CO-DESIGNING SYSTEMS FOR SUSTAINABLE ENERGY TECHNOLOGIES IN INFORMAL SETTLEMENT HOUSEHOLDS IN NAIROBI

A CASE STUDY OF MATHARE VALLEY INFORMAL SETTLEMENT

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A project thesis report submitted to the School of the Arts and Design, University of Nairobi, in partial fulfillment of the requirements for the award of a master's degree in art and design.

DECLARATION

I **Christer Adelaide Anditi**, registration number **B51/87418/2016** declare that this project thesis is my original work and has not been presented for any examination in any other institution of higher learning.

	10th August 2018
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DEDICATION

I dedicate this research project to my family especially my mother for always believing in me. I also thank my children Lessan and Semon for inspiring my efforts and strength for the best possible output in taking on this project. Special gratitude goes out to my friends and classmates for their emotional and moral support. Most importantly, I thank God for his eternal greatness and immeasurable love in giving me life and getting me this far.

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I also acknowledge the entire Mathare fraternity; the enthusiastic co-researchers and community leaders who assisted in organizing and accessing the community during the survey, the friendly and willing respondents from the sample villages and the energy suppliers within Mathare for participating in the workshop.

I also acknowledge the experts from various fields of study including, engineers, environmentalists, energy experts and academic experts who gave important insights by willingly sharing their knowledge and experience in support of this research.

Finally I acknowledge the support of the Kenyan government through the ministry of energy and petroleum for assigning policy enactors and energy experts to contribute knowledge and participate in the workshop. In concurrence, I also acknowledge the ministry of public health for also assigning health experts to participate in the HCD workshop.

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ACRONYMS

SET	Sustainable Energy Technologies
UNEP	United Nations Environment Programme
KCJ	Kenya Commercial Jiko
MOEP	Ministry of Energy And Petroleum
CBAM	Concerns- Based Adoption Model
PSUP	Participatory Slum Upgrading Program
HCD	Human Centered Design
SPSS	Statistical Package for Social Sciences
LIRA	Leading Integrated Research for Agenda 2030
ERC	Energy Regulatory Commission
KEBS	Kenya Bureau of Standards

ABSTRACT

Empirical data shows that there is limited adoption of sustainable energy technologies especially by residents of urban informal settlements in Kenya. This is because informal settlement dwellers, such as those living in Mathare valley, have little incentive to switch from unsustainable energies such as kerosene and illegal electricity connections to more sustainable energy sources. Mathare valley is one of the oldest informal settlements within Nairobi, housing over 200, 000 residents. Given that the settlement is growing exponentially, and is characteristic of informal settlements in the city, it is imperative to study the challenges encompassing the adoption of sustainable resources by low income households in the settlement, in order to propose systems that would potentially improve adoption. The overarching methodology of this research anchors on socio-technological reciprocity as an approach that borrows from the Actor Network theory (ANT). In socio-technological reciprocity, people and technologies interact continuously to reproduce environments that disable or enable the adoption of sustainable energy technologies. Using the case study of Mathare, the study analyses how disabling and enabling environments hinder or promote the adoption of sustainable energy technologies. Using a household survey of 100 households, a participatory mapping exercise and a focus group discussion, it is established that in the current disabling environment, resistance to adopting sustainable energy can be attributed to: inaccessible technologies; constraining socio-economic factors; restrictive micro-politics; and a detached macro-policy framework. To counter this, the study proposes the use of design thinking to facilitate an enabling environment in which an integrated socio-technological approach promotes the acceptance of sustainable energy technologies. To demonstrate the use of design thinking, two focus-group sessions were conducted. The first one is a multi- stakeholder HCD workshop that engaged respondents from various households in Mathare, energy providers among other stakeholders of the energy systems in Mathare, as well as policy actors from the Ministry of Energy. The second was a policy seminar that brought together residents from Mathare, energy and health experts, as well as policy actors. The two sessions highlighted the importance of co-designing informal settlement solutions with the informal settlement dwellers themselves, as well as the need for integrated policy dialogues. The end result of the research is the proposal of sustainable product-service systems that can be used to foster the adoption of the existing sustainable energy technologies.

CHAPTER ONE
INTRODUCTION

The first chapter of this project paper introduces the background of the study, states the problem the researcher has identified. It thereafter outlines the theoretical framework that the research will work around, its scope and justification.

1.1.Background of Study

The period from 2012 to 2014 presented an increase in renewable energy consumption by about 1.6% but still the global demand for energy continuous to grow rapidly. This saw a reduction in the intensity of energy consumption by the world's largest energy consumers. Though there has been increase in the consumption of more efficient and renewable energies, 85% of the world's population, including half the population in developing countries, still functions without electricity(UN, 2017). Energy is a key enabler in any given economy. Electricity, petroleum and renewable energy sub sectors have the most potential. To meet the growing demand for energy Kenya as a country needs sustainable supply of energy. Among other major consumption sectors, wood fuels are the most consumed fuels as per the current statistics (KIPPRA 2010).

Sustainability is one of the major global trends that are broadly considered in the consumerism of goods and services. Unsustainable energy has so far been determined as major setback especially in informal settlements. Nigel et al (2000), acknowledges that half the population in developing countries is reported to rely on coal and biomass in the form of wood, dung and crop remains for household energy (Nigel et.al. 2000). Sesan (2012), reiterates that it is estimated that a large population in developing countries depend on solid biomass fuels for cooking and heating. According to a 2010 report quoted by Sesan there are about 2.7 billion people worldwide falling under this category (Sesan, 2012a).

Unsustainable high carbon emitting energies result in to several health risks. Women and children have proven to be the most affected so far. When these materials do not burn entirely, this incomplete combustion poses a lot of health risks. These health risks include, health, environmental and behavioral risks. The women and children who work closely with theses energies are continuously exposed to emissions from these fuel combustion and consequent indoor air pollution (Nigel et.al 2000).

A large population in Kenya is dependent on biomass for their daily household energy needs. (Yonemitsu, Njenga, Iiyama, & Matsushita, 2014), in their research on household energy consumption state that charcoal is the most consumed energy source by households in urban areas

with lower smoke emissions and more heat retention. In comparison to wood fuels charcoal is the most preferred fuel used in cook stoves. During sunny seasons charcoal is sold for up to 1600/= per sack making it quite affordable and economical (Business daily, 2013). It is also convenient especially for people in informal settlements due to the ease of access as most charcoal production in Kenya is mainly done in the informal settlements (Wanjiru & Omedo, 2016). A study of Kibera informal settlement reveals that 90% of the households in Kibera use charcoal as an energy source, 71% use briquettes, and only 53% use kerosene.(Yonemitsu et al., 2014)

The growth of urban informal settlements in Sub-Saharan Africa has outstripped the provision of household energy, which is needed for cooking, lighting and heating (Karekezi, 2002).To tackle the challenge of energy-poverty, many interventions have been carried out with two main aims of providing more sustainable sources of energy and improving health outcomes for poor households. To achieve these aims, household energy interventions have been implemented in three main approaches: one common option is to change the source of pollution such as distributing improved cook stoves or supplying alternative energy sources such as low smoke briquettes. A second option is to improve the living environment such as through better kitchen design to improve ventilation. The third option is to modify user behavior such as by changing cooking practices to reduce smoke inhalation (Hutton, Rehfuess, & OMS, 2006).

These three options have nevertheless failed to significantly reduce the inefficient use of biomass and paraffin in low income households because: they are often implemented in isolation, or with little understanding of the socio-cultural, behavioral and economic specificities of targeted populations (Sesan, 2012a). Household energy interventions also fail to adequately address the strong gendered dimension of energy-poverty thus reproducing gender inequalities in poor settlements (Shankaar, Onyura, & Alderman, 2015). There is therefore need for a more nuanced and contextualized understanding of household energy choices and behaviors; an understanding that can support consumer focused interventions (Frederiks, Stenner, & Hobman, 2015).

Some of these interventions include, the solar cookers, the jikos that use less wood or coal, fireless cooker borrowed from ancient days, the bio fuel cookers and the LPG gas cooker with one burner. Some of these systems cannot be used to prepare an entire meal to completion and often have to be integrated with other energy forms. This includes the fireless cooker which can only prepare preheat food and the solar cooker which can only be used with the suns energy. These limitations among others have made it difficult for these interventions to work and be adopted by the targeted populations.

Before only about 32% of the population had access to electricity, in the recent past national government has since prioritized the 'last mile energy project' by reducing the cost of connecting poor households to the electricity grid, with the goal of achieving 70% electricity access by 2017 (Ministry of Energy And Petroleum, 2015). Nevertheless, connecting households to the electricity grid is not enough to meet household energy demand, since most households only use electricity for lighting (ibid). The problem of energy for lighting seems to have been adequately addressed by the Kenyan government. It is for this reason that this research is focused only on energy for cooking and heating.

While Renewable energy is a great opportunity to decrease costs, amplify the access to electricity in informal households and generate jobs/income opportunities in the communities. These energy systems are yet to be adopted by those who live in informal settlements (Kovacic, Smit, Musango, Brent, & Giampietro, 2016)). The considerable amount of time spent in sourcing for fuel in poorly planned settlements is time that is taken away from other income generating activities, family responsibilities and opportunities for self-improvement (Hutton et al., 2006)

1.1.1. Renewable Energy Potential in Kenya

Organizations such as the Kenya international renewable energy congress have been installed to instigate matters on the opportunities for renewable energy in the country. These congresses are designed to pivot and accelerate renewable energy developments across Kenya In alignment with the Vision 2030(KENREC, 2017).

Several policies have been enacted that determine the extent of adoption for renewable energy in Kenya. One of the policies is the energy Act 12 of 2006, enacted by the Ministry of Energy and Petroleum. So far this energy act has set up an independent energy regulatory commission. It has also promoted the use of biomass cogeneration for heating and lighting and alternative fuel production using sugar mills. Renewable energy systems are divided into two broad categories in Kenya: of on grid energy projects and off grid energy projects. On grid renewable energy projects entails the sales of power to others and to utilities. Off grid energy projects on the other hand includes small and large off grid systems. Small off grid systems are products made mainly for residential solar home applications and for small scale commercial PV applications. Large scales off grid systems are products that distribute power to large institutions such as schools, health centers among others (Boampong 2016). Some of the renewable energies in Kenya are discussed below.

Solar Energy: Solar has widely been accepted and adopted by the Kenyan population. Currently Kenya's solar market is the leading solar market globally for off grid solar uses with more than 320000 solar home systems (Ondraczek, 2013). Solar water heating and PV systems in sub-Saharan Africa has gained firm ground with the rural and informal sector classes determing the purchasing power of solar systems. Solar water heating systems are mainly used in homes, hotels, hospitals and learning institutions. The growing demand for solar has been spun by operationalization of the energy regulations (KEREA, 2016). Several companies like IRUWA solar are trying to reach people on the ground to create solar systems that they can easily operate (Geerts, 2016).

Wind Energy: KEREA (2016) notes that, the Kenyan landscape comprises of the rift valley, a number of mountains and highland areas, which form impeccable wind regimes. This has allowed the government to tap wind energy across the country mainly in the northern parts and at the edges of the rift valley. These have been established to be the windiest areas in the country. This wind energy is then converted to electricity that is then fed to the national electric grid. Due to the monsoon winds, a variation in the wind resources is expected characterized by low winds in the months of May and august. There various metrological stations in Kenya which determine wind resources through winds speed data (KEREA, 2016).

Geothermal Energy: In KEREA (2016) it is stated that Kenya has several geothermal resource spread across the country in areas such as Suswa, Longonot, Olkaria, Eburru, Menengai, Arus-Bogoria, Lake Baringo, Korosi, Paka, Lake Magadi, Badlands, Silali, Emuruangogolak, Namarunu and Barrier. These geothermal stations generate electricity which is again fed into the country's electricity grid. There are other uses of this geothermal aside from generating electricity. In Naivasha the oserian flower company uses geothermal heat in flower farming to boost productivity and to conform to international regulations on carbon emissions. (KEREA, 2016)

Hydro Energy: According to KEREA, Kenya has a considerable drainage system comprising of five major basins namely Lake Victoria; Rift Valley; Athi/Sabaki River; Tana River; and Ewaso Ng'iro North River. This is where the bulk of the country's hydro resources are. The potential for electricity generated from these waters is estimated at 3000MW nationwide(KEREA, 2016).

Biogas: significant advances have been made with biogas technology in the country for over fifty years with over 100 digesters being built around the country by trained Kenyan technicians. Several challenges have resulted into slow adoption of the biogas as an energy source including, high cost of installation, lack of capacity and failure of previous systems, poor management and maintenance, inadequate post installation support, lack of awareness and scarcity among other factors(KEREA, 2016).

Biomass: According to KEREA (2016), by the year 2000, 89% of rural households and 7% of urban residents use wood fuels. Charcoal on the hand is reported to supply 89% of urban households and 34% of rural households. Each household was estimated to consume 5-10kg of wood fuel per day and 1kg of charcoal fuel per day.

Bio fuels: With reference to KEREA (2016), Bio fuels are expected to reduce the over dependency on volatile global oil markets. Ethanol and diesel are two main sources of these fuels in Kenya. There are specially designed machines that are used in the production of Ethanol using starch and sugar containing crops in blends of above ten percent. Biodiesel on the other is made with vegetable oil that is derived from oil-bearing plants such as castor, coconut, cottonseed, croton, jatropha, rapeseed (canola) and sunflower. No special systems are required in blends of up to 20%. There is currently no specific legislation on bio-fuels in Kenya. However this legislation under the 2007 energy act allows the ministry of energy an petroleum to up hold the development of biodiesel and bio ethanol as renewable energy technologies (KEREA, 2016).

1.1.2. LIRA 2030 Research

This research was part of a broader research project by the leading integrated research for agenda 2030 in Africa (LIRA). The research was entitled co-designing energy communities with energy poor women in urban areas; case studies in Kenya, Uganda and South Africa. This was a collaborative research between the university of Nairobi, Kampala University and university of Stellenbosch in South Africa.

The overarching research approach of the project was Trans disciplinary in nature. This means that diverse and relevant academic and non-academic partners actively participated in the research project, with the aim of co-designing and co-producing socially relevant knowledge that can inform sustainable solutions (Lang et al., 2012). As required in Trans disciplinary research, the proposed project: used evolving and reflexive methodologies; transcend boundaries of disciplines;sought the participation of stakeholders; and aim for social transformation (Gaziulusoy & Boyle, 2013). To transcend academic boundaries, community members were co-opted as long-term co-researchers. Relevant stakeholders also participated in the project to ensure that the outputs had potential for achieving transformative social change in household energy provision.

The overall research was headed by Dr. Amollo Ambole of the University of Nairobi who was the principal investigator. The researcher, who was the research assistant in the overall project, was the main facilitator of the HCD workshop. The workshop engaged a selected group from the respondents in the preliminary survey and policy enactors. The researcher supervised and also participated in the

issuing and answering of questionnaires to various households. In the compilation of findings and analysis the researcher used the data collected from 100 households after keenly participating in the process.

1.2.Problem Statement

There is poor adoption of sustainable energy technologies for cooking and heating within Nairobi specifically in the informal settlements. A number of household energy interventions have been implemented in three main ways: one common option is to change the source of pollution such as distributing improved cook stoves or supplying alternative energy sources such as low smoke briquettes. A second option is to improve the living environment such as through better kitchen design to improve ventilation. The third option is to modify user behavior such as by changing cooking practices to reduce smoke inhalation. These three options have nevertheless failed to significantly reduce the inefficient use of biomass and paraffin in low income households because: they are often implemented in isolation, or with little understanding of the socio-cultural, behavioral and economic specificities of targeted populations.

1.3.Purpose of the Study

The purpose of the study was to propose systems of adoption for sustainable energy technologies for cooking and heating in mathare through an integrated approach of co- design to improve energy services for informal settlements. The study was guided by the following objectives:-

1. To establish the energy sources and technologies, identify acquisition points and determine accessibility to renewable energy sources in mathare that are currently being used for cooking and heating
2. Determine the socio-economic factors for preference for the current energy systems in use for cooking and heating
3. Visualize the micro-political environment that influences energy accessibility
4. Critique the current policy framework and how it addresses the needs of urban informal settlement households.
5. To co-design sustainable product service-service systems with stakeholders including, householders, service providers and policy enactors.

1.4.Research Questions

1. What is the level of penetration of sustainable energy technologies for cooking and heating in households within Mathare?
2. What socio economic factors influences choice in the type of energy adopted for cooking and heating at the household level in Mathare?
3. Who are the decision-makers/ gate-keepers who influence energy access at community level in Mathare?
4. How does the current policy framework for energy in Kenya cater for the energy needs of urban informal settlement households?
5. How can design thinking be applied to improve adoption of sustainable energy technologies?

1.5.Justification of Proposed Research

Previous research shows that the problem of limited adoption of sustainable energy technologies has seen the Kenyan community seeking interventions yet none has made any significant impact neither has any proposed the use of the Design thinking approach in tackling community challenges. This makes the research unique in methodology as it seeks to understand in depth the source of the problem by involving the specific stakeholders through a Human Centered Design workshop.

The research may contribute widely in proposing possible solutions for the adoption of sustainable energy technologies in informal settlements in Nairobi as a whole and even nationally given the similarity in of the challenges in the energy sector in the country's informal settlement's households. The proposed system can be adopted by the Kenyan ministry of energy and overall body of energy policy enactors as a basic solution for this problem.

1.6.Scope of the Study

This research is centered on household energy in Mathare Valley. The Kenyan government has sufficiently ensured the access of electricity in the informal settlements which is mostly used for lighting. However energy for cooking and heating still pose a great challenge for residents of informal settlements. Sustainable energies are being proposed to enable indefinite supply of the much needed energy products and services.

1.7.Limitations of the Study

The following were the limitations of the study:-

1. The study only focused on residents of mathare valley hence findings may not be generalized to other areas
2. The researcher used questionnaires to collect which are prone to biasness
3. The HCD workshop had an aggregate of stakeholders with different backgrounds that were not easily agreeable in achieving the workshop's objective

1.8.Theoretical Framework

This study applied the actor network theory which was developed by Latour, Callon, Law and Arkish in 1980 and complemented it with the socio-technological reciprocity model developed by Ambole in 2016. Actor Network theory (ANT) is a socio-anthropology approach that has been used in studying varied contexts, from human geography to innovation studies. It is a relational approach that theorizes the world as complex and increasingly interconnected, and therefore characterized by hybrid models of intertwining socio-economic, political, technological and environmental factors (Müller & Schurr, 2015). As such, ANT has been used to analyze power relations between actors who either use their power or collaborate to enable or disable the realization of new energy technologies. In other cases, ANT has been used to visualize non-traditional actors and processes by widening the analyses of energy beyond the technocratic system. In this way, ANT opens up alternative pathways to co-designing technologies with people in ways that are more sustainable (Wong, 2016). For this study, the ANT approach is used to analyze how disabling and enabling environments hinder or support the adoption of sustainable energy technologies.

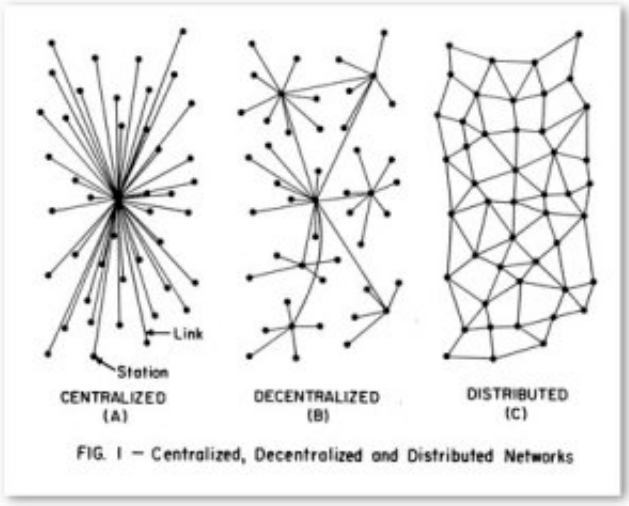


Figure 1: Illustration of the ANT

Despite its popularity, users of ANT have been blamed for not articulating their research methods in a way that would make the methods meaningfully replicable (Heeks & Stanforth, 2015). For this study,

the socio-technological reciprocity (STR) model developed by Ambole 2016, to strengthen the ANT stance of the study, by articulating the interfaces between the social and technical aspects of energy access in the case study. The articulation of reciprocity in this way, 'enforces the metaphorical capacity' (ibid pp 83) of the energy system, thereby turning it into a system of engagement. Just as in ANT, technology itself is viewed as an actor in the STR model because it has agency and is an integral part of the system. Keeping in mind that human beings, technologies and even policies are actors in ANT and STR; figure 2 shows the interfaces that occur between technology components; between people and technology and between users and providers.

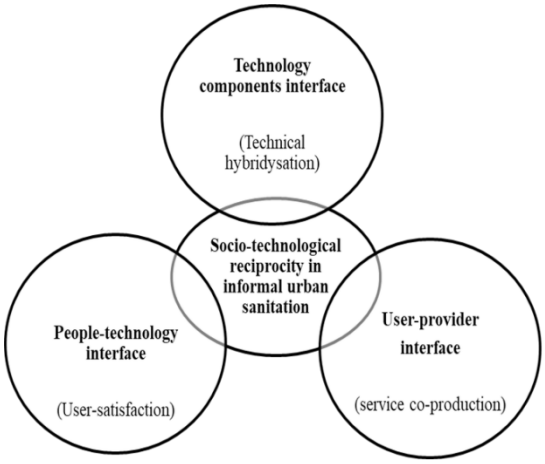


Figure 2: A socio technological reciprocity model

For this study, this model was used to visualize the interfaces that occurred at the micro and macro levels of sustainable energy access using the case study of Mathare.

CHAPTER TWO
LITERATURE REVIEW

2.1. Sustainable Energy Technology Options for Cooking and Heating

The following interventions have been proposed and also implemented by previous research bodies. The implementations have often been proposed in isolation which has resulted to failure. These interventions have failed despite being more health efficient, environmentally friendly and cost effective.

2.1.1. Solar Cookers

“Most solar cookers work on basic principles within which sunlight is converted to heat energy that is retained for cooking. One or more mirrors or shiny surfaces concentrate sunlight on a dark pot within the cooker. The pot usually has a tight-fitting lid to hold in heat and moisture” (Schaeffer, 2010)

2.1.1.1. The Adjustable Solar Cook Kit

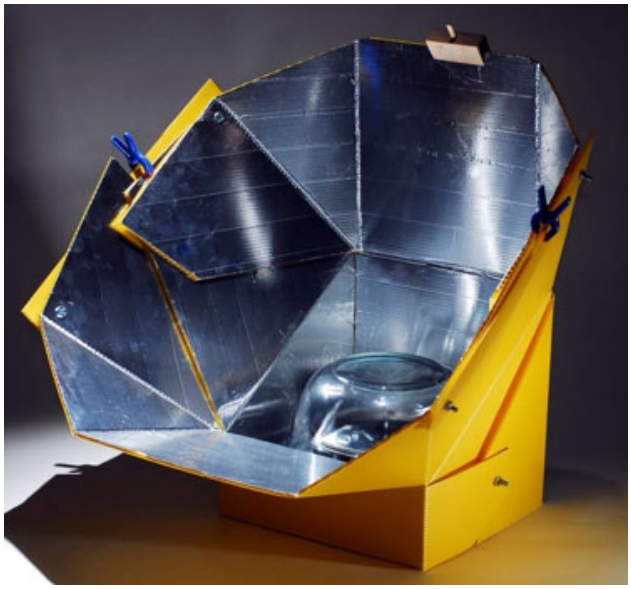


Figure 3: Adjustable solar cooker

In consonance with the solar cookers international (2017), the lightweight compact cook kit panel solar cooker is the most popular solar cooker in the world. With readily available and malleable materials such as cardboard and aluminum foil used in its manufacture the cooker can simply be folded, unfolded and seized in place for use (Solar Cookers International, 2017).

Schaeffer (2010) notes that the main materials in the manufacture of the adjustable solar cook kit are cardboard and aluminum foil. The cook kit is mostly used in food preparation and water sanitization. Its reflective foil and black paint ensure maximum solar absorption and heat retention (Schaeffer,2010).

In keeping with Oregon (2017)'s documentation, the Adjustable Solar Cooker is inexpensive hence affordable by most people living in informal settlements. Its size and ability to dismantle makes it easily portable. The adjustment mechanisms are simple and allow optimum solar cooking efficiency unlike the non adjustable solar products that have no mechanisms of optimizing solar energy. In addition Oregon (2017) states that, the Adjustable Solar Cooker simplifies solar cooker positioning as it remains in one place and is adjusted according to the suns given position at the time. This logistics follow the scientific fact that the earth rotates around the sun hence the ever changing positions of the sun. Oregon goes on to elaborate that the adjustable solar cooker sold together with a trivet and sun site is the most adaptable cooker on the market. Simplified forms can also be made using locally available materials but may not exhibit such high efficiency as the mechanically produced one. It is therefore safer and easier to cook with the adjustable solar cooker than any other cooker in its class (Oregon, 2017).

According Maccaferri (2014) the key components in the construction of the adjustable solar cooker are a cardboard box and aluminum foil. The cardboard is laid flat and covered with reflective aluminum foil or a reflective material such as ti foil. The side of the board are angled such the sunlight is focused into the center area where the cooking pot is placed. This pot is preferably black. According to empirical experiments, cooking food in plastic bags has yielded better results compared to coking in the pot alone. The adjustable cooker is therefore easy to construct from local materials, easy to use and portable. These are some of the advantages it has over other solar cookers (Maccaferri, 2014).

Figure 4: Homemade Solar Cookers Being Used By Women at a Refugee Camp

2.1.1.2. The Parabolic Solar Cooker

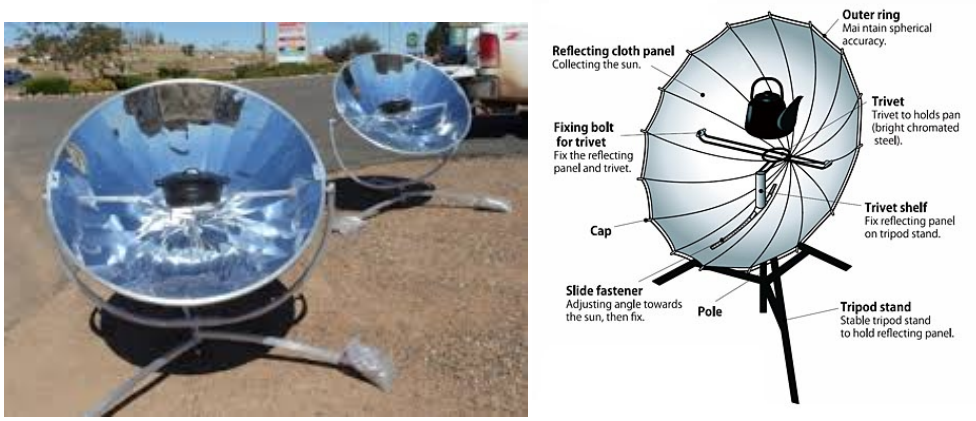


Figure 5: A Parabolic Solar Cooker and Structure (Schaeffer, 2010)

With reference to Schaeffer (2010) the parabolic cookers come in all types and sizes but conventionally in comparison to other solar cookers they are quiet large. Even so there are smaller parabolic solar cookers currently in the market that fold up like an umbrella. The parabolic cooker shell is made from a unique aluminum coated polyester cloth. Along the outer edges are flexible plastic poles that support the entire structure from the center allowing it to stand stable. A metal pot stand fixed to the shell at two points on top of the foldable tripod holds the lightweight shell. a zipper in the shell is what connects the central pole of the tripod to the pot stand. Solar cookers are overseen to have the ability to raise living standards especially in developing countries and also aid in environmental conservation (Schaeffer, 2010).

2.1.1.3 Solar Oven

On a good sunny day the solar oven can heat up to 93.3 degrees Celsius. Though the oven will still bake as the conventional ovens it will take a little longer to complete the baking process(Maria, 2014).

Figure 6: Solar Oven (Touchette, 2017)

Touchette, (2013) discusses the mechanics of the solar oven stating that through reflection which is the bouncing back of light and heat in this case, the shiny foil throws back the suns energy inside the oven. The inside of the oven is usually covered in black material to ensure maximum absorption of heat. During the baking process the hot air heat up by the sun should not leave the oven. To create this air tight effect a plastic wrap is used to trap in the air. The insulating materials often perform the function of heat containment inside the oven (Touchette, 2013).

There are no related health issues with the use of solar. The cookers also heat up to very high degrees ensuring that germs and parasites are killed while cooking. There is also better water conservation in the closed solar cooker while cooking. It also saves money and time on fuel and water costs. Because of no subsequent burns cooking pots are easily cleaned without scrubbing(Vojta, n.d.). after use the surfaces of the solar cooker are wiped off and occasionally the foils are replaced as a way of maintenance of the cooker (Maccaferri, 2014)

The use of solar eliminates exposure to smoke that would otherwise cause diseases such as lung cancer, respiratory tract infections, cardiovascular disease and cataracts and pollute the environment among others (WHO, 2017). The potential of solar cooking adoption is rather high for rural and informal settlements in Kenya where the average fuel consumption is low and danger of accidental fires eminent (UNEP, 2011). According to Sesan, while the solar cooker may not be economically and culturally appropriate it is very technologically appropriate and sustainable(Sesan, 2012a). in keeping with UNEP, the major benefits of the solar cookers especially in developing countries are better health conditions, easy access to energy and overall poverty alleviation (UNEP, 2011).

Another upside to solar is that it can be home built. The construction is simple as explained above and the wooden ones are also strong and durable. Solar cookers are easy and safe to use even around small children. The food in cooking cannot burn or overcook with solar cookers. Supervision time is reduced remarkably as food does not need stirring or turning. This also assists in preservation of food nutrients (Vojta, n.d.)

Other than cooking and heating of food, solar cookers can also be used to disinfect equipment. These include medical objects such as bandages and sterilizing items that must remain dry once the cooker reaches 149 degrees. This would require a thermometer to ascertain. Solar can also be used in preservation or canning foods. The can jars are filled with the fruit, water, juices, etc., and loosely cover. The inside of the cookers can also be used as fireless cookers. Different types of foods can also be dried using solar(Vojta, n.d.).

Unfortunately, solar technology is limited to day light. In places with little or no sunlight the cookers can barely function. These are places where cooking is mostly done indoors and firewood and other biomass are readily available. In such cases, solar cooking can be used together with other energy efficient technologies (Solaripedia, 2010)

In pursuant to UNEP (2011), promotion of solar cookers worldwide has never been focused on profit making with non governmental bodies funding the production and distribution of such systems. For most entrepreneurs this has is not financially beneficial as it does not offer the best returns on investment. (UNEP, 2011)

Maccafferri acknowledges compared to traditional methods of cooking the solar cooker is considerably slow and takes a rather long time to get food ready. For instance, the solar cooker cooks for half the time or less that firewood would. This would require advance and better planning when considering to cook as one would need to cook ahead of time (Maccaferri, 2014).

Maccafferi also writes that heavy meals such as ugali would take a while for the general population of Kenya to get used to preparing food using solar. A period of adjustment and experimentation would be needed to spread and adopt the knowledge on how to prepare traditional meals using solar. Solar cookers are weather dependent. On colder days, solar cookers may be unable to cook food to completion. In such cases a backup cooking system may be required hence families may have to incur additional costs of having two cooking systems (Maccaferri, 2014). Society may not find comfort in the fact that solar cookers can only be used outdoors and this may eventually invoke cultural issues (UNEP, 2011).

2.1.3 Fireless Cookers

Figure 7: Fireless Cooker (Okello, 2017)

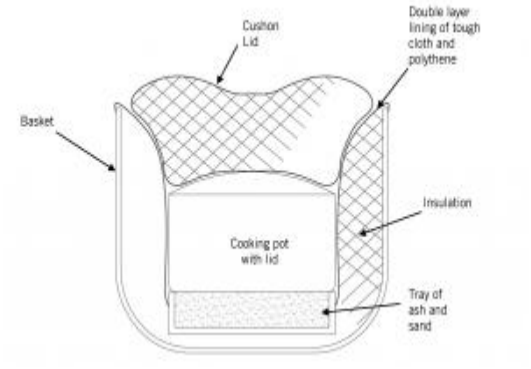


Figure 8: Structure of a Fireless Cooker (Practical Action, 2017)

In outlining the history of the fireless cookers Reber (2012) states that like the current crock pot, fireless cookers were quite trendy in the early 1900s. As required when using a fireless cooker, food was heated in tin pots then placed in the fireless cooker to continue cooking. Preheated Soap stones, that would automatically shut off after the food had gotten to the right temperatures were placed under ovens an pots (Reber, 2012).

In concurrence with Reber, Weisberg et al (2012) also delineates the process of using the fireless cooker. He explains that to use a fireless cooker one has to bring the food to the right temperature then extinguishes the energy system in use and let the fireless cooker do the rest of the cooking. This would work by the cooker maintaining the heat at a steady temperature (Weisberg, Bot, F, & Grafman, 2012).

According to Lovewell, whittemore, and Lyon (2013), the primary objective is not only to save the time and strength of the cook but also to save and minimize the energy used in preparation of the

food. In their words "Women may be so busy doing, in the laborious service of the Biblical Martha, that they find no time to accept the invitation, "Come ye apart and rest awhile," whereby to gain steadiness of purpose and power to meet the exigencies which must arise in all daily life." (Lovewell, whittemore, & Lyon, 2013).

Weisberg states that there is assured safety in using the fireless cooker which is a great advantage that comes with it. The fireless cooker ensures complete non exposure to smoke which would otherwise lead to health problems. The fireless cooker is portable. It is also convenient in that it keeps food warm for up to eight hours taking away the need to plan for time for food preparation in advance. It also takes away the worry of food getting burnt during preparation (Weisberg et al., 2012).

Other advantages noted by Lovewell are that the fireless cooker aside from saving fuel also brings to table some of the most cost effective and most nutritious foods as it simmers in the wholesome content of the dish. This helps to save the family some income and still allow them to enjoy some of the most deliciously cooked foods (Lovewell et al., 2013).

With reference to Weisberg, the fireless cooker emits negligible heat in comparison with other cookers to the environment. This goes a long way in providing a comfortable environment in the kitchen that's void of excessive heat. This quite applicable in warm and hot weather or climate and in poorly ventilated kitchen. Overlay the cooker helps to save both money and energy (Weisberg et al., 2012).

According to Sesan the fireless cooker has negligible appropriateness in technology and also economically despite being culturally acceptable. The other eminent challenge is that the rate of cooking if quite slow with the fireless cooker despite the fact that it saves energy (Sesan, 2012b).

Some of the materials and requirements noted by Weisberg in the making of a fireless cooker include; a large but simple Basket capable of housing a sauce pan. Lining material used to cover the inside and the cover of the basket. Sustainable materials such as jute, cotton, wool, bark cloth are some of the materials that can be used as lining. Threading material and a large needle are also required in sewing the basket together. More importantly is the insulation material that would be place just below the lining (Weisberg et al., 2012).

1.  2.  3.  4. 

5.  6. 

Figure 9: Fireless Cooker Making Process

According to a nongovernmental organization in Kenya called Practical Action these are the step by step guideline in making a fireless cooker. This process is more or less the same one that Weisberg discusses; only it's applicable to the local context in Kenya. The materials used can also readily be found locally.

Insulating materials such as fiber, recycled clothing is collected. These insulating materials are then sawn on the inside of a strong basket or box. The lining material is then glued or nailed to hold the insulating material in place. Using dry heat resistant polythene is then used to line the lining cloth on the inside to protect the stuffing. One cloth cushion is then attached at the bottom and a second one is packed at the top. The fireless cooker is then complete and ready to use (Practical Action, 2017).

2.1.1.4. Training Institutions in Kenya for Construction of Fireless Cookers

1. Energy centers across the country

The new government energy centers provide demonstrations and training, especially for women and young people in rural areas and informal settlements(Wanzala, 2014)

Figure 10: Women in Training at an Energy Center (Wanzala, 2014)

2. Non governmental bodies: Micro Aid and Practical Action

Micro aid defines itself as an organization that provides knowledge that is beneficial in the advancement of livelihoods of the poor. The materials that microaid promotes in the making of fireless cookers are natural and easily accessible for the common citizen (Micro Aid, 2012)

Okello reviews Practical Action's work stating that it is spread across northern, central, and southern parts of Kenya and neighboring countries. The main focus for practical action are the everyday challenges such as food security, agriculture, disaster risk reduction, and urban water, sanitation and waste management service(Okello, 2017)

Figure 11: A Micro Aid Training Session (Micro Aid, 2012)

In Nairobi readymade Fireless cookers are also available in super markets and at the ministry of energy offices in at Jamhuri energy centre for purchase.

2.1.2. Improved Jikos

Initially, jikos were made purely from metal that conducted away heat in to the environment. More energy was lost in the air than was used for cooking (Rasmusen, 2006).

Figure 12: First Jikos (Rasmusen, 2006)

2.1.2.1. The Kenyan ceramic jikos

Kammen (2011) states that, “The Kenyan ceramic jiko was the second phase in the development of the jiko. It is a portable improved charcoal burning stove consisting of an hour-glass shaped metal cladding with an interior ceramic liner that is perforated to permit the ash to fall to the collection box at the base. A thin layer of vermiculite or cement is placed between the cladding and the liner. A single pot is placed on the rests at the top of the stove. The KCJ is the result of research on stove design, efficiency, and patterns of usage initiated in the 1970's and actively continued through the 1980.” (Kammen, 2011).

“If used and maintained properly, the KCJ can reduce fuel use by 30 - 50%, although not surprisingly there is considerable variation based on the extent of training and outreach efforts, stove quality, and cooking practices. The KCJ also significantly reduces emissions of products of incomplete combustion such as carbon monoxide, nitrogen and sulfur oxides and various organic compounds, as well as particulate matter that would otherwise contribute to a variety of health risks” (Kammen, 2011)

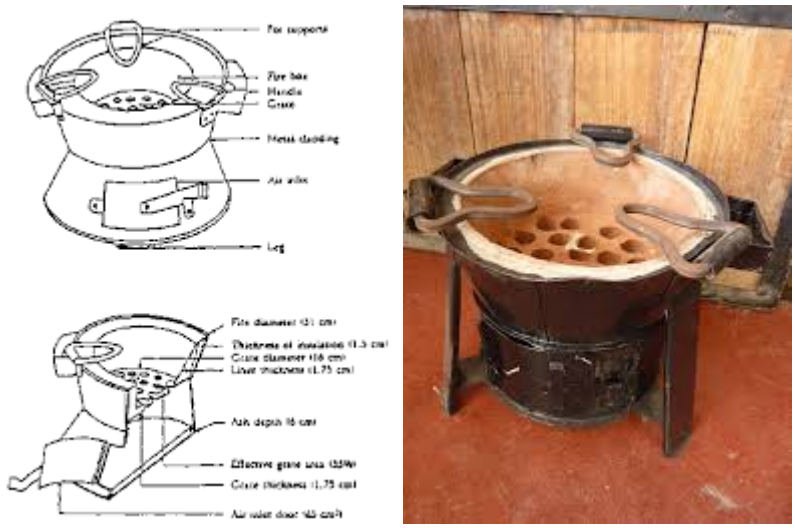


Figure 13: The KCJ Jiko

2.1.2.2. Improved ceramic jikos

Figure 14: Jiko-okoa

The Ashden (2015) states that the jiko-okoa uses 50% less charcoal than the Kenyan ceramic jiko. It also cooks 50% faster than the KCJ. The jiko is defined by a ceramic insulation that maintains high temperature and is lighter in weight. It is designed to withstand up to 1300cc. this characteristic keeps the jikookoa cool to touch. The outside lining of the jikookoa is made from stainless steel metal that is highly durable and balance fuel and air mixture (Ashden, 2015).

Ashden elaborates further that the jiko has ergonomically designed handles that are easy to use and will not overheat. Underneath the grate of the jiko is the ashtray that allows temperature control during cooking and helps to keep the jikokoa clean. To light the jiko from underneath, the tray can easily be moved in out to facilitate this. This tray area also allows one to control the airflow and rate at which the jiko burns. The function of the ceramic wool insulation underneath the ashtray is to cut heat loss. The components of the jiko fit tightly together to prevent air leakage and even futher heat loss (Ashden, 2015)

Ashden further states that, “The jikookoa itself represents a step-change in the design and efficiency of charcoal-burning cook stoves, dramatically improving the health and wellbeing of its users. As well as being an inspirational household product, it cuts down on smoke and soot by more than 60% compared to the widely used Kenya ceramic jiko, and significantly reduces the time spent cooking and collecting wood” (Ashden, 2015).

The Botto- Solar (2017) also agrees that jikookoa which is designed for household is quite sufficient and can cook up to twelve liters in size. In basic measurements, this is enough food for a family with as many members as eight. The jikookoa is characterized by a smart external finish, curved surfaces that are coated in black powder and stainless steel for the exposed metallic parts. Despite all these the targeted users still preferred it to be the size of the Kenyan ceramic jiko.

Another improved ceramic jiko defined by Botto-solar (2017) is the mama Safi stove that is built with multiple burners. This stove allows one to cook more a meal at a time depending on the number of burners. It is best suited for institution because aside from the multiple burners it comes in different sizes and can cook great amounts of food the kind required for example in boarding schools. Its ability to cook meal at a time enables one to cut on fuel cost and even on consumption. The stove also features an optional oven compartment which can be used in baking, heating and food storage (Botto-Solar, 2017).

Figure 15: The Mama Safi Jiko (Botto- Solar, 2017)

The mama Safi stove has an inbuilt chimney system that channels 90% of the smoke outside, away from the kitchen. This helps to improve indoor air quality and circulation. Smoke that might eventually result in to various health problems through indoor air pollution is also alleviated and channeled out to the environment. Apart from prevention of illnesses it makes it easier to maintain a clean kitchen. Materials used in the construction of the mama Safi stoves are also non toxic and do

not pose any health risks. They include: high quality stainless steel, mild steel, aluminum, bricks and fireproof cement (Botto- Solar, 2017).

“Mama Safi Stoves reduce the amount of fuel and in specific firewood by supplying a home or institution with clean, renewable energy from biomass. By using less firewood and providing more energy, mama Safi stoves are a convenient choice for cutting carbon footprint down to size while maintaining a comfortable lifestyle” (Botto- Solar, 2017).

“A Mama Safi Stove can drastically reduce one’s monthly firewood bill and electricity bill by 50-70% hence it financially beneficial to the user. This drastically improves your bottom line as an institution. With proper use, care and timely maintenance, the Stoves have a projected lifespan of over 10 years of active service making it quiet viable for people living in informal settlements with low income” (Botto- Solar, 2017).

Mama Safi Stoves have high heat retention ability due to the brick lining that absorbs and retains heat increasing considerably the cooking speed of the stoves. Less firewood is therefore consumed reducing the wood fuel costs and contributing to environmental conservation (Botto- Solar, 2017).

2.1.3 The Bio Fuel Cook Stove

Figure 16: bio fuel cookers (TEL, 2016)

TEL (2016) defines bio motto as a round bottom stove that has a heating capacity of twenty liters with a lifetime of 25 years. This innovative system is manufactured and processed in Kenya and cooks just about all types of food. It weighs about three point five kilograms.

According to TEL (2016), “Bio motto is fueled using bio fuel. This spirit fuel is processed from purchased, weighed stalk of sweet stalk sorghum that is grown by rural base of pyramid communities in economically marginalized, arid and semi-arid areas for food, fodder and fuel feedstock. The processing bio refineries built in the feedstock production areas create a permanent fair trade industrial market for commercial rural agricultural production.” (TEL, 2016).

As stated in Venture Capital (2016) Bio motto is relatively durable, safe, zero explosions and zero fuel spills. It is Carbon neutral has no carbon print hence environmental and health friendly. It is fueled by Bio Fuel from waste stalk of Hybrid Sweet Sorghum crop, grown in arid and semi arid economically marginalized zones for food, fodder, Bio fertilizer and the Bio fuel feedstock (Venture Capital, 2016). A half a liter of the bio fuel burns for five hours and costs only twenty five Kenyan shillings making it cost effective and very efficient (Musembi, 2017).

2.1.4. Liquid Petroleum Gas

"Liquid petroleum gas (LPG) is a clean-burning, efficient, versatile and portable fuel, produced as a by-product of natural gas extraction and crude oil refining. It can be up to five times more efficient with high calorific value than traditional fuels, produces less air pollutants than kerosene, wood or coal, and emits about 20% less CO2 than heating oil and 50% less than coal; it also reduces black carbon emissions. Historically the main obstacles to wider LPG use in developing countries have been affordability and availability" (World LP Gas Association, 2014).

Despite the higher fuel costs, supply issues cultural preferences and fear of accidents, women still prefer the LPG gas over other types of fuel (World LP Gas Association, 2014).

LPG is 100% technologically appropriate. It is also culturally accepted though it is a little expensive for people in informal settlements (Sesan, 2012b). LPG is a clean fuel whose emissions are below the critical level of 10µg per m3.this contributes to various health benefits as the user is not exposed to any smoke or excess toxic gases. Women and children who mostly undergo physical strains while collecting other biomass fuels like wood, charcoal among others are no longer exposed to such health risks. Women especially those who fetch firewood experience physical drudgery such as neck aches, headaches, backaches, bruises, animal attacks prolapsed uterus and degeneration of the cervical spines (World LP Gas Association, 2014).

2.1.5. Biogas

The energy centers in Kenya also promotes biogas technologies for informal communities as a sustainable form of energy(Wanzala, 2014). Due to the imitations of solar to sunlight energy, biogas is a recommended supplement for energy especially at night. Biogas can also be used in cooking foods that may be difficult to prepare with solar cookers and can be acquired at a cost of a thousand Euros per unit. One unit is enough to serve up to four families (Project surya, 2009)

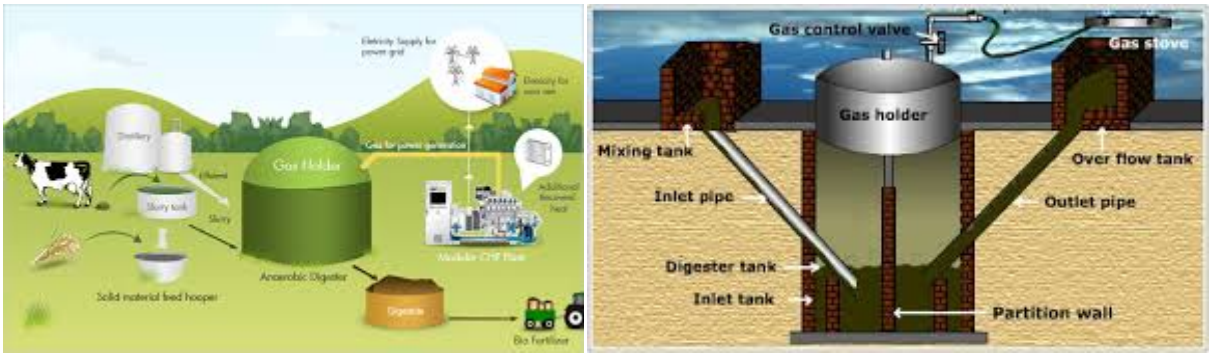


Figure 17: Biogas Digesters for Electricity and Cooking Respectively

Probiopol (2015) simply analyses the process of biogas production. Is states that, "In the standard process of biogas production, the bioorganic material is processed before being fed into the biogas plant. The plant consists of a mixer, two digesters and gas storage. The digesters are also called fermentation tanks and are the crucial components of the plant since they provide the anaerobic conditions in which the bacteria generate biogas. The substrates have to be constantly heated and stirred in order to ensure their homogeneity and the consistent discharge of gas. The gas holder is normally an airproof steel container that, by floating like a ball on the fermentation mix, cuts off air to the digesters (anaerobiosis) and collects the gas generated. In one of the most widely used designs, the gas holder is equipped with a gas outlet, while the digesters are provided with an overflow pipe to lead the sludge out into a drainage pit"(Probiopol, 2015).

One of the major benefits clearly outlined by Nielsen (2009) is that it is affordable and once bought with very little maintenance required is a way to recycle organic waste. It also goes along a way in maintaining environmental health. Biogas also reduces on green house gas emissions and reduction in diseases caused by pathogens through sanitization. The end product of the biogas digester is fertilizer for land used in planting. Biogas also helps to eradicate bad odors from the environment and nuance flies. Apart from fertilizing land it is also economical for the farmer who no longer has to buy fertilizer. The other advantage of biogas is that it can be communal and outlet pipes directed to different households (Nielsen et. al. 2009).

2.1.6. Briquettes

Figure 18: Briquettes

Briquetting is an effective waste recycling technique. It is a cheap fuel source with sustainable and renewable energy. Available in a variety of shapes a briquette can last up to four hours and saves a substantial amount of fuel consumed per year (Ngusale, Luo, & Kiplagat, 2014).

Once you have bought the briquette making machine, the process of briquette manufacturing begins with Collection of Raw Materials. Usually, any biomass material that has burning capacity like wood, sawdust, wheat straw, wood chips, leaves among others can be transformed into briquettes (Tilala, 2015).

The second phase is Preparation of raw material. Moisture level at any given time will determine the burning rate of a given material. Preparation of material may include drying and mixing different materials in right ratio and mixing of binders in the raw material. shredding or wood powder making machine can be applied to reduce size of the raw materials (Tilala, 2015).

The third phase is the compaction stage. This is where the materials are converted into briquettes. Extreme pressure is applied on the materials under high temperatures to bind the materials in the form of logs. The final stage involves cooling and storage of the manufactured briquettes. Once the briquettes have been cooled they should be stored in a cool and dry place for use (Tilala, 2015).

Advantages of using briquettes

One advantage that briquettes have over other biomass fuels is that it is concentrated and the process of making briquettes makes them harder, denser and more compact. This compacting of briquettes make them burn slower and enables them to burn for a lot longer than other biomass fuels.

Due to their low thermal content and higher heating value breaks have proven to be more efficient than other biomass fuels. They are also smokeless with no soot or carbon deposits. As they burn, briquettes do not emit any toxic gases or chemicals like sulfur and leave behind just a little fly ash after burning (Pantuhan, 2011).

Biomass for briquette production is readily available even from waste matter making briquettes easily accessible. Briquettes are also easy to make, store and transport.

Briquettes are also generally less expensive than other fuels. Briquettes are also renewable as they are made from organic matter(Pantuhan, 2011).

2.2. Energy Regulations

Introduction

The government of Kenya in the energy act has given provision for an energy regulation board outlining within its mandate certain responsibilities and powers. These are given to ensure proper energy governance structure within the country. There is need for the common Kenyan citizen venturing into the energy business to understand their responsibilities to the government and also to the consumer in their sales. The energy commission is an independent body tasked with the responsibility to regulate the generation, exportation, importation, transmission, distribution and supply of various energy forms such as electricity, petroleum, renewable energy and other energy forms. The powers to formulate enforce and review regulation codes and standards for the energy sectors lies squarely with this commission. Also within its mandate is to protect consumer, investor and other stakeholder interests. The commission is also tasked with granting and enforcement of licenses and permits within the energy sector. (Energy act)

KIPPRA in its study on energy consumption patterns in Kenya argues that energy use in residential area is mainly a factor of consumption while in the commercial sectors it is an ingredient of the production process. In households energy consumption is controlled by two factors namely energy stacking and switching. Where energy stacking would entail the use of multiple sources of energy in one household energy switching would mean the adoption of a different kind of energy as a substitute for a former energy source. These two factors are both reliant on the socio economic status of a give household. The economic growth of a household would determine whether it can afford another type of energy form to use. There is a defined advancement where households are seen to transform step y step from primitive fuels such as animal waste, agricultural waste and firewood to transition fuels such as charcoal, coal and kerosene and eventually to advanced fuels. Theses advanced fuels such as bio- fuels, LPG, and electricity though sustainable are more costly than the other fuel categories. (kippra)

The energy regulations provides that if any case a user, manufacturer, retailer or distributor should have a complaint or any dispute in relation to a certain type of energy they should be able to contact the commission for a resolution. It is at the commission that the matter may be determined within the commission's rules of natural justice. After twenty one days the dispute must be determined and the commission must be able to give reason for their determination(Republic of Kenya, 2016)

Manufactures on the other are also required to submit annually records of the number of energy appliances that they have sold. Failure to make this submissions , the manufacturers are liable to be

fined an amount of up to one hundred thousand every month for the period of time that they fail to account for their products(Republic of Kenya, 2016)

A manufacturer whose certificate of registration is revoked is expected to immediately stop distribution of their products. Those products that will still be in retail shops or with distributors will then be recalled within six months of the notice. A register for all energy appliances in the market are kept by the commission(Republic of Kenya, 2016)

2.3. Energy Policies and Strategies

Kenya is endowed with several renewable energy sources. these sources include geothermal energy, hydro power,, biomass, bio-fuels, biogas, solar, wind municipal waste , co- generated energies, feed in tariffs and other renewable energy sources (Republic of Kenya, 2012, p. 314). Short term, midterm and long term policies and strategies have been laid out to enhance production and harvesting of the various renewable energy sources within the country (MoEP, 2015).

Geothermal energy

“Some of the policies on geothermal energy are that the government will support and fund geothermal projects across the country. This funding is meant to cover geothermal risk and also act an incentive to attract investors. In addition to this the government also provides monetary incentives to promote research development and capacity building. To accelerate the process of geothermal development, the government streamlines licensing and allocation of geothermal blocks in various parts of the country. The government in addition, enforces compliance with regulatory requirements that ensures that the best available technology is used to optimize resources and conserve reservoirs. The implementation of these technologies is the way the government enhances and promotes early geothermal generation”(MoEP, 2015).

Hydropower

Most hydropower is harvested in drought infested areas. These hash conditions has seen the government introduced policies to alleviate hydro risk to cushion the various stakeholders including, generators, transmitters and consumers. The coordination and management of water resources are to be enhanced to ensure conservation of the reservoirs. The government is also to fund water catchment areas investing more in storage capacity to enhance hydro production. The hydro projects are to be implemented by the government as multipurpose projects financing prefeasibility studies to assist in the identification of hydropower sites across the country. The short term policies for small hydro on the other hand are that the government is to invest hydrological data collection, management and

dissemination. Aside from providing incentives for public private partnerships, the government is to also promote capacity and knowledge on usage of appropriate technologies for the small hydros. (MoEP, 2015).

Biomass

"The policy on biomass provides that the government is to formulate a strategy that coordinates biomass energy research across the country" (Mugo & Gathui, 2010). In support of this the government is to develop, update and disseminate information on biomass energy resources in the country .(MoEP, 2015)." In line with this the government is also to integrate biomass energy issues including research into the education system"(Mugo & Gathui, 2010). In continuing in the creation of awareness, the government is to undertake public sensitization and awareness programs that drive environmental management, protection and conservation.(MoEP, 2015). According to (Mugo & Gathui, 2010), "To promote environmental conservation, the government is to license biomass like charcoal to encourage its sustainable commercial production. The policy aims for increasing the rate of adoption of efficient charcoal stoves from 47% in 2004 to 80% in 2010 and to 100% in 2020 in urban areas; and to 40% by 2010 and 60% by 2020 respectively in the rural areas. It also aims for increasing the rate of adoption of efficient fuel wood stoves from 4% in 2004 to 30% in 2020; promoting inter-fuel substitution; increasing the efficiency of the improved charcoal stove from the 2004 level of 30-35% to 45-50% by 2020.

Promoting introduction of efficient charcoal kilns for charcoal production; promoting use of fast maturing trees for energy production; promoting establishment of commercial woodlots including peri-urban plantations; and offering training opportunities for Jua Kali artisans at the village level for the manufacture, installation and maintenance of renewable energy technologies including efficient cook stoves." In keeping with (MoEP, 2015), " The policy on biomass also provides for the promotion of alternative sources of energy and technologies such as LPG, biogas and solar as substitutes for biomass."

Bio-fuels

The main aim of the bio-fuels policy and strategy is to increase accessibility to bio-fuels and subsequently reduce dependency on imported petroleum products by 2030. In concurrence to this, the Kenyan government is looking to boost biodiesel production in rural areas by reducing the use of wood fuels. This would ensure that farmers in those areas have an opportunity to grow feedstock for biodiesel production (Diaby, 2011). The government is to achieve this by providing incentives for bio-fuel production and projects consumption. The government is also to collaborate with

stakeholders to ensure efficient use of land resource for bio-fuel feedstock, food production and other human needs by creating stakeholder awareness and sensitization on the importance and viability of bio-fuel production and consumption. Another policy is to implement the bio ethanol pilot program and to initiate and implement the biodiesel program. (MoEP, 2015).

Biogas

The first policy on biogas was drafted in 1987 to help alleviate the adverse effects of oil importation on the country's domestic economy. Though there was a bid to promote renewable energy sources in the in the energy act 20006 there was no regulatory framework specific to biogas that would address issues of its establishment and production(Matoke, nd).

The absence of biogas standards and guidelines has derailed the adoption process of this significant technology. Without these standards consumer health, safety and reliability issues are left unaddressed undermining consumer confidence in the technology(catherine, 2016)

The draft policies of 2015 by the ministry of energy provides that; the government shall endeavor to create awareness on the imminent benefits and considerable potential of the biogas energy; the government will also promote the various biogas technologies available; manufacturers of biogas plants and equipment to receive monetary incentives from the government; to introduce biogas technology in the education system; develop legal and regulatory requirements on biogas; to support domestic and community based plants and promote its usage as an alternative to wood fuels and kerosene and to lay out initiates to supply public institutions such as schools prisons and hospitals(MoEP, 2015)

Solar

"The main policies regulating the use of solar for cooking and heating provide for; Regular review of standards for solar energy technologies and equipment; Provision of incentives to promote the local production and use of efficient solar systems; Enforcement of regulations on building codes on water heating and lightning; Enhancement of penalties for theft and vandalism of solar systems; Support of hybrid power generation systems involving solar and other energy sources to manage the effects caused by the intermittent nature and availability of solar energy." (MoEP, 2015).

Municipal waste

According to (MoEP, 2015), " the municipal waste policy is to develop and implement legal, regulatory and collaborative framework for Exploitation and management of municipal waste . Another policy is to develop programs for data collection and dissemination on the potential of

municipal waste. There is also provision for development of pilot programs for generation of electricity using municipal and industrial waste and incentives for conversion of these wastes to energy"

2.4. Factors That Influence the Adoption of Technology

Beliefs and attitudes are formed over a long period of time and they play a major role in the decision making on whether one will adopt a particular technology or not. There are several theories that have been formulated regarding adoption. These theories view adoption as the choice an individual makes in order to accept or reject an innovation. In this case the innovation is in concrete and not abstract form. The adoption theory focuses on the many factors that that influence the adoption of any kind of technology. The theory merges adoption and diffusion as interdependent factors. Though diffusion defines better the spread of knowledge of a technology over a period of time adoption is mainly focused on what informs one's decision to take up a form of technology(Straub, 2009).

There are a number of models that have been formulated for the adoption of technology. The main model for technology adoption is the concern based adoption model (CBAM). Other models are the technology acceptance model and the universal technology adoption and use theory. These are based on computer science specifically. Fundamentally all these models have been formulated to answer question about technology adoption. CBAM models would be more appropriate in for analyzing the adoption of energy as it focuses on view of the adoptees and considers mainly concerns of those who are to adopt the technology. These concerns according to CBAM would determine how the technology will be adopted(Horsley, 2005)

There are several assumptions that CBAM is based on. It assumes that change is a personal experience and can only be accomplished by an individual. It also assumes that change occurs over a period of time and does not happen in a moment or an instance. It also assumes that perception is acquired over time and develops gradually. Theses among others are the basic assumptions of the CBAM model.(Straub, 2009)

It is the technical and economic characteristics of renewable energy sources that determine their adoption in the market systems. It is obstacles against these aspects that eventually prevent their diffusion. These obstacles can include size limitations. This is a technical aspect that hinges more on culture. What is cultural acceptable. The parabolic solar cooker for example is quite huge and may not fit into a 4 by4 meter house. This would definitely discourage slum dwellers whose housing typologies are characterized by such limited spaces. The mechanisms of energy production by some of these renewable energy sources are not continuous making them unreliable to its users. Renewable

energy sources play a vital role in environmental renewable energy source conservation and improvement of lively woods. Despite this fact the renewable energy sources are facing a difficulty in trying to compete with the existing energy technologies that may not be sustainable. (Menanteau, Finon, & Lamy, 2003)

Cost and reliability are some of the eminent factors affecting the adoption of this renewable energy sources as some of the conventional energies still are more affordable and durable hence appeal more to users especially those low income earners. This however can be achieved gradually over time. It is only with better understanding of the functionalities and the subsequent advantages that consumers can be persuaded to opt for these renewable energy sources. “it is not because energy is efficient that it is adopted but rather it becomes efficient when it is adopted”.(Menanteau et al., 2003)

There several factors that inform the decision making process that leads to the adoption of a technology or any practice for that matter. The fundamentals of adoption must guarantee at the very least that one is able to purchase the technology or practice that is being instigated. In economics the expected financial or economical benefits when one is making a decision to adopt or not adopt ascertain innovation or technology is referred to as the rational accounts. These benefits though uncertain play a major role in the thought process leading to the assertive decision before one buys a product. For most people the expected benefit is the ultimate factor that would determine whether they adopt or not. Outlining the benefits and assuring the consumers of what specifically they could gain from using a new technology is mostly the right incentive that a certain percentage will surely adopt. As diffusion increases consumers tend to gain more certainty with the products enhancing its adoption. (Ansari, Fiss, & Zajac, 2010)

One of the ways of ensuing cost reduction on renewable energy commodities is through Issuing subsidies. The German economy for example has improved immensely after the passing of the renewable energy sources act that saw the German Government Issue subsidies on renewable energy sources like electric energy. In this case electricity that was generated from a renewable source had its rates subsidized by about ten percent in comparison with the conventional electricity generation. This saw an upscale improvement in the renewable energy sector as there was creation of better conditions for investment in green energy. Opening grounds for investors and issuing subsidies resulted into a major boost in the adoption of renewable energy for the German government. Subsidies affected reduction of cost even in the retail prices of the renewable energy sources which eventually appealed to the citizens.(Frondel, Ritter, Schmidt, & Vance, 2010)

Once the rational account threshold is crossed assurances of efficiency tend to be replaced by social pressures. In this case you find that a consumer may opt to use a given technology for the reason other people are using it with less consideration for its effectiveness(Ansari et al., 2010)

Once a technology is ready to be introduced to the consumers one major consideration should be that it is can be a perfect substitute for the conventional technologies. This is referred to as fit. It is the ability of a situation to complement another. There is always a pressing need that people maintain the status quo when it concerns cooking matters. It is for this reason that fit becomes an important factor in the adoption of technology and innovation. For example the parabolic solar cooker is a good technology innovation but the eminent question is, does it fit (Ansari et al., 2010). The staple food in most Kenyan homes even for low income households is ugali but its need for constant turning and pounding limits the possibilities of being able to prepare it on a parabolic solar cooker. In addition there has be to constant heat which unless there is enough sun to supply the necessary heat makes ugali almost impossible to prepare (Mutono, 2013). Both the fireless cooker and solar cookers take up so much space due to their large sizes in comparison with the conventional cookers. Does this fit with the special definition of the houses in informal settlements? According to Kolodinsky a technology or new innovation should be compatible with consumer needs, values, experiences, beliefs and habits.(Kolodinsky, Hogarth, & Hilgert, 2004)

In a study to determine the factors that influence adoption, awareness ranked the highest. For any technology the ability of the consumers to acquire information to the specifics about the technology or to just know that it exists goes a long way in positively influencing its adoption. In creating awareness the consumers can be trained on how to use a particular technology and how not to use it. Safety measures expected as one uses the technology are also an important aspect of awareness. It is also prudent that the consumers are well aware of the limitations they could face in adopt a technology so that the choice that they make is informed (Pagani, 2004)

Another aspect of adoption is Simplicity. A consumer has to be able to have a perception of the given product. The way that a consumer perceives a product determines their judgment on simplicity and ease of use. Past experiences can derail attempts to introduce a new technology if the technology seems complicated to use. People in the informal settlements are rather semi literate and are easily turned off by ideas that they cannot easily navigate. Simplicity is therefore is key in the adoption of any technology.(Kolodinsky et al., 2004)

The ability of a consumer to experiment and realize the need to adopt a certain technology is an important factor kin adoption. This is referred to by kolodinsky as the triability stage. This can be realized through a period of promotion of the new technologies. This period is usually characterized

by less extremely subsided prices on the given commodities on promotion to persuade the buyer to try the new product. “empirical renewable energy sources earch has shown that there is a consistent positive relationships between usefulness and to a lesser extent, ease of use, and the adoption of a variety of specific technologies.”(Kolodinsky et al., 2004)

Once the consumer has experimented on a product, they are the able to determine to what degree the product varies from the conventional one that they are used to. This is referred to as the relative advantage. It could be that the product saves the consumer time, money and is convenient compared to the conventional one hence the relative advantage. For some products, this could be a relative disadvantage if in any case the consumer finds that the new technology is not as beneficial to them.(Kolodinsky et al., 2004)

Another aspect in adoption is observability or availability. When a consumer can see the actual product i.e. observe it, it is easier for them to relate to it easing the adoption process. Observability can be achieved by making products available for example in energy shops frequented by buyers where they can see and enquire about it.(Kolodinsky et al., 2004)

There are ultimate up sides in the promotion of renewable energy sources. A renewable energy source is sustainable and ensures energy security for a country. This also comes with tremendous job opportunities that could contribute in wading of unemployment. In the long run, through subsidies and other avenues, the retail cost would be reduced making the renewable energy sources affordable even for the low income earners. Technological innovation and environmental renewable energy source conservation are the obvious results that would be realized through adoption of the sustainable energies.(Frondel et al., 2010)

2.5. Design Thinking

Design thinking is a problem solving method that incorporates various tools and principles such as the human centered design principle and toolkit, the participatory mappings and stakeholders mappings(Arkin Efeoglu, Charles Møller, Michel Sérié, & Harry Boer, 2013) different disciplines are drawn together everyday not by a common definition, methodology, philosophy or anything else by but by a common need to conceive and plan. The world is facing a tremendous number of challenges that a single entity on its own cannot presume to offer a solution for everything. The problems facing the world come in range of dynamism that can only be handled through collaborations. Professional designers through design thinking are able to address different problems. Design thinking being a multidisciplinary tool reaches out to any kind discipline and together with the designers comes up

with a series of possible solutions. The design thinking model comes in a number of variations but these variations are ultimately related to each other(Cross, 2006)

According to Brian Lawson design has evolved tremendously over the years. Traditionally students were taught design with emphasis on a studio based learning of design history and students were presented with a series of problems to solve within the studios but in the twentieth century this changed. Design began to be appreciated not just as a style but as a process. The view of a direct connection of contemporary modernism to the style of design began to change. The process of design thinking began to gain appreciation as a fundamental in the process of design. Design is now defined periodically through evolution of style and as a unit that uses historical analogies to inform the style in design and not one that uses design history work in its own right (Brian Lawson, 2005).

The design process has now gained ground with designers using design tools to find possible solutions to more complex social problems. The design thinking process is now being well appreciated by different fields: academics, businesses and government projects among others(Tim Brown & Jocelyn Wyatt, 2010). Social challenges in their study of the shanty situation in India proved to require a system approach In providing solutions that are well based and aligned to user needs. The design thinking process is a collaborative process that tackles problems that are not conventionally in line with traditional design(Tim Brown & Jocelyn Wyatt, 2010).

However there are certain fields where despite being a compelling approach of study, design thinking is yet to be fully recognized and sufficiently applied. In fields like entrepreneurship education, the immense potential in the design thinking process is yet to be well established(Von Kortzfleisch, Zerwas, & Mokanis, 2013). Design thinking now plays a major role in technical research with a variety of ideas and methodologies all anchored under the process. Its diversity in research has made it a flexible tool in any research (Cross, 2006)

Design thinkers find different ways to navigate through constraints when handling a project in creative ways. For a designer the entire process of finding solutions is creative (Tim Brown, 2009)

2.5.1. **Design Thinking Methods and Tools**

2.5.1.1. Personas

This method is especially used during the empathy or definition stages of the design thinking process. In this phase the most important thing is the user experience with a certain product or service. This phase focuses on the human perspective of the situation or challenge. It helps in understanding

consumer segments and behavior in relation to a service or product. Eventually this process helps to understand user needs and desires (Dimitra Chasanidou, Andrea A. Gasparini, & Eunji Lee, 2014).

2.5.1.2. Rapid prototyping

Rapid prototyping is a method used in seminars, workshops and other collaborative settings to illustrate visually ideas that are most effective. In these settings participants are involved in prototyping as a way to express their ideas. This therefore enables a more elaborate understanding of specific concepts and therefore fostering immediate feedback on the technological appropriateness of the given prototype(Dimitra Chasanidou et al., 2014). Through prototyping ideas and scenarios are converted into actual products or services that the end user can immediately relate to. According to the IDEOS process of design thinking, the prototyping methods fits best in the implementation stage of the process. This way, through prototyping, designers get to realize certain unforeseen challenges that would by and large reduce on the expense of a failing product. This stage allows a product to enter the market at a mature stage and limit the chances of the said product being rejected by the end users. (Tim Brown & Jocelyn Wyatt, 2010)

"An example of RP software tools is Axure RP, which provides wire framing, prototyping and specification tools needed for RP. It has a graphical user interface for creating mock-ups of websites and applications. Axure RP can help users generate fast ideas to immediately improve the design and obtain direct feedback."(Dimitra Chasanidou et al., 2014)

2.5.1.3. Business model innovation

With reference to Chasanidou et al., a business communication model is the tool of the design thinking process that anchors the business perspective. It allows organizations and companies to sufficiently relate to the decisions that the users make before deciding to buy a certain product and opting out of another. It can effectively be used in the ideation phase of design thinking. BMCs are created using a software tool that is called strategizer.

2.5.1.4. Stakeholder mapping

Various situations are defined by different kinds of stakeholders. A variety of stakeholders may play different roles that at the end contribute to certain eventuality. A stakeholder's map is therefore a physical representation of the various groups involved in a given product or services and outlines their roles. The nexus and relationship of this stakeholders can be used in the definition process of the design thinking(Dimitra Chasanidou et al., 2014).

2.5.1.5. Customer journey maps

This tool defines the delivery process of a service highlighting the touch points from the beginning to the end. A touch point I defined as a potential point of interaction or communication between a customer and service provider. This tool is most applicable during the empathy stage. As the researcher or designers get to understand the user context, he is able to clear define at what the entire circle of a service from the beginning to the end. This is usually done using a touch point dashboard which s web based system for creating customer journey maps (Dimitra Chasanidou et al., 2014).

2.5.1.6. Service blue print

This tool illustrates the steps and nexus of service delivery which are related to the stakeholder's roles and process. It is meant to illustrate what goes on when the customers and providers interact. It applies to both the business and technical perspectives of the design thinking. Creativity is the tool used to create blue prints and is emulated from the early version of service blueprints by Shostack who basically introduced the blueprint systems. (Dimitra Chasanidou et al., 2014)

2.5.2. **Exemplars of the HCD Toolkit**

2.5.2.1. Case 1: IDEOS: Batela Lobi Na Yo DRC project

IDEO is rated as "one of the most innovative and award-winning design firms in the world" with their main design principle focusing majorly on end user empathy. Their style entails a process of monitoring user behavior, empathizing with the user for example through emersion to help in understanding user challenges better. This first hand user experience is there main tenet when it comes to the overall design process. It is IDEO'S belief that having that user experience and incorporating the user in thinking up solutions is the best way a designer can develop the appropriate solution to a life challenge (IDEO, 2015).

In the Batela Lobi Na Yo project IDEOS partnered with a marketing firm in Congo that focuses on reproductive health on a new social initiative in its capital city. Using the HCD toolkit the project managed to prompt 5000 teens to visit a clinic with 75% adopting a contraceptive method. The project due to its success rate has now been expanded from Kinshasa to three new regions in the Democratic Republic of Congo (IDEOS Batela, 2016).

2.5.2.2. Case 2: the BOMA project 2017

The BOMA Project empowers women in arid areas by encouraging them to venture as small business entrepreneurs. The project not only focuses on women in rural areas but also offers training for women in rural areas on how to start up small businesses. This projects enable women to own productive assets for income generation and opens up their world to something more than the drought threatened livestock industry (BOMA, 2017).

BOMA's new targeting method now includes three components: Participatory Rural Appraisal is a community-based wealth-ranking process. Residents "map" their community, define its socio-economic categories, and assign all households to those categories using pictures, symbols and other visual cues. Rural villagers then analyze this data before handing it over to a BOMA Location Committee (BLC) for vetting. BLC members are nominated by fellow villagers and 50% must be women. The BLC reviews the pool for balanced representation of clans and ethnic groups. BOMA field staff interview potential participants in their homes, using the BOMA-developed Participant Targeting Tool, specifically designed for the pastoralist communities in which we work. The PTT collects information on household demographics, conditions and assets to create a composite poverty score, similar to surveys used by BRAC in Bangladesh. (BOMA, 2017)

2.5.2.3. Case 3: participatory slum upgrading program (PSUP)

The Participatory Slum Upgrading Program is a united nation initiative where the slum dwellers themselves are engaged in understanding challenges and devising strategies to improve their living standards at all levels from the immediate surroundings to the national level. In this process all stakeholders found in the definition of a certain challenge are directly involved. Together these stakeholders design frameworks that help in reshaping the future of their towns, cities while catering for the needs of all urban dwellers and empowering informal settlement dwellers (UN Habitat, 2012).

This methodology process works on the founded opinion that once a people have experienced and are part of a participatory planning they can easily reuse the same methodologies when dealing with other projects or challenges. This participatory process by and large also plays a major role in resource allocation to slum dwellers by both the local and national government. also it assists in driving long term developments by government for the slum residents(UN-Habitat, 2012).

2.5.2.4. Case 4: design thinking in a Mumbai slum

The HCD toolkit has been used together with children from India's Mumbai slum Bharat Nagar (Vashi Naka) propose possible solutions to everyday slum challenges. These challenges include violence, addiction and sanitation.

A HCD workshop was organized where children from the slum would learn how to think about problems in their community in a new way, and gain confidence in their ability to think and act as a catalyst for change. The goal was to change their perceptions about everyday problems and get them to realize their potential as change makers.

The workshop itself was based on the principles of Human Centered Design, and staying true to its essence, was highly participatory and interactive. The driving theme was how to solve social problems in the community? The kids were provided with themes like emotional/physical violence, garbage disposal, toilets, addiction and politics. The session was broken down into sub sessions of problem identification, collaborative brainstorming on the problem, brainstorming the root causes, ideation, concept presentation and finally prototyping (Brahmabhatt, 2015).

An overview of the above case studies will present three major stages in the human centered design process. These phases are inspiration, ideation and implementation. According to the IDEO's methods these three phases can be approach using different methods. In the inspiration stage tools such as photo journals, forming once challenge, recruitment tools, interviews, analogous inspirations, conversation starters, focus group discussions and observation among others. These tools aid researchers in understanding whoever they are designing for and their background. This allows them to have a broad perspective of what and their challenges begin to form roots. The ideation phase involves tools like journey mappings, brainstorming, possible frameworks and co-creation session among others. The last phase which is the implementation stage would involve tools such as business model canvas, integrate feedback, live prototyping among others.(IDEO, 2016)

2.5.3. Sustainable Product Service Systems

Vezzoli (2012) acknowledges that in addressing a problem the focus must not only be on products, services and production services. It is vital that factors like Patterns of consumption, lifestyles and the institutions that enforce them are addressed concurrently if society is to be transformed through sustainable societal processes. Crises such as rapid rise in prices of commodities, global food crises, inflation, recession rising unemployment, credit crises and the overarching crises can be converted into opportunities to maintain a sustainable balance (Vezzoli, Ceschin, Diehl, & Kohtala, 2012a).

Most people are still quite green when it comes to understanding sustainable product service systems. A lot is yet to be achieved through sensitization and other workable approaches to discourage the

notions of radical innovations that people get when they hear of SPSS. An integrated system of products and services goes along away in ensuring consumer satisfaction for goods and services(Vezzoli, Ceschin, Diehl, & Kohtala, 2012b). Manzini and Vizzoli both agree that SPSS provides a continuous, warm and mobile circle where various user needs are met through providence of end user function (Manzini & Vezzoli, 2003).

(Morelli, 2006) sees the designer's role as fundamental in the actualization of a PSS even as it only focuses on specific aspects that arise during the use of a service. The designer is tasked with defining the elements that interplay in a given system. These elements that require management under an SPSS are: technological infrastructure, personnel, marketing, customer relations, and communication(Morelli, 2006).

2.5.3.1. The lens approach: the Method For System Design For Sustainability (MSDS)

Vezzoli, Delfino and Ambole organize this method into five major phases:

Strategic analysis; this phase entails the collection of necessary information that would guide idea generation process. It contains an analysis of project proposers and the carrying structure of the system and analysis of the best practices. Thereafter priorities are established from these analyses for a sustainable design intervention (Vezzoli, Delfino, & Ambole, 2014).

Exploring opportunities; using promising strategic possibilities available ideas are generated outlining a number of design scenarios individually and also in groups or clusters (Vezzoli et al., 2014).

Designing system concepts; some of the more mature concepts are selected are then developed into system concepts. "This system concept consists of one or more product and service mixes that characterize the offer; the relative interaction system between the actors involved; potential environmental, socio-ethic and economic improvements". This eventually contributes to environmental, socio-ethic and economic enhancement (Vezzoli et al., 2014).

Designing system details; "This phase is meant to develop the most promising system concept(s) into the detailed version necessary to its/their implementation. This is achieved through Detailed system design and Environmental, socio-ethical and economic assessment."(Vezzoli et al., 2014)

Communication; Vezzoli denotes this as the final phase and it involves making illustration documents that correspond to the general and sustainable characteristics of the proposed system design (Vezzoli et al., 2014)

End results of an SPSS system

According to Vezzoli sustainable product service system is categorized into three major parts: (Vezzoli et al., 2012b)

Stakeholder system map

Figure 19: stakeholder system mapping

Vezzoli states that the purpose of the stakeholder system mapping is to demonstrate visually the designed or co designed system patterns. “It consists of a graphical representation containing stakeholders involved and physical, financial, informational and labor performance flows/interactions.” (Vezzoli et al., 2012b).

Interaction table and story board

Figure 20: The interaction table and story board

"The interaction table and story board is meant to design (co-design) and visualize the functioning in time of the system as a set of narratives, one story for each stakeholder, of both the front-desk and back-stage interactions between other stakeholders. It consists of a graphical representation containing the sequence of images, representing the various interactions of the different stakeholders and short texts, describing the specific role played by each stakeholder in each single interaction."(Vezzoli et al., 2012b).

Satisfaction offering diagram

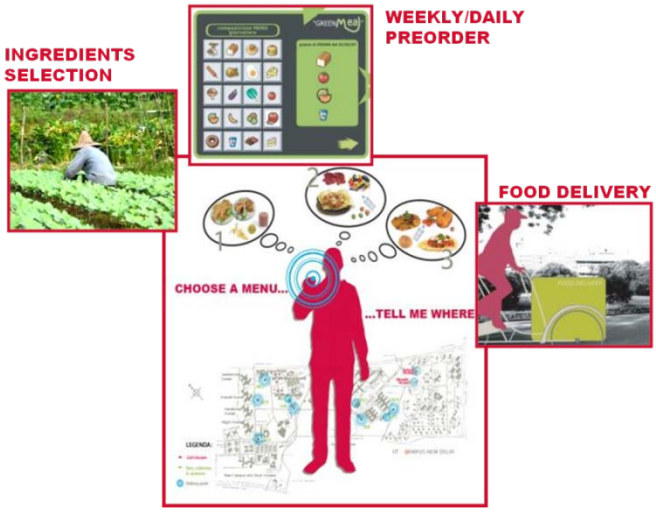


Figure 21: The satisfaction offering diagram

Vezzoli explains that the satisfaction offering diagram describes the satisfaction offered to the user/customer, and how this is delivered. "It also consists of a graphical representation containing visualization of the core satisfaction provided by the system, the visualization of the sub-offers through which the satisfaction is delivered and the description of how the sub-offers will be delivered." (Vezzoli et al., 2012b).

CHAPTER THREE
METHODOLOGY

3.1.Research Design

In this study, a mixed methods research design that uses both qualitative and quantitative analytical methods was applied. According to (FHI, 2015), qualitative research is fundamentally based on the target populations experience of a given research matter. This research sought to establish its results based on the perception of the target population which is Mathare informal residents, on the current conventional energy technologies and the sustainable energy technologies. The research findings were both thematic and numeric and were analyzed both qualitatively and quantitatively.

To obtain these information questionnaires with both numerical output and thematic output were issued to respondents. Thereafter a workshop based on design thinking methods and processes inferring to the findings from the questionnaire was conducted to validate the main objective of the research. As in any quantitative research there was a determination of the relationships of the various variables to one another (Labaree, 2009).

3.2.Area of Study

This research was carried out in Mathare Valley. Mathare Valley is an urban informal settlement in Nairobi, Kenya. This informal settlement falls under the Nairobi County Council and is recognized as one of the oldest in the area consisting of approximately 200 000 residents. As an informal settlement, Mathare Valley is divided into 13 villages which are governed by a local council of village elders. As a constituency, Mathare is headed by a member of parliament who sits in the national assembly. The constituency is further divided into six wards headed by ward representatives, who sit in the Nairobi city county assembly. The villages boundaries are defined by history for example beginning of settlement, spatial characters majorly the housing typologies and geographic for example the Nairobi river. There is also a small but significant variance in the social –economic status of the residents (Githira, 2017).

The project was carried out in ‘Kosovo, 4A, Mlango kubwa and kyamutisya’, which are some of the 13 villages in the settlement that is in the ‘Hospital’ ward. University of Nairobi researchers, in collaboration with other partners, carried out a comprehensive upgrading plan for Mathare from 2008 to 2011. The upgrading plan was aimed at improving the living conditions of Mathare Valley residents. This included the proposal of several renewable energy systems that were to be adopted for use by the residents but failed. The research report shows that only 9% of residents have formal

electricity connection. A further 68% of residents tap into the electric grid informally, while 22% have no electricity at all. The illegal electricity connections pose a constant risk of fires and electrocution due to haphazard connections. For cooking, charcoal and paraffin are the most common fuels for households in the settlement (SDI et.al 2015). A major gap in existing studies in Mathare is the lack of in-depth investigation into delivery of affordable and adequate household energy and its health-related implications, and use of Tran's disciplinary approaches to co-design solutions with the urban poor, which was a key contribution proposed in this project.

The researcher selected mathare informal settlement as the preferred area of study because, of the various informal settlements in Kenya. Mathare hosts a diverse group of urban dwellers exhibiting the three major housing typologies characterized by urban poor sharks, upgraded housing and tenements. Figure 1 is a map of the Mathare informal settlement in Nairobi which is the location for this research.

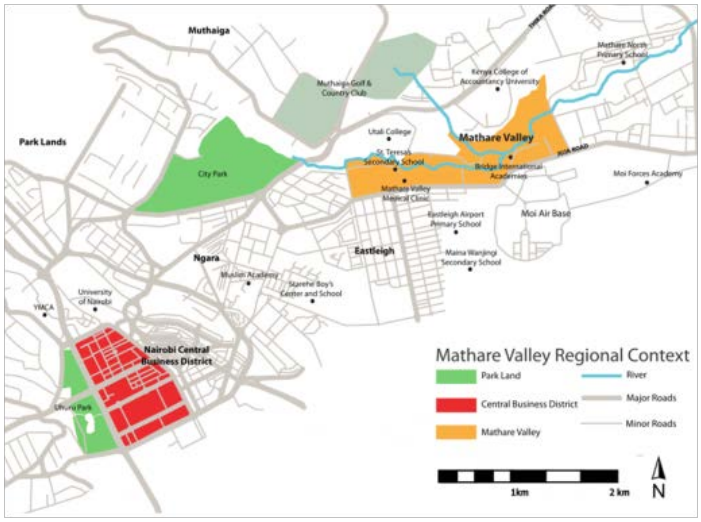


Figure 22: Map of mathare valley ("About Mathare," n.d.)

3.3. Target Population

The target populations for this research are the energy poor families who are largely found in low informal settlements. Mathare was selected for this research among other informal settlements due to its cosmopolitan nature. It hosts residents from some of the major tribes in Kenya. Mathare also contains the different housing typologies of informal settlements that need to be represented in this research including: sharks, tenements and up graded houses.

3.4.Sampling Technique and Sample Size

The researcher used purposive sampling method to identify the four villages where the field work was carried out. The four villages were found to be the best representative of the four housing typologies within the mathare valley. These housing typologies are tabled above including: tenements, sharks and upgrade housings. Table 12 shows the four villages sampled for the study and there population sizes and housing typologies.

Table 1: Sample Village Characteristics

Village	Density and Shape	Housing typology
Kiamutisya	Dense and compact	Shacks (Approx. 90%)
		Tenements (Approx. 10%)
Kosovo	Dense and lengthy	Shacks (Approx. 95%)
		Tenements (Approx. 5%)
Mathare 4A	Dense and lengthy	Shacks (Approx. 80%)
		Upgraded housing (Approx. 20%)
MlangoKubwa	Averagely dense and compact	Tenements (Approx. 90%)
		Shacks (Approx. 10%)

A mapping exercise was conducted to aid the sampling of respondents and place the energy source locations and various facilities within the location. This was done cognizant of the fact that the four villages vary in sizes and population capacities.

The researcher together with other co-researchers participated in a training session prior to the mapping exercise. In this session the mapping expert taught the team how to find their bearing using the maps during the survey, navigate the sample grids, map energy sources, facilities such as health facilities, toilets, schools, religious facilities and business corridors.

The sampling of the respondents was done using the stratified random sampling method. The respondents from the villages were located pro rata based on the 1999 national population and housing census. According to (NCSS, 2012), this census gave sample proportions of 17 for Kyamutisya, 20 Kosovo, 30 for Mathare 4A and for Mlango kubwa. This gave an aggregate of 100 respondents who participated in the survey. To aid sampling the mapping was done such that regular grids of two geographical minutes or 62 meters apart were overlaid on the maps. Respondents were then randomly allocated to grid cells. Due to the disparity in their special definitions, each village used a different allocation approach to allow for the best possible results.

3.4.1. Kyamutisya sampling

There were eight alternate grid cells within the map of Kyamutisya. One grid however took three respondents because of the uneven number of seventeen respondents required from the area.

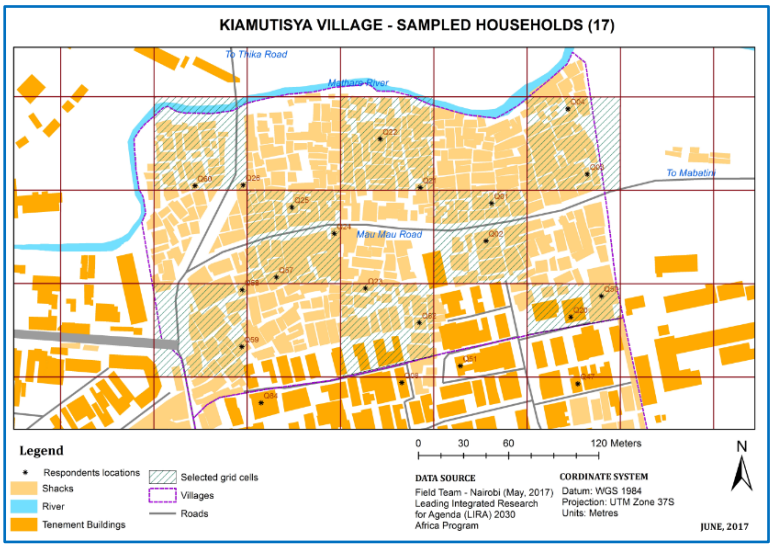


Figure 23: Sampling in Kyamutisya Village

3.4.2. Kosovo sampling

Due to the horizontal based lengthy shape of the village Kosovo the respondents was picked from each double alternate grid cells. Two respondents were then selected randomly from each grid cell.

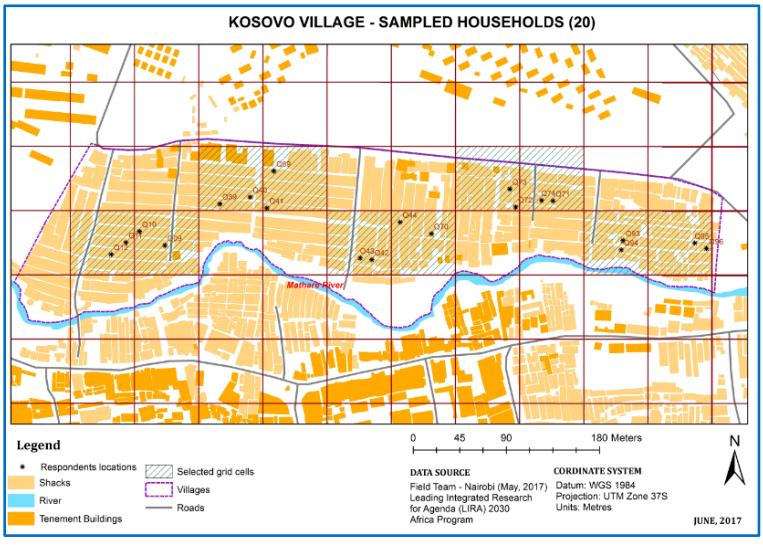


Figure 24: Sampling in Kosovo Village

3.4.3. Mathare 4A

The sampling in mathare 4a was similar to that of Kosovo only this time there were 3 respondents from each cell. In the cases of the single cells along the edges of the settlement one or two respondents were sampled. However, only two respondents were selected from a single cell.

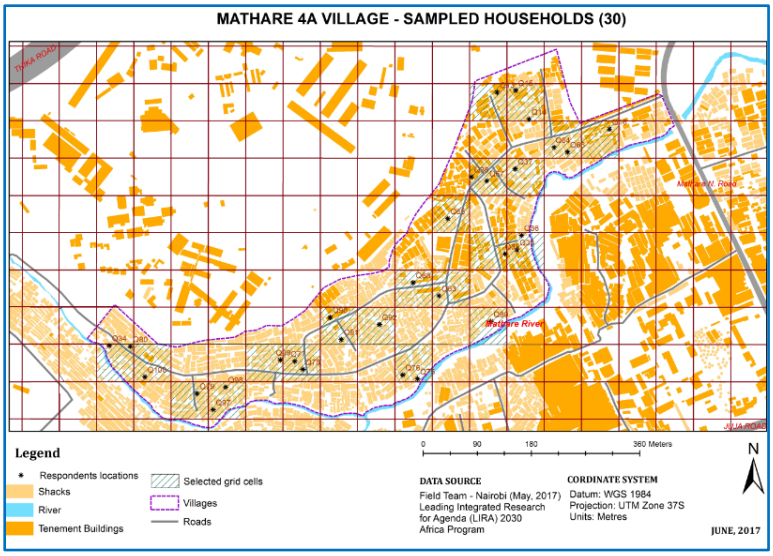


Figure 25: Sampling in Mathare 4A

3.4.4. Mlango kubwa

Due to its large population, two respondents were sampled from each cell with certain cells at the edges being allocated just one respondent.

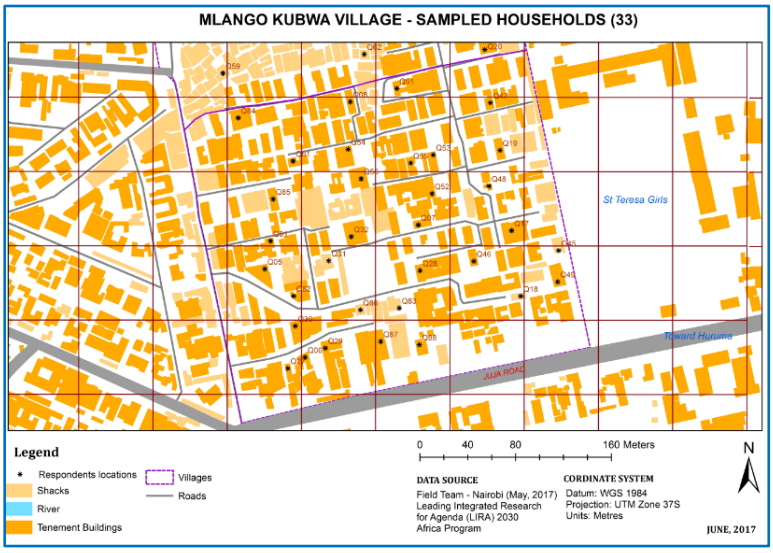


Figure 26: Sampling in Mlango Kubwa

3.5.Data Collection Methods

3.5.1. **Design Thinking Workshop** (Application of the HCD toolkit)

Nigel Cross states that the entire concept of design thinking can be categorized into two major phases: the problem definition phase and the problem solution phase. The problem definition is seen to be more analytical while the problem solution is define as synthetically(Cross, 2006). According to Tim Brown, the design thinking process grows in four major stages the divergent phase, the convergent phase, the analysis and synthesis phase and finally the (Tim Brown, 2009). According to IDEOs the design thinking process is defined as a progression of the following phase's inspiration, ideation and implementation(Tim Brown & Jocelyn Wyatt, 2010). the international design management conference in Boston on the other hand define the design thinking process beginning by discovery, definition, development and then delivery.

Inspiration

According to Tim and Jocelyn, the design thinking process begins at the inspiration phase where a brief is formulated to give a logical framework that outlines the goals and objectives of a certain project in consideration of the challenge at hand. This is where possibilities are weighed on a scale of what's logically possible given the available resources to offer a plausible solution or solutions (Tim Brown & Jocelyn Wyatt, 2010). In Tim's analysis on the stages of innovation, the inspiration stage is conceived through the realization of a problem or an opportunity(Tim Brown, 2009). Herald in analyzing the role of design thinking in entrepreneurship concurs with the above two that the first phase in the process involves understanding client needs and expectations. In this phase he also makes it clear that this phase evaluates to what degree a solution can be given to a specific challenge by considering the available resources to tackle the problem.

Empathy

The practicality of a design process is anchored on the fundamentals of understanding the user needs. This is mainly done through empathy. It is essential in design thinking that to solve a challenge that's affecting a user one must be able to walk the user journey and by this understand the user's interactions with various stakeholders. This next phase in the design thinking process involves getting insight on how those experiencing a certain challenge are affected by that challenge. This process evaluates stage by stage how a user is connected to their environment and to a certain product or service. This is where the design thinking team undergoes form of divergent thinking to try come up with alternative realities and provide more choices to the situation. (Tim Brown, 2009).

According to the Boston conference by Alkaya, the entire essence of empathizing is to connect emotionally to a user. They categorize user emotions into three levels the visceral, behavioral and the reflective level. The visceral defines the immediate emotional impact of a service or product on a consumer. The behavioral is concerned mainly with function and not appearance. The user in this instance will consider a product because of what it does and not by its outlook. The reflective level is determined by consumer knowledge and cultural influences. This is where the consumer's decision to buy a product is well evaluated depending on their beliefs and whatever information is available about the given product.

According to Boston conference, one's subjective experience with the user needs and desires helps to create an emotional link with the user. The empathy phase in the Boston conference summery falls under the discovery phase. (Mahir Alkaya, Visser S. Froukje, & Cristine De Lille, 2012). Through empathy a designer is able to connect and therefore understand one's experience with certain situations. Empathy plays a major role in allowing the designers insights on the situation in the early stages of problem solving. Pricilla explains that that empathy can be gain in three main ways, through observation, through enquiry and also by emersion(Esser, 2017). The Boston conference seems to agree with Esser's illustration of empathy when they define the different phases of empathy as the discovery, immersion, connection and detachment phase. (Mahir Alkaya et al., 2012) In his comparative study on empathy as defined by different authors Kouprie determines that the common component of the process is the immersion phase where each other seems to appreciate that to empathize, one must be able to experience the users ways in relation to a product or service(Kouprie & Sleeswijk, 2009).

Stages of empathy

Discovery

According to Esser, this phase involves making contact with the users to assist n understanding their experiences(Esser, 2017). This is where the designer first makes contact with the user by approaching them and getting in touch through observation or in person. This eventually is expected to arouse in the designer a certain curiosity on realization of opportunity to get to understand the user. (Mahir Alkaya et al., 2012)

Immersion

This according to Esser is the point at which the designer begins to actively participate in data collection by being user for a while. The data from this stage is mostly characterized qualitatively to

inspire genunnity in the data. (Esser, 2017). According to kouprie this phase allows the designer to get to know the user better and what influences their experiences(Kouprie & Sleeswijk, 2009).

Connection

In his book on connecting people Christian Keysers discusses the importance of empathy. He states that in the 1990s scientists discovered a part of the brain called the mirror neuron to be in control of the ability of humans to empathize with others emotionally. He explains that this part of the brain is the reason one does not have be another to feel the pain or sadness or happiness that they are experience in relation to a given situation(Keysers, 2011). Both esser and kouprie agree that this phase involves an emotional connection with the user. Kouprie goes ahead to elaborate that the designers at this phase are able to relate cognitively and affectively with the users understanding both their feelings and meanings(Kouprie & Sleeswijk, 2009).

Detachment

At this stage the designer moves away from the user and retires into a solution finding mode. Once the designer has experienced what the user experiences it is now time to go back and reflect and come up with ideas and insights to solve the problem that he had subjectively experienced during the connection and other phases. (Esser, 2017)

Definition

This a pre- phase to the ideation phase of the design thinking process. According to dam it is important that a designer should master the definition of a challenge to enable him to properly synthesize it the right way. Dam and Siang' are convinced that this is the most crucial phase of the design process as it will determine how efficiently one can find solutions to the challenge(Dam & Siang, 2017).

According to Anna this is not a very popular stage among designers. She seems to think of it as a technical phase while unlike the next half of the design thinking process which are more creatively involving. Anna defines this stage as a determination of the underlying problem outline what the problem is, who it affecting and why it is a problem. It is also referred to as the point of view statement. The user needs are specifically stated and the most surprising or awkward insights outlined(Zaldarriaga, 2016). In addition Plattner elaborates that this phase is not just about define what the challenge is but about addressing the right and most important challenge among one's findings(Plattner, 2010)

According to Plattner there is a way that one should define. The definition phase begins by first weighing the most important challenge by analyzing patterns that may emerge. Thereafter in defining the point of view, the designer must stay aware of the person that they are designing for so that the challenges are articulated in line with their needs. The designer is able to do well having had experienced the user challenges in the previous stages. The designer is then expected to synthesize and select limited, most pronounced set of needs to address. This way the designer can finally articulate well the problem statement(Plattner, 2010).

Ideation

Plattner suggests that in transitioning from the definition stage to the ideation stage one could create subtopics from the problem statement that might aid in a brainstorming session. He defines this phase as a bridge of possible solution for the challenge at hand. He elaborates that design thinking is not about finding one solution to a problem but a number of possible solutions. This he attributes to the fact that a problem may affect two separate people differently and in coming up with just one solution then the other party may be left out(Plattner, 2010).

Johnson defines design ideation as a basic element of thought that could be visual, abstract or concrete. He adds that ideation an essential part of a design process. He also notes that despite free hand sketching being the main ideation tool in the traditional essence there are other tools that are being formulated. These tools are especially digital as technology continuous to evolve. However he is of the opinion that the role of free hand sketching in this phase is yet to sufficiently be determined(Jonson, 2005).

As Dorta et.al discusses the ideation gap they mention that the ideating phase of design should be digitally supported. They define the phase as a time when the designers get to visually express their imaginations. Through qualitative and not necessarily precise images, designers get to interact with their mental images. They argue that it is essential that technology be part of each design process as technology in itself is invaluable to design. With this they introduce the hybrid ideation space as an ideation tool that would ease the phase. Comparing the HIS to other cad tools Dorta et.al agrees that this tool is more efficient than other CAD tools. Its flow they say depends on the balance created between one's skill and weight of the challenge at hand. (Dorta, Pérez, & Lesage, 2008)

According to shah idea generating methods can be categorized as either intuitive or logical. "Intuitive Methods have been sub- classified into five categories3, 4: Germinal, Transformational, Progressive, Organizational, and Hybrid. Germinal methods aim to produce ideas from scratch. Some examples are Morphological Analysis5, Brainstorming6 and the K–J Method7. Transformational Methods

generate ideas by modifying existing ones, and include methods like Checklists6, RandomStimuli8, and PMI Method8. Progressive Methods generate ideas by repeating the same steps many times, generating ideas in discrete progressive steps. Examples of Progressive Methods are Method 6359, C-Sketch10, and Gallery Method11. Organizational Methods help designers group generate ideas in some meaningful way. The Affinity Method12, Storyboarding11, and Fishbone Diagrams13 belong to this class of methods. Hybrid methods like Synectics14 combine different techniques to address varying needs at different phases of ideation."(Shah, Smith, & Vargas-Hernandez, 2003).

Shah goes on to categorize the logical method into two: historical based and analytical. He explains saying that historical methods uses solutions that have been previously formulated and preserved in some kind of database for reference. The analytical methods on the other hand discuses solutions based on relations, patterns or chains and negative and positive qualities(Shah et al., 2003).

In Joel et. Al an experiment is done to explore the extent by which various factor including analogical distance, commonness of examples and modality influence the conceptualisation of ideas. The findings thereafter reveal that there is a significant influence by analogical distance and commonness of example designs on the idea generation of a designer. "conceptualized as ranging over a continuum from far-field (from a different problem domain) to near-field (from the same or very similar problem domain), where analogies closer to the far-field end point share little or no surface features with the target domain, while analogies closer to the near-field end point share a significant number of surface features." It is stated that the creative potential for a designer is clearest when two situations being compared are superficially different(Chan et al., 2011).

Prototyping

According to Tom Brown the prototyping phase falls under the implementation stage of the design thinking process by IDEO. It forms the core of the implementation stage where the best generated ideas are made concrete and conceivable. (Tim Brown & Jocelyn Wyatt, 2010). Plattner on the other hand defines prototyping as "the iterative generation of artifacts intended to answer question that get one closer to the ultimate solutions." He elaborates further that a prototype is anything that the user can actively interact with such as model, post it notes, a role playing activity or even a storyboard. Eventually a prototype has to be something that user can experience and relate with(Plattner, 2010)

There are certain advantages of prototyping outlined by brown such as the unveiling of unforeseen challenges that may occur during the implementation phase. With the realization of these challenges the product is reinforced making it more reliable than it could have been introduced to the market before prototyping and testing. In developing countries where resources are scarce and poverty

elevated it may be difficult to develop new products hence prototyping is conceived as very essential to help save on costs and materials for production(Tim Brown & Jocelyn Wyatt, 2010).

The other reason why prototyping is important besides allowing the designer to think better is that a prototype is communicative. With a prototype a designer can use any form that he deems suitable for the end user to pass across a message. Once the message is passed a conversation can ensue between the designer and the user. This conversation is already directed by the designer with an intention to capture a specific issue for the user. Once this conversation has happened the designer can easily get feedback on the appropriateness of the prototype. If it fails then it fails quickly and cheaply. The prototype can be repeated as many times as necessary until the user needs are met correctly. By creating a prototype one may be able to trigger new ideas that could be an alternate solution to the prototype. Through building a prototype the intended solution synthesis can be managed by the designer by "breaking it down into smaller testable chunks."(Plattner, 2010).

Test

This is the second last phase of the design thinking process. This phase is another opportunity for the designer to empathize with the user. This time the designer is experiencing the solution with the user and not experiencing the problem. The phase fundamentally allows the designer to solicit for feedback from the user. By doing this the designer gets to learn even more about the user and refine the prototype and solutions and the problem statement(Plattner, 2010).

When testing, the designer should allow the user to experience the product on their own without explaining anything. The designer lets the user interpret the product the way they see fit. If anything the designer should just watch from a distance and determine for himself the appropriateness of the prototype. The designer is allowed to expose the user to multiple prototypes if available and let the user determine which solution is better for them(Plattner, 2010)

Iteration

This is whereby the designer makes recommended change on the prototype following feedback from the end user. This can be done at one's by introducing multiple prototypes at a go or by cycling through the process multiple times(Plattner, 2010).

3.5.2. Questionnaires

The actual field work began with a baseline survey of the area of study. This was conducted by use of questionnaires that were conducted in 100 households within Mathare. The aim of the baseline surveys will be to establish the energy sources and technologies that are currently used for heating and cooking in mathare and to determine reason for preference for the current energy systems in use for cooking and heating. It will also assist in identifying acquisition points and determining accessibility to renewable energy sources in mathare. In addition it will assist the researcher to determine what influences preference for certain technologies to others.

Given the length of the questionnaires the interviews, the interviews took about one hour for every respondent. Some of the questions were open- ended while others were closed depending on the type of answers expected. The interviews were conducted face to face from one house to another. According to an Australian research program, issuing questionnaires online electronically or by mail may be more efficient in reach and ensuring privacy for the respondent(WACHPR, 2010). This however was not applicable in this research as the target populations were mostly low income earners with little access to computers to allow an online interaction.

3.5.3. Participatory Mapping of Facilities

Due to the multidisciplinary nature of the wider research the participatory mapping was conducted by professionals from other disciplines. The designer however, was a keen participant in these data collection processes and was able to borrow from the results of the outcome. Participatory mapping on the hand is a bottom-up approach that presents researchers, planners, policy makers, as well as local communities with an opportunity to co-generate spatially-linked knowledge using cognitive mapping techniques to harness local knowledge and produce qualitative data on perceptions of space, proximity or preferences. This method had advanced to encompass techniques of modern mapping that rely on Geographic Information Systems (GIS) and related equipment.

The main purpose of the participatory mapping was to identify acquisition points and determining accessibility to renewable energy sources in mathare.

3.5.4. Focus Group Discussions

The researcher conducted a focus group discussion that mainly engaged the suppliers of fuel for cooking and heating within the settlement. This was done to document the views of the sellers on

energy usage within Mathare and to get more insights enhancing the information that had already been acquired using the questionnaires.

3.6.Pilot and Pretesting

Once the research team had been trained there was a pilot test of the questionnaires. This test was conducted across the four villages sampled for the study and determined whether the respondents understood the questions and in the same way. The researcher also established whether the research team was well trained to locate and handle the respondents rightfully and fill their maps(Center for Evaluation and Research, 2011). Once this was done, any adjustments dimmed necessary were made to the questionnaires and anything unclear was clarified for the research team.

3.7.Data Analysis

Quantitative data from the questionnaires were analyzed using descriptive statistics such as percentages. Qualitative data from the HCD workshop and focus group discussions were transcribed and thematically analyzed.

3.8.Logical and Ethical Considerations

This research set in place in view of the fundamental protection of the rights of the participants informative choices that would address any ethical or logical considerations during the survey and workshops(Walton, 2015). This options was given to participants to help reduce the margin of error and to enhance knowledge and truth during the answering of the questionnaires. In keeping with research ethics the research prohibited falsification and misrepresentation of data(Resnik, 2015).

Given the specification of the focus of the research on household energy, the researcher required access to the respondent's household and where possible the researcher was able to observe and collect more data. The respondents were however informed on the rights of privacy prior to answering the questionnaire. This was also stated farther on the questionnaire for emphasis. The respondents were allowed to answer the questionnaires only to the extent that they were willing to. They were expected to give only the information that they were comfortable disclosing and they were not coerced into answering. The respondents were also informed of their right to allow or refuse the researcher entry into their houses. Another aspect of consideration was confidentiality. The respondents were informed that their identities would not be disclosed to anyone or attached to whatever information they gave no matter how sensitive. The respondents were well informed of their choice to accept or refuse to participate in the interviews before the start of the survey (MEERT et al., 2008).

The questionnaires and any other information from the participants given in confidence were well protected and once dimmed unneeded this information was discarded. This was done to ensure safety and general security of the participant and the information given. Aside from this the respondents were well informed of the ownership of the intellectual property that was to be crafted from the information they gave. The credit of authorship remained with the researcher and not the respondent(Smith, 2003).

CHAPTER FOUR
FINDINGS

4.1. Experience Narrative

Walking into the mathare slums one is met by the disturbing site of congestion and filth. The open sewers run along the facades of the houses presenting a major challenge in accessing the residents. One has to literally maneuver through the open sewers, mad and filth to reach the houses. Even with the unhygienic outdoor conditions you will not miss to spot here and there children playing unmindful of their surroundings. Most of them are born to this pathetic conditions and have since not experienced a better life. They have learnt to play in the filth as that is the normalcy that they have been born to.

Despite the deplorable living conditions in mathare, its residents were quite friendly and not once did we experience any form of hostility as I had feared would be the case. We walked along the corridors of the villages and not once was I or the co-researchers harassed by any of the residents. None of our items were stolen or snatched. There is the fear when getting into a community like this where residents are always portrayed as hostile and unfriendly that you would be faced with insecurity issues. Fortunately that was not the case for us. The respondents received us warmly with only a few of them being reluctant in letting us into their houses but still did not refuse to answer the questionnaire.

In that polluted environment, residents go about their daily routines running small businesses most of which are eateries and groceries. It is in 4b, one of the villages, that one will spot the changaa brewers distilling their liquors in the Nairobi River that is now so polluted that it seems like a wide and open sewer on its own. The river runs across the mathare valley defining certain village boundaries but also acts as the resident's garbage dump site and also their liquor brewery.

Going back to matters energy, eateries along the residential areas operate mainly outdoors. These are mostly people preparing the resident's delicacies which I had a chance to partake of. These delicacies include foods such as mandazis, chapattis, porridge, githeri, tea among others. The preparation of this foods is mostly done using firewood and sometimes charcoal. Even for the indoor eateries, the foods are mostly prepared outdoors at the back of the small restaurants. What I took was the French fries as I wanted to play it safe. But even I had never seen oil that cooks as clean as the fries were. It was later after enquiring from one of the co researchers, a resident of Mathare that he informed me that the oil was oil from the transformer. It was the oil used to cool the electric transformers which they had illegally acquired and were using as a substitute for the ordinary cooking oils. What was most

repelling was the proximity of the cooking to the open sewers. The comfort with which food is prepared just above or close to an open sewer is unbelievable. I could feel my stomach blot just at the thought of how the food was prepared. The entire walk within the village I would define as a nose twitching experience. There was always a bad stench coming from somewhere.

You only realize how limited resources are when you want to use the washrooms I mathare and you have to go to the public latrines which are what the residents all use for their toilet businesses. On arrival at one of the latrines in Kosovo at the entrance, the attendant who collects the fee on entry gladly accepted my ten shillings. But as I walked to enter I hesitated. The place was very dark and I could not see anything at all. I stood their expecting some light to go on and give sight to what a-waited but all I had was the irritated sound of the attendant urging me to go in and use the latrines. So to improvise I switched on my phone's sport light and what I saw in one of the toilets made my bowels shrinks so much that I had to hold on till the end of day to use a toilet in the CBD. This goes to illustrate how basic the basics are in Mathare.

Once, on entry into one of the villages I managed to witness a fire. Apparently someone had forgotten to blow out their paraffin stove and that is what had caused the fire. I watched in disbelief as several shanks went up in flames and property got destroyed. It was only the day after that that some of the community leaders who we had been working with informed us that a child had actually died in the fire and a few residents injured trying to escape and put it off.

4.2. Disabling Environmental Factors

4.2.1. Inaccessible Technologies

Through the survey the researcher identified several outlets that distribute the different energies to the mathare residents. These outlets include kiosks, petrol stations and supermarkets. Most kiosks are located along the roads and paths that run through the mathare valley and so are the petrol stations. These are the areas where most businesses run within mathare. Of these distribution points within the settlement SETs are only but available in the supermarkets. With the survey indicating only 1% of the population sourcing their energies from the supermarkets, there is clearly limited access and exposure to the SETs. Even the 1% percent only go to buy the LPG gas from the supermarkets and not any other technologies such as the fireless cookers or bio-fuels. Below are the specific points of distribution for charcoal, paraffin, gas and wood.

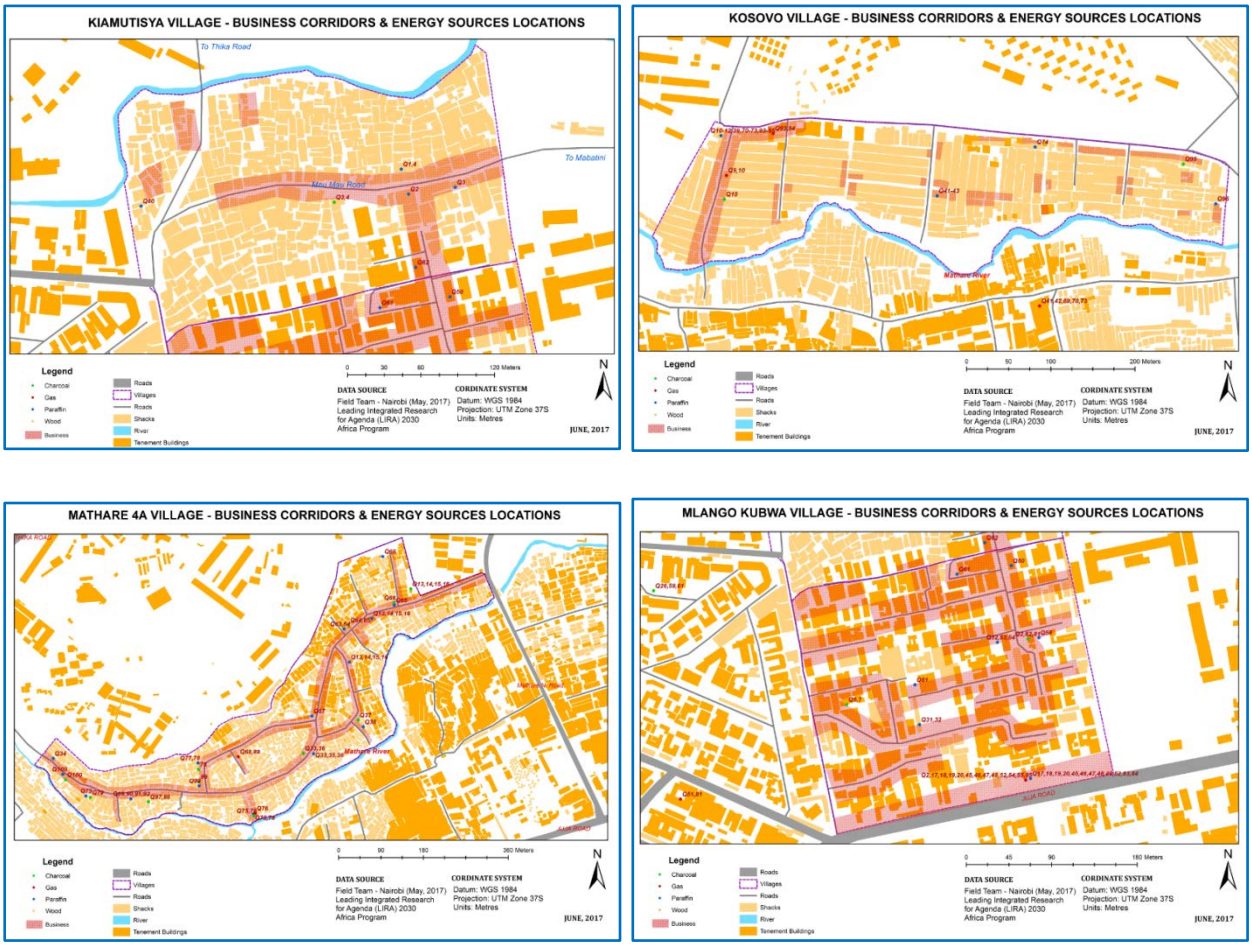


Figure 27: Energy Accessibility Maps in Mathare

Most of the residents source there cooking and heating fuels from the kiosk. Kiosks are the most popular distributors of both paraffin and charcoal with all household charcoal being from kiosks. This is followed by petrol stations which are the most popular gas sources though some of the households buy their gas from kiosks and supermarkets. From the focus group discussion with some of the distributors of energy within the settlement and from some of the survey reports it was evident that there is extreme lack of awareness by the residence on where to source the sustainable energy technologies in the markets as the main access points which are the kiosks do not stoke the SETs

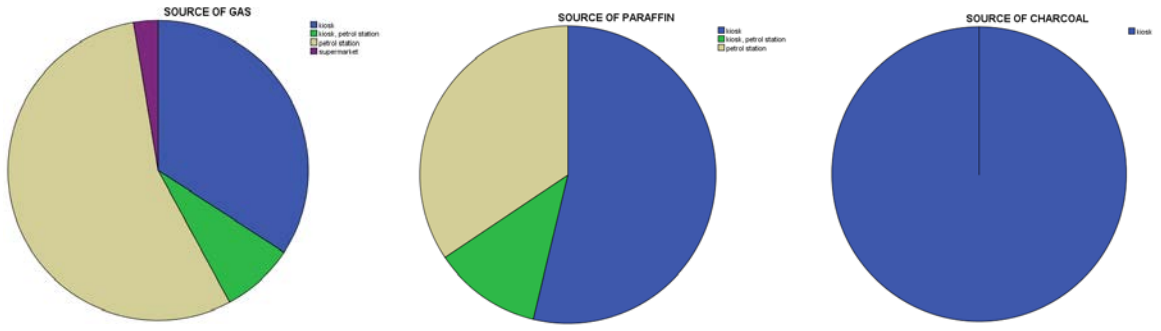


Figure 28: Pie Charts on Sources of Fuels in the Sampled Villages

Table 2: Sources of Gas

SOURCE OF GAS					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	kiosk	13	13.0	13.0	13.0
	kiosk, petrol station	3	3.0	3.0	16.0
	none	62	62.0	62.0	78.0
	petrol station	21	21.0	21.0	99.0
	supermarket	1	1.0	1.0	100.0
	Total	100	100.0	100.0	

Table 3: Source of Paraffin

SOURCE OF PARAFFIN					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	kiosk	50	50.0	50.0	50.0
	kiosk, petrol station	11	11.0	11.0	61.0
	none	7	7.0	7.0	68.0
	petrol station	32	32.0	32.0	100.0
	Total	100	100.0	100.0	

Table 4: Sources Of Charcoal

SOURCE OF CHARCOAL					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	kiosk	36	36.0	36.0	36.0
	none	64	64.0	64.0	100.0
	Total	100	100.0	100.0	

For their cooking and heating needs the researcher established that the residents of Mathare mainly use paraffin, charcoal and gas with the majority giving preference to paraffin at 34%. Of these fuels only the LPG gas is sustainable yet only 8% of the households use it exclusively to cook and only 3% to heat. Like any other typical Kenyan society, the people of Mathare community do not just use one kind of fuel for cooking but rather they practice energy fuel stacking. Several of them combine different kinds of fuel depending on their financial capabilities and convenience. These practices of stacking were done to either supplement or substitute other fuels. Most the respondents gave preference to paraffin or gas for the foods that needed longer cooking like boiling of beans ad maize. From the survey it was determined that only 1% of the residence do not cook I their households and prefer to have their meals at small eateries or restaurants within the settlement. The table below shows the energy fuels used for cooking and heating.

Table 5: Frequency Table for Type of Fuel Used in Cooking

Fuel for Cooking					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	paraffin	34	34.0	34.0	34.0
	paraffin, charcoal	22	22.0	22.0	56.0
	paraffin, gas,	20	20.0	20.0	76.0
	paraffin, gas, charcoal	10	10.0	10.0	86.0
	gas	8	8.0	8.0	94.0
	charcoal	3	3.0	3.0	97.0
	none	1	1.0	1.0	98.0
	paraffin, gas, electricity	1	1.0	1.0	99.0
	paraffin, kplc	1	1.0	1.0	100.0
	Total	100	100.0	100.0	

Table 6: Frequency Table for Type of Fuel for Heating

Fuel for heating					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	none	52	52.0	52.0	52.0
	charcoal	20	20.0	20.0	72.0
	paraffin	12	12.0	12.0	84.0
	electricity	10	10.0	10.0	94.0
	gas	3	3.0	3.0	97.0
	charcoal, electricity	2	2.0	2.0	99.0
	charcoal, paraffin	1	1.0	1.0	100.0
	Total	100	100.0	100.0	

There was evident limited of use of any sustainable energy technologies to cook and heat such as biogas, fireless cookers, solar cookers, and improved jikos. 100% of those who used charcoal did not use any of the improved jikos but rather used the KCJ that has lesser heating efficiency. The only renewable and sustainable fuel that seems to have gained ground in the settlement is the LPG gas used with one burner gas cookers.

Below are frequency charts illustrating the usage of energy for cooking and heating in Mathare.

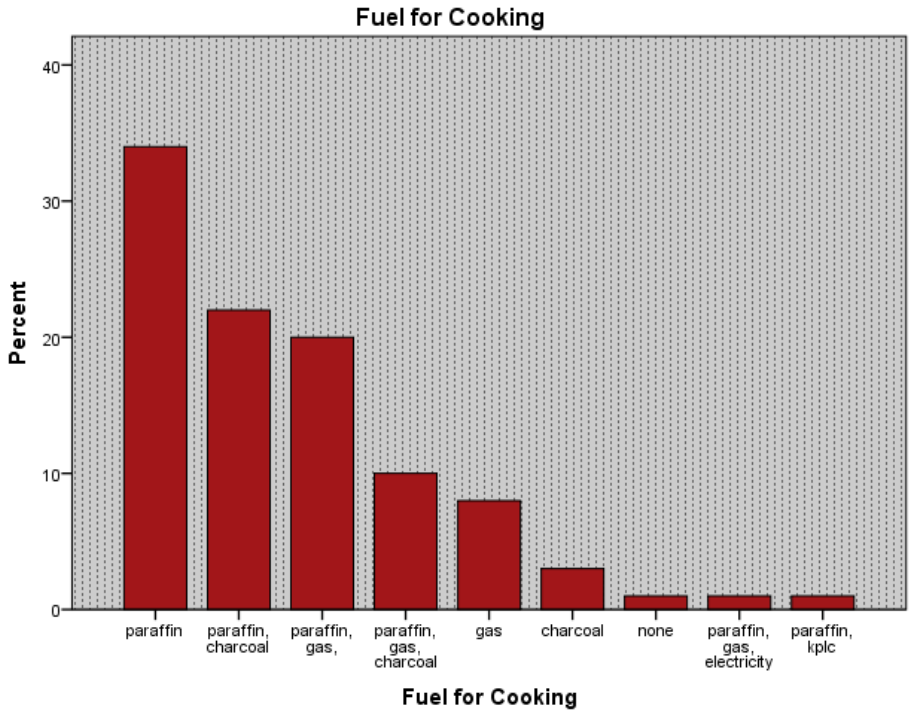


Figure 29: Bar Chart on Types of Fuels Used in Cooking

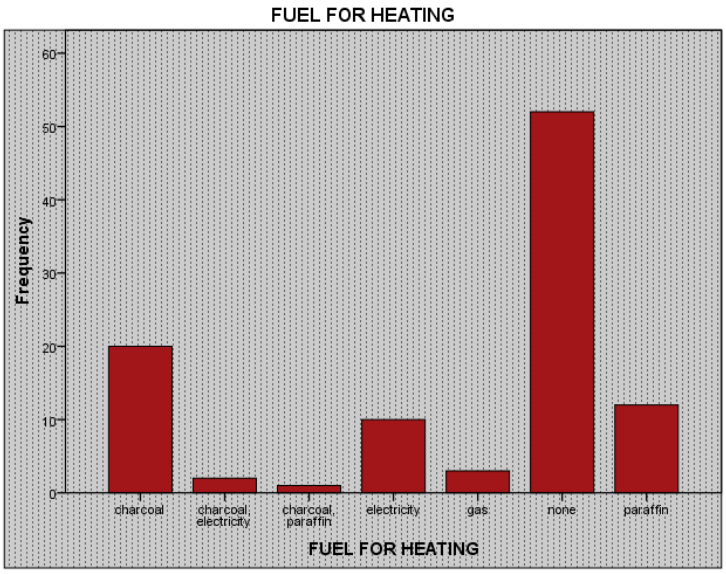


Figure 30: Bar Chart on Fuels Used for Heating

A considerable number of mathare households do not heat their houses. If they do, then it is mostly done when preparing food even with gas cookers and after using the left over fuels such as charcoal after cooking. 52% do not heat their houses while 35% of the 100 households use either charcoal or paraffin to heat their houses. 12% use electricity to heat. This they achieve by leaving their bulbs on every time they are in their houses while some leave their electric bulbs on all through the night during cold season. There were those who did not switch of their electric bulbs unless there is a black out and consequently no electric supply. Majority of those who left their bulbs on the entire night were mostly those who had babies and young children.

4.2.2. Constraining Socio Economic Factors

4.2.2.1. Influence on choice

The survey determined that what influences the residents of Mathare the most as they decide on which energy type to use in cooking and heating is it's of use. The process of lighting a fire to start to prepare a meal must be very simple if any type of energy has to be adopted in Mathare. Cost came second in ranking to ease of use. One's financial capability to own a certain type of energy is one of the major factors just like in most product cases that would determine the purchasing power. Ease of access came third at 56% followed by related health outcomes at 6% then family and friends was the list influential in energy type at 2%. Despite the direct link between energy and health, a large percentage of the Mathare residence did not seem affected by this. Though 82% had experienced

symptoms such as itchy eyes, running noses, shortness of breath among the other symptoms that one would exhibit while using carbon emitting energies only 73 percent of the 82 respondents associated the symptoms with the type of energy that they were using. Given that the larger percentage of the respondents use unsustainable carbon emitting fuels most of this symptoms are most likely due to this energies. Below is a frequency bar chart showing the rank of influences on energy choice

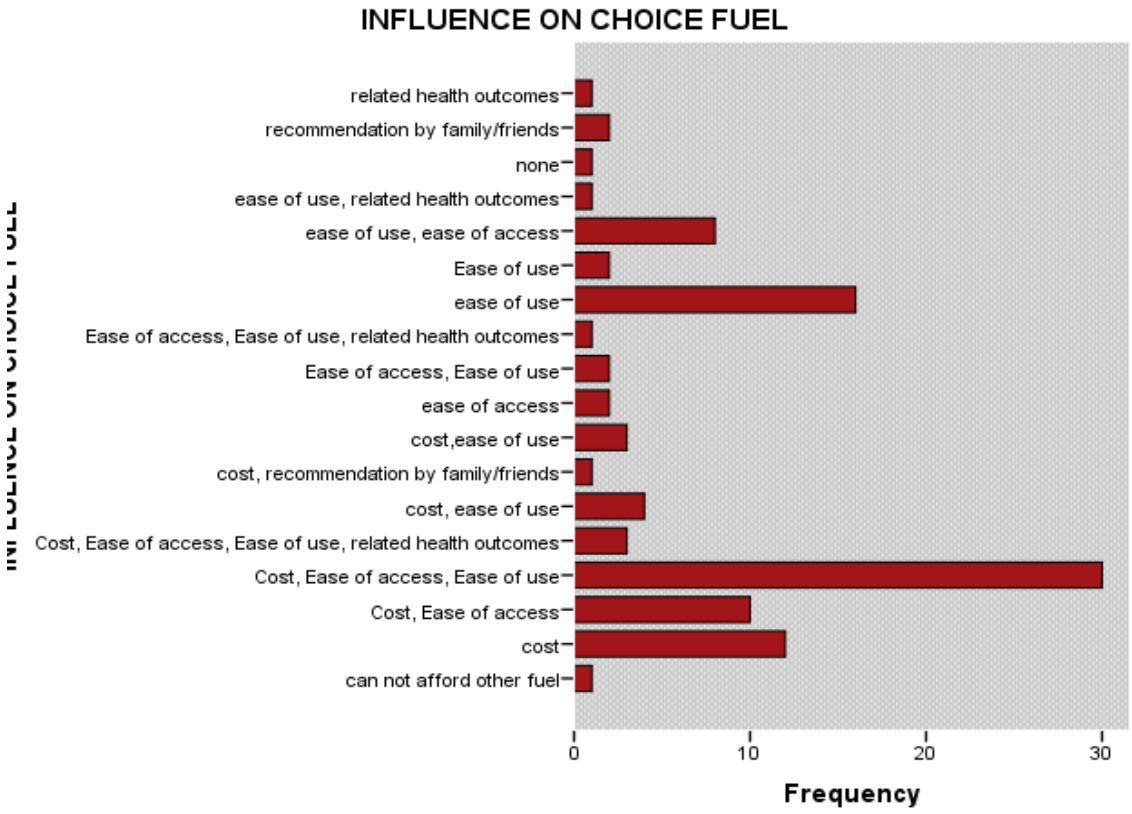


Figure 31: Bar Chart on What Influences Choice of Fuels

4.2.2.2. Cost comparisons

Cost is the major economic factor that has influenced choice of cooking and heating energies within mathare. The table below analyses the cost constraints with a comparison of the cost of the current energy technologies to the SETs.

Table 7: Cost Comparisons Between Sets and Conventional Energy Technologies

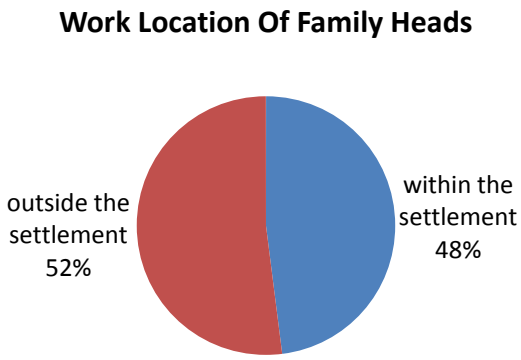
SETs	Conventional energy types
Briquettes- 1000-1500ksh/50kg bag	Charcoal-1100- 1600/sack-50kgbag
	firewood
Bio-fuel- 120ksh/lit	Paraffin-between 77- 91ksh/lit
Bio-fuel cook stove- 2500/=	Paraffin cook stove- between 600- 1800
Gas	
3kg- 530/= 1950	
6kg- 1090/= 3660	
13kg- 2290/= 6490	
22.5kg- 3960/= 11160	
50kg- 8800/= 18500	
Fireless cooker- 2000 -3500/=	
Jikookoa- 4300/=	KCJ from250/=

4.2.2.3. Security

From the focus group discussion insecurity emerged as another factor that has hindered the adoption of SETs within Mathare. The group informed that the residents shun new technologies as they are perceived to give a different status which is not necessarily true. The mere fact that the technology one is using may seem unusual and unique would attract the wrong people and make one a target of theft and expose one to other forms of insecurity. They exemplified this with the case of liquid petroleum gas. When the resident started to adopt these technologies its pioneers in reception were not happy. Most of those who owned these gas cylinders were stolen from. The solar distributor who also participated in the discussion also had the same insecurity concerns. Solar has to be installed on the outside as it uses the suns energy he elaborated. It is for this reason that the majority of the residents have shunned the idea for fear of insecurity.

4.2.2.4. Work location

About half of the population's family heads work within the settlement constituting 48%. This contributes to lack of exposure when about half of the household decisions makers are unexposed to the available sets. Lack of exposure in this case amounts to lack of awareness leading poor adoption of the sets.



4.2.3. Restrictive Micro-Politics

A few other facts about mathare emerged in the focus group discussion held with energy providers/ distributors within the settlement. The discussion indicated that Mathare is run at two different governance levels. There is the informal governance structure that was adopted from the traditional onset of the settlement. This structure is defined by the 13 villages of Mathare. Each village is headed by a village elder and under him a few self appointed community mobilizers. These mobilizers from the findings refer to themselves as community leaders. They are individuals who have once had a chance to lead in certain community project mostly nongovernmental projects. Some of them have vied for political seats in the past and did not succeed. They have since then with the help of their former political supporters earned or taken these positions as community leaders.

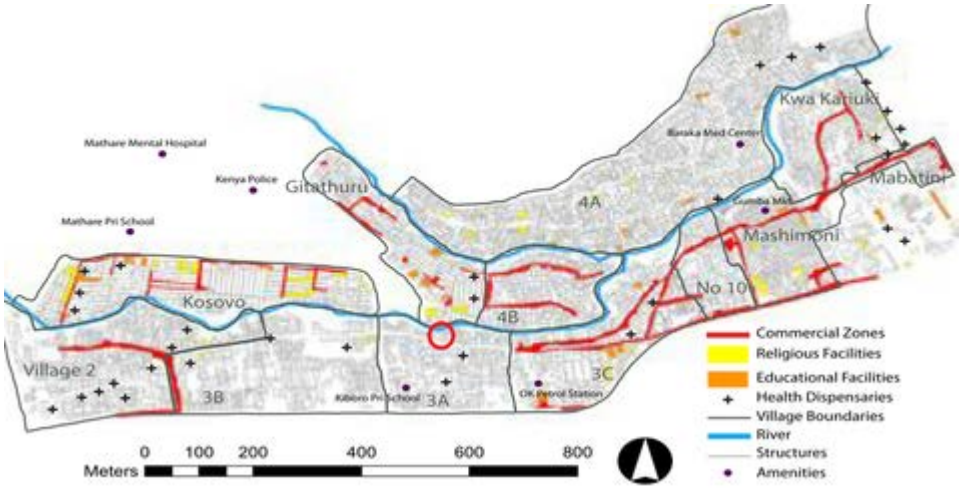
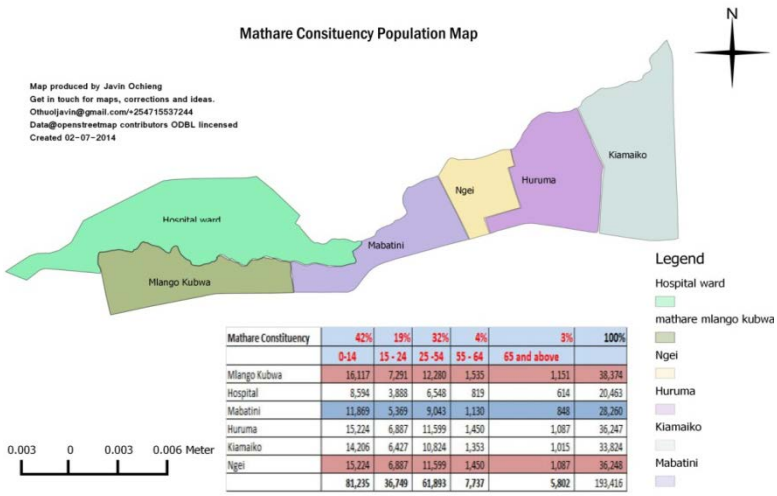


Figure 32: Map of Mathare villages(Sarah, n.d.)

There is the second governance structure. This is the formal structure with hierarchy from the national government. According to this structure, Mathare is a constituency divided into 6 wards. Each ward is governed by a member of the county assembly. These wards include hospital ward, Mabatini,

Huruma, Ngei, Mlango kubwa, Kiamaiko(Kokoyo, 2012). Below is a map of the six wards of the settlement.



Mathare Constituency	42%	19%	32%	4%	3%	100%
	0-14	15 - 24	25 -54	55 - 64	65 and above	
Mlango Kubwa	16,117	7,291	12,280	1,535	1,151	38,374
Hospital	8,594	3,888	6,548	819	614	20,463
Mabatini	11,869	5,369	9,043	1,130	848	28,260
Huruma	15,224	6,887	11,599	1,450	1,087	36,247
Kiamaiko	14,206	6,427	10,824	1,353	1,015	33,824
Ngei	15,224	6,887	11,599	1,450	1,087	36,248
	81,235	36,749	61,893	7,737	5,802	193,416

Figure 33: Map of mathare wards(Sarah, n.d.)

The other is the cartels who also run their own governance structure and even determine how certain things are done. There means are mostly illegal and therefore they are very sensitive to outside help. We couldn't even take photos in one of the villages despite the then aspiring MCA and resident advocating for our course. This is because the cartels who deal in illegal drugs would not allow it.

Theses governments determine how projects are instituted within the settlement. However they have over time failed to agree on many matters hence hindering development within the settlement. Every time there is a project that promises financial gain to the one that runs it, each government demands its cut from the project failure to which they sabotage the project for good.

An example the group gave was the biogas plant that was a non- government project. The different governments could not come together and agree to a specific location where the structure would be put up or how it would be run. The residents who would have been the major beneficiaries of the project also opposed to it citing cultural and health issues. Those who lived near the intended location of the plant objected to it as they imagined that it would subject them to filth and feces when that is never the case. The land owners could not agree with each other either. Apparently the owners of the lands are not the tenants of the houses. Both these parties however have to agree before any construction is done on their property and they could not do it. The biogas plant therefore could not be installed and the people lost due to misinformation and micro politics of the community. This was the same case with the upgraded housings that were to be built in Kosovo and public toilets that due to the same micro politics failed tremendously.

4.2.4. Detached Macro-Policy Framework

The current policies in general do not address the energy poverty specific to informal settlements within the country. However, the policies acknowledge the inexplicable poverty levels within these kinds of settlements and address the need to create rural – urban balance through improved access to basic needs in relation to energy quality. The policies acknowledge that sustainability, efficiency and the overall socio- economic factors in energy technologies is key in the creation of the rural- urban balance reckoning with the country's vision 2030(MoEP, 2015). Searching through the policy drafts there is mention of the informal settlements whose establishments are rather different from those of rural areas. The draft national energy and petroleum policy, the energy act chapter 314, the situational analysis of energy industry, policy and strategy for Kenya all do not mention any regulations specific to the informal settlements.

An example is the electrification project for the urban poor that saw the Kenya power install prepaid meter boxes with radio boards in the settlement. The project failed significantly for several reasons. The project had one energy-saving bulb, socket and meter box installed in every house. The bulbs and sockets were placed without any ergonomically consideration with most of them being installed near the ceiling where the households could not reach. The government also introduced a tariff to mitigate the expenses on electricity for the urban poor people. This tariff allows that the first 50kwh are bought at a subsidized rate. Even with this subsidy the rates are still very unaffordable for those in informal settlements. 50kwh costs about 1000ksh while the average payment for electricity per month within the mathare households as per the survey is ranges between 200- 300 ksh per month. This therefore failed significantly with 90% of the residents still tap illegally in the electric grid accessing the energy cheaply at a standard rate of between 200 and 300 shillings a month.

4.3. Creating an Enabling Environment

4.3.1. Co-Designing with Users- The Design Thinking Workshop

The adoption of sustainable energy technologies in informal settlements has been slow over time with some of these energies not being adopted at all in these settlements. This has widely contributed to the energy poverty in informal settlements in Nairobi and increment of poor living conditions. This has been attributed to introduction of these technologies in isolation or without proper consideration

of the socio techno and economical status of the target populations. So many issues need to be addressed before these energies can gain ground in this areas.

Lack of sustainable systems in various communities has proved to be the major deterrent to development in various parts of the country especially in informal settlements. In these workshop challenges that have contributed to this problem of limited or no adoption of energy technologies are discussed by the participants to assist in formation of sustainable systems that could enhance adoption and implementation.

Table 8: Workshop Facilitators

Facilitators	Role
Christer Adelaide Anditi BA design Masters student UoN	Project lead and main facilitator
Julia Kamuiru Lecturer UoN Product Designer	Co- facilitator
Nelson Cheruiyot BA in Design MA student at UoN	Photography and schematics

4.3.2. Participants' Selection and Attendance

The workshop was intended to host a variety of stake holders within the energy sector of Mathare. These stakeholders included the policy makers, experts, energy providers within Mathare, community leaders from the four villages of mathare and household owners. The community leaders were selected from the four villages that had been purposively sampled in the baseline survey for data collection. The experts included two health experts, a research expert and an environmental expert while the policy makers were from the ministry of energy and petroleum.

The energy providers were selected on the basis of the most popular energies used in cooking within Mathare and most unpopular yet sustainable source of energy. These providers were a paraffin sales lady, a gas sales lady, a charcoal sales man and a solar distributor.

The total number of attendance was anticipated to be twenty participants. Each group of stakeholders had four invites. The workshop received a reverberating attendance from the invites that had been sent with only four absentees reported. Due to the political stalemate in the current at the time the workshop that was earlier scheduled to be held on the seventh of September 2017 but had to be postponed to the fifteenth, unfortunately two of those in the ministry assigned to attend the workshop had been reassigned on other duties and could not be present on the day of the workshop. One research expert from the university could not attend the workshop including one household owner.

Figure 34: workshop participants

4.3.3. Participants in Attendance

Table 9: Participants in The HCD Workshop

STAKEHOLDER TYPE	EXPECTED ATTENDANCE	NUMBER IN ATTENDANCE
Policy makers	4	2
Health experts	2	2
Environmental expert	1	1
Research expert	1	0
Energy providers	4	4

Community leaders	4	4
Household owners	4	3
Total	20	16

4.3.4. Workshop Setting

The workshop began at about ten o'clock in the morning. The space was arranged designating sitting positions for each group with colors. Each group was defined by a differently colored set of chairs from the rest of the groups. Each group was also provided a table on the side that they would later use to in the balloon challenge and for prototyping. Next to each groups table was a board covered in blue Manila paper that the group would use to stick on their ideas as the workshop progressed. The workshop was expected to be very interactive and this was what advised the lack of tables for participants to sit around during the workshop. This was to discourage participants from leaning, phone charting and working on computer devices during the workshop.

Figure 35: The workshop space

There was also one extra board labeled the idea board. This is where any ideas not necessarily related to the groups work but relevant to the course of the workshop would be presented. Participants were allowed at any time of the workshop that they had an idea about the issues at hand or any ideas on improvement of the workshop to write and post their ideas on this board. There was also a table where the tools that were to be used in the workshop were arranged located just by the entrance.

Figure 36: The idea board and The tools table

On entry each there were trays each labeled according to the type of stakeholder it would serve. These trays contained pieces of paper numbered one to four and sealed as for each stakeholder category the expected attendance was four people. Each stake holder was expected to pick a name tag, a workshop hand book, a marker pen and a piece of paper from the tray of once group designation. People from the ministry picked from the tray labeled M, household owners picked from the H, providers picked from P, community leaders picked from C and experts picked from E.

These papers were numbered and picked randomly by participants to allow for a non bias seating arrangement. Each group was numbered one to four. Depending on whatever number one picked they would seat in the group labeled with that number. The expected outcome of the arrangement would be that each group would have one policy maker, one expert, one community leader, one provider and one household owner. A total of five participants of different capacities in each group would be the expect sum.

4.3.5. Workshop Activities and Results; The HCD Toolkit

The workshop was quite vibrant with each participant being engaged at their different capacities. The workshop proceeded in the following stages consecutively: empathy, definition, ideation, prototyping and testing.

4.3.5.1. Empathy: 3 Things in 3 Minutes

Every participant in the workshop had a part to play in the consumption and supply of various energies for cooking and heating within Mathare. This phase entailed getting to know ones partner. This was a random exercise where each participant partnered up with their neighbor. Each was then

expected to introduce themselves to their partner then the partner introduces them to everyone else. This was meant for the participants to discover one another's interest, the way they do things and the reasons behind their actions, their needs as stakeholders and what is meaningful to them as individuals. Some of the questions in this phase were such as; who are you? What matters to you? This kind of introduction was meant to deter participants from telling the rest only what they already knew like their names but also to touch base with what they like, dislike or expect. This would enable them to connect on a more personal level and also encourage a relaxed environment breaking any tension whatsoever. This phase revealed that most of the participants were happy to be part of the workshop while others were yet to understand their roles in the entire proceedings. This process took about 30 minutes.

Team building and balloon challenge

The participants, sitting in their groups of five were issued with various tools for the team building balloon challenge. Among the tool given to each group were a park of balloons, a pair of scissors or cutters, masking tapes, straws and strings. With these tools each group was expected to build a structure of their choice within a period of fifteen minutes. This was to test their team building skills and evaluate how each team was able to indulge their members without discrimination or intimidation.

Among the structures that were built was a baby holding a balloon, a tree, a Christmas tree and an abstract structure. It was evident that the groups that worked together and deliberated their work among members did their work faster. These groups also came up with bigger better structures. Group one who worn the challenge had a structure that was quite easy to define. Almost everyone could tell that it was a baby holding a balloon. From the evaluation of the groups, it was noted that the group worked together well. Every member was designated a role to play right from the start of the challenge and together they worked well and fast. Every member knew prior to making what structure they were working to create. This showed that they actually sat together and decided very fast on what they wanted to make. Group two with the yellow balloons did not have a defined structure. When asked, none of the members knew exactly what they were working towards. It was clear that they could have taken less time to build if only they had agreed on what it is that they wanted to build.

Group 1: Structure of a baby holding a ball

Group 2: abstract structure

Group 3: structure of a tree

Group 4: Structure of a Christmas tree

Figure 37: The balloon challenge team output

4.3.5.2. Definition

Once the balloon challenge session ended, the team had a sense of team building and tension had worn out. The lead facilitator then made an introduction on what the workshop was about. The facilitator gave a problem statement on the current situation on adoption and implementation of energy technologies. She also outlined the general bottom line of the research. She explained that the research was a collaborative research that involved research and professionals from different academic disciplines working together to improve the energy situation in informal settlements with case studies in Kenya, Uganda and Tanzania. The facilitator also gave an overview of what the expected output of workshop would be. This was sustainable product service systems that would be proposed to address the issues on adoption and implementation of sustainable energy technologies in Mathare.

4.3.5.3. Ideation

Brainstorming

After listening to and understanding what the problem was and the current situation, the team was now ready to embark on the next session of the workshop which was to brain storm on the difference challenges that have lead to limited or no adoption of sustainable energy technologies. The brainstorming session was still organized in groups. Each group came up with various challenges. With the deliberate integration of different stakeholders each stakeholder was required to contribute in their different capacities what challenges they have witnessed or experienced.

Figure 38: Brainstorming sessions

Every time a member of any given group contributed or made a suggestion he or she wrote the points down on a sticky note. Each member had a different color of sticky note so that each noted there points on specific color. If in any case as it was in one group that a certain member could not write then they selected one member who would then note down each member points on a different sticky note as they went along. The members were also expected to suggest solutions that quickly came to mind and also note those down. Once the brain storming session ended, every member put up there sticky notes on the group's designated board.

4.3.5.4. Clustering: 4 Teams 4 Questions

The clustering session followed right after the brain storming. Clustering was aimed at identifying various themes that had emerged from the four groups and depending on the frequency of appearances of a theme as it appeared in the different groups a thumb note was placed against it.

The four groups merged and together moved from one group to another. At every group one of the members volunteered to make a presentation on what the group had come up with and some possible solutions while the rest of the team listened. As the presentations continued, the facilitators noted down the challenges as they emerged from the presentations. The frequency of emergence was represented with a thumb note. For each group the facilitator used a different colour or shape of thumb note to separate the sources. This was done until each of the groups had had a chance to present their work.

Some of the themes that clearly emerged from the brain storming session as the challenges that currently limit or stop the adoption of sustainable energy technologies were noted as: Hygiene, Cost, Health, Transportation, Poor technology, Security, Population diversity, Awareness, Regulation implementation, Infrastructure, Energy staking, Community resistance, Lack of production resources, Illegal Administrative structures (cartels).

After the clustering session, the team selected the four most frequent themes that emerged. On top of this they also pointed out the most unexpected or awkward themes that were later combined with any of the four in accordance to relevance. These four most common themes were cost, health, poor technology and awareness in order from the highest frequencies. The most awkward theme was culture while the theme that scored the same number of points as awareness was infrastructure. The team then decided that it was prudent to combine both awareness and culture as culture they felt that it was a major consideration to make if one needed to create awareness. It was also agreed unanimously by the team that those handling the theme of poor technology were better placed to handle the theme of infrastructure that had had a tie with one of the themes.

Figure 39: The clustering session

The lead facilitator then wrote the main themes on papers. Each theme was written on a different piece of paper. Then randomly the papers were picked by a representative from each group.

4.3.5.5. Prototyping

The team then diverged into their different groups for the prototyping stage. This process began by each group chanting and jolting down some of the solutions that had been proposed in the presentations during the clustering session. Other possible solutions were also written down together with those prior ones.

Each team was provided with a table surface. On the tables were different tools that they would use to create systems. These tools included pens, Pencils, plasticine moulds, masking tapes, card boards, Manila paper, colored papers, straws, and strings among others. They were to use these tools as they saw best to make three dimensional systems where possible or drawings of possible systems depending on the challenge they had to tackle.

4.3.5.5.1. Factors That Influence Adoption and Their Proposed Systems

Cost

The biggest influence on adoption of sustainable energy technologies from the workshop was cost. Cost of technology, cost of transportation, cost of maintenance, cost of consumption and cost of raw materials were some of the factors surrounding the aspect of cost that emerged from the discussions. When handling the aspect of cost the group proposed two different systems. One system was on policy regulations and another was a comparative analysis on energy options in a bid to sensitize the informal population on use of better energy technologies.

Policy system on cost

Figure 40: Policy system on cost

According to the stakeholders dealing with cost, once the government comes up with policies and regulations on the various energy options, the energy regulatory commission enforces these policies through subsidies such as tax exemptions. The Kenya bureau of standards on the other hand is tasked with standardization of quality and quantity of products and cost. The ministry of roads and transport is also tasked with ensuring better roads and general infrastructure.

The result of addressing issues on reduction of prices by these institutions is expected to realize more affordable energy technologies for residence in informal settlements. Energy becomes easily available through better infrastructure. Use of locally available materials in production was seen as a way to reduce cost of production. Standardization of products also ensures quality and quantity hence reducing the cost of maintenance. The integration of these factors was presumed to subsequently result in cheaper energy for the end user.

Comparative system on cost

Figure 41: Comparative systems on cost

In the discussion on cost as a socio economic factor that influences adoption an analysis on some of the different sustainable energy technologies and the conventional technologies is given. These systems compare the cost of using LPG gas to cook to that of using paraffin. This demonstration determines the cheaper fuel to be LPG which is also sustainable. This is expected to sensitize the informal settlement residence on more affordable and sustainable energy options for their cooking and heating needs.

Sustainable product service system on cost

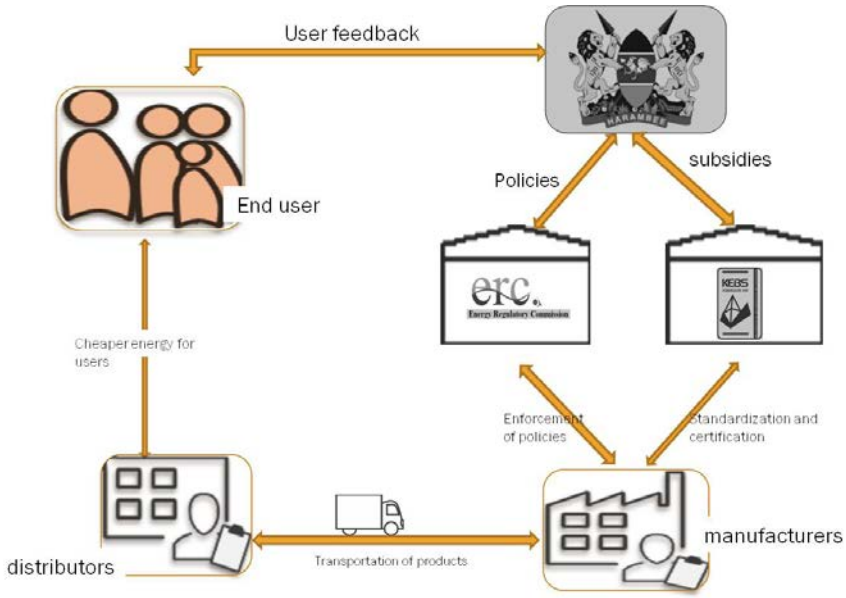


Figure 42: SPSS on cost

Health

Health during the clustering process emerged as the second largest influence on the adoption of energy technologies. To addresses the issue on health the group proposed a system that would sensitize people on the health benefits of using a certain energy technology. They picked on jiko okoa

to illustrate the kind of system they would propose. Jiko okoa is one of the sustainable energy technologies that have been introduced in the market with an intention for it to replace the Kenya ceramic jikos. So far the adoption of this technology has been quite low despite being associated with higher efficiency and lower carbon emissions in comparison to the Kenya commercial jiko. The group proposed a comparative system running through the following steps.

Introduction

The system is intended to first give a preamble on what jiko okoa does and what it is intended for. This process would begin by making and issuing of brochures to the target population. The brochures would then give a prelude on what the jiko is and also the venue where training sessions would be held. In this stage the group proposed that the target population should have a chance if possible for live demonstrations on what the jiko okoa is and how it functions. To compliment this technology they would also expect that the jiko okoa demonstrations be done using briquettes a new low carbon emitting fuel that would replace charcoal energy.

Figure 43: System on health

Training

It was proposed that the trainings could be done through community forums and at workshops. In the training sessions the participants would be educated on the health benefits of using a new technology. They would also be trained on the health risks posed to them by the old sources of energy. Some of the health benefits that the group outlined were reduction of carbon emissions there reduced respiratory tract diseases. The other factor was that the new technologies would allow them a cleaner kitchen environment with limited or no soot at all. Financial empowerment as these energy technologies would be more durable increasing the replacement intervals. This way the family uses less money on energy purchases and saves more.

Figure 44: System on health

Another way to ensure the cooking process is a healthy one would be by ensuring the housing structure is well designed. In informal settlements most houses have one small window or no window at all. The group proposed that a healthy housing structure be demonstrated during this session to educate people on the health benefits of proper ventilation. These housing models would have windows or at least one window, chimneys and would a little more specious than the conventional ones in the informal settlements.

The trainings would mostly be comparative. Comparing two different technologies, the old and the new, the advantages of the new technologies would clearly be outlined in contrast with the disadvantages of the old technologies.

Sustainable product service system on health

Figure 45: SPSS on health

Poor technology and infrastructure

Figure 46: System on technology and infrastructure

Poor technology and infrastructure imaged as one of the four major issues themes that determine adoption and implementation of sustainable energy technologies. The group selected liquid petroleum gas as one of the sustainable energy technologies in the market and how poor technology has influence its uptake so far. To determine this deterrence to adoption and implementation the group brook down the issue of poor technology and infrastructure defining it in terms of quality, affordability, access, safety and efficiency. These are the general factors which the group worked out that would determine whether the technology was poor or not. Scaling around these factors the group discussed the various ways in which the challenge of poor technology should be addressed.

The group began by outlining the major stakeholders when it comes to LPG gas and the adoption cycle. These stakeholders emerged as the government, the manufacturers of LPG gas, the distributors and the users. With each stakeholder the group clearly outlined their specific roles to the best of their knowledge.

The government was seen as the body in charge of policy making, issuing subsidies on energy products and running energy projects. This they are seen to achieve through the following institutions: the energy regulatory commission, the Kenya bureau of standards, and civil societies through training institutions. This bodies each plays a different role in determining the appropriateness of energy technology before it gets to the end user. In this case the LPG gas.

According to the group the Kenya bureau of standards sets standards on which goods are produced and also issues. They also certify labels for different products. They are also tasked with issuing burns on counterfeits and ensuring the right warrantees and guarantees for different goods here so the gas cylinders and type of gas filed in the cylinders.

The government is also in charge of the formation of the energy regulatory commission which is then tasked making policies that govern the energy products and processes. They are also tasked with ensuring that the public is well aware of these policies. Above all the policy makers are also tasked

with considering and appreciate the diversity of the Kenyan population before coming up with these policies. In doing this the group believes that they will then be able to come up with favorable policies for every citizen no matter where they come from.

The projects run by the government are expected to indulge the users, the distributors and the manufacturers. All of them are to be trained in their different capacities. Through these projects they all are able to provide necessary feedback about the energy products. These projects should also provide avenues for the government to be able to create awareness on any new technologies in the market, provide training on efficient use and storage of a given technology, and provide information on the policies that govern a given product to the public among others. The government is expected to simply use these projects to link them with all other stakeholders.

According to this group the manufactures who are the next ranking form the government have certain responsibilities which they outlined as among others assurance of quality and quantity of the energy products. After the Kenya bureau of standards has come with the right standards they ensure these standards are maintained during the refilling of gas cylinders and also during their manufacture. The energy regulatory commission is also expected at this point to clearly enforce the regulations on the manufacture of the LPG gas. They are to clearly outline which products are tax free and for which products are subsidized in price for what type of citizen.

The distributor who is the next in chain from the manufacturer is expected to safely transport the gas to the distribution points and sell them at the right prices. They are to ensure the gas is clean and reliable as they retail them to the user. The user on receiving the gas is expected to give the necessary feedback to the government through the training bodies or to the distributor who would then inform the manufacturer who later gets back to the government. Below is the system created by the group illustrating what their SPSS system addressing poor technology should be like.

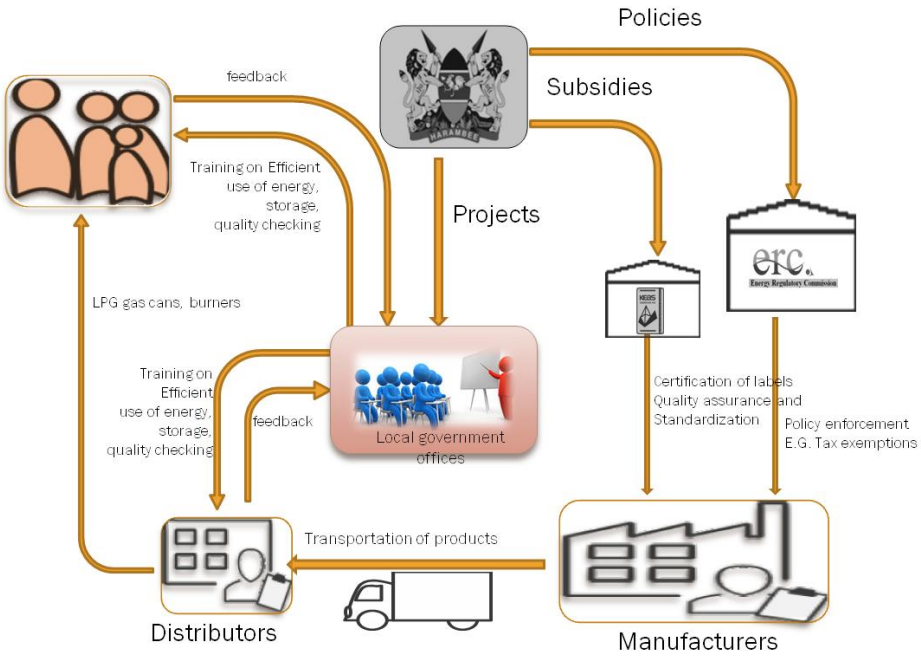


Figure 47: SPSS on technology and infrastructure

Factors that define technology

Affordability

According to the group, affordability is one of the factors that determine the efficiency of a technology. The group explained that if a technology is introduced into the market and none of the consumers can afford to buy it then the technology is inefficient. Affordability of a product therefore they said is very important when designing any form of technology. The common occurrence usually is that once a technology emerged the prices are subsidized during the promotion stage. Later on, the prices shoot up and cannot be afforded by people living in informal settlements who are mostly low income earners.

It was noted that LPG being a government run energy production source. The said government should be able to subsidize prices to allow the low income earners to afford. One of the government officials interjected saying that the government was already in the process of introducing smaller gas cylinders which could also be afforded by low income earners. He reiterated saying that the government was undertaking a process where the paraffin prices were being hiked to discourage people from using paraffin and instead opt for gas that was now being made available in smaller amounts.

It was also noted that another reason why technology would be unaffordable would because of the raw materials. It was argued that a given technology would perhaps only be manufactured using only exotic materials making it more expensive. An alternative of finding ways to use locally available

materials when making and introducing certain raw materials was suggested to help cab the issue on affordability.

Quality

Another concern raised was quality of goods as a factor that would effect technology. It was noted that as a technology is introduced in the market. Counterfeits of the same products would begin to emerge from black markets. Some manufacturers would begin to make low standard products that when introduced in the market would eventually discourage the users from adopting the product. For example one may buy a counterfeit gas cylinder without realizing it. Later on when they need a refill, it becomes impossible to exchange a standardized cylinder with a counterfeit. The user is discouraged and opts for other forms of energy. It was suggested that government should screen any new technologies ensuring it is the right quality and the expected standards. There should also be ways for the public to be able to differentiate counterfeits from original products

Safety

There are also a lot of random fires across these settlements that people fear that gas would be even more volatile than the other energy sources that have caused these fires in the past like paraffin. It was argued that turning on a gas cooker is quiet easy and anyone even small children can do it unknowingly. This would then result into big fires that may burn not just one but a number of households in given area of the settlement. Safety of a technology would become therefore a key factor in its adoption.

Insecurity in informal is quite rampant. People are quick to steal products that may seem unique. A new product may come in the market but people reject it because they become targets of theft. Some of the users reiterated on this saying that most people fear to own gas cooker despite its advantages for the mere reason that it would be stolen from them before they can use it. This is another angle that may not always be considered.

Efficiency

Even though it was agreed that gas cooks faster, the fact that the gas may finish anytime time without warning made it an inconvenient choice. It was suggested that there should be an alert system through which the user could be informed of the gas level to allow them time prepare for a refill. This is especially for the single burner gas cylinder. The maintenance cost of having to replace the burner every once in a while did not also augur well with the users. They were of the opinion that a more durable material should be used in making the burner to reduce the replacement frequency.

It was also noted that users should be able to get training on how to operate any new technologies. This goes a long way in ensuring safety of use and also storage. User manuals should be provided with the technology to guide the user on how to operate a given product. General awareness should also be created by the government on new products. All these factors were seen to contribute to the efficiency of the product.

Awareness and culture

Lack of awareness was seen as a major deterrent to adoption of sustainable energy technologies. It is amazing what fear people have with things that they do not understand. It was noted with great concern that certain people would reject a technology just because they never saw it before and imagine risks that do not exist. There are also so many stereotypes that come with culture that hinder people from buying new cooking technologies. To cub this problem of lack of awareness and limitations inspired by cultural beliefs the group three drew up this systems.

These systems involves a chain of stakeholders all working in a continuous circle to ensure awareness on sustainable energy technologies is created. For example once the government has new technology or sees the need to sensitize people on a certain technology. They first approach the local administrative chiefs of mathare. These chiefs will then approach local leaders in different capacities. These could be church leaders, village elders, business community, youth leaders, women leaders or the CHWS. These leaders would then be tasked with the duty of passing on information to the community. This they could achieve according to the proposed system through various forums such as radio stations, barazas, holding live demonstrations and exchange programs. Through these avenues they can easily reach a large population of the community educating them on the various aspects of different sustainable energy technologies. This way the community have places they can ask questions and be answered, give feedback and raise concerns if any on any given technology.

Figure 48: System on awareness

A concern was however raised about places that are governed by cartels and illegal administrations and cheap politics that may otherwise hinders these endeavors. In such cases the group suggested that the government should contact the community directly through their community leaders to ensure the end users benefit from what they intend to achieve. Community leaders have been known in informal settlements in the past to have a great hold on those they are leading. They are also able to

directly give feed back to the government on the community's response as long as there are avenues allocated for doing this.

Sustainable product service system on awareness and culture

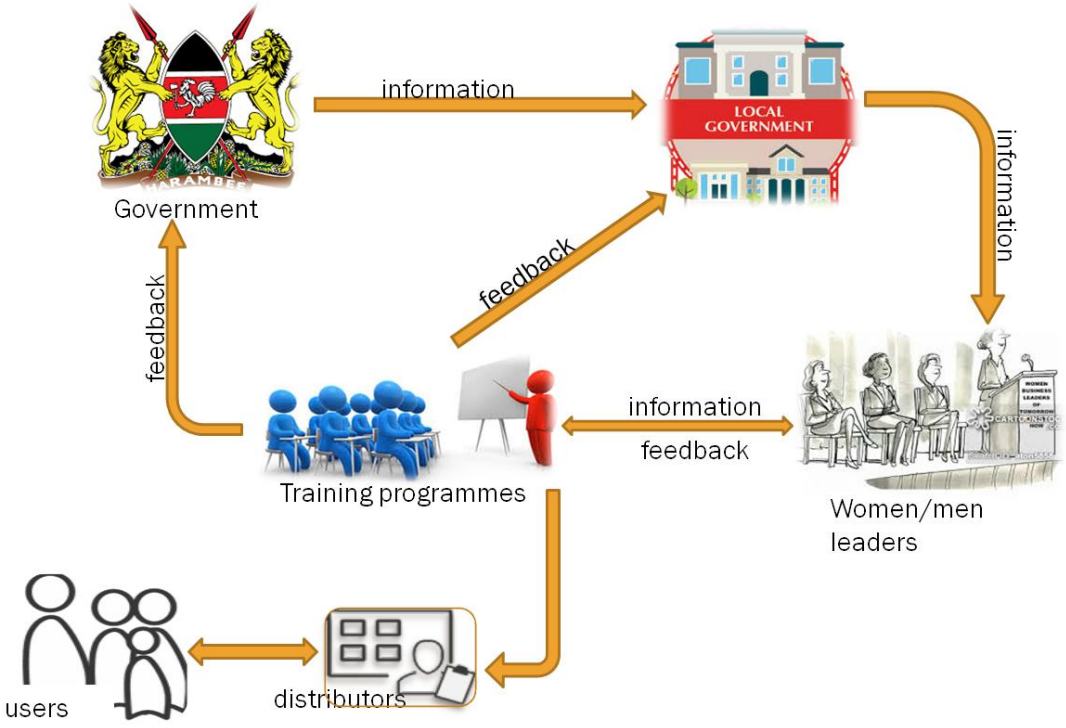


Figure 49: SPSS on awareness

4.3.5.6. Testing

Once the groups had detailed systems defining how they would contribute to enhancing adoption and implementation of energy, these systems were tested. During the testing phase, the groups all merged into one. Together the team moved from one group to another. At each group one attendee in the capacity of an end user was randomly selected by the lead facilitator to try making sense of the systems. At every point, once the users had presented. The group received feedback on what improvements they needed to make to their systems for better communication.

This exercise proceeded successfully with each group receiving needed feedback on their systems. Once it was done, the groups reconstituted and made the recommended changes to their systems.

4.3.2. Policy Seminar and Expert Opinions on The SPSS

4.3.2.1. Expert advice on SPSS for cost

It was the experts' advice that subsidies should not be in any way connected with KEBS. They informed that KEBS was not an institution that oversaw or implemented subsidies rather it was the ERC that dealt with policies including those that affected and implemented subsidies in Kenya. They however stated that KEBS worked closely with ERC in certain issues such as quality checks and compliance. The experts also added that subsidies could also be issued by nongovernmental sponsors of certain projects to enhance the uptake of those projects exemplifying the case of biogas plants. To install the plants at one time there was sponsorship and these sponsors gave subsidies on installation cost for those willing to install the plants. They would then pay the installers directly the money that they subsidized. They were of the opinion that users should also be informed on the additional transportation and delivery costs on the products from the manufacturers. The experts also informed that the ERC regulates all parts of the economy from the users, distributors and to manufactures.

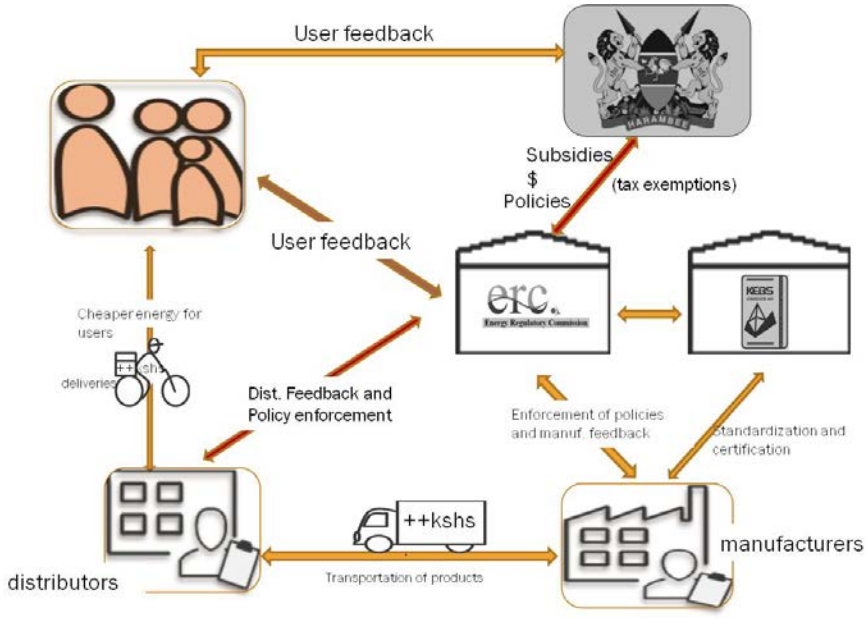


Figure 50: Expert analysis on the SPSS on cost

The experts later advised that the systems should be limited to the parts that are directly linked to the users as the systems are meant for their consumption. This simplification would enhance the understanding of the system by the users some of whom are illiterate.

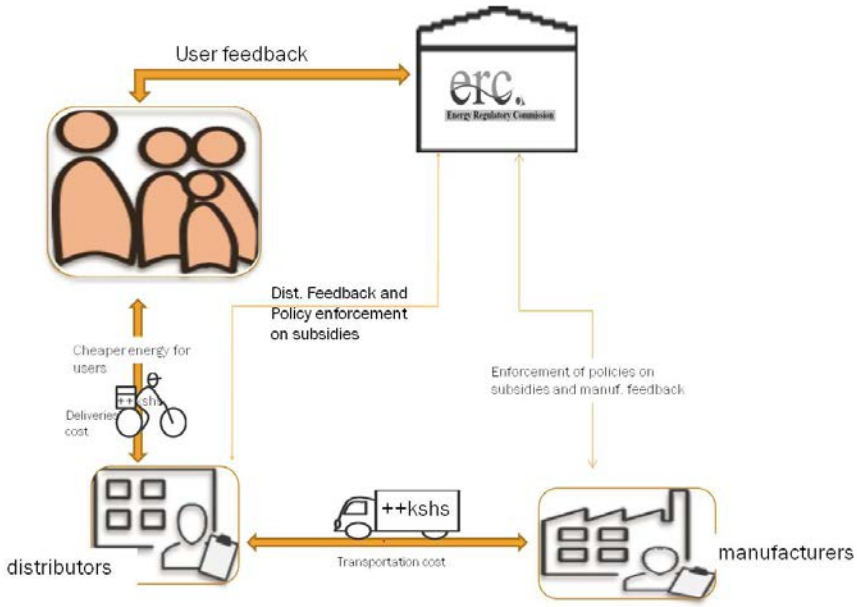


Figure 51: Expert analysis on the SPSS on cost

4.3.2.2. Expert opinions on the health SPSS

Findings from the policy seminar

A policy seminar was held by the LIRA to determine certain policies that would be suggested in the energy sector. In this seminar the researcher had chance to present the health system. It was met with a lot of criticism from the experts present at the seminar. One of the major criticism was on the comparative structure and the experts argued that for the system to be comparative the comparison have to come in equal measure. They stated that it was inappropriate to compare the burning of charcoal and burning of briquettes in a comparison that was majorly targeting the type of stove to be used. It was either a comparison on the fuel types or on the cooker type and not both at the same time. Another issue that came up was the presentation of the burn jiko okoa as a better option to the KCJ jiko. The energy experts present at the seminar argued that theses jikos both gave just about the same carbon emissions and to compare their carbon emission presenting the jiko-okoa as one that emits less carbon was unjustifiable. It is by this criticism that the system was restructured as represented below.

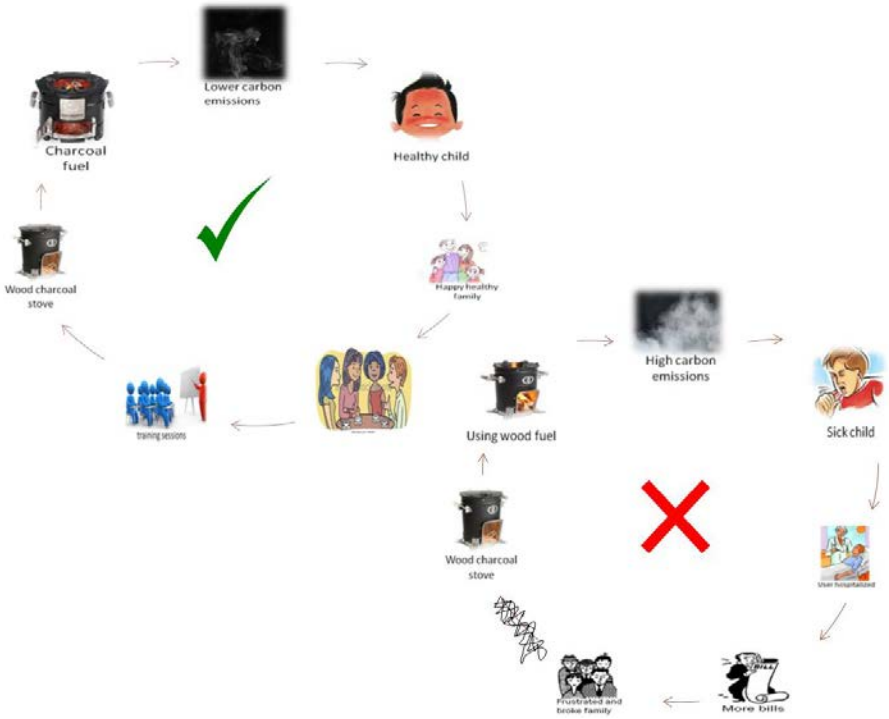


Figure 52: Policy seminar Analysis on the health SPSS

Expert's opinion

The researcher went ahead to seek further expert opinion on the systems. The experts recommended that the additional bills and illustrations of the user in hospital were rather dramatic. The advised that even without these illustrations the system would still communicate as it should. The issue on bills will be inclined more on cost effects overwriting on the health issues that are the main communicative agenda of the systems. This is what the suggested end system looks like.

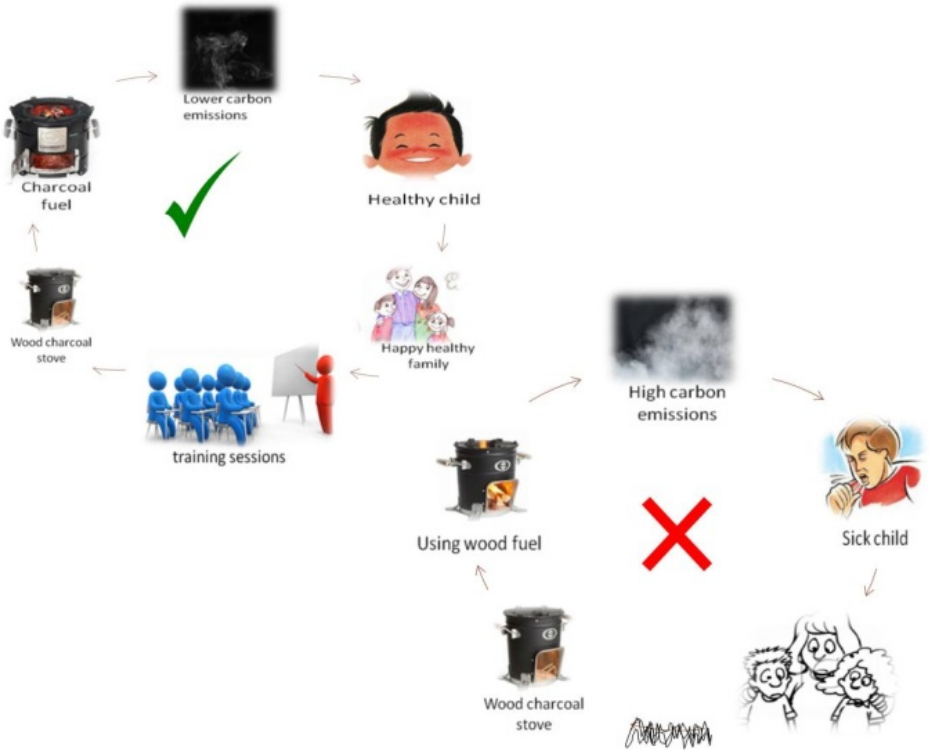


Figure 53: Expert analysis on the health SPSS

4.3.2.3 Expert opinion on the SPSS on technology

The experts advised that it was essential that the system was aligned to only the parts that related directly to the user on the issue of technology to avoid confusion. They also advised that KEBS did not deal with subsidies but ERC did. The issue on infrastructure had mostly applied to the manufactures, regulators and the national government; it therefore had to be excluded in the system as the users had no link to it.

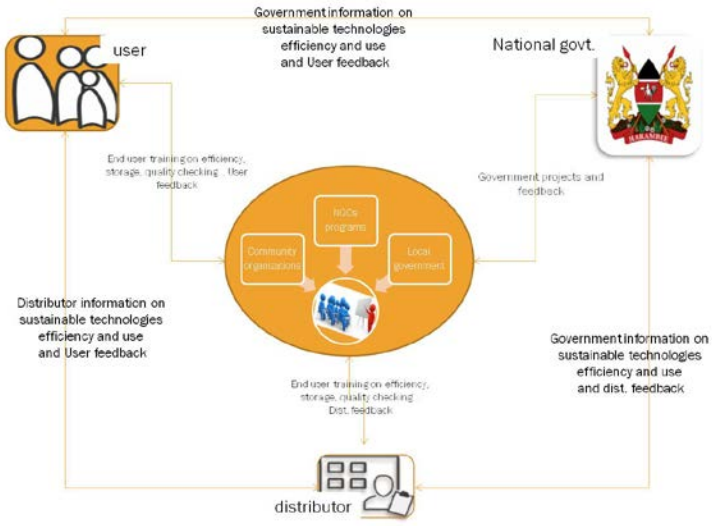


Figure 54: Expert analysis on the technology and infrastructure SPSS

4.3.2.4. Expert opinion on the SPSS for awareness

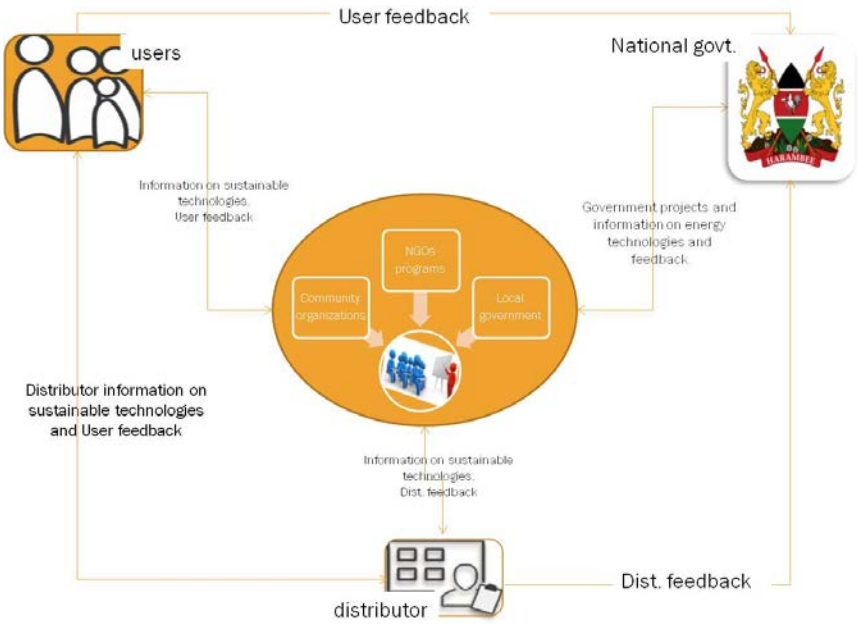


Figure 55: Expert opinion on the SPSS for awareness

4.4. Proposals

4.4.1. Meta analysis of the systems

Having considered all the systems, the researcher went further and analyzed them to come up with one system that would efficiently address the needs in every system. This system addresses the gap that was realized in every system. In all the systems, there was one common factor and that was the link between the end users and the aspect on energy they needed addressed. The researcher then realized that the missing link was a centre where the community could be informed more about cost and the application of subsidies; where awareness could be fostered; where community is kept a base with new technology and taught on the relationship between health and energy. All the other factors such as distribution, manufacturing and government involvement remain constant and can only be strengthened.

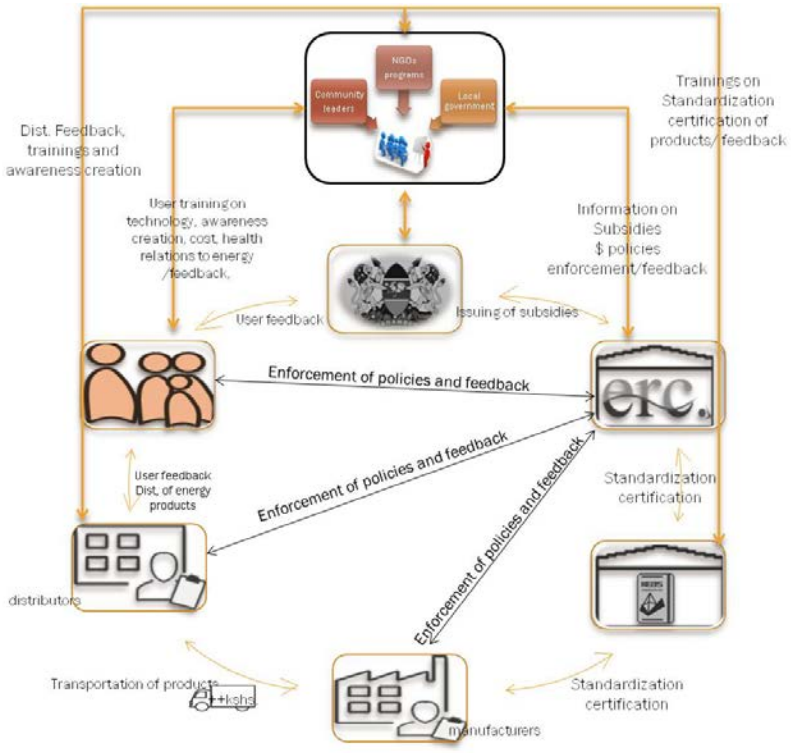


Figure 56: Combined SPSS for cost, health, awareness and technology

Below is a simplified user centered system.

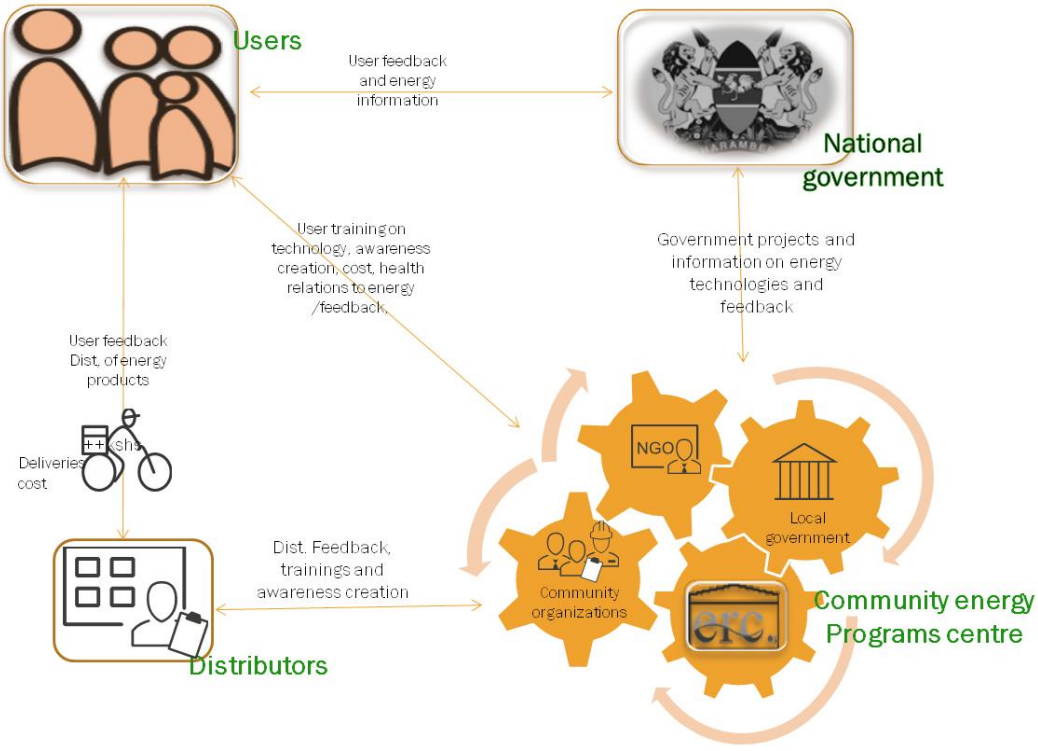


Figure 57: Simplified Combined SPSS for cost, health, awareness and technology

4.4.2. The socio-technological reciprocity model

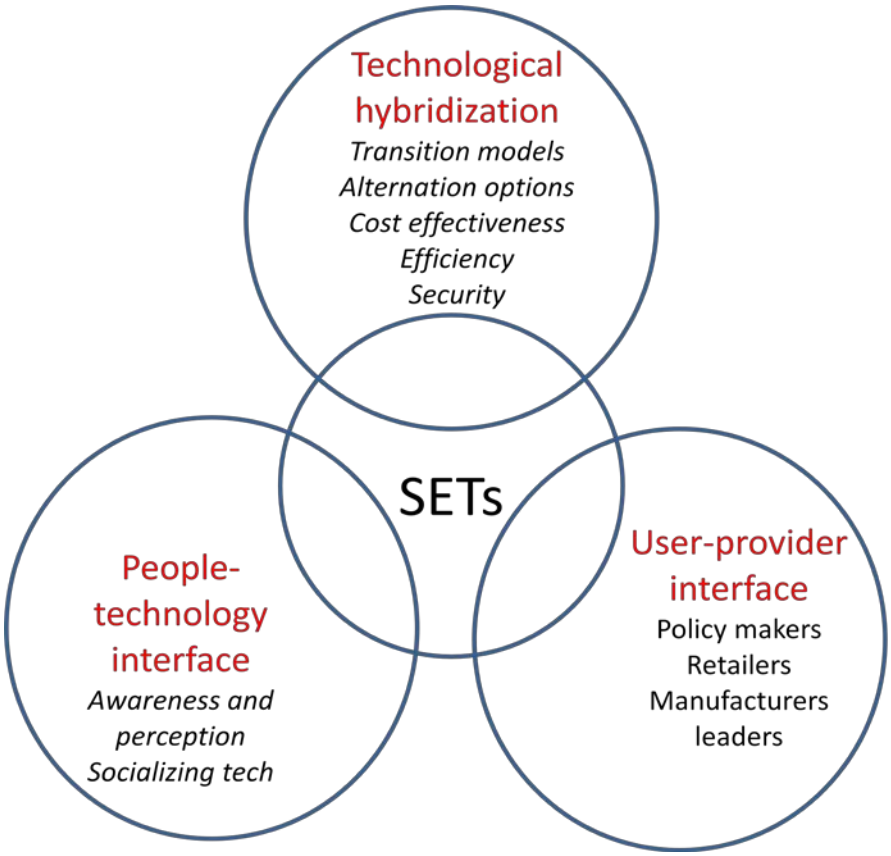


Figure 58: The socio technological model for SETs

The main actors in this study are evidently the users, providers and the technology. The interaction among these three actors is most important in the enhancement of adoption of the sustainable energy technologies. The main is the user considering that design thinking focuses majorly on user needs and user centeredness. A summary of the disabling and enabling factors are presented in the table below …

Table 10: Disabling and enabling socio technological factors

DISABLING FACTORS	ENABLING FACTORS
Inaccessible technologies	Co-designing with users
Constraining socio-economic factors	socio-technological reciprocity model
Restrictive micro-politics	
Detached macro-policy framework	

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1.Conclusions

In addition to the empirical data that assisted in the realization of the gap that the research identified, the research findings have widely validated that there is limited and some cases no adoption of sustainable energy technologies for cooking and heating especially in informal settlements. In the entire sampled population only 1% of the population used solar. Though a few on the respondents affirmed knowledge of some of the existing sustainable energy technologies through various sources like radios or through friends, none of them was in direct usage of these technologies. The few people that I questioned on the matter during the survey stated reasons. They majorly blamed their lack of initiative to use these sustainable technologies on lack of awareness and cost effects.

The human centered design process which was the main methodology of the research has proven efficient in establishing a functional system to facilitate adoption of sustainable energy technologies in informal settlements. Having been involved in the various phases of this research, the functionality of the systems designed in this research to enhance the adoption of sustainable energy technologies has been certified by the end users. The systems were retested on some of the respondents who clearly understood their roles and stakes and how they could handle every kind of challenge including cost, health, poor technologies and awareness by following the systems. Having established the functionality of the system the research has achieved its main objective and can contribute without dispute to the improvement of livelihoods within mathare and other informal settlements as a whole.

5.2.Recommendations

Design thinking strategies should be adopted to promote the use and adoption of more sustainable energy technologies within informal settlements. The entire process of design thinking anchors on mere empathy. That to solve a problem one must be able to relate to its origins. There are very many non tangible things that affect human behaviors or decisions in any matter. The matter could be social, technical or cultural but the only way one can truly offer a solution that’s sustainable is by experiencing the problem first hand and that is what design thinking process advocates for.

With reference to this research, collaborative approaches to community challenges are very constructive. No societal problem can possible have one solution. This is mostly based on the fact that people experience different challenges differently as individuals. The four main challenges that were tackled in the human centered design workshop were just among other many challenges that were

outlined by the participants to be affecting the Mathare community. One may not have been able to adopt a certain technology because they are not able to afford it while another because they just don't understand it. In this case if a solution is offered that reduces cost but does not improve technological function or awareness then clearly the problem will still persist. It is for this reason that this research advocates for collaboration because one stakeholders problem may not be another's even though it might affect another stakeholder. It is only through joined efforts, minds and pursuits that community challenges can be tackled.

A sustainable solution that has empathetically been sought will always be a feasible one. Engaging the different stakeholders involved in a problematic situation will always validate the feasibility of a project as the proposed solutions are always from a practical point.

It is imperative that institutions of research and community projects to support collaborative and user centered research to ensure that proposed solution for the energy nexus challenges are actually practical and essential. Researchers from various professions must get over themselves and get together when necessary to handle community challenges. This how we make the world a better place.

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APPENDICES

Appendix 1: Questionnaire

Project title:

Co-designing energy communities with energy poor women in urban areas;

Case studies in Kenya, Uganda and South Africa

Principal investigator:

Dr. L. Amollo Ambole (university of Nairobi)

Project Summary

The goal of this project is to produce knowledge about co-designing household energy services that are gender responsive, have better health outcomes and are economically viable. To do this, studies will be undertaken in two urban informal settlements in Kenya and Uganda, and the findings compared to ongoing research in an urban informal settlement in South Africa. In each case, stakeholders, such as: settlement dwellers, experts and policy actors will be engaged. Through these engagements, the project will propose improved technologies and better policies that contribute further to national energy goals in the three countries; as well as to Sustainable Development Goals on: good health and wellbeing, gender equality, affordable and clean energy, and sustainable cities and communities.

What we will ask you to do: If you agree to be in this study, we will conduct an interview with you. The interview will include questions about your job and household. The interview will take about one hour to complete. With your permission, we would also like to take photographs and do drawings of your house.

Risks: There is the risk that you may find some of the questions about your household conditions to be sensitive.

Your answers will be confidential. The records of this study will be kept private. In any sort of report we make public we will not include any information that will make it possible to identify you. Research records will be kept in a locked file; only the researchers will have access to the records.

Taking part is voluntary: Taking part in this study is completely voluntary. You may skip any questions that you do not want to answer. If you decide to take part, you are free to withdraw at any time.

This work is based on research supported wholly by the LIRA 2030 Africa Programme, which is implemented by the International Council for Science (ICSU) in partnership with the Network of African Science Academies (NASAC) and the International Social Science Council (ISSC), with support from the Swedish International Development Cooperation Agency (Sida).

Date Time_____

Interviewer Village (Indicate on map) _____ Interviewee (Name and contact in case you are interested in future participation)

Gender of Interviewee (Please circle) M / F

GENERAL QUESTIONS

What is your preferred language? (Please tick)

English

Swahili

Which year were you born? (indicate the year)

What age group do you belong to? (Please tick)

0-4

5-9

10-14

15-19

20-24

25-29

30-34

35-39

40-44

45-49

50-54

55-59

60-64

65-69

70-74

Above 75

Are you the head of the household? Y / N

A) When did you move into this village in Mathare? (indicate the year)

B) Where did you initially immigrate from? (Please tick)

Another village within Mathare

Another informal settlement in Nairobi

Another informal settlement outside of Nairobi

Another part of Nairobi that is not an informal settlement

Another town

Rural area

Other (specify)

Are you a tenant or owner in this house? (please tick)

Tenant

Owner

DETAILS ABOUT MEMBERS OF THE HOUSEHOLD AND THE HOUSEHOLD

Person No.	Age	M	F	Employment		Highest Level of Education						
				Self	Contract	In Pre-primary	Pre-primary	Primary	Secondary	Professional certificate: (indicate the course)	Tertiary: College/Polytechnic/ University (indicate the degree)	None
1												
2												
3												
4												
5												
6												

7												
8												
9												

How many people in the household earn an income?_____

B) How many hours/minutes per day are spent doing unpaid work?

(Indicate in table for each person: Adult (A), Child (C) or Senior (S) and Male (M) or Female (F))

Person type (A, C, S and M/F)	Caring for others (e.g. babysitting; looking after elderly)	Housekeeping (cleaning and maintaining the house)	Cooking	Food gardening
P1				
P2				
P3				
P4				
P5				

What is the total household income? Indicate per Week (W) or Month (M)

_____

HOUSEHOLD ENERGY

Please indicate which fuel type you use for the following activities: (Please tick)

	Cooking	Lighting	Water heating	Electric goods	Other (specify)
Paraffin					
Cooking Gel					
Wood					
Gas					
Candles					
Charcoal					
Briquettes					

Solar					
Biogas					
Batteries					
Car Batteries					
Generator(petrol/diesel)					
Kenya Power electricity					
Other (please specify)					

Where do you get the fuels from? (Please tick)

	Collect from environment	Kiosk/Shop	Petrol station	Produce own	Other (specify)
Paraffin					
Cooking Gel					
Wood					
Gas					
Candles					
Charcoal					
Briquettes					
Maize cobs					
Solar					

Biogas					
Batteries					
Car Batteries					
Generator(petrol/diesel)					
Kenya Power electricity					
Other (please specify)					

How much of each fuel type do you use per week?

	Kg	Unit	Litres
Paraffin			
Cooking Gel			
Wood			
Gas			
Candles			
Charcoal			
Briquettes			
Solar			
Biogas			
Batteries			

Car Batteries			
Generator(petrol/diesel)			
Kenya Power electricity			
Other (please specify)			

What is the unit cost per fuel type?

	Collect Ksh/Kg	Ksh/Unit	Ksh/Litres
Paraffin			
Cooking Gel			
Wood			
Gas			
Candles			
Charcoal			
Briquettes			
Solar			
Biogas			
Batteries			
Car Batteries			
Generator(petrol/diesel)			
Kenya Power electricity			

Other (please specify)			

How much does the household spend per week on each fuel types (on the average)?

(Indicate in Kshs)

	Kshs/Unit
Paraffin	
Cooking Gel	
Wood	
Gas	
Candles	
Charcoal	
Briquettes	
Solar	

Biogas	
Batteries	
Car Batteries	
Generator(petrol/diesel)	
Kenya Power electricity	
Other (please specify)	

What appliances do you use for the following services?

Cooking services

Type of Appliances	Number of appliances	Type/ size of burner	Year of purchase	Quantity of fuel use per month Kg/litres/units	Hours of use per day	Hours of use per week
Gas cooker						
Paraffin stove						
Cooking gel stove						
Wood burning jiko						
Charcoal burning jiko						

Briquette burning jiko						
Solar cooker						
Fireless cooker						
Biogas cooker with direct connection						
Biogas communal cooker						
Others (specify)						

Heating

Type of Appliances	Number of appliances	Type of fuel used	Hours of use per day	Hours of use per week
Stove				
Jiko				
Electric heater				
Others (specify)				

What is your strongest influence in choosing a fuel type? (Please tick)

Cost

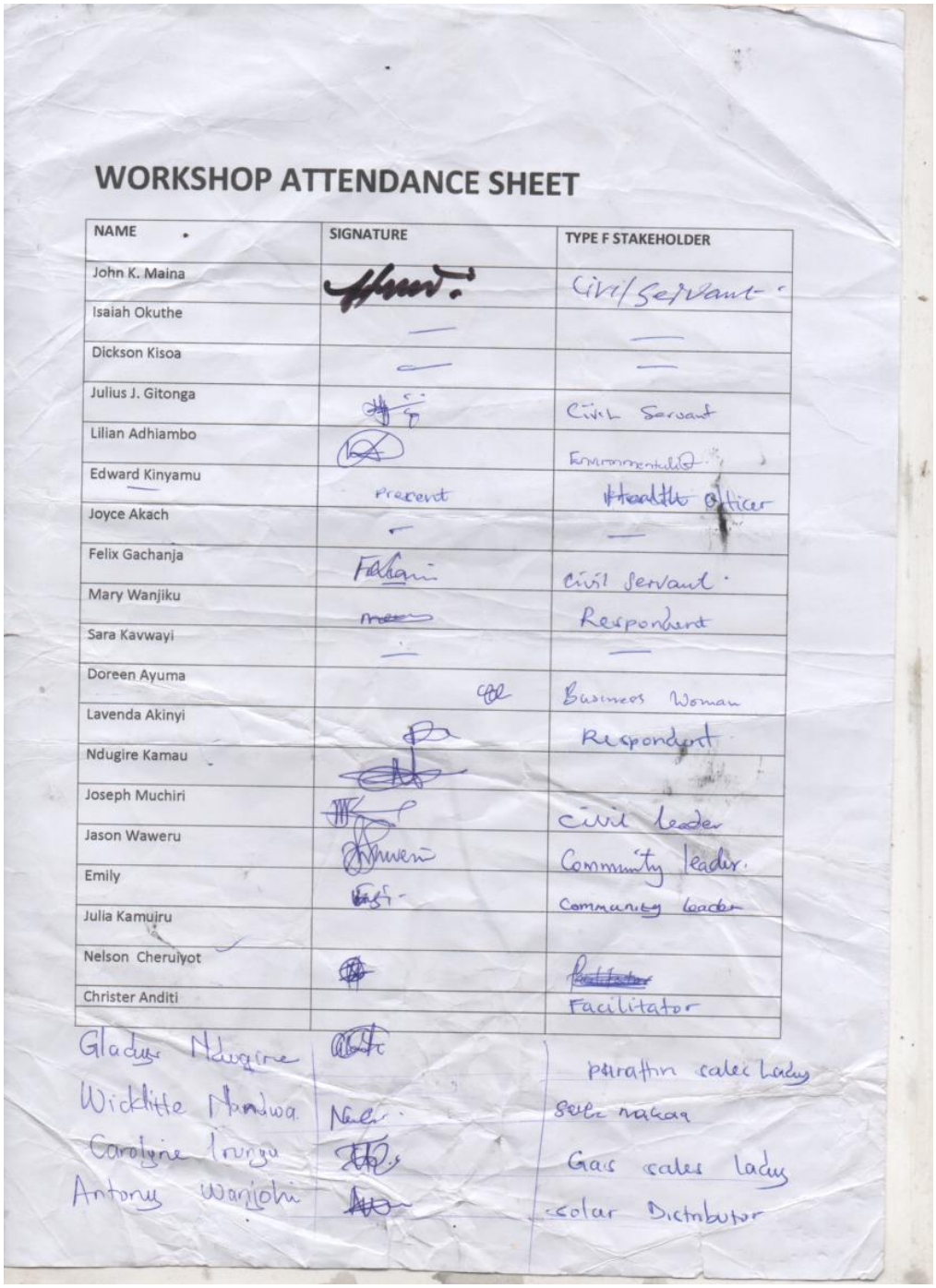
Ease of use

Ease of access

Related health outcomes

Recommendation by family/friends

Appendix 2: Workshop Attendance Sheet



WORKSHOP ATTENDANCE SHEET

NAME	SIGNATURE	TYPE F STAKEHOLDER
John K. Maina		Civil Servant
Isaiah Okuthe		—
Dickson Kisoa		—
Julius J. Gitonga		Civil Servant
Lilian Adhiambo		Environmentalist
Edward Kinyamu	Present	Health officer
Joyce Akach		—
Felix Gachanja		Civil Servant
Mary Wanjiku		Respondent
Sara Kavwayi		—
Doreen Ayuma		Business Woman
Lavenda Akinyi		Respondent
Ndugire Kamau		
Joseph Muchiri		civil leader
Jason Waweru		Community leader
Emily		Community leader
Julia Kamuiru		
Nelson Cheruiyot		
Christer Anditi		Facilitator
Gladys Ndugire		paraffin sales Lady
Wickliffe Mandwa		Solar makar
Caroline Irungu		Gas sales Lady
Antony Wanjohi		Solar Distributor