rarely mentioned improved health as an advantage with ICS, while in Moshi this was mentioned as an advantage by two thirds of the non-users. One explanation of the different views among the non-users is that the policies for preserving forest, prohibiting charcoal and keeping the Kilimanjaro snow cap from melting which has been implemented in the Kilimanjaro region, have made the population in Moshi more aware of the consequences from cooking.

In the literature, Grieshop (2011) states how ICS adoption can improve health and Troncoso (2007) shows how this is somewhat important for the households. However, the monetary benefits are still a more important driver. This is somewhat confirmed by the results from our household interviews, but there are no real evidence from our study that the monetary benefits would be more important than the health benefits. The two categories got about the same amount of responses, both in closed questions and open questions. That the monetary benefits are more important than health is also stated by both Shankar (2014) and Ruiz-Mercado (2011).

A problem can be seen in that over 50% of the household respondents stated that less smoke is an advantage for ICS compared to traditional stove, while only 4 out of 16 stakeholders see this as a driver. Even though it is not the most important advantage for the households it could play a difference in the advertising of the stoves, at least when a household has the possibility to chose between several models.

8. DISCUSSION

In this part of the report we will discuss the outcome of the work. The chapter includes a discussion on how the results differs from and corresponds with the hypothesis, how the results are in line with and/or differing from previous research and thereby how the research adds to the field. We will then discuss the uncertainties of the execution of the work and how it could be improved, as well as possible improvements for future research and future research areas.

At the planning stage of this research project, a hypothesis was formed about what the expected results would be. One expected result was that the cost parameters would play the main role as both driver and barrier which has been confirmed by the study. What was not expected was how big of a role quality and the awareness of quality and ICS models would take. In the hypothesis, awareness is included in form of knowledge. The term knowledge in the hypothesis refers to awareness about health benefits, reduced environmental impact and time-savings, constituting possible drivers for ICS adoption. From the results, unawareness of the existence of several ICS models and the difference between them seems to cause a barrier for ICS adoption.

No literature has been found that analyses the differences in drivers and barriers for households and the conceived drivers and barriers by the stakeholders. There are however many published works discussing the drivers and barriers for the households; how they are valued and how they can be addressed. The ones we found through the interviews are coherent with those found in the literature, i.e. no new drivers or barriers were documented. The interesting part of this study is however not the drivers and barriers themselves but how they are valued and how they correspond between the households and the stakeholders.

There are some uncertainties in this study, especially from the household interviews. One of the greatest uncertainties of the study lies in the relevance of the collected data. If the category *Better for the environment* in Table 9 and Figure 15 is compared, we can see a difference in the results. This happened as the respondents were asked to rank the relevance of how important different factors were when asked about the reasons to buy an ICS as a closed question, compared to when asked about the advantages of ICS as an open question. This implies the necessity of a critical approach to the data, especially to the answers from the closed questions as long as it is not coherent with an answer from an open question that can confirm the data.

Another uncertainty comes from designing an interview with only literature as sole experience of the subject, together with our inexperience of conducting interviews which leaves room for errors. It might have been better to perform a couple of interviews as a test and then re-design the questionnaire and interview questions, although this was not possible because of time restraints. The questions in the questionnaires and the interviews were designed to be as little leading as possible, but because of the translation to Swahili it is hard for us to know if the questions were translated literally or if the interpreter made own interpretations. During a couple of interviews it was noted that the answers were not answers to the question asked. The question was then re-explained to the interpreter until it was clear that the respondent answered the correct question. This may have resulted in more leading questions.

Improvements that are possible to do to continue this research could be done in several ways. One could be to re-design the interviews/questionnaires with the results from this work in mind

in order to go more in depths. Another could be to include more households and stakeholders as well as including other urban areas to see the consistency of the results. To further advance in the area we would suggest research on awareness. For example, it would be interesting to see the effects from an awareness campaign which explains the monetary benefits of the stoves and how to climb upwards on the "stove ladder". This should be done in a couple of regions while having other regions as control groups. After a couple of months, or a year, a follow up should be done to see the effects of the campaigns.

Important to keep in mind is that the market and use of cookstoves will change. Depending on the price trends, both on LPG and charcoal, the market could in some years be dominated by another technology than the charcoal stoves which are the most common stoves today. Also, the governmental strategy and their willingness to influence the cookstove sector will be very important for both the short term and the long term development. If the government prohibit charcoal production, implement a tax on charcoal or through other means act in a way to decrease the use of charcoal, the market can change rapidly.

Even though the study is performed in one specific country (and in two specific cities) it may be applicable also in other regions, especially in East Africa. The results from the study can be important for the companies and the organizations working with ICS. They have to increase the awareness of how to save money with the models available on the market and also increase the quality of the critical parts of their models. By increasing the quality, the consumers would benefit more in form of reduced cost and the willingness to buy an ICS would increase. This would lead to increased profit for the ICS producers/sellers (due to more sold cookstoves) which would enable further improvements.

9. CONCLUSION

The aim of the study was to address key drivers and barriers for ICS adoption in urban areas in Tanzania, and investigate how these influence the adoption rate. One more objective was to conduct a market survey to collect data about the stoves and fuel prices on the Tanzanian market. To achieve the goal of the study, interviews with stakeholders and households were done.

The financial performance seems to be a central part in the households' choice of cookstove, but only to the extent of their awareness of different types of ICS. This appears to be a central part even though previous generations' habits and culture make parts of the population conservative in how to cook and what cookstove and fuel to choose. The possibility to save money with ICS due to the low fuel consumption is the main reason for the households to use an ICS. Also the time-savings due to efficient cooking and the improved health due to less smoke are high valued advantages with ICS by the households.

The importance of the economy is seen also by looking at barriers for ICS adoption. High investment cost is the main reason to not buy an ICS according to those households who do not have an ICS. ICS have in general a higher investment cost compared to the traditional cookstoves and some households feel they do not have the capacity to invest in such an expensive cookstove. Here, the effects from the poor quality of some ICS models and the low awareness about different models and their individual performance are two important barriers. In many households, the quality of ICS is perceived as very low. This is because they are not aware of the different models available on the market and refer to those of low quality when they think of ICS. The problem that many households are using ICS models of poor quality is, according to some stakeholders, caused by that the households do not look at the life cycle cost of a stove. Almost all households only look at the investment cost when they buy a new cookstove which make them choose one of those of low quality. When the stove breaks they complain about the poor quality, affecting the attitude of ICS in a negative way.

One way to solve the problem with models of poor quality and the low awareness among the households about the performance of each model is to introduce a system with standards. The standards would become a driver for the producers to increase the quality as well as facilitate for the consumers to increase their knowledge about different ICS models' performance. However, increasing the quality of most stoves could be counterproductive as increased quality goes hand in hand with a higher investment cost and many designs are already at high quality and price. Instead, for those stoves it would be more important to have it evaluated and have the ratings displayed for the customers as a proof of its performance.

Another way to improve the market for ICS is to increase the influence by the government. The government can strengthen the institutions and organizations working with ICS adoption, enable their work to have a larger impact. Also, the government can through different policy instruments (taxes, regulations, information etc.) affect the development of the cookstove sector. The governmental strategy can increase the awareness about the effects of cooking and lead the development in a desirably direction. This may result in an increased use of charcoal-fired ICS or a fuel shift towards briquettes or gas, depending on the strategy used.

The conclusions about key drivers and barriers for ICS adoption, and how they are coherent between households and stakeholders are:

- The cost-benefit works as an important driver for ICS adoption (through decreased cost for fuel). This is acknowledged as the most important driver by the stakeholders and as the third most acknowledged driver by the households.

- The investment cost is a strong barrier for the adoption of ICS. By the stakeholders it is seen as the most important barrier while the household sees it as a barrier but not as the most important. This could be because of the low awareness regarding different models.

- The most acknowledged barrier by the households is the poor quality of ICS while the stakeholders do not support this claim. Once again the problem is the lacking awareness that the households have about the different models of ICS.

- Improved health is seen as an important advantage by many of the households and few of the stakeholders. The reality is most likely that in order for this factor to work as a driver other obstacles have to be removed before hand, e.g. the investment cost.

- Time-savings is seen as the most important factor for ICS adoption by the households while only three of the stakeholders saw this as a driver. This factor is the one where their opinions differ most while it cannot be explained by something as low awareness.

- The main conclusion we have from the study is that awareness about different models of ICS is the most important barrier for the adoption of ICS. This is because even those who can afford higher-end models (even including the original Jiko Bora) cannot purchase them if they are not aware of their existence. The companies and organizations have to increase their focus on advertising this knowledge.

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APPENDIX I – Interviewed stakeholders

Burn Design Lab: A non-profit research institution located in Washington (Burn Design Lab, 2015). Burn Design Lab is working with prototyping, lab- and field tests, market research and design for manufacturing of both institutional and household cookstoves. The founder has extensive experience in biomass conservation technologies and has been working with cookstove development in the developing world during the last two decades. Burn Design Lab is working globally and has experience from projects on three continents. Their distribution in Tanzania started five months ago (Nyer, 2015).

Costech - Tanzania Commission for Science and Technology: A parastatal organization that became operational in 1988. The organization works with co-ordination and promotion of research and technology development activities in Tanzania (Costech, 2015). Costech began its operation in 1988 and has worked as the chief advisor for the government in questions and research regarding science and technology and how they affect the socio-economic development of Tanzania. They made adjustments to the Jiko Bora (mainly adding a small air outlet and making the pot cover the fire completely) which made it a new stove called Kuute stove (Shemdoe, 2015).

GVEP – Global Village Energy Partnership (GVEP International, n.d.)**:** A non-governmental organization with head-office in UK. The organization is working with increasing the access to renewable energy in developing countries to reduce poverty. They focus on supporting development and growth of small- to medium-size, local enterprises who work with energy products and services to the poor.

REA – Rural Energy Agency (Rural Energy Agency [REA], 2015)**:** A non-profit (Nyamo-Hanga, 2015), autonomous agency under *Ministry of Energy and Minerals* of the United Republic of Tanzania (REA, 2015). REA started in 2007 and works mainly with development in rural areas, where they promote and facilitate modern energy services. The agency is working in collaboration with other Governmental agencies, Non-governmental organizations, Community based organizations and the private sector. Within the cookstove sector, they support projects, manufacturers and institutions (schools, prisons etc.) in their work for ICS adoption (Nyamo-Hanga, 2015).

SIDO – Small Industries Development Organization: A parastatal organization started in 1973 under *Ministry of Trade, Industry and Marketing* (Small Industries Development Organization, 2014). SIDO is working with development of small to medium industries in Tanzania with a focus on transfer and dissemination (Benedicto, 2015). Improved cookstoves are a part of their work.

SNV – Smart Development Work: An international not-for profit development organization working in the three sectors: *Renewable Energy, Water Sanitation and Hygiene* and *Agriculture* (SNV, 2014a). The organization is based in Netherlands and was established in Tanzania in1971. Their work with cookstoves focuses on improving the quality of already existing products (Sebastian, 2015) and they offer services to players at all stages along the supply and demand chain (SNV, 2014b). SNV founded the private/public initiative *Global Alliance for Clean*

Cookstoves led by the United Nations Foundation. During the Clean Cookstove Summit in New York, SNV made a commitment to facilitate and disseminate one million clean cookstoves (biomass and biogas stoves) in Africa, Asia and Latin America.

TaTEDO – Tanzania Traditional Energy Development and Environment Organization: A non-governmental organization based in Dar es Salaam working with modern, sustainable energy development (TaTEDO, 2013). The organization has long experience (20 years) in sustainable energy development projects and is active in more than 10 regions, 30 districts and 70 villages in Tanzania. TaTEDO was formed and began education artisans in 1990th (Sawe, 2015), while they also started the work with creating a demand and awareness of ICS in small households. The organization is mainly working with the ICS model *Jiko Bora* and are today selling about 120 000 stoves/year (can be compared to the about 500 000 sold stoves/year of KCJ in Kenya).

Most of their stoves are sold through private retailers but they also have their own stores for marketing and demonstration of their products. One of their store employees was also interviewed.

TIRDO - Tanzanian Industrial Research and Development Organization: A multi-disciplinary research and development organization established in 1979 (Sawe, 2015). The main task is to, through technical expertise and support services, assists the industrial sector in Tanzania in order to improve their technology base. In ICS, they have performed tests to increase the energy efficiency to support manufacturers (Nindie & Wilson, 2015). TIRDO also works with dissemination, where part of the work consists of demonstrations to increase the awareness of ICS among households.

Dr. Hassan Rajabu University of Dar es Salaam: A part of his work goes to quality and performance testing of ICS. The stoves are tested with both water boiling tests and kitchen performance tests. He possess knowledge about most stoves on the Tanzanian market and can give an objective view of their performance as he is not linked to any company or organization involved in development or production (Rajabu, 2015).

Companies

ARTI Energy: A collaboration between the non-governmental, non-profit making organization Appropriate Rural Technology Institute Tanzania (ARTI-TZ) and the commercial enterprise ARTI Energy Limited (Envirofit, 2015). ARTI Energy works with identification of appropriate clean energy solution and provides these on the market. Their focus is on meeting local demands and adjusts their products to local needs before they produce and introduce them on the market. In Tanzania, they are selling five different models of cookstoves from the brand *Envirofit* (Tarimo & Thonus, 2015). Four of these are for households (two charcoal stoves and two firewood stoves), one is for institution.

Most of their stoves are sold through private retailers but they also have their own stores for marketing and demonstration of their products. One of their store employees was also interviewed.

Envotec: A company producing and selling various types of improved cookstoves for small to medium-size households as well as for institutions and restaurants (Mwambije, 2015b). They produce and sell firewood, charcoal and LPG stoves (Mwambije, 2015a). Envotec also works with promoting, marketing manufacturing and researching to achieve better efficiencies of the stoves (Mwambije, 2015b). With their work they hope they can contribute to better health, reduced death, decreased fuel consumption and decreased deforestation (Mwambije, 2015a).

Fivestar Hardware Ltd: A company producing metal tools, wheel barrows, chairs and desks for primary schools etc. in their metal workshop and they also repair trucks. In co-operation with Kiwia & Laustsen Ltd. they have begun to produce the gasification stove Jiko Makini and the briquettes used as fuel. Previously, they has worked with NGOs producing cookstoves and designed a rocket stove (Lesiriam, 2015).

Kiwia & Laustsen Ltd: The company has developed and produced stoves and pellets/briquettes both by themselves and in co-operation with NGOs, and they also sell applications for solar lights. Currently based in Karatu but production is now mainly at Fivestar Hardware Ltd. in Moshi. They offer the only gasification stove on the Tanzanian market. The company has had other names before, such as Kiwia & Laustsen Ltd (Laustsen, 2015).

Seller on Makumbusho market place: A local producer of improved cookstoves who sells various types of Jiko Bora at the market in Makumbusho. They stoves are of the lower quality type, i.e. not produces according to the TaTEDO standards.

APPENDIX II – Questionnaire for households using ICS

Questionnaire – Improved cookstove

1. **Which Improved cookstove(s) does your household use?**

_____

2. **Which cookstove(s) does your household use except for the Improved cookstove?**

_____

_____

3. **For what kind of food does your household <u>not</u> use the Improved cookstove?**

My household does not use the Improved cookstove for following food: _____

_____

_____

Why? _____

_____

4. **For what kind of food does your household use the Improved cookstove?**

My household uses the Improved cookstove for following food: _____

_____

_____

Why? _____

_____

5. **How did your household get the Improved cookstove?**

Bought it with saved money: ☐

Used a microloan: ☐

Bought it to a subsidized price: ☐

Get if for free: ☐

Other: _____

For the following question; value each statement by ticking one box 1 to 5, where 1 is not relevant and 5 is very relevant.

6. **What would make your household use the Improved cookstove(s) more than you do today or for all cooking?**

	Not relevant 1	2	3	4	Very relevant 5
Increased market cost for fuel:	☐	☐	☐	☐	☐
Better knowledge of how to cook with the Improved cookstove:	☐	☐	☐	☐	☐

Other:_____

_____

7. **Name five advantages with an Improved cookstove compared to traditional cookstoves. Name them in merit order and start with the most important advantage.**

1._____

2._____

3._____

4._____

5._____

8. **Name five disadvantages with an Improved cookstove compared to traditional cookstoves. Name them in merit order and start with the most important disadvantage.**

1._____

2._____

3._____

4._____

5._____

APPENDIX III – Questionnaire for households not using ICS

Questionnaire - Improved cookstove

For the following questions; value each statement by ticking one box 1 to 5, where 1 is not relevant and 5 is very relevant.

1. **Why doesn´t your household use an Improved cookstove?**

	Not relevant 1	2	3	4	Very relevant 5
High investment cost:	☐	☐	☐	☐	☐
Don´t need one:	☐	☐	☐	☐	☐
Availability:	☐	☐	☐	☐	☐
Difficult to cook some dishes with the Improved cookstove:	☐	☐	☐	☐	☐
Lack of functions:	☐	☐	☐	☐	☐

If you miss any functions, name them here: _____

_____

Other reason(s):_____

_____

2. **If your household would buy an Improved cookstove, what would be the reason(s)?**

	Not relevant 1	2	3	4	Very relevant 5
Decreased demand for fuel/cheaper in the long run:	☐	☐	☐	☐	☐
Improved health/less smoke:	☐	☐	☐	☐	☐
Enable cooking of a larger amount of food:	☐	☐	☐	☐	☐
Better for the environment:	☐	☐	☐	☐	☐
Time-savings:	☐	☐	☐	☐	☐
High safety:	☐	☐	☐	☐	☐

Other: _____

_____

3. **What would make your household buy and use an Improved cookstove?**

	Not relevant 1	2	3	4	Very relevant 5
Decreased market price:	☐	☐	☐	☐	☐
Financial help:	☐	☐	☐	☐	☐
Increased knowledge of how to cook with the Improved cookstove:	☐	☐	☐	☐	☐

Other:_____

_____

4. **Name five advantages with an Improved cookstove compared to traditional cookstoves. Name them in merit order and start with the most important advantage.**

1._____

2._____

3._____

4._____

5._____

5. **Name five disadvantages with an Improved cookstove compared to traditional cookstoves. Name them in merit order and start with the most important disadvantage.**

1._____

2._____

3._____

4._____

5._____