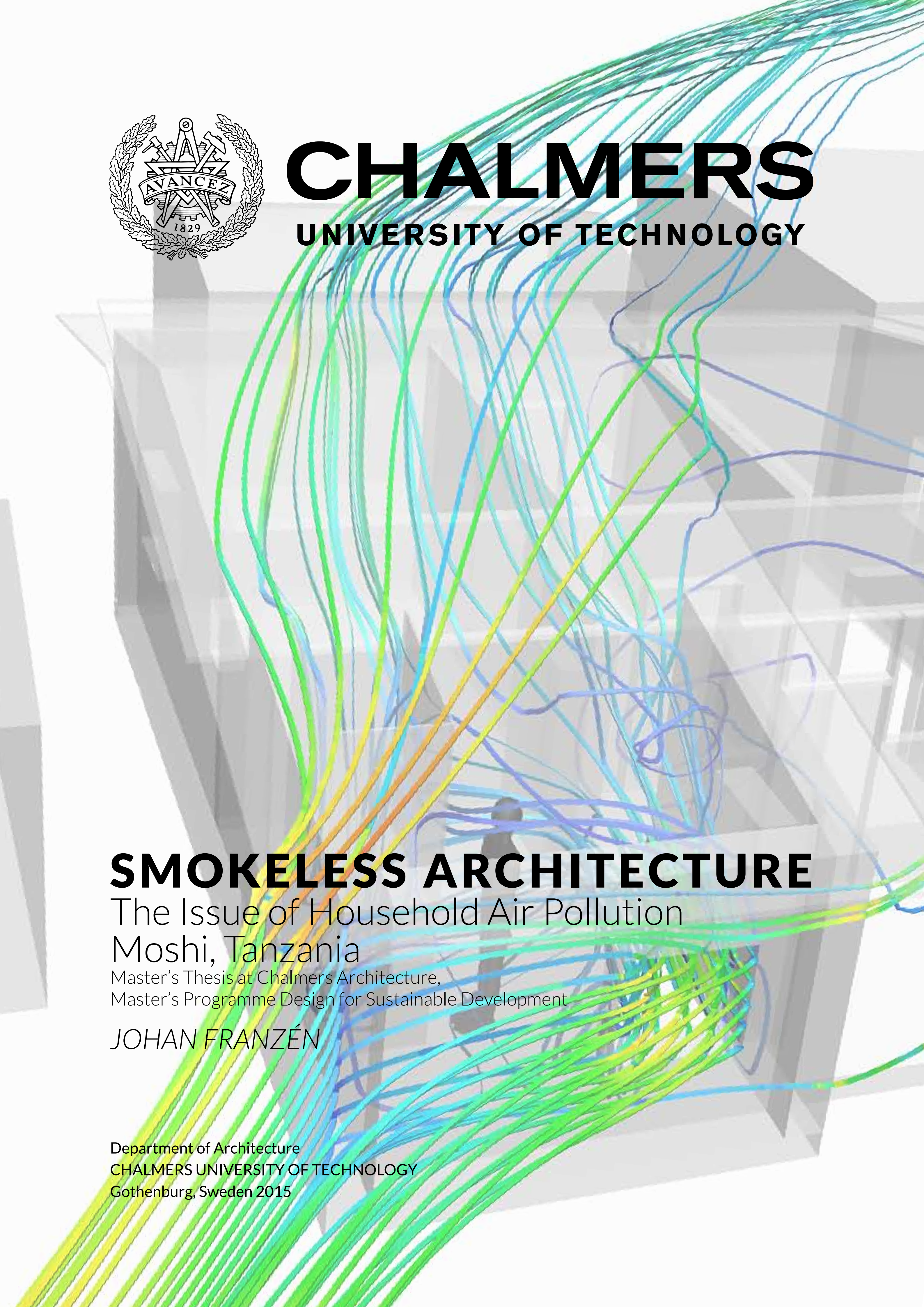

CHALMERS
UNIVERSITY OF TECHNOLOGY

SMOKELESS ARCHITECTURE

The Issue of Household Air Pollution
Moshi, Tanzania

Master's Thesis at Chalmers Architecture,
Master's Programme Design for Sustainable Development

JOHAN FRANZÉN

Department of Architecture
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2015

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Master's Thesis 2015
Department of Architecture
Master's Programme Design for Sustainable Development
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone: +46 (0)31-772 1000

Cover: Image showing trace particles from Autodesk CFD simulation on case study.

Teknologtryck
Gothenburg, Sweden 2015

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ABSTRACT

One third of the world's population use some kind of solid biomass fuel for cooking. When burned in simple inefficient stoves these fuels produce harmful smoke. It is estimated that household air pollution (HAP) cause 4.3 million premature deaths globally, every year.

Many organisations and institutions have worked with, and are still addressing household energy issues globally with focus on the environment and health. With greater awareness, better stoves, better fuels and improved ventilation the issue of HAP can be averted. Due to increased population globally, the need for biomass fuels will most likely continue to be high, therefore it is important to focus on both short- and long-term targeted solutions that actually work in the local context.

The kitchen is often neglected when building in developing countries, and there is a need for integrated design were different professions are involved at an early stage. There is also a need for research-methods that can evaluate what interventions work, and where. The results of this thesis are based on an interdisciplinary field study in Tanzania from February to April 2015.

The focus of this thesis is to investigate the local situation regarding HAP and health in Moshi, to test different research-methods and to evaluate a workflow of using computer simulations for finding the best intervention for a specific context.

The study was divided into one quantitative and one qualitative study, Part I & II.

Part I consisted of interviews with mothers (with a child below 2 years of age) attending public health facilities in Moshi. Through interview questionnaires we gathered information about the health of the child, household and building characteristics.

Part II consisted of household visits. This part was conducted as a pilot-study to evaluate different study methods and tools.

One house was selected as case study to test the workflow of using computational fluid dynamics (CFD) software to compare different interventions.

Keywords: Architecture, HAP, Revit, Simulation CFD, Carbon monoxide, Public health, Moshi.

Rökfri Arkitektur
Problemet med förorenad inomhusluft, Moshi, Tanzania
Examensarbete inom Arkitektur
JOHAN FRANZÉN
Institutionen för Arkitektur
Mastersprogram Design för Hållbar Utveckling
Chalmers Tekniska Högskola

SAMMANFATTNING

En tredjedel av jordens befolkning lagar mat med ved, träkol eller annat fast biobränsle. När dessa eldas i ineffektiva spisar bildas farlig rök. Det uppskattas att förorenad inomhusrök, household air pollution (HAP), årligen orsakar 4.3 miljoner förtida dödsfall globalt.

Många organisationer och institutioner har arbetat med, och arbetar fortsatt med frågor gällande hushållsenergi globalt, med focus på miljö och hälsa. Genom en större medvetenhet, bättre spisar, bränslen och förbättrad ventilation kan problemet med förorenad inomhusluft undvikas. Som följd av befolkningsökningen globalt kommer troligen behovet av ved och träkol vara fortsatt högt, därför är det viktigt att fokusera på både långsiktiga som direkt lösningar som verkligen fungerar i den tänkta kontexten.

Köket försummas ofta när man bygger i utvecklingsländer och det finns ett behov för integrerad design där olika professioner är involverade i ett tidigt skede. Det finns också behov av metoder för att utvärdera vilka interventioner som gör skillnad och i så fall vart. Resultaten från det här examensarbetet baseras på en tvärvetenskaplig fältstudie i Tanzania mellan februari och april 2015.

Fokus för det här examensarbetet är att undersöka den lokala situationen i Moshi när det kommer till förorenad inomhusluft och dess hälsoeffekter. Fokus har också varit att testa olika undersökningsmetoder och att utvärdera användet av datorsimuleringar för att hitta den bästa interventionen för en specifik kontext.

Studien var uppdelad i en kvantitativ och en kvalitativ del, Del I & II.

Del I bestod av enkätintervjuer av mammor (som hade ett barn under 2 år) som besökte vårdcentraler i Moshi. Vi ställde då frågor om barnets hälsa, hushållet och byggnadens uppbyggnad och karaktär.

Del II bestod av hembesök. Den här delen utfördes som en pilot-studie för att utvärdera olika metoder och verktyg.

Ett hus valdes ut som fallstudie för att testa möjligheterna med att använda ’computational fluid dynamics’ programvara för att jämföra olika interventioner.

Nyckelord: Architecture, HAP, Revit, Simulation CFD, Carbon monoxide, Public health, Pneumonia, Moshi.

PREFACE

This is a Master's Thesis in Architecture. It comprises 30 credits and has been carried out during the spring term of 2015. The thesis is based on a 10 week SIDA Minor Field Study (MFS) in Moshi, Tanzania from Februari to April, 2015.

The field study was conducted together with Sofie Franzén, medical student, the Sahlgrenska Academy, University of Gothenburg.

Supervisor in Sweden: Emilio Brandao, Chalmers University of Technology, Gothenburg
Supervisor in Tanzania: Dr. Daniel Mbisso, Assistant Lecturer, Ardhi University, Dar es Salaam

Examiner: Maria Nyström, Professor, Chalmers University of Technology, Gothenburg

ACKNOWLEDGEMENTS

First of all I would like to thank all participating women, children and families in Moshi, making this thesis possible. I would also like to thank Sr Celina Mayo , for her help with visits and interviews at health care centres in Moshi and Mary Joseph for assisting and translating during household visits.

Sia Msuya and Baltahazar Nyombi from KCMC for their patience and practical help during the field study.

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Rune Andersson, Susanne Skovbjerg, Matilda Emgård and the Sahlgrenska Academy for presenting this opportunity for us, for inspiration and support throughout the project.

Johan Boman, professor in atmospheric science at Chalmers, for providing us with the appropriate technology and knowledge about CO-measuring.

Maria Nyström, my tutor and examiner for your passion and dedication to this cause and your insights and tips regarding qualitative studies, kitchen, cooking and household energy in developing countries.

Emilio Brandao, my supervisor at Chalmers for support and constructive feedback throughout the project.

I would also like to thank:
Clive and Bodil Ashton, our hosts and friends in Moshi for introducing us to the culture and people of Moshi and Tanzania.
Familiy and friends for their support and interest before and during this project.

Last but not least I would like to thank my wife and co worker Sofie Franzén for your love, patience and constant support through ups and downs, in frustration and in joy. For taking me on this andventure and for putting up with me a dull monday. For your kindness and your way of seeing all people and meeting them with love and respect.

CONTENTS

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INTRODUCTION

One third of the world's population use some kind of solid biomass fuels for cooking. When used together with simple stoves with incomplete combustion they produce harmful smoke. In Tanzania it is not one third of the population who are depending on solid biomass fuels for their daily energy needs, it is 96%. This means the majority of the people are affected by the burdens of Household Air Pollution (HAP) in one way or another. (The Global Alliance for Clean Cookstoves, 2014b)

Buildings and kitchens in poor areas often lack adequate ventilation, and since women and children are the ones staying at home most parts of the day, they are the ones most affected by HAP. (S. B. Gordon et al., 2014)

To address the issue of HAP and improve health, interventions on multiple levels are needed. The long-term goal must be to make clean energy available to all, parallel to this; short-term solutions have to be implemented to improve the situation for people suffering from HAP worldwide. The available cheap fuels have to be made cleaner, the stoves made more effective to improve combustion, and the ventilation and smoke alleviation more efficient (S. Gordon & Lane, 2014).

CONTEXT OF THESIS

This master's thesis in architecture was carried out during the spring term of 2015. It is based on information collected during an interdisciplinary field study together with Sofie Franzén, medical student from the Sahlgrenska Academy, University of Gothenburg.

This project had a long preparation phase and was introduced to Sofie Franzén in the spring of 2014 by Rune Andersson, professor in global health, Md, Phd. During the autumn of 2014, the structure and aim of the project was discussed together with Rune Andersson; Susann Skovbjerg, Md, PhD (supervisor for Sofie); professor Maria Nyström (examiner for this master's thesis project), with support from Matilda Emgård (PhD student at the Sahlgrenska Academy with experience from a similar project) and Johan Boman, professor in atmospheric science, PhD. Sia Msuya, Md, MPhil, Phd (department of community health) and Baltahazar Nyombi, PhD (clinical laboratory department) at Kilimanjaro Christian Medical Centre (KCMC) in Moshi provided support and handled the logistics on site. Supervisor for the architecture part in Tanzania was Dr. Daniel Mbisso, Ardhi University, Dar es Salaam. Through him I got access to information necessary for the project and he directed me to different contacts to learn more about the local context of Tanzania and Moshi.

The results from the field study is presented in this report and in a master's thesis report by Sofie Franzén titled: Nasopharyngeal carriage of pathogenic bacteria in relation to household air pollution among children in Moshi, Tanzania.

The experiences and evaluation of methods for household visits and monitoring will be used in preparation and planning of coming field studies.

HOUSEHOLD ENERGY

The kitchen is the place where most household energy is used in developing countries. It is also strongly connected to our culture and many questions about health and well-being is somehow connected to kitchen activities. The term “household energy” includes; time and energy spent collecting fuel, time and energy spent preparing and cooking food and drinks, energy used for lighting, energy for space heating or cooling etc.

Household energy in development projects has often been associated with cookstoves. The history of improved cookstove projects started in India in the 1950s. The smokeless stove called Mangan Chula, and the first period of improved cookstove projects had the main goal to improve the living conditions for poor people and focused on health and socio-economic issues (Karekezi, 1992).

Since then focus has over time shifted from socio-economic to technical-scientific and environmental, with concerns about energy consumption and deforestation. During the 1970s and 1980s macro-level strategies dominated and more efficient stoves was seen as a way to stop deforestation. Many of these strategies did not pay enough attention to the user perspective, or to the cultural and social context or the stove’s immediate environment, the cooking area (Nyström, 1994).

The person in charge of cooking may not consider energy efficiency as important as improved health, working conditions, speed and safety. Therefore it is crucial to consider the user perspective and needs. From 1980s and forward the goals have been both socio-economic and technical-scientific (Karekezi, 1992).

Since the beginning of the 1990s, there has been a shift in terminology from a focus to improved cookstoves to household energy. Also, the focus on stopping deforestation has lost some importance (Nyström, 1994).

With the backing of WHO and the international community the Global Partnership for Clean Indoor Air (PCIA) was launched in 2002. 590 partner organisations joined together to contribute resources and expertise to reduce smoke exposure from cooking and heating around the world (www.pciaonline.org/).

In 2004, The World Health Organization (WHO) estimated that HAP was associated with around 1,6 million deaths per year in developing countries (WHO,2004).

In 2012, PCIA was integrated with the Global Alliance for Clean Cookstoves (The Alliance), a public-private partnership hosted by the United Nations Foundation. The alliance was launched in 2010 with the 10-year goal to foster the adaptation of clean cookstoves and fuels in 100 million households by 2020. At this point (2014) about 20 million clean cookstoves are in use and The Alliance claim that global awareness about the issues posed by HAP has grown significantly (The Alliance,2014a).

Even though The Alliance has a focus on cookstoves, there are many organisations and institutions involved in different aspects of household energy. There are projects on solar cooking, heating and lighting, renewable energy from water or wind and projects on biogas for cooking.

The United Nations programme for sustainable human settlements development (UN-Habitat) is working towards a better urban future. They state that without effective urban planning and infrastructure development the consequences of the rapid urbanisation globally will be dramatic, both concerning pollution and health (UN-HABITAT, 2015).

They emphasise the need for integrated design were different professions are involved at an early stage of development, so that both technical, social, economical and environmental aspects are considered, both in new development and upgrading the existing buildings and neighbourhoods. Unfortunately, today, the kitchen is often neglected, even in new development, and left for the occupants to design. It is a workplace where most activities are carried out by women and children, and often a hazardous environment with smoke, high temperatures, high humidity, and a high risk of injury.

Looking at the house as a whole and not just the stove is important when discussing household energy. Good design, adapted to the specific climate and conditions of the site, can reduce the need for energy for cooling or heating, creating a healthier environment for the inhabitants and making use of prevailing winds, solar energy and rain-harvesting.
Increasing household ventilation is a very cost-effective measure and whatever the kind of fuel or stove used the main aim should be to design the kitchen in order to maximise natural ventilation (UN-HABITAT, 2014).

Elimination of inequalities in energy access and air quality in households around the world will lead to substantial health and development benefits (WHO, 2014b).

REASEARCH GAP

In the Lancet Respiratory Medicine Commission (The Commission) published in September 2014, the authors refer the recent randomised controlled trials that show that a reduction in disease is possible. More studies of this kind are taking place around the world, from Nepal to Ghana and Malawi.

Studies using different technologies to both reduce exposure to HAP and to determine the exposure-response of interventions are needed to provide a evidence base to understand how much exposure levels need to be reduced to improve health worldwide.

Most research on air pollution has focused on the health effects linked to exposure to outdoor air pollution in high-income countries. Ambient levels of pollution affect the individual during a day, but exposure to emissions from indoor sources probably dominates the total daily intake for many pollutants. The research should consider the totality of exposure and assessment of personal exposure is therefore likely to be the most important factor when trying to find the link between air pollution and respiratory ill health (S. B. Gordon et al., 2014).

In a conversation about the background and highlights of The Commission Stephen Gordon concludes: “what is needed the most is knowledge that interventions make a difference.” (S. Gordon & Lane, 2014).

To fill research gaps, The Commission suggests different study designs and approaches. Intervention-based studies are important to strengthening evidence for disease outcomes and for evaluation of intervention effect. Quasi-experimental studies, before-and-after studies, with and without control groups can be useful in initial field evaluation of acceptance and effects of interventions on HAP and exposure. The use of data from households helps to limit confounding though seasonal changes must always be considered. Laboratory testing can provide important data about emissions and efficiency of different cooking technologies and fuels. Though, laboratory data alone cannot be used for assessment of exposure in any given situation.
In the WHO indoor air quality guidelines (AQG) on household fuel combustion, it

is stated that data from laboratory stove testing is generally more reliable than field measurements. Though there are relatively limited data on field emissions and generalisations made over large geographical regions are limited by a lack of understanding of the factors that drive variability in emissions. There is evidence from direct comparisons between laboratory and field tests that the laboratory tests are not representative of the emission concentrations that are seen in the field. Emission rates tend to be higher in normal use than in laboratory-based protocol defined tests. These findings highlight the need for enhanced methods for testing of emissions in normal use.
So, among the most important of the research needs identified by WHO are studies on the use and impacts of improved household energy technologies and clean fuels under real life conditions to further estimate effectiveness of interventions (WHO,2014c).

PROBLEM DESCRIPTION

The kitchen and household is a hub for questions connected to many different subjects: culture and tradition, household economy, local and global environment, education, health and hygiene, equality, building standards etc. The complexity of the issue of HAP requires an interdisciplinary approach.

Not one home is the other alike in all aspects. So how can interventions on different levels be evaluated to find the most appropriate solution in different contexts? It is not realistic to think that one model or study method can answer all questions or consider all geographical-, cultural-, seasonal- and behavioural changes. But to perform new studies regarding all these aspect in different settings is both costly and time-consuming.

The good thing is that the issue of HAP can be avoided, removed and helped. There is a need for better or more efficient evaluation methods that can help to shift focus, time and money from observing the issue to instead apply the best solution in all unique homes around the world.

PROJECT AIM

The aim of this field study and project is to collect data about the situation in Moshi regarding health and household air pollution through observations and measurements, to evaluate methods for quantitative and qualitative studies to be conducted in a larger scale or in a different context.

Another aim is also to spread knowledge about the issue and increase awareness on how to improve the situation or reduce exposure on a household level.

AIM OF MASTER'S THESIS

The aim of this Master's thesis is to study the local context of Moshi, measure carbon monoxide concentrations and map household and building characteristics of 10 households. To test and evaluate a workflow for analysing and testing different types of interventions to reduce exposure to HAP through computer simulations. All with a technology-neutral starting point (no focus on a specific product), using site-specific information and data from available research.

RESEARCH QUESTIONS

- How is cooking habits and culinary culture connected to smoke exposure?
- What interventions are relevant and feasible to implement as short-term solutions to the issue of HAP?
- What interventions prove most

effective in reducing harmful smoke?

- Is it possible to use cloud-based services to evaluate interventions in the context of Moshi.

- How can computer simulation software be used to evaluate different interventions during varying conditions?

- How can an interdisciplinary field study and research be conducted in order to reach both common and specific goals?

DELIMITATIONS
This thesis and its results are based on a field study in Moshi, Tanzania, between the 1st of February and the 10th of April, 2015.
The results reflect the situation during this period and do not in depth consider seasonal changes.

This thesis will mainly focus on smoke and ventilation and will not discuss comfort issues or economy in relation to different interventions. Nor will it focus on energy or environmental issues.

This thesis will not in depth investigate the situation globally, but will focus on a study population in the suggested study area.
In order to evaluate the method and workflow concerning intervention testing through computer simulations, one case study house will be chosen.

THESIS OUTLINE

WHY? WHAT? HOW? - AHA! HMM... OK.

This introduction, describing the context of the thesis, research history and research gaps have tried to answer the question: Why?
Below are a short description of the contents of the following chapters:

BACKGROUND
This chapter answers the question: What?

The background will give an understanding about the issue of household air pollution and the effects on health and environment. It will also present information about the local context of the field study, on city and household level. In the end of the chapter is a summary of different interventions.

METHOD
This chapter answer the question: How?

The method is described in two steps, first preparations, data collection and analysis for study Part I, and then Part II.

RESULT
This chapter presents the information gathered and results produced in Part I and Part II.

DISCUSSION
The discussion is the chapter where the results and methods of the study will be analysed in relation to the background, project aim and research questions. Here I will also pose some recommendations for further research.

REFERENCES
Reference list and references to tables and figures.

APPENDIXES
Additional information or documents of interest. A help to better understand the project.

BACKGROUND

This chapter will give an understanding about the issue of household air pollution and the effects on health and environment. It will also give information about Moshi, Tanzania and the local context of the field study. Then, different aspects of household air pollution on a household level will be presented (materials, smoke sources, cooking, comfort etc.). In the end of the chapter different interventions will be introduced and presented in short followed by four reference projects.

HOUSEHOLD AIR POLLUTION

Household Air Pollution (HAP), also referred to as Indoor Air Pollution (IAP), has probably been a health and comfort issue since human beings started using fire for cooking and heating. But the long-term health outcome of the smoke has not always been obvious. In our modern times, when well known communicable diseases often make headlines, HAP remains a relatively unknown issue.

In 2014, WHO presented new numbers and new estimates that around 3 billion people cook and heat their homes using solid biomass fuels and inefficient cookstoves, and that in 2012, 4.3 million premature deaths globally were attributable to HAP. This large increase compared to previous estimate is mainly due to the fact that new evidence has become available regarding the relationship between exposure and health outcomes, new health outcomes has also been included in the analysis and there have been an increase in non-communicable diseases globally (WHO, 2014a).

Solving the issue of HAP will help to achieve several of the Millennium Development Goals (MDGs); MDG 4 – Reduce child mortality, MDG 5 – Improve maternal health, MDG 3 – Promote gender equality and empower women, MDG 1 – Eradicate extreme poverty and hunger, and MDG 7 – Ensure environmental sustainability.
Information on household energy fuels and related estimates of HAP are compiled by WHO in a Global database for household fuels. This database is used to inform a number of global estimates including the MDG database, UN initiative Sustainable Energy for All (SE4All), and burden of disease estimates (WHO,2014c).

Studies have shown that exposure levels in many African homes are high. In a study from Malawi all homes included in the study had levels of respiratory dust higher than WHO recommendations for outdoor air pollution (Fullerton et al., 2009).
Similar results were found in a study from Zimbabwe where the guidelines were exceeded in 95% of the studied homes (Rumchev, Spickett, Brown, & Mkhweli, 2007).

POLLUTANTS

Just like cigarette smoke, smoke from incomplete combustion of solid biomass fuels contains a wide array of pollutants, or products of incomplete combustion (PICs). All are more or less harmful to both humans and the environment. It is widely agreed that the two main components of biomass smoke that should be monitored when looking at the issue of HAP are carbon monoxide and particulate matter (Practical Action, 2005).

CARBON MONOXIDE (CO)

Carbon monoxide is one of the primary PIC. It is a colourless, non-irritant odourless and tasteless toxic gas. It is produced by incomplete combustion of wood, petrol, coal, natural gas and kerosene – carbonaceous fuels.

The sources of CO are both outdoor and indoor. Low levels are present in traffic areas but the really high levels are found inside poorly ventilated homes around the world.

The combustion in fireplaces can generate lethal emissions. At the beginning of combustion, the pollutants released are mainly particulate matter (PM) but CO dominates towards the end. Combustion of natural gas, butane or propane usually produces much less CO. But if stoves are not properly maintained to ensure complete combustion or house vented to extract smoke, the levels can still be lethal.
CO is slightly soluble in water and in the human body it reacts with haemoglobin in the blood cells and forms carboxyheamoglobin (COHb). CO competes with oxygen for haemoglobin binding sites and remains bound for a much longer time. Continued exposure to CO leaves less haemoglobin available for carrying oxygen, hypoxaemia occur. Sympthoms that occur include headache, fatigue, nausea, dizziness, confusion, shortness of breath and cardiac palpitations.

WHO has established guidelines for indoor CO concentrations for different time periods (Table 1). The 15 minutes guideline to protect against short-term peak exposures that might occur from an unvented stove; for 1 hour to protect against excess exposure; for 8 hours (which is relevant to occupational exposures and has been used as an averaging time for ambient exposures); and for 24-hours to address the risk of long-term exposure (the standard time-period used in various epidemiological studies), (WHO, 2010).

PARTICULATE MATTER (PM)
Particulate matter is a mixture of solid particles and liquid droplets of a broad range of physical and chemical properties, suspended in the air. (WHO, 2010)
The particulates are classified according to size. Particles with aerodynamic diameter of 10 μm or less are called respirable particulate matter, $PM_{10.}$ Particulates with an aerodynamic diameter less than 2.5 μm are called fine particulate matter, $PM_{2.5}$ (WHO, 2014c).

The effects of inhaling particulate matter have been widely studied in humans and animals and can result in asthma, lung cancer, cardiovascular issues, and premature death (MacCarty et al., 2007).

AVERAGING TIME	Concentration (ppm)	Comment
15 minutes	100	Excursions to this level should not occur more than once per day - Light exercise
1 hour	35	Excursions to this level should not occur more than once per day - Light exercise
8 hous	10	Arithmetic mean concentration - Light to moderate exercise
24 hours	7	Arithmetic mean concentration - Awake and alert but not exercising

TABLE 1. *CARBON MONOXIDE GUIDELINE LEVELS*
Guidelines developed by the World Health Organisation for different time periods. (WHO, 2010)

HAP AND HEALTH

BURDEN OF DISEASE

A systematic analysis published 2012, had studied 67 independent risk factors for burden of disease and injury over 20 years. One of the measured risk factors was HAP, which is responsible for almost 5% of the global disease burden, making it globally the single most important environmental risk factor (Lim et al., 2012).

The most recent estimates from WHO suggest that exposure to household air pollution from cooking resulted in around 4.3 million premature deaths year 2012 (WHO, 2014a).

HAP is also a substantial contributor to outdoor air pollution-related deaths, responsible for around another 0.4 million premature deaths (Smith et al., 2014).

HAP is associated with many health effects, some well studied, other just suggested. The effects occur as both acute and chronic disorders. Except respiratory effects, cardiovascular disease like ischaemic heart disease and stroke are associated with HAP (Bloomfield et al., 2012; Rajagopalan & Brook, 2012).

HAP is linked to stillbirth, low birth weight and impaired cognitive development when prenatal exposed. HAP is also linked to eye disease (cataract). (Martin et al., 2013)
There is also a big risk of burns and scald from open fires or simple stoves, especially to children. Fuel collection can also lead to injuries and risk of assault (S. B. Gordon et al., 2014).

RESPIRATORY TRACT DISEASE - ADULTS
There are studies showing association between HAP and respiratory infections, respiratory tract cancers and chronic lung diseases. Among the chronic lung diseases the knowledge about the situation in low-income countries is weak. Nevertheless there is good evidence that exposure to HAP is associated with an increased risk of developing chronic obstructive pulmonary disease (COPD). The question is if the obstruction responds on treatment or not, and to measure the accurate burden of disease diagnostic tools like a simple spirometer in low-income countries is needed (S. B. Gordon et al., 2014).

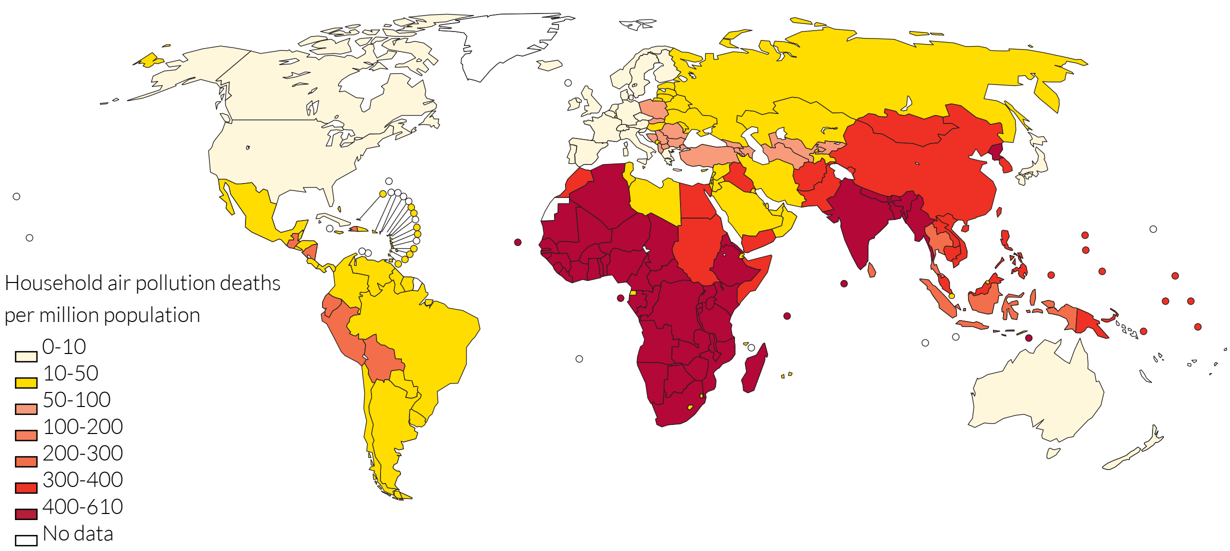


FIGURE 1. *MAP OF HOUSEHOLD AIR POLLUTION AND MORTALITY*
World map of poverty (not shown) shows nearly identical geographical distribution. © WHO 2005.
(S. B. Gordon et al., 2014)

RESPIRATORY TRACT DISEASE - CHILDREN

A study in Nepal year 2013 compared use of kerosene or solid fuel for cooking to electric stoves and the rate of clinically diagnosed acute lower respiratory infection (ALRI) in children younger than 36 months. Compared with electric stoves, kerosene and use of solid fuels were both significantly associated with ALRI (Bates et al., 2013).

The strongest association of exposure to HAP and respiratory health is found among the youngest children, their physical characteristics and the fact that they stay close to the mothers during cooking, make them more susceptible (Po, FitzGerald, & Carlsten, 2011).

Smoke from the combustion of solid fuel is a potential trigger for asthma excerbations, but supporting evidence is rare. The International Study of Asthma and Allergies in Childhood year 2013 published a report supporting an increased risk of asthma due to cooking with solid fuels, based on information about open fire-cooking and wheezing (Wong et al., 2013).

Each year, about two million children below 5 years of age die from pneumonia, mainly in Africa and South-East Asia. Pneumonia is defined in different ways in different studies, though it is consistently estimated as the leading single cause of childhood mortality. In general, the African region has the highest burden of child mortality. Tanzania is among the 15 countries with the highest estimated number of deaths due to clinical pneumonia (estimated mortality rate 52.6/10 000 under-five population).

The burden varies within the country, since definite risk factors are related to the host and the environment (Rudan, Boschi-Pinto, Biloglav, Mulholland, & Campbell, 2008).

The exposure to unprocessed solid fuels increases the risk of pneumonia by a factor of 1.8 (Dherani et al., 2008).

HAP AND THE ENVIRONMENT

Household air pollution, or smoke from incomplete combustion on a household level is not only a threat to people's health. It is also a threat to the environment. The pollutants emitted contribute to global warming and unsustainable use of wood as fuel can potentially contribute to deforestation and desertification. Greenhouse gas (GHG) emissions from biomass burning account for a large percentage of the total emissions in many developing countries and in year 2000, about 20% of the carbon monoxide emissions came from residential solid fuel burning (WHO, 2008).

Unfortunately, the number of people depending on solid fuels for cooking is likely to rise with increased population globally. Many of the gases or products of incomplete combustion (PICSs) emitted when burning solid biomass fuel generally have a greater impact on the climate, higher Global Warming Potential (GWP) than CO_2. The dominant contribution of black carbon (soot) in the atmosphere is from cooking fires. It is one of the most important absorbing aerosol in the atmosphere with a GWP 680 times that of CO_2 (MacCarty et al., 2007).

MOSHI, TANZANIA

Moshi Municipality (lat 3°20' S; long 37°20' E) is located on the southern slopes of Mt. Kilimanjaro in the North Eastern part of Tanzania at an altitude of 700 to 950 meters above sea level from south to north. The Region, called Kilimanjaro Region is bordered by Kenya to the North and East, Arusha Region to the West, Tanga Region to the East and Manyara Region to the South (Figure 2). The area of Moshi Municipality is about 58km^2, making it the smallest municipality in Tanzania by area.

GENERAL INFORMATION

Moshi was established as a military camp in 1892. In 1956, it attained the status of a Town Council, and was designated a Municipal Council in 1988. It is now (as of January 2015) in the final stages of becoming a City. Moshi Municipality has grown from a small urban area of about 8 000 residents in the end of 1940s to over 180 000 in 2012.

LAND AND POPULATION

The traditionally allocated land from the older Tanzania land tenure system has made it difficult for landowners to release their lands for urban development and because of this the Municipal Council have had trouble to manage development. As a result, areas zoned for planned residential, institutional and industrial development are instead subject of unplanned residential development based on owner buyer agreement.

The Municipality is divided into 21 smaller administrative wards (Figure 3).

In 2008, 16% of the municipal area was planned residential area and 37% unplanned residential area. 15% was institutional area, and 10% was used by industries. About 70% of the population lived in the unplanned areas that lacked adequate infrastructure and basic services. The population growth in Moshi Municipality can be attributed to a great extent by the unchecked high rate of rural-urban migration (Moshi Municipal Council, 2008).

ECONOMY

The economic structure of Moshi Municipality has traditionally been closely related to that of Kilimanjaro region. Along the slopes of Mt. Kilimanjaro there are coffee plantations and dairy and floriculture farms. Decline in coffee production has forced many people from rural areas to move to urban areas to look for income. Most of the industries in Moshi are located in the wards of Njoro, Bondeni, Karanga, Rau, Pasua and Kaloleni.

The major sources of income for people in the Municipality are from private employment, public employment and self-employment. Many of the town's economic activities are based on servicing and over 90% of the population depends on income generation activities in the informal, micro and small-scale enterprises (Moshi Municipal Council, 2008).

ENERGY AND WASTE MANAGEMENT

The types of energy commonly used are charcoal, firewood, electricity, kerosene and Liquefied Petroleum Gas (LPG). Few use biogas or solar.

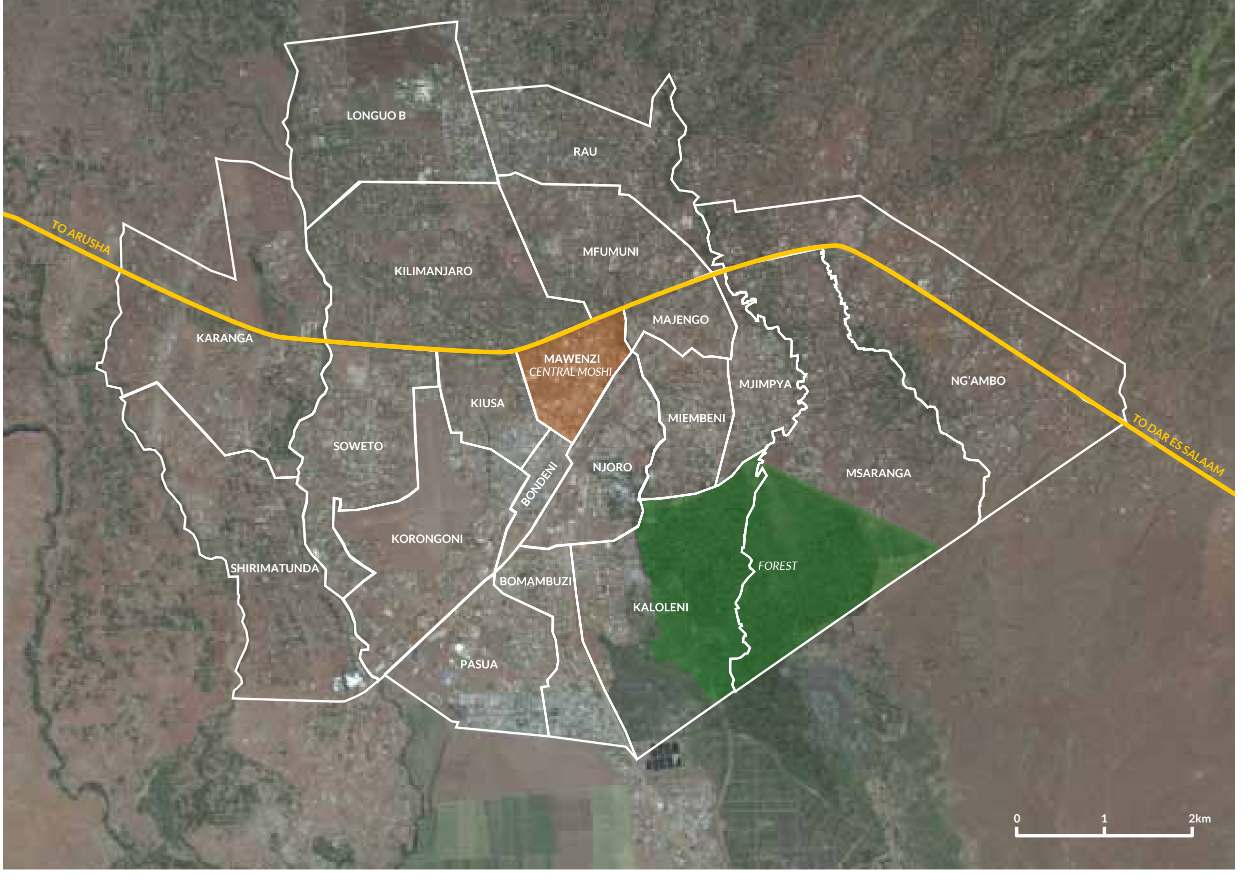
The municipality is supplied with hydro-electricity from the national grid managed by TANESCO. Many of the households use electricity for lighting.

Forests are source for firewood and charcoal that are used for different activities by households, industries and small-scale enterprises. Deforestation affects the access and price of charcoal and firewood and droughts reduce electricity supply and results in power rationing.

In 2008 a total of 200 tons of solid waste was generated daily of which the Municipal Council managed to collect and dispose of 50% (landfill). The remaining waste was burnt, buried, used as compost or as

FIGURE 2. *MAP OF TANZANIA* - Location of Moshi, Kilimanjaro Region

FIGURE 3. *MAP OF MOSHI URBAN DISTRICT* - Municipal administrative wards



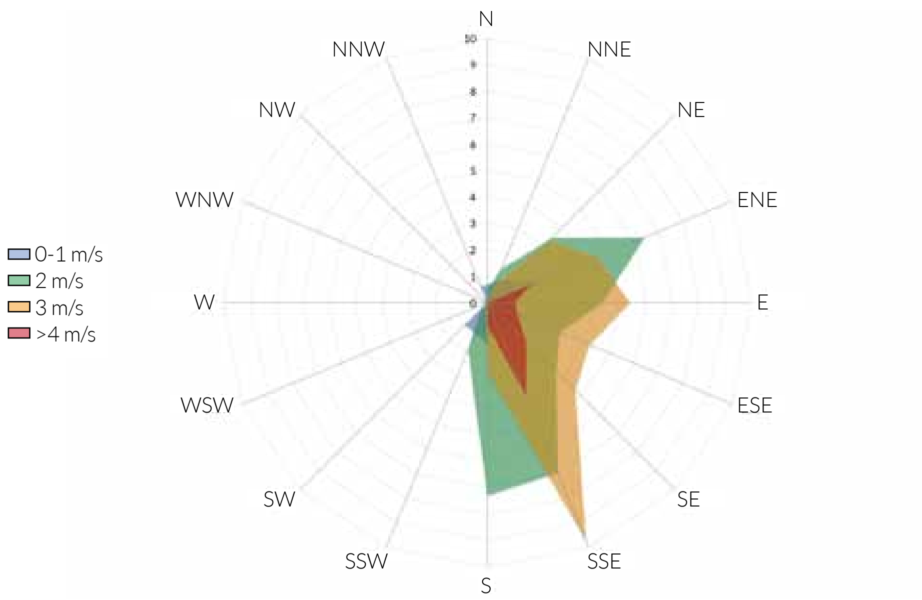


FIGURE 4.
WIND MOSHI
Average wind speed and direction in Moshi based on the conditions during the first day of the month between 2000-2012. Color indicates wind speed and radial scale represent time. For monthly conditions see Appendix A.

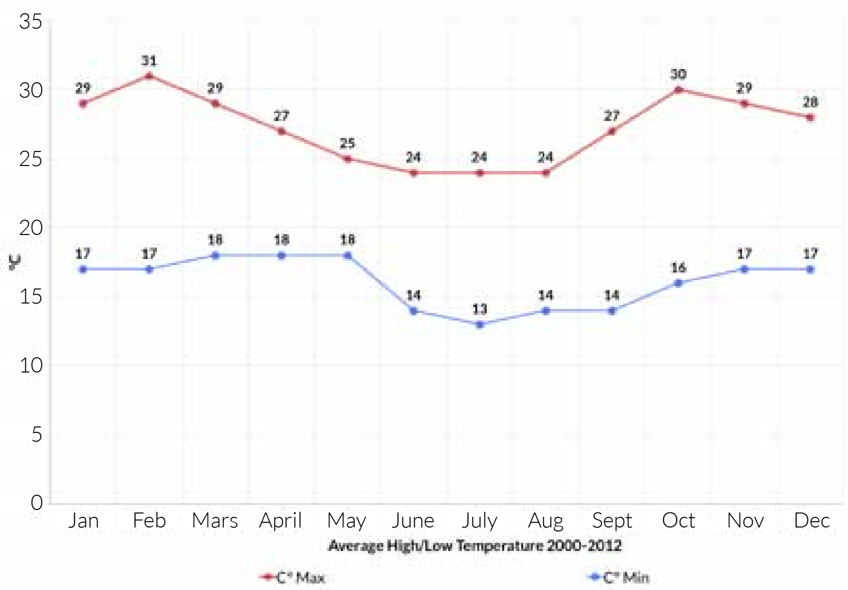


FIGURE 5.
TEMPERATURE MOSHI
Average monthly high/low temperature 2000-2012 (World Weather Online, 2015).

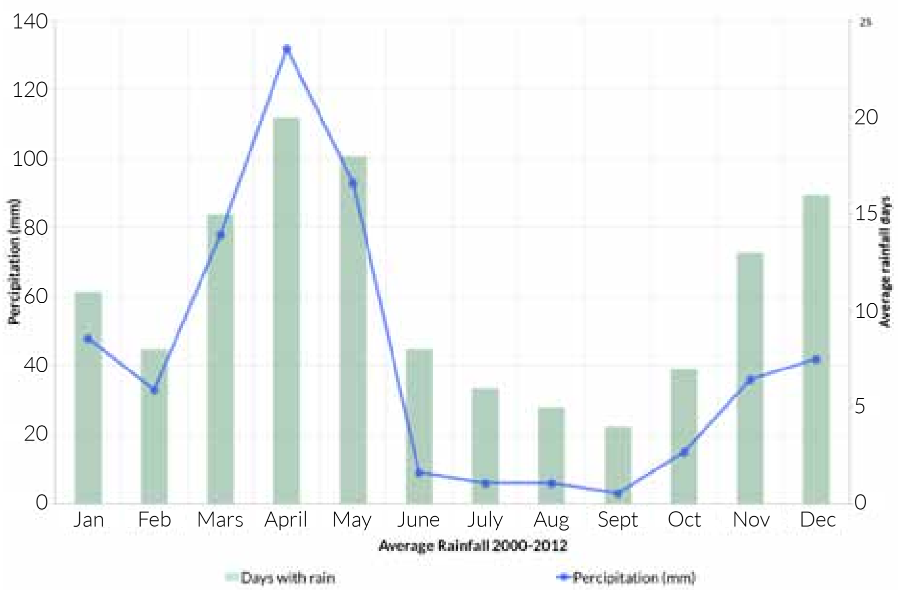


FIGURE 6.
RAINFALL MOSHI
Average rainfall 2000-2012. Graph showing average days with rain and average percipitation (World Weather Online, 2015).

animal feed. Most residents, especially in the outskirts buried or burned their waste (Moshi Municipal Council, 2008).

HEALTHCARE AND EDUCATION

Moshi Municipality is home to many institutions and international organisations. The population is relatively well educated and the region is slightly richer than the average Tanzanian regions. Moshi Municipal literacy rate was 92% in 2008, compared with 73% in the country. Moshi also has the highest number of secondary schools in the country.

Moshi Municipal has both preventive and curative health services through NGOs, religious organisations, the private sector and governmental facilities. Kilimanjaro Christian Medical Centre (KCMC) is one of seven hospitals, serving as a national referral hospital. It is also a medical college. Moshi has seven health facilities and 47 dispensaries that serve the population. Though the ratios are reasonable, most services are located in the central area leaving the peri-urban underserved (Moshi Municipal Council, 2008).

CLIMATE

Moshi is situated on the border between two climate zones. The difference in altitude results in quite different weather-conditions in the southern rural areas (hot-semi arid/savannah climate zone) in comparison with northern rural areas (upland climate zone), (UN-HABITAT, 2014).

The mean annual temperature is 25°C with the coldest month being July and December the warmest (Figure 5). Moshi receives short rains from October to December with the lowest relative humidity October through February and long rains from March to May with the highest relative humidity March through June (Moshi Municipal Council, 2008).

The weather station at Moshi airport (west of the city centre) received an annual average of 500mm rain between 2000-2012 (Figure 6), with the rainiest month being April (132mm) and September the driest (3mm). But as mentioned, the altitude differences with winds pushing the air with high moisture content up the mountain can result in very local conditions with no rain in the south and a lot of rain a few kilometres north up the mountain.

The East-North-East winds from the Indian Ocean are referred to as Anti-trade winds and they arrive in November-December and last until March, being interrupted by the East-South-East trade winds from March to October. For monthly wind distribution see Appendix A.

HOUSEHOLD LEVEL

We live most of our lives in houses. We sleep, play, eat, cook, work, study within the physical boundaries of a house. The location of the house, the design, construction and materials are all factors that affect our quality of life. It affects comfort, need for and access to energy and transport as well as contact and integration in a social and cultural context. The houses we live in affects our daily life and as physical structures they will probably affect both current and future generations. Housing is therefore central to sustainable development.

Around the world, and also in Moshi, Tanzania, there are people living in unplanned urban areas, who often lack adequate housing, water access, access to sanitation and energy. One of the biggest issues for people living in unplanned areas or informal settlements is insecure tenure. Not owning your house, or not being sure that you are going to be allowed to stay makes inhabitants reluctant to invest in improving their housing. This makes it very complex when working with upgrading of buildings and unplanned areas (UN-HABITAT, 2014).

Therefore integrated design where different professions are involved at an early stage of development is important, so that technical, social, economical and environmental aspects are considered, both in new development and upgrading the existing buildings and neighbourhoods. In many climate zones, a knowledgeable use of traditional materials and thermal mass combined with natural ventilation can reduce the need for energy for heating and cooling and may be sufficient to produce a comfortable indoor climate and a smokeless home (UN-HABITAT, 2012b).

BUILDING CONSTRUCTION

Why, what and how we build is based on many different factors: the basic need for shelter; dreams of a better life; economic possibility; ambition; available material etc.

In the context of Moshi, the building process of many houses can be described with the words: step-by-step.

When you have the money, you take the next step. What that step is, depends on the need and priorities of the occupant. Some houses are built from the ground up, resulting in many empty shells waiting to be completed, and some houses are built one room at a time, adding rooms when needed or when having enough money to continue building.

Building materials play an important role in sustainable architecture. The choice of materials is crucial from the perspective of both thermal performance and environmental impact of the building.

In all tropical countries, traditional construction materials and methods are still used, but the use of modern materials is increasing, mainly in urban areas. Traditional materials have various advantages over some modern materials.

Local materials are often easily available to no or low cost, they are developed and adapted to the local climate, can be handled by local skilled labour for production as well as building and maintenance, and have a low environmental impact.

Modern building materials or construction methods used in developed countries are often imported or copied and generally have a larger environmental impact.

Thus it is important to focus on alternate materials and constructions that combine tradition and innovation to reduce costs, energy consumption and improve the indoor environment (UN-HABITAT, 2014).

BUILDING HISTORY

The history of vernacular architecture and traditional building techniques in Tanzania is thoroughly described in the doctoral thesis by Cyriacus Lwamayanga. The historical movement of people in eastern Africa and the formation of settlements are closely connected to traits of the area and possible livelihoods. For nomads, depending on green pastures for their grazing livestock, architecture has traditionally had the meaning of organisation of the territory and constructions played a secondary role. For the Masai a house was among the families portable equipment. Today though, villages are slowly becoming semi-permanent and new construction skills are adapted. But to great extent the attitudes and processes related to house and building have been maintained. Houses are temporal, not central.

In contrast, other groups in the northwestern part of Tanzania settled in traditional villages. The Chagga, the biggest ethnic group in Kilimanjaro region, lived of the land and built permanent houses. Meaning that they could construct a house, live in it, maintain it, and/or reconstruct it on the same place without moving.

FIGURE 7.
MUSHONGE
A local name for a circular house of integrated wall and roof of grass thatch. The Chagga house is a conical structure with partition walls for zoning. In Kilimanjaro region, these structures are rare and possibly only found in cultural sites or museums (Lwamayanga, 2008).

Picture by unidentified german photographer pre 1916.

FIGURE 8.
MSONGE
A local name (at national level in Tanzania) for any circular house with distinct wall and roof of different materials. The picture shows a Masai-village in Arusha region west of Kilimanjaro region. The circular structures are no longer found in urban or peri-urban areas in Kilimanjaro region, but are common in many other regions in Tanzania. The construction is usually wattle-and-daub; poles, reeds, clay infill, and plastered with clay or dung (Lwamayanga, 2008).

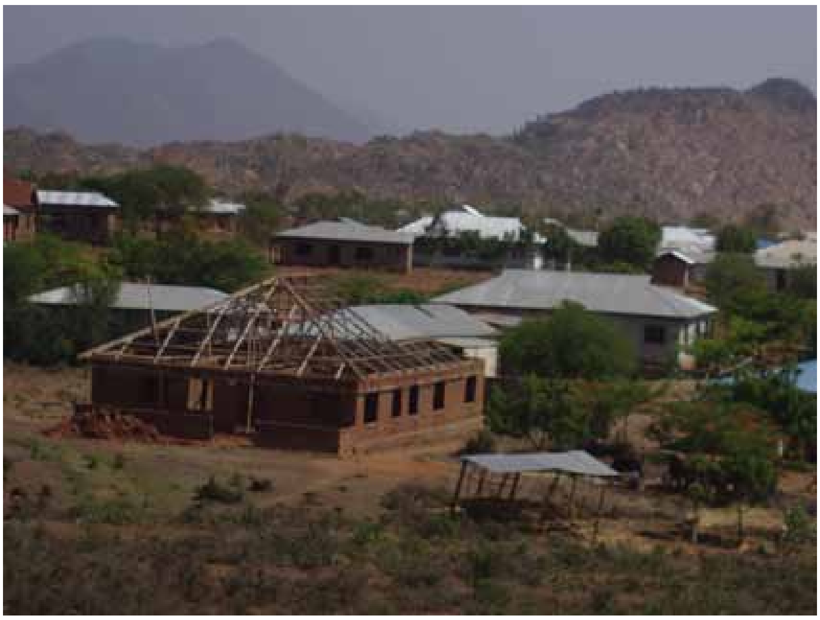


FIGURE 9.
BANDA
A local name (at national level in Tanzania) for any rectangular house. The houses with a rectangular plan were introduced by the influence of early explorers, missionaries and the Arab slave traders. Traditionally, construction materials for the Banda are very similar to those used in circular houses, but with structural wooden rafters supporting the grass thatched roof (Lwamayanga, 2008).

The constancy of land strengthened the concept of a home, and the house became the centre for organisation of the territory. The construction of the house was definite and a family activity. The main building typologies for single-family houses that could or can be found in Kilimanjaro region are generally the Mushonge, Msonge or Banda (Figure 7-9), (Lwamayanga, 2008).

MATERIALS

According to the Moshi Municipal Council, most of the houses in the municipality are constructed of concrete blocks and corrugated iron sheets (Moshi Municipal Council, 2008).

Statistics from the 2012 Housing and Population Census show that, almost 92% of the households in Kilimanjaro region have iron sheets as roofing material while about 6% have grass or leaves. The most common wall material is stabilised Compressed Earth Blocks (CEB, or cement bricks) followed by burned bricks, wattle-and-daub, sundried adobe bricks and timber. 56% have cement floor and more than 40% have earth or sand as floor material (Table 2), (National Bureu of Statistics, 2012).

In a thesis by Tom Sanya, four different building materials and techniques were compared from a sustainability perspective and showed that wattle-and-daub and adobe construction are to prefer over brick and CEB construction in the context of Uganda, though when considering the need for recurring maintenance and social acceptability the positions on the list may change and in some contexts brick or CEB construction may be more sustainable in a long-term perspective (Sanya, 2007).

METAL SHEETS

Iron sheets (Figure 10) are one of the most common roofing materials, but it has many drawbacks. The sheets are thin with no

FLOOR MATERIAL IN MAIN DWELLING UNIT - Five most common materials (%)

REGION	Cement	Ceramic Tiles	Wood Planks	Earth/Sand	Animal Dung
Rural	18	0.2	0.3	80	0.9
Urban	74	3.5	0.1	22	0.1
Kilimanjaro	56	1.2	0.8	41	0.5

WALL MATERIAL IN MAIN DWELLING UNIT - Five most common materials (%)

REGION	Cement Bricks	Sundried Bricks	Burned Bricks	Timber	Wattle-and-daub
Rural	3.8	33	28	0.8	32
Urban	51	15	25	0.3	7.3
Kilimanjaro	34	12	23	8.7	20

ROOFING MATERIAL IN MAIN DWELLING UNIT - Five most common materials (%)

REGION	Iron Sheets	Tiles	Asbestos	Grass/Leaves	Mud and Leaves
Rural	52	0.2	0.2	35	11.6
Urban	91	0.8	0.3	6.0	1.0
Kilimanjaro	92	0.3	0.2	5.6	1.4

TABLE 2.
BUILDING MATERIALS IN TANZANIA.
The tables show data on materials used as floor, walls and roofs in rural and urban areas in Tanzania mainland in comparison with Kilimanjaro region (National Bureu of Statistics, 2012).

FIGURE 10. *METAL SHEETS*

FIGURE 11. *GRASS AND LEAVES*

FIGURE 12. *WOOD*

FIGURE 13. *CLAY*

FIGURE 14. *CONCRETE*

FIGURE 15. *COMPRESSED EARTH BLOCKS*

FIGURE 16. *BURNED BRICKS*

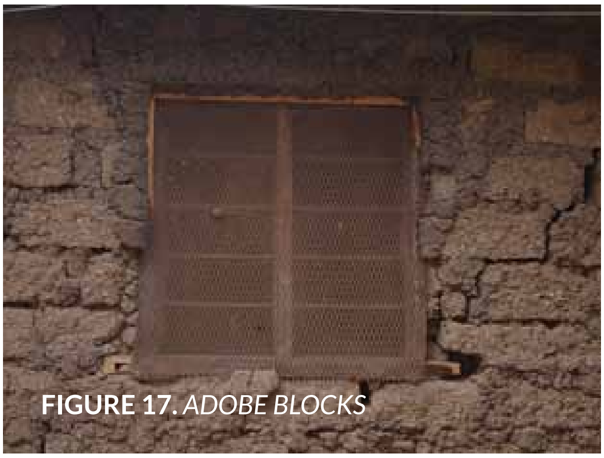


FIGURE 17. *ADOBE BLOCKS*

significant thermal resistance and rapid cooling at night may cause condensations in humid climates. When aged it looses reflectivity and re-radiates the solar radiation into the building creating high indoor temperatures during daytime. To improve the reflectiveness and increase their lifespan, such roofs should be painted in a light colour, but even with frequent maintenance it has a short lifespan and it is very noisy when it rains.

An alternative to the iron sheets is sheets made from aluminium. They have a high degree of reflection; have low maintenance costs and a longer lifespan than iron sheets. Even with the higher initial price they are definitely a better choice than iron sheets. Though, without insulation or a ventilated cavity below the roof they are still a bad choice regarding thermal and acoustic performance (UN-HABITAT, 2014).

GRASS AND LEAVES
Thatch roofing (Figure 11) is widely used in rural situations throughout East Africa. It is suitable for the tropical climate with better thermal and acoustic properties than metal sheets. It is made from locally available material and therefore cost efficient. Even with a relatively low durability the lifespan of an average thatch roof is 7-10 years if properly maintained (UN-HABITAT, 2014).

WOOD
If legally and sustainably produced, wood is the most environmentally friendly of conventional building materials. Wood is a strong and flexible material suitable for many types of constructions and building elements (Figure 12). It is easy to work with and easy to repair and change. But wood also has some disadvantages including it being a scarce and expensive resource in some contexts due to deforestation and regulations to control the use of wood. Wood also burns easily, and treatment against humidity and pests can be poisonous to occupants (UN-HABITAT, 2012a).

CLAY
Clay is often locally available and a component in many different constructions and building blocks. It can be used as a binder (adobe blocks), as plaster on walls, as infill in wattle-and-daub constructions (Figure 13). Clay can also be added to a mould, formed into bricks and burned (burned bricks).

CONCRETE
Concrete is the product of cement, sand or gravel and water. Strong concrete products can be made on-site with low-cost methods using one skilled worker and small-scale equipment. Such products include roof tiles, ventilation blocks (Figure 14) and concrete blocks (or stabilised compressed earth blocks). Concrete is not seen as an environmentally sound material, though sometimes it can be better to use than other materials if it prolongs the lifespan of the building (UN-HABITAT, 2012a).

COMPRESSED EARTH BLOCKS
Stabilised compressed earth blocks (CEB) have been used for the past 25 years in Africa. The blocks are made from locally found soil and sand, mixed with water and 4-6% cement and compressed with either hand operated or motorised machines. The uniform blocks minimise the need of mortar, construction is fast and the blocks are of comparable strength to locally burned bricks, without their environmental impact. The CEB machines can be transported to remote locations and used on site with local material by supervised unskilled labour (Figure 15). The durability may be a problem if the blocks are exposed to wind and/or rain and there is a need for reinforced concrete sections in larger buildings to handle high pressure and provide stability.

Blocks can be made in different shapes for interlocking, with holes to make them lighter and increase their thermal insulation ability
(Sanya, 2007; UN-HABITAT, 2014).

BURNED BRICKS

Bricks and the masonry technique was introduced in East Africa by the colonialists. Burned bricks (also sometimes referred to as "baked bricks" or "fired bricks"), are made from clay or earth that has dried in the sun and stacked into a "kiln" (Figure 16). The kiln is a structure or oven, which is covered with sand and clay to keep the heat when starting a fire in bottom/centre of the stacked bricks.

When constructing a wall, the bricks are bonded together with sand-cement or clay mortar. The burning of the bricks demand a lot of energy and firewood and the finished bricks do not always have a uniform size or quality depending on the material used and the placement of the bricks in the kiln (Sanya, 2007).

ADOBE BLOCKS

Approximately one fifth of the world's population lives in adobe/rammed earth constructions (Figure 17). The production of simple earth blocks only requires around one thousandth of the energy needed for burned bricks. Earth in plastic state is shaped in a mould to make blocks, the blocks are dried in the sun and bound together with earth mortar to build walls. There are many local variations and use of for example straw in the blocks to make them stronger. Adobe blocks have very low embodied energy and have good heat and sound insulation capabilities, but if they are not plastered or protected from rain/sun and properly maintained, their lifespan can be greatly shortened (Sanya, 2007; UN-HABITAT, 2012a, 2014).

(BAMBOO)

Bamboo is a versatile material that can be used in many different building elements. Both as structural elements and as finish materials in roof, floor and walls. It is widely used in hot-humid zones globally but has not been used to a great extent in Tanzania. The structural frame of a bamboo construction is similar to traditional timber frames, and with scarcity and high price of timber it can be an attractive alternative. Bamboo is easy and rapid to cultivate and can be used without complicated techniques or tools (UN-HABITAT, 2012a, 2014).

HOUSEHOLD CHARACTERISTICS

In 2012, 74% of the households in Tanzania owned their house but over 30% lacked legal right to the land on which the house was built. Most households had 2-3 rooms for sleeping, about 6-8% had 5 rooms or more and almost 20% had only one sleeping room. The average number of household members were 5 in rural areas and 4.2 in urban areas. In Kilimanjaro region 80% owned a mobile phone and 3% had a computer. Only 6% had a refrigerator or freezer but 20% had television. Almost 80% of the households in Kilimanjaro region and around 70% of all Tanzanians had a farm or land for farming and owned a hand hoe. 47% of all household waste in Kilimanjaro region was burnt and 20% was buried, only 4% was regularly collected (National Bureu of Statistics, 2012).

ENERGY

Housing is responsible for as much as a quarter of the global operational energy demand (embodied energy used in construction excluded). The energy is used for heating, cooling, cooking, lighting etc. The use of energy is a necessary condition to support life and social activities in houses. Table 3 shows the minimum standard for household energy services to support decent wellbeing (Practical Action, 2012).

Millions of people do not have access to the infrastructure needed to provide the basic energy services, and even if they do, they cannot afford the quantities needed to reach the minimum standard, leading to the phenomenon of "energy poverty".

76% of the 900-million people living in Sub-Saharan Africa (SSA) rely on solid biomass fuels for their household energy needs. Biomass energy sources contribute

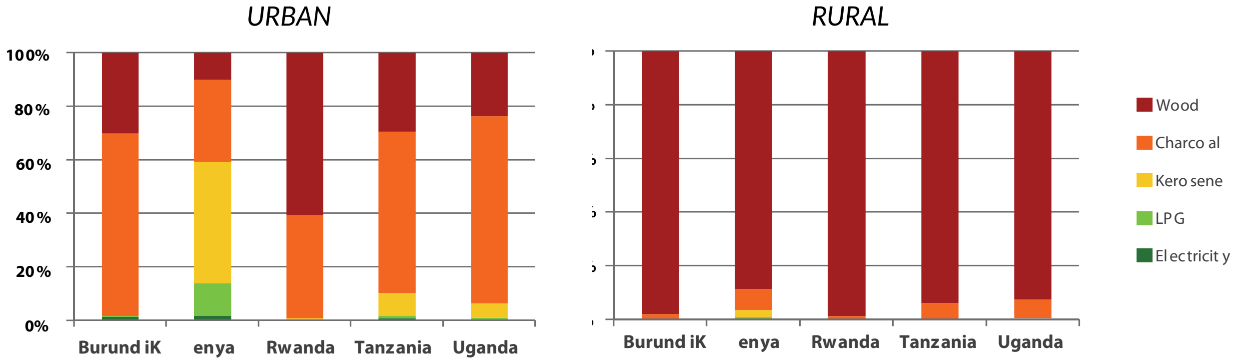


FIGURE 18. *PRIMARY SOURCE OF COOKING ENERGY*
Urban and rural context in East African Community states (EEP, 2013).

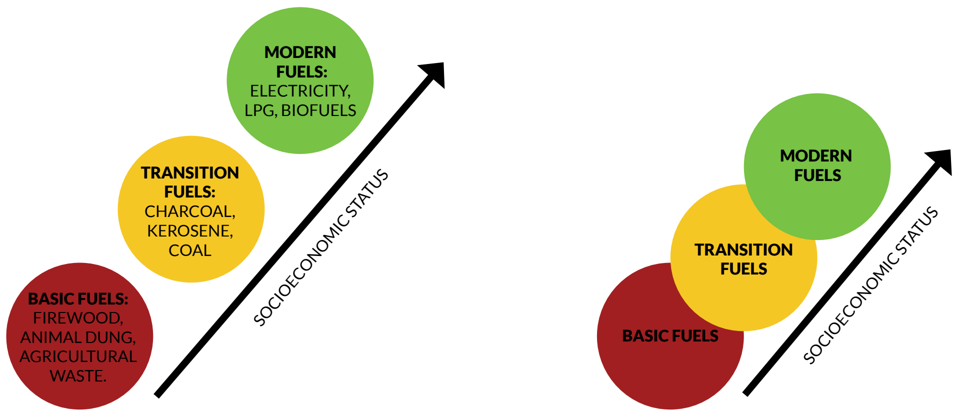


FIGURE 19. *ENERGY LADDER*
With higher socioeconomic status people tend to "climb the energy ladder". But instead of making a clear fuel and technology shift, often basic-, transition- and modern fuel are used in parallel (EEP, 2013).

ENERGY SERVICES	Minimum standards
Lighting	300 lumens for a minimum of 4 hours per night at household level;
Cooking	1 kg woodfuel or 0.3 kg charcoal or 0.04 kg LPG or 0.2 litres of kerosene or biofuel per person per day, taking less than 30 minutes per household per day to obtain; Minimum efficiency of improved solid fuel stoves to be 40% greater than a three-stone fire in terms of fuel use; Annual mean concentrations of particulate matter ($PM_{2.5}$) < 10 μg/m³ in households, with interim goals of 10 μg/m³, 10 μg/m³, amd 10 μg/m³;
Space heating	Minimum daytime indoor air temperature of 18°C;
Space cooling	Maximum apparent indoor air temperature of 30°C;
Refrigeration	Households can extend life of perishable products by a minimum of 50% over that allowed by ambient storage;
Information and communications	People can communicate electronic information from their household; People can access electronic media relevant to their lives and livelihood in their household.

TABLE 3. *HOUSEHOLD ENERGY STANDARDS*
Minimum standards for household energy services to support decent wellbeing. Adapted from Practical Action (Practical Action, 2012).

more than 75% of the total primary energy supply in each of the five East Africa Community (EAC) states of Burundi, Kenya, Rwanda, Tanzania and Uganda.

The poorest people living in the rural areas have throughout history had access to fuel to a low or no monetary cost. The time for collecting is mostly spent by women and children, who often have low status in the poor communities. It is estimated that 85% of all energy funds to SSA go to electricity-related projects. Rural electrification is seen as a key to poverty alleviation, though non-grid systems seldom produce enough power for cooking, and people who are very poor cannot afford it for anything more than basic lighting. In 2009, 35 SSA governments had set national electrification targets, but only eight mentioned targets for improved biomass energy based stoves. A view on biomass fuels as dirty, without considering the type of combustion, have resulted in a situation where the biomass energy sector lacks structured market incentives.

With a large percentage depending on solid fuels and no possibility to use electricity for cooking, scaling up modern energy along with improving fuels and combustion technologies should be priority in developing countries (EEP, 2013).

The EAC has set a target of ensuring that at least 50% of all households have access to modern cooking fuels by 2015 (EAC, 2007).

Supporting more efficient use of traditional fuels and enabling the switch from traditional to modern cooking fuels, climbing the “energy ladder”, are two complementary approaches to start to address the energy issues in SSA (EEP,2013).

FUELS

To address the energy deficiency in Sub-Saharan Africa there are mainly two complementary approaches. The first is to support more efficient use of traditional biomass sources, the second is to enabling the switch from traditional to modern cooking fuels. Choice of fuel is strongly linked to the availability and cost of materials in different areas.

In 2008 and 2009, a qualitative study about the issues of bioenergy access was conducted in several areas in Kenya.
The following short descriptions of different fuels, their advantages and disadvantages, are based on focus group discussions and surveys from this study (UK’s Department for International Development, 2010).

FIREWOOD

Firewood is the most commonly used fuel for cooking in the rural settings. Firewood is often considered cheap and easily accessible. But it is harder to get access to good firewood during the rainy seasons. With deforestation it is also harder and takes longer time to collect, a burden that lies on the women and children. Firewood is also used to a high extent when producing bricks.

CHARCOAL

Charcoal is used all over the world, and is more commonly used for cooking than firewood in the urban settings. Charcoal is produced in a kiln, by heating wooden sticks in an oxygendeficient combustion. This gives a light and energy-rich fuel that burns for longer and with higher temperatures than regular firewood. It can be put out, and reused to some extent, which makes it flexible and economic.

KEROSENE

Is liquid fossil fuel that is mainly used in the urban areas. It ignites fast and gives a consistent heat. It is often used as a complementary way of cooking to charcoal or wood. Is considered a transition fuel going from basic fuels as firewood to advanced fuels like cooking gas, electricity or biofuels. Kerosene is an energy dense

FIGURE 20. *FIREWOOD*

FIGURE 21. *CHARCOAL*

FIGURE 22. *KEROSENE*

FIGURE 23. *LPG (GAS)*

FIGURE 24. *BRIQUETTES*

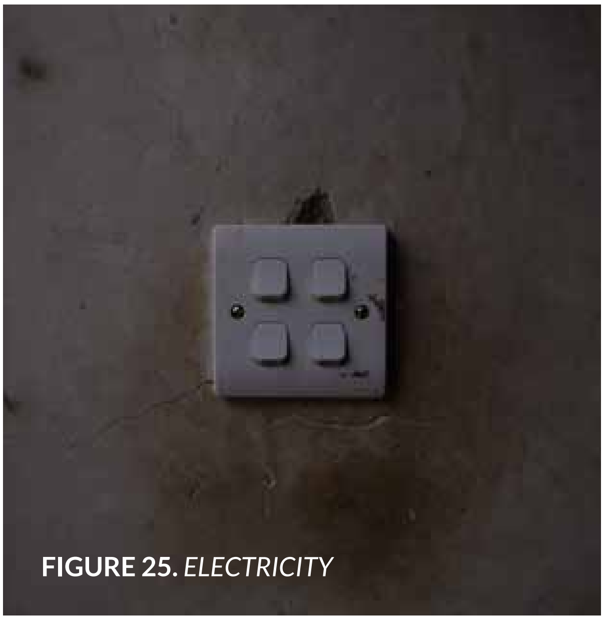


FIGURE 25. *ELECTRICITY*

fuel, but the disadvantages is that it is a fossil fuel, that still produce harmful particles and it demands a separate stove. Kerosene is also used in lanterns for lighting in both urban and rural areas.

LPG

Liquefied petroleum gas (LPG) is used to some extent in the urban areas and is mainly used for short-time cooking (less than an hour). The use of LPG has increased in the mid and high income urban households. But high initial cost and lack of distribution capacity makes it rare in poorer households and in rural areas.

Some small projects have started to deliver LPG in smaller cylinders in order to make it more affordable and accessible for people who cannot pay the high deposit for the larger cylinders. LPG has the advantages that it is cleaner than solid biomass fuels in the sense that it doesn't produce as much smoke, it is also easy to use and is fast and easy to economise.

BRIQUETTES

Briquettes are compressed biomass that may or may not have been carbonised. Briquettes can replace charcoal and firewood, especially for space heating, but also for cooking. They can be made from crop residues, paper pulp, sawdust etc. They come in different shapes and sizes, and are produced in both large and small scale. There is a lack of standards and distribution channels. Briquettes can be a better alternative for the environment than charcoal and firewood, but used in inefficient stoves they still produce harmful smoke.

ELECTRICITY

Electricity is considered an advance and modern fuel. For the user, it is a clean fuel, convenient to use and does not produce any smoke. Though, if not installed correctly it is a risk accidents and fires. In the context of East Africa, electricity is expensive, and the irregular supply in many areas makes it hard to be dependent on electricity for cooking. The equipment also has a high initial cost and often a subscription is required. Even if electricity is clean when used, it is not a climate neutral source, depending on the production methods.

STOVES

Here follows a short description of the most common stove types in Moshi, and in Tanzania.

Based on availability and cost of fuel, occupation (time), and cooking (eating) habits, families often use one or more stoves for different tasks. This is known as stacking, and it is also common in kitchens in developed countries with oven, cooker, toaster and microwave for different tasks. The biggest difference is that most of these appliances run on electricity. (S. B. Gordon et al., 2014)

THREE-STONE-STOVES

This is the most common stove in rural areas. As the name implies it is essentially a fireplace of three stones or bricks placed on the ground to act as a base for pots and pans. The stones are moved to fit pots of different sizes. Between the stones a fire is lit and longer sticks and pieces of firewood are gradually pushed in or retracted from the fire to control the heat.

A well constructed three-stone-stove protected from wind and handled by a skilled operator can reach 20-30% thermal efficiency but when using moist wood and used with no attention to wind thermal efficiency can be as low as 5% (PCIA, 2010).

CHARCOAL STOVES

This is the most common stove in most urban and peri-urban areas. It is often made out of thin metal sheeting with or without an insulating ceramic layer. Most stoves are locally made and can be bought in small shops or in the market. There are different sizes for different pots and needs.

MAIN SOURCE OF ENERGY FOR COOKING - Five most common sources (%)					
REGION	Firewood	Charcoal	Kerosene	LPG (Gas)	Electricity
Rural	90	7.7	1.0	0.1	0.2
Urban	25	62	0.3	2.4	4.2
Kilimanjaro	80	11	0.2	1.5	1.7

MAIN SOURCE OF ENERGY FOR LIGHTING - Five most common sources (%)					
REGION	Kerosene	Electricity	Torch/Rechargable lamp	Candles	Solar Energy
Rural	66	5.4	20	1.0	1.7
Urban	43	46	4.8	2.1	1.0
Kilimanjaro	63	27	2.4	0.7	3.5

TABLE 4. *HOUSEHOLD ENERGY IN TANZANIA.*
The tables show data on sources of energy for cooking and lighting in rural and urban areas in Tanzania mainland in comparison with Kilimanjaro region (National Bureu of Statistics, 2012).

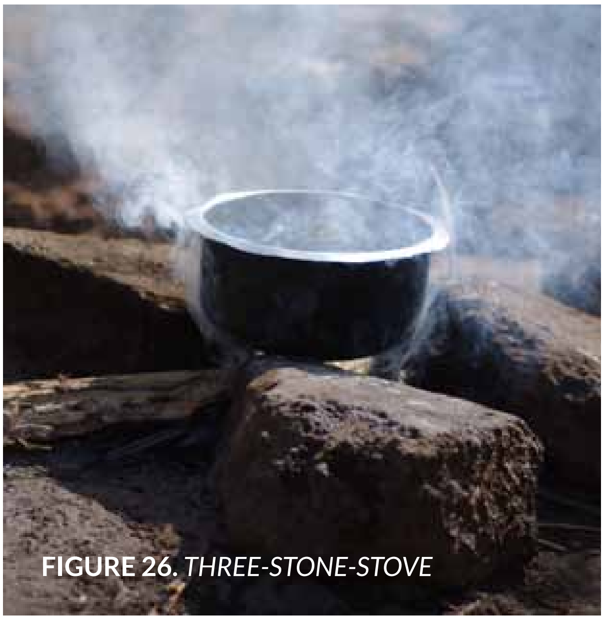


FIGURE 26. *THREE-STONE-STOVE*

FIGURE 27. *CHARCOAL STOVES*

FIGURE 28. *KEROSENE STOVE*

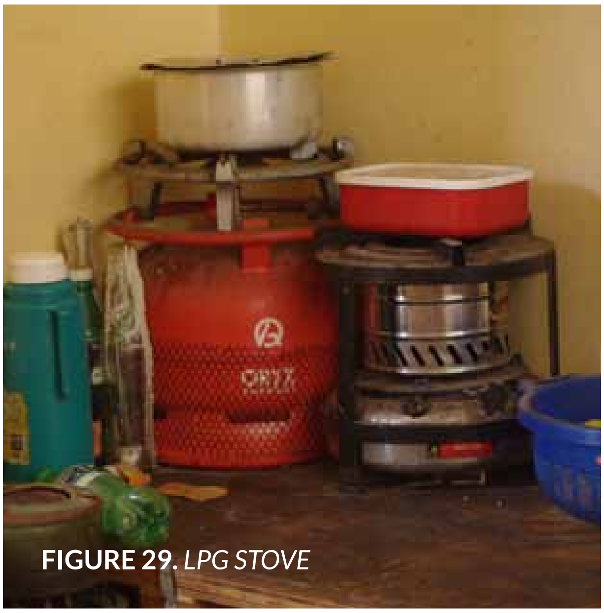


FIGURE 29. *LPG STOVE*

KEROSENE STOVES
As all kinds of stoves, kerosene stoves come in different sizes and shapes. They are mainly imported and are not always that stable when using bigger pots. Hence locally made "stands" are available to accommodate bigger pots.

LPG STOVES
The gas stoves are also available in a range different types. Since the gas runs through tubes, one cylinder can be used for more than one burner at the time. Though, the most common LPG stove is the stove and burner that is attached directly on top of the cylinder. As the cylinder is quite heavy, it acts as a god base and makes cooking stable. Burner on a red 6kg LPG cylinder next to a kerosene stove is shown in Figure 29.

COOKING
The kitchen is often a neglected part of the home and territory of the woman. It often lacks security and comfort, is often polluted and dark. All this is possible to change, but is seldom prioritised, mostly because the one in charge of the family economy is the husband, who rarely takes part in household work, or cooking.

When studying the kitchen, which is a hub for household activities, Nyström has formulated criteria to notice; health and hygiene, safety, comfort and energy efficiency. It is a complex area, an area without defined walls, since the activities are taking place both indoor and outdoor. So instead of focusing on the "kitchen" one should consider the flows and activities connected to cooking. The culinary chain starts with the preparation of food and include cooking, washing up, eating, drying and storing.

It is important to consider these aspects when formulating and suggesting changes. The mentioned activities are in turn related to a variety of equipment. The posistion of each function seems to be more connected to the space available rather than the relation to their function. All these things make the kitchen a dangerous workplace. The position of the person responsible for cooking will influence the risk of accidents such as burns, slipping and falling. The ergonomics are seldom considered. The zooning of the space for different activities might also increase the risk for contamination and fecal-oral transmission that spread disease (Nyström, 1994).

COMFORT
Temperature, humidity and airflow are all conditions that determinie whether humans feel comfortable in a given climate. Most people feel comfortable when indoor

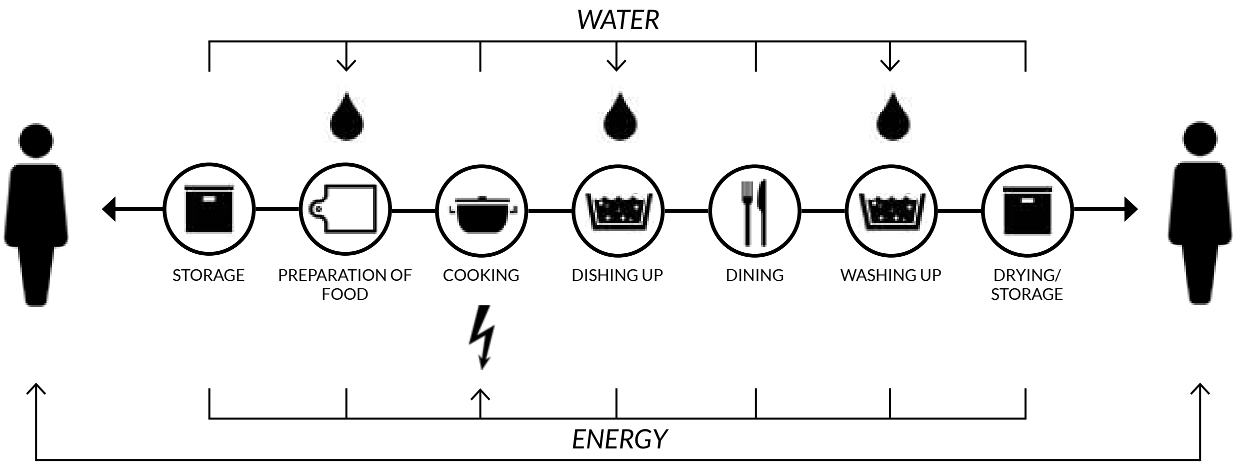


FIGURE 30. *CULINARY ACTIVITY CHAIN*
The kitchen system and the culinary activities, water and energy supply. Adapted from Nyström (2003).

temperature is between 22°C and 30°C and the relative humidity is between 20% and 80%. In the 1970s a Danish researcher developed a model - called the predicted mean vote (PMV) - to estimte optimal climate conditions for a group. The PMV is defined as the mean thermal sensation vote on a standard scale for a large group of persons for any given combination of ther thermal environmental variables at a set activity and clothing level (Knudsen & Seidlein, 2014).
It is also important to consider the ergonimcs when designing a workplace like kitchens.

The comfort conditions in the hot-semi arid/savannah and upland climate zones of Moshi are generally quite pleasant. In higher altitudes the temperature can drop below the lower limits of the comfort zone and it can be chilly during July and August. High daytime temperatures that prevail during most of the year can be critical, but steady breezes often alleviate the heat of the afternoon (UN-HABITAT, 2014).

INTERVENTIONS

In this thesis, the meaning of the word "intervention" is a technology, building alteration or activity with the intention to reduce smoke or smoke exposure. There are a variety of interventions, and in this section interventions are grouped into three different categories: behaviour- and fuel-related interventions; improved cookstoves; improved ventilation and smoke extraction. In Table 5 different interventions are placed in a time/ technology matrix for adaption or implementation of interventions in immediate- medium- and long-term scenarios.

The issue of HAP is, as described earlier in this thesis, complex. Mostly because it is so closely connected to the traditions and culture in the home, region, country etc. There is no "quick-fix" to apply in all homes, because all homes are unique in some way. There is a need for information about which interventions work in a specific setting and it is important to demonstrate the sustainability and acceptability of any given intervention (WHO, 2005).

Interventions regarding fuel and stove types have shown effective in reducing exposure to HAP, but other household characteristics as kitchen location, ventilation and kitchen structure are also important to explore (Yamamoto, Louis, Sie, & Sauerborn, 2014).

TIME / CONTEXT	User	Fuel	Kitchen
Immediate term	Cooking to conserve - techniques User education	Better fuel preparation such as drying	Cooking outside on a shielded fire
Intermediate term	Behavioural interventions such as identifying a safe place for an infant to stay away from the cooking fire	Fuel combinations such as fireless cooker	Using a portable improved stove
Long term	Spending less time in the kitchen, made possible by better fuel burning techniques	Fuel switching Use of gas, solar cookers, and other clean energy technologies	Building an improved kitchen, including a smoke hood and inbuilt stove

TABLE 5. *TIME / TECHNOLOGY MATRIX FOR INTERVENTIONS*
Table for adaptation of smoke-alleviating interventions in short-medium and long term perspective. Example from Kenya. Adapted from Practical Action (Practical Action, 2005).

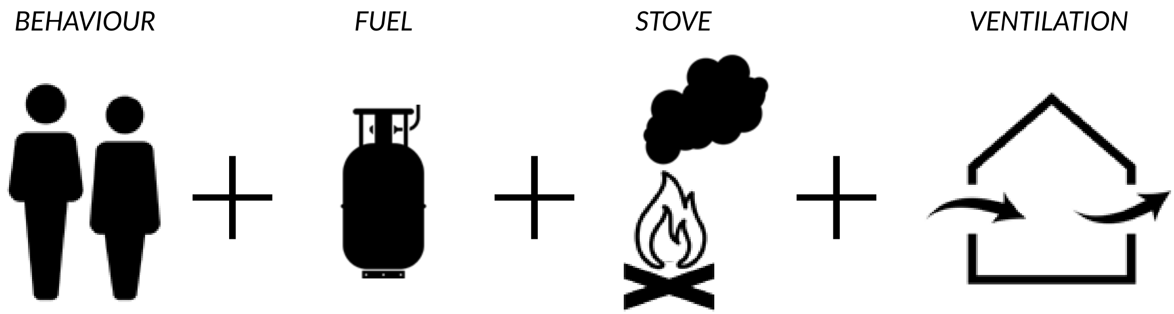


FIGURE 31. *TYPE OF INTERVENTION CATEGORIES*
Interventions to reduce exposure to household air pollution can concern awareness and behavioural change, new or more effective fuels, better stoves and improved ventilation or smoke extraction.

In some homes it might also be a need for a combination of interventions in order to reduce the levels of harmful particles enough to make a difference to health (WHO,2014c).

EVALUATION METHODS
Even the most efficient technology fails if adoption is only for a brief period after introduction. To reduce HAP it is crucial that households and communities appreciate the benefits of change. In fact, it is unusual for communities to change behaviour to achieve health-reletad benefits. More attractive benefits include convenience in cooking, economy of fuel use, time savings etc. (S. B. Gordon et al., 2014).

The health effects or health impacts of different changes or hazards in the micro or macro environment can be assessed, and in a similar way it is possible to evaluate the effectiveness of interventions through health impact assessments (HIA). But as described above, the local community may consider other benefits more important; therefore it is also important to evaluate the cost effectiveness of different interventions both in regards to health but also energy (WHO, 2005, 2014c, 2015b).

In a cost-effectiveness analysis (CEA) from 2004, three different cooking systems and combination of cooking systems were compared for different regions. The study addressed the economic aspects of gains in healthy years from averted illness and annual cost for different cooking systems on a household level. The result from the study showed that cleaner fuels have a larger impact on the health than improved stoves, but due to the high initial cost for a new cooking technology and higher fuel cost, improved cookstoves using basic fuels offer the most cost-effective way of improving health per unit of investment. Improved stoves are therefore a recommended intervention until people have access to cleaner fuels (Mehta & Shahpar, 2004).

BEHAVIOUR- AND FUEL-RELATED INTERVENTIONS
These interventions can be both simple and hard. They are simple in theory, but hard to apply in the sense that they require people to change their habits or traditions.

LOCATION
The location of the stove affects how the wind transports the smoke and who gets exposed. Moving the stove outside or moving away from the stove can be easy steps to reduce exposure significantly. If the stove is placed at waist height, the direct exposure from leaning over the stove is reduced.

FOOD PREPARATION
Some foodstuff can be prepared to reduce cooking time, hence reducing smoke production-exposure, (e.g. soaking beans).

COOKING
Using a lid reduces cooking time. Some foodstuff can be put in a “fireless cooker” or “hay box” (insulated container into which pots containing already-boiled food are placed), to reduce the time of having the stove lit. Only using dry fuel will also significantly improve combustion and reduce smoke. Therefore fuel storage and drying, as a preparation before cooking is an important intervention.

IMPROVED COOKSTOVES

Improved cookstoves (ICS) can be divided into many different categories and what is “improved” can be debated and often consider energy efficiency and fuel consumption. But improved, cleaner burning stoves have many benefits beyond fuel consumption including improved health, timesavings, cleaner kitchens etc.

In 2010, the Partnership for Clean Indoor Air, published a report on test results from performance testing of 18 different stoves and dived them into six categories: Wood burning stoves without chimney; Wood burning stoves with chimneys; Wood burning stoves with electric fans; Charcoal stoves; Liquid fuel stoves and solar cooker. In the report they list a number of recommendations in order to improve efficiency and combustion when designing solid biomass fuel stoves, some of these are:

- A hotter fire burns cleaner – Insulating the stove is important
- Burning too much wood at once creates smoke – Steady flow of material
- Controlled airflow – A steady airflow improve the mixing of fuel, air and spark.

Below are short summaries of different types of stoves using solid biomass fuel:

INSULATED CHARCOAL STOVE
This stove is made using simple materials and tools by local small-scale enterprises. The basis of the design is to protect the fire, reduce smoke and direct the flames and hot air up to the pot. It is a mobile design and does not have a permanent placement. It is usually a cheap improvement and has a thermal efficiency of about 30% and can reduce fuel use with up to 50% compared to the three-stone-stove, though many models do not improve conditions regarding smoke and production of harmful pollutants at all.

FIXED STOVE WITH CHIMNEY
A fixed stove with chimney is safer to use than mobile stoves placed on the ground. If well-design and using local materials they can be both cost effective and very successful in reducing fuel use and indoor exposure to smoke. It is suitable for users who own their house and cook inside consistently in a fixed position making it a good option for institutions and schools.

GASIFIER STOVES
Gasifier stoves are metal stoves that are designed in a way that the fuel is first converted into combustible gases through intense heating, which then burns with a clean flame. It is not limited to a specific fuel but can use both firewood, sawdust, agricultural waste etc, as long as they are cut down to the right size. The airflow can be controlled either through natural draft of forced draft (using an electric fan). It is very effective reducing the amount of smoke and emission levels. The stove requires an advanced production facility and is often imported.

ROCKET STOVES
Rocket stoves are stoves that essentially uses a feeding-tray for firewood, lifting the fuel from the ground and allowing good airflow from below through natural draft, improving both fuel efficiency (fuel saving up to 50% compared to a three stone fire) and smoke production. The stove can be locally made, scalable to different needs and comes in a multitude of forms.

FAN-SUPPORTED
Adding a fan to a wood-burning stove dramatically reduces emissions. Designs using electric fans are often advanced, expensive and imported. Some models use batteries and some models use a thermo-electric generator to produce electricity from heat, that in turn powers a fan, excess electricity can also be used to charge lamps or mobile phones. These stoves can reduce smoke levels with up to 95% compared to three-stone-stoves and fuel saving up to 50%.

IMPROVED VENTILATION AND SMOKE EXTRACTION

The best thing is to reduce smoke production, but better airflow has positive effect on both comfort and air quality when it comes to heat, humidity and spreading of different particles suspended in the air. What type of intervention to implement depends on location of the building, location of kitchen, fuel/stove use, cost of intervention etc.

Below are short summaries of different interventions and principles to improve ventilation and smoke extraction:

CHIMNEY
Chimneys are one of the most effective interventions when it comes to reduction of indoor smoke levels. The design of the chimney and materials used varies depending on the different applications like: stove integrated chimneys described in previous section; smoke hoods, solar chimneys. The length of the chimney and the material of the roof have to be taken into account in all three applications in order to minimise re-entry of smoke particles into the living area.

SMOKE HOOD
A smoke hood is a metal or brick hood built over a stove or open fire. When cooking the smoke goes up into a chimney or flue so that it is taken out of the house. A well-designed smoke hood can remove up to 80% of the smoke.

SOLAR CHIMNEY
As the name implies the solar chimney makes use of the solar radiation to heat air inside a chimney to increase draft and enhance airflow. The solar chimney may be used together with a flue and smoke hood as smoke extraction, or as a roofing or construction detail to improve ventilation in general.

NATURAL VENTILATION
Natural ventilation is driven by some basic principles and natural forces (Figure 38-43), which can be simplified and described as horizontal air movements due to wind, and vertical air movement caused by the “stack effect” (when heated, the density and weight of the air gets lower, therefore warm air rises), (UN-HABITAT, 2014).

There are many methods and design principles on how to control air movements to protect inhabitants or to improve comfort and smoke extraction. In a handbook on sustainable building design for tropical climates, UN-habitat describes principles and applications to manage airmovements in buildings. They discuss the placement and size of openings, windows and door and the effect on cross ventilation; the effect of vegetation, bushes and trees, outside and in front of openings; the design of solar shading and the effects on ventilation from wind-forces; the wind direction and orientation of the building and placement of different functions as well as design-applications (solar chimneys etc.) to make use of solar radiation and the stack effect to improve natural ventilation (UN-HABITAT, 2014).

In a kitchen environment in developing countries there are two main strategies when working with natural ventilation described by Nyström (2003): direct ventilation through doors and windows (openings in a solid wall) or diffuse ventilation through permeable walls.

FIGURE 32. *INSULATED CHARCOAL STOVE*

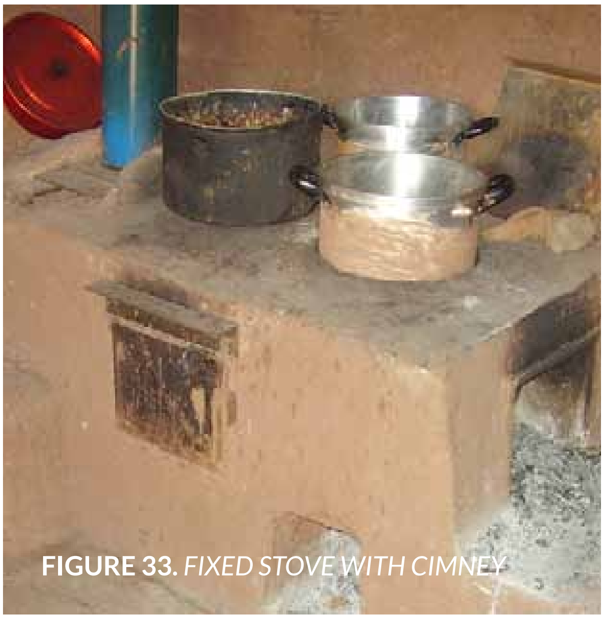


FIGURE 33. *FIXED STOVE WITH CIMNEY*

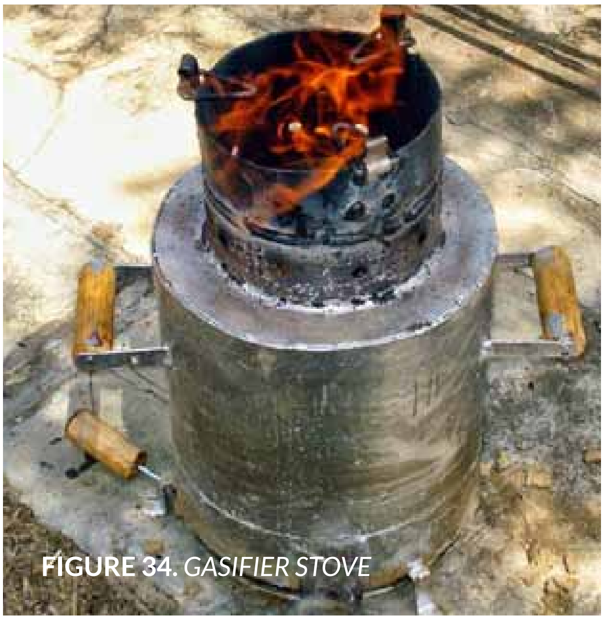


FIGURE 34. *GASIFIER STOVE*

FIGURE 35. *ROCKET STOVE*

FIGURE 36. *FAN-SUPPORTED STOVE*

FIGURE 37. *SMOKE HOOD*

FIGURE 38. *VENTURI EFFECT*

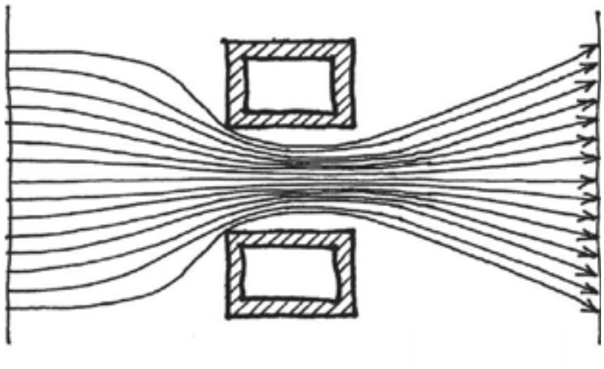


FIGURE 39. *WIND PRESSURE DISTRIBUTION*

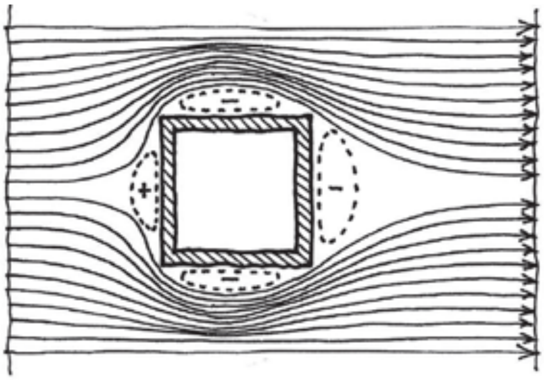


FIGURE 40. *STACK EFFECT*

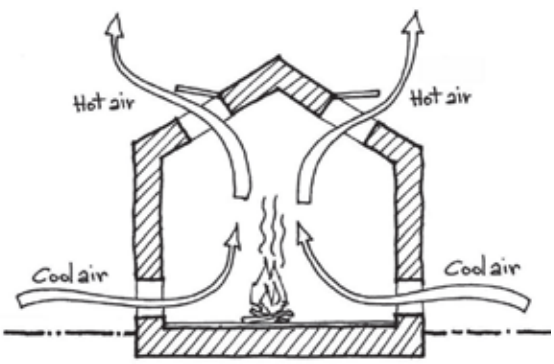


FIGURE 41. *SOLAR CHIMNEY*

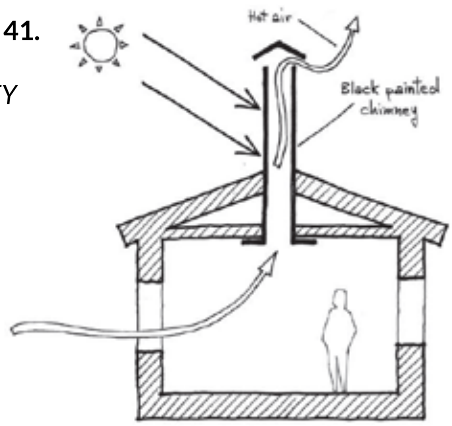


FIGURE 42. *FLOW PATTERN IN RELATION TO POSITIONING OF OPENINGS*

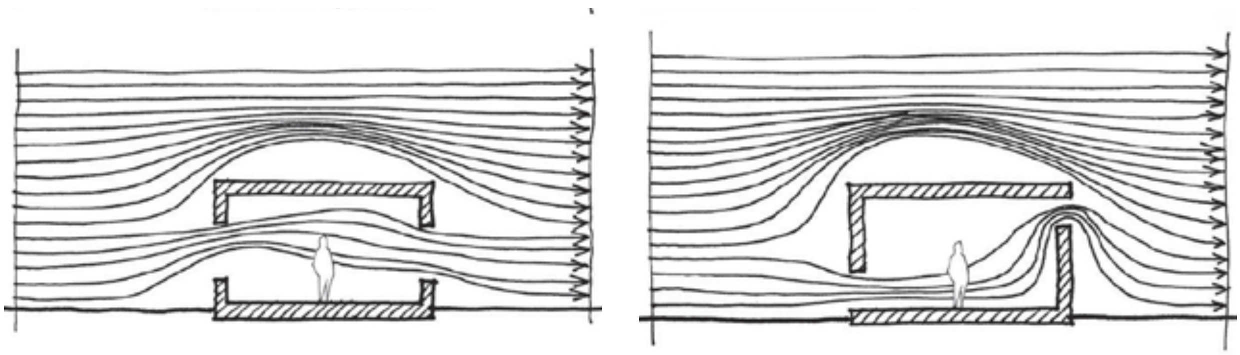
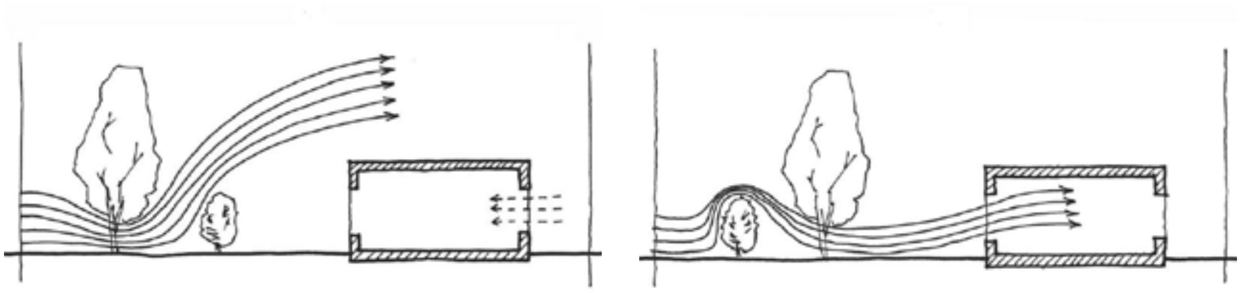


FIGURE 43. *EFFECT ON WIND ON TREES AND BUSHES CLOSE TO BUILDING*



(UN-Habitat, 2014)

INSPIRATION

HEALTHY HOMES PROJECT
The book: Healthy Homes in Tropical Zones - Improving Rural Housing in Asia and Africa by Jakob Knudsen and Lorenz von Seidlein, was published in 2014. It covers topics of building characteristics and construction, comfort, ventilation in relation to health issues and risk of mosquito-borne infectious diseases such as malaria in Asia and Africa. It gives a detailed understanding of local building styles and describe a series of house modification to improve ventilation and enhance comfort (Knudsen & Seidlein, 2014).

The continuation of the project is now an on-going construction of 6 concept homes in Magoda in Tanzania. The focus is to improve ventilation.

KITCHEN 2.0
Kitchen 2.0 is a design team at Michigan Technological University looking for innovative ways to reduce health impacts for people around the world using biomass for cooking. They have been working with HAP models using open source software for application in developing countries. They have also done field testing and physical full-scale testing in a controlled environment (Ruth et al., 2013).

SCHOOL KITCHEN NAIROBI
School and orphanage in the outskirts of Nairobi. Has both a big kitchen with LPG stove and area for food preparation. In a separate room there are two big firewood-stoves with chimneys. The roof has a outlet for smoke and the walls are made of slanting bricks that allow for cross ventilation.

C-RE-AID
C-re-aid is a Belgium-Tanzania NGO with focus on architecture and social enterprises with a base in Moshi Tanzania. The main work is conducted through summer projects were volounteers and/or architecture students help families from communities around Moshi who are in need of architectural interventions of some kind. The goals are both to research the social, psychological, physical and motivational impact that architectural interventions can have among people confronted with poverty, to increase awareness about vernacular architecture among architects in the West and to create change through improved living conditions and to inspire entire communities (C-re-aid, 2015).


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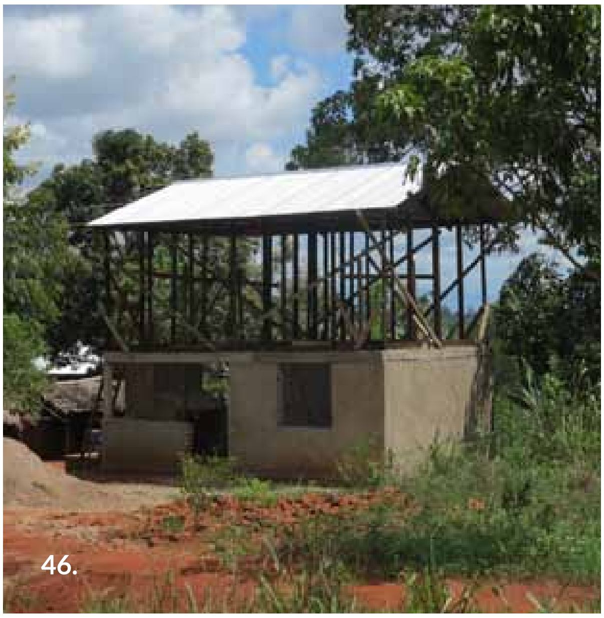
FIGURE 44-47.
HEALTHY HOMES PROJECT
Magoda, Tanzania



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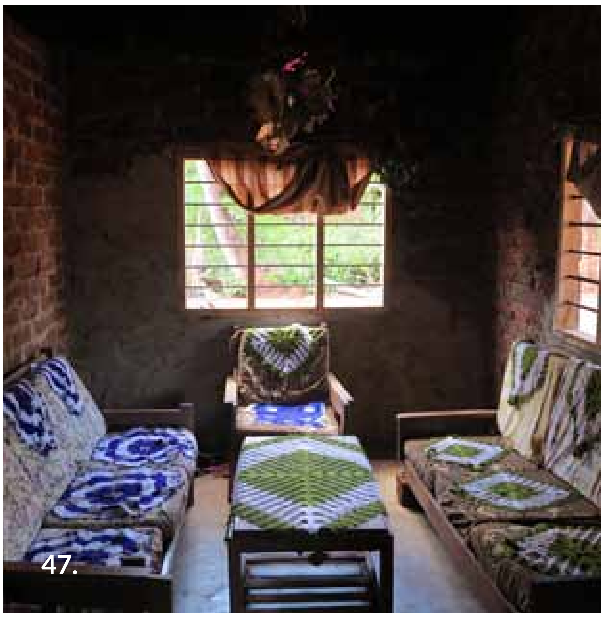

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FIGURE 48-50.
KITCHEN 2.0
Michigan, USA
Tanzania

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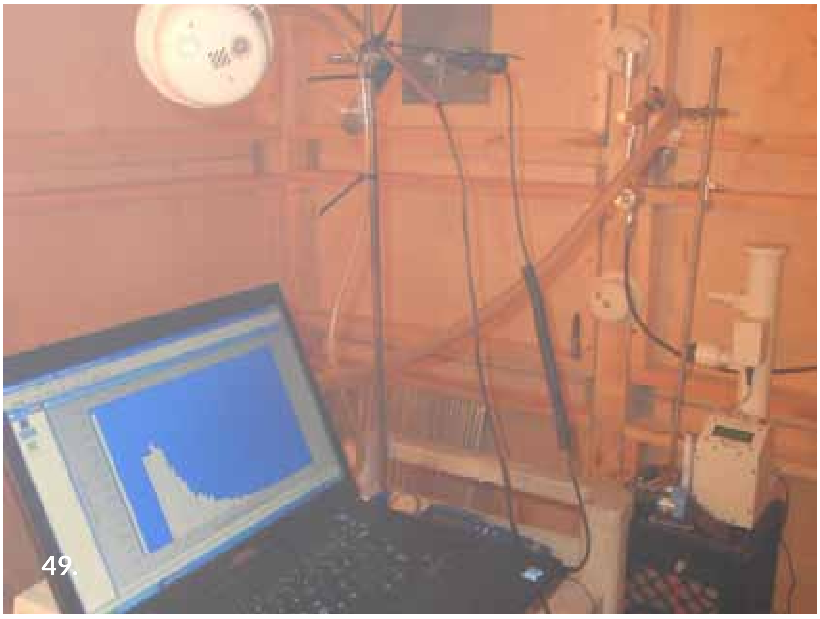

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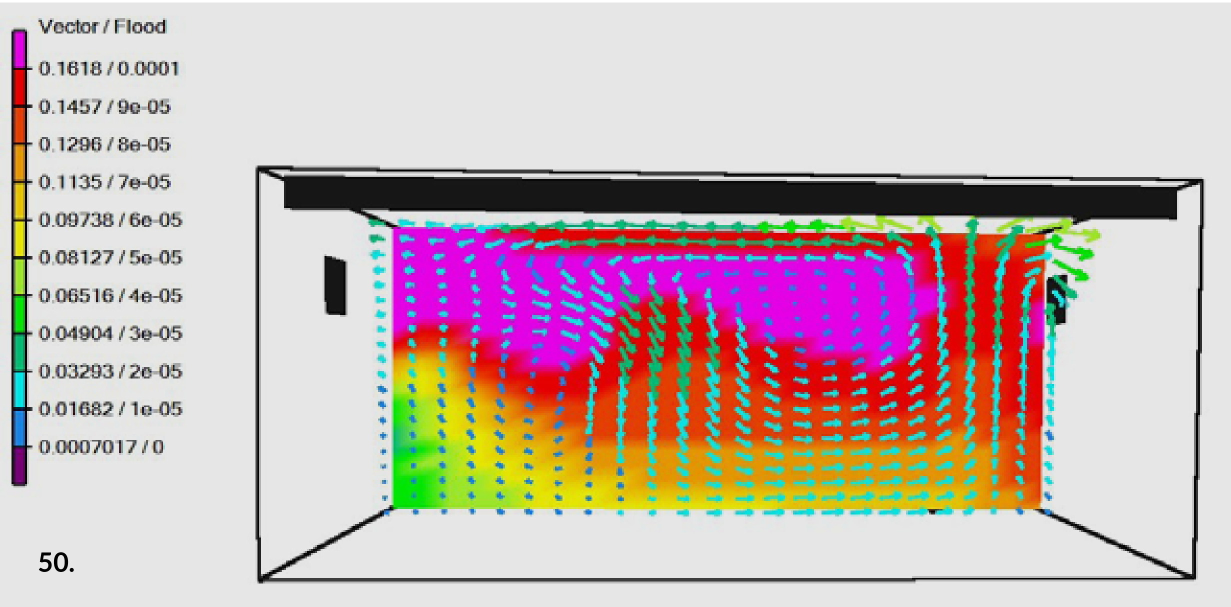

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FIGURE 51-54.
SCHOOL KITCHEN
Nairobi, Kenya


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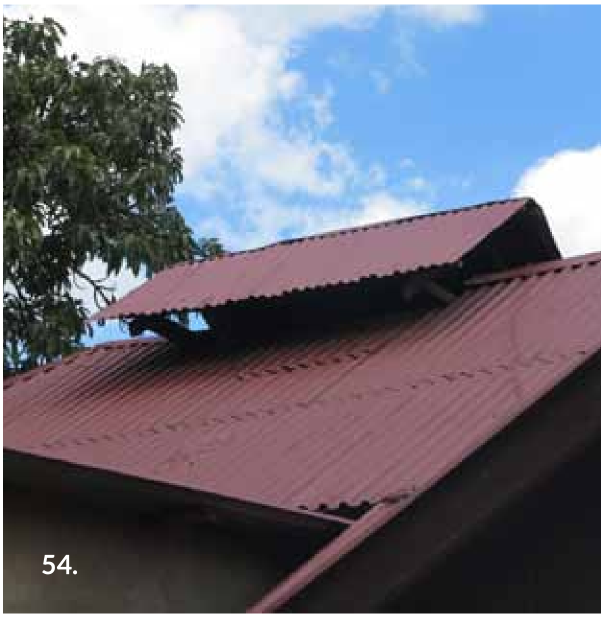
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FIGURE 55-56.
C-RE-AID
Arusha, Tanzania


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METHOD

This chapter will describe the project process, the methods and tools used and ethical considarations. The first section is about the quantitative study, Part I (interviews and questionnaires), data collection and data analysis. Questionnaries and forms are found as appendix. The second section is about the qualitative study, Part II (household visits), Methods used during visits and tools used when processing data and short workflow description.

PART I - QUANTITATIVE STUDY

Quantitative methods when working with household air pollution can include performance testing, indoor air pollution monitoring and questionnaires (WHO, 2005).

The reason for performing a quantitative study was to gather enough data to find possible correlations and to get a good understanding of the context, but it was also a method to find households for Part II.

The quantitative study was performed in Moshi municipal during February and March 2015. One public health centre (Pasua) and two dispensaries (Bondeni, Njoro) were chosen and approved by the Municipal Medical Doctor of Health at Moshi Municipal Council (Figure 3, map).

ETCHICAL CONSIDARATIONS

Ethical application was submitted to KCMU College Research And Ethics committee, and etchical clearence was recieved (Appendix B).

Permission to conduct the study at Municipal health centres and dispensaries was received from the District Medical Officer (DMO). The same permission also covered household visits.

A letter of permission (Appendix C) and information to the chosen facilities were given before starting the study.

The parent or caretaker of the child was invited to the study and informed in Kiswahili about the aim and procedure of the study. Oral consent was given before conducting the interview.
The participants were given an ID-number, no names were noted for participation in study Part I.
In the end of the interview, the parent was informed about the next step in the study. The information was translated to Kiswahili with help from bullet points written in English (Appendix D) In accordance with WHO guidelines they were informed that their service at the clinic would not be affected, whether they decided to participate or not (WHO, 2015a).

The participation was on voluntary basis. If the family was willing to welcome the study team to their home, the ID-number was written together with name and phone number to the mother or father and kept separate from the filled questionnaire datasheet.

STUDY POPULATION

Parents and caretakers to a child 1-24 months of age visiting the facilities for different reasons were asked to participate in the study. Both healthy and sick children were examined. Very sick children and caretakers under the age of 18 were excluded for the study.

QUESTIONNARIE

To gather data we developed a questionnaire based on versions used in Moshi by previous medical student from the Sahlgrenska Academy. The questionnaire was also supplemented with questions about the participant's house and kitchen. These questions and alternate answers were inspired by studies conducted by Practical Action in Kenya between 2003-2007 (Household Energy Network, 2010).

The questionnaire was written in English and later translated into Swahili (Appendix E).

The questions were both close-ended and open-ended. In some cases, according to availability, information was collected from medical notebooks brought by the careteker. The questions concerned the child's health, socioeconomic status of the family, living conditions, kitchen and building characteristics of the home.

A separate paper with sketches was used to clarify and to avoid misunderstandings regarding some questions about the house, cooking and kitchen (Appendix F).

DATA COLLECTION

We visited health facilities from about 9am-13pm.

An interview was performed using a questionnaire. The questions were asked in English and translated by a nurse to Swahili and the answers were then translated back to English and noted in a data-collection sheet (Appendix G).

Current length and weight of the child were noted.

At the end of the interview, the participant was informed about study Part II, and then asked to participate. People living in hostels, or in need of permission from husband or relatives, or persons without access to mobile phone were excluded for practical reasons.

An experienced nurse performed the sample collection from the posterior wall of the nose of the child (nasopharynx). During the procedure the parent held the child, and the medical student held the head of the child in a fixed position.

Each interview including examination took about 10-20 minutes.
The samples were transported and processed later the same day at the clinical laboratory at KCMC.

DATA ANALYSIS

The data was processed in two programs and breif workflow is described below:

MICROSOFT EXCEL

All answers from the questionnaires were noted on a datasheet as mentioned before and transferred to a Microsoft Excel document later the same day.

SPSS

The raw-data from Excel was imported into IBM SPSS Statistics version 22 for Mac for further data analysis. Some of the variables were recoded into different values and crosstabulations were made to analyse the data. Fisher's exact test was made to calculate statistical significance, i. e. p value."

PART II – QUALITATIVE STUDY

Qualitative methods help to reveal the perspectives of individuals or communities and provide important contextual data to explain the results of quantitative analyses. They include in-depth, open-ended interviews, direct observations of behaviours and participatory methods (WHO, 2005).

In the end of Part I, the caretaker was asked to participate in Part II. Willingness and available contact information (name and phone number) was an absolute criteria for participation in Part II.

For logistical reasons in this pilot study only families visiting Pasua Health Centre were selected for household visits. The remaining participants were filtered based on the answers given in the interview questionnaire in Part I to find households of different type, size, socioeconomic status and with different kitchen characteristics.

The households were not chosen based on the respiratory health of the child.

ETHICAL CONSIDARATIONS

At household visit, the mother or the person responsible for cooking was given an informed consent form (ICF), written in Kiswahili (Appendix H). Two copies of the form were signed, both by participant and medical researcher. No treatment was given by the research team.

As a token of appreciation for the families opening up their home, a Kanga (an African piece of fabric) was given as a gift at the second visit. This was not part of the terms presented on beforehand.

The result from the CO measurement was given to participating households in individual letters, available at Pasua Health Centre (Appendix I).

DATA COLLECTION

The family was contacted by phone one to three days before the planned household visit. For logistical and practical reasons we were not able to spend the whole day in one household. Instead the day was divided in two, as shown in Figure 57.

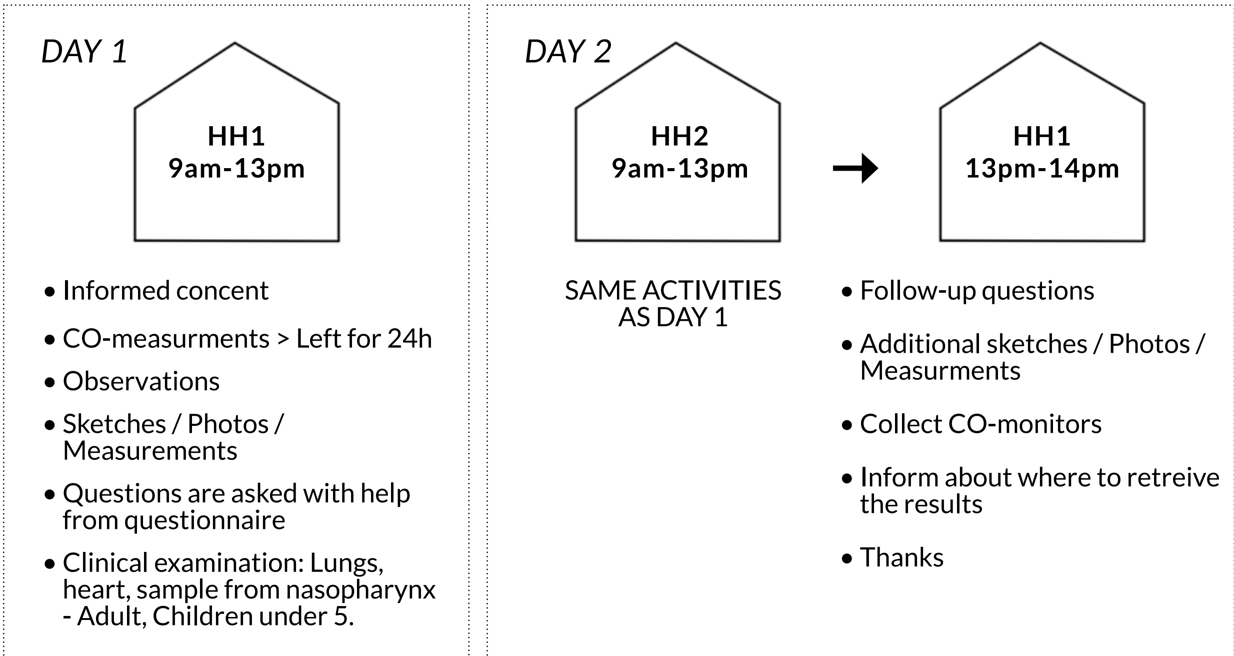

FIGURE 57. *HOUSEHOLD VISITS* - What activities, when and where.

At 8 am we came to Pasua health centre with a car from KCMC. The local nurse called the household to get detailed directions.

When we arrived at the house, we were welcomed inside. We then sat down, described the purpose of our visit and read through the ICF. Then we asked for a tour of the home and started the monitoring, measuring and observations as described below.

At around 13pm a driver picked us up and drove us to the household we visited the day before to retrieve equipment and ask additional questions.

At an early stage a data-collection-matrix was made as a help to categorise and concretise what type of data could or should be collected during a household visit (Appendix J).

The information collected during the household visits can be divided into four categories:

SITE

Using a GPS-equipped smartphone we logged the location of the household to easily find our way back. The weather conditions and wind direction was noted on a datasheet (Appendix K), this information was later checked against online weather information from Moshi Airport (World Weather Online, 2015).

A quick site-plan sketch was made to be able to remember the site conditions; nearby buildings, water and sanitation, vegetation etc.

BUILDING PROPERTIES

During our visit, after introduction of the family and household, sketches of the house (plan and section, not to scale) was drawn on a datasheet, and then using a folding ruler, measurements were added to the sketch. Starting with exterior measurements then interior. Placement and size of openings, windows and doors were clearly marked.

A DSLR Camera, two different lenses and a tripod (Pentax K7, Pentax SMC 50mm, Pentax SMC 18-55mm) were used to photograph the exterior and interior of the household as well as details of building material, cooking environment and on-going activities. In some households the house or kitchen was photographed 360° in order to try out a mapping process called "Photogrammetry".

CARBON MONOXIDE EXPOSURE AND INDOOR ENVIRONMENT

On an early stage in the planning of this study it was decided to measure carbon monoxide (CO) exposure. The reasons for choosing to measure only CO were that several studies have shown that CO work as a relatively good marker for other pollutants when measuring smoke from burning solid biomass fuels (Practical Action, 2007; Yamamoto et al., 2014).

The available equipment for measuring CO is also light, easy to use and cheap in comparison to for example equipment used for measuring particulate matter (Practical Action, 2005).

Two sensors (LASCAR EL-USB-CO Carbon Monoxide Data Logger and LASCAR EL-USB-2-LCD+ Humidity and Temperature Data Logger) were placed on a mobile wooden stand to measure area exposure and the indoor environment (Figure 60-62).

The stand was built to a height of 145cm, which is the average breathing height of a standing woman with a young child carried on her back (Yamamoto et al., 2014).

Where possible the stand was placed at a distance of at least 100cm from both stove and openings in the cooking area.

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FIGURE 58-59.
PREPARATION
”Calibration” of sensors, and two identical wooden stands.

FIGURE 60-62.
AREA EXPOSURE
Placement of stand in kitchen. Data-loggers attached to stand.

FIGURE 63.
PERSONAL EXPOSURE
CO-sensor attached to womans clothing.

A second sensor (LASCAR EL-USB-CO Carbon Monoxide Data Logger) was attached to the woman's clothing close to the breathing area (Figure 63). During the night, the woman was asked to place the sensor next to the bed.

Before starting Part II the sensors were "calibrated". They were placed next to each other in close proximity to a fire during a short period, the result from the measuring was later checked so that the sensors showed approximately the same values (Figure 58).

The sensors were programmed to start measuring from 9 am and to continue "real-time" measuring until manually stopped. The sensors were left for at least 24 hours to capture one day of cooking and logged the concentrations and conditions every tenth second. The time for starting monitoring was noted on a datasheet.

COOKING AND HEALTH
While on-going data collection described above, the medical student was observing the person responsible for cooking. The observations included cooking habits, position of the child during cooking, surrounding area and neighbours. The observations were noted in a datasheet (Appendix L), while questions about health and kitchen were asked and noted into an interview questionnaire (Appendix M). The questions were repeated and asked in a different way when there were difficulties understanding.

The mother and all children at home below five years of age underwent a health examination. The examination included heart and lung auscultation, including heart and lung rate. Signs of respiratory tract disease including cough, running nose, sneezing and a sore throat was observed as well as running eyes. The results were noted in a datasheet (Appendix N).
The person responsible for cooking also performed a spirometry (a lung function test).

Children under the age of 5 as well as the person responsible for cooking were sampled for bacteria from the posterior wall of the nose (the same type of sample collected from the child 1-24 months of age when visiting the health care centre for Part I). A local nurse conducted the sampling.

When collecting the equipment, questions about the last day were asked, including cooking times, used fuels, exposure to cigarette smoke and the last day's experience of wearing the sensor.

DATA ANALYSIS
The data collected during household visits was processed in four programs and breif workflow is described below:

LASCAR EASYLOG SOFTWARE
The sensors were plugged into the USB-port and the logging stopped. The data was transferred to EasyLog Software 4.3, saved and later exported as comma delimited file (.csv). Graphs from the program showing mean, min and max values were saved as picture files (.jpg).

MICROSOFT EXCEL
In a new document the data was first imported (File-Import-CSV) then all dots were replaced with commas (Edit-Replace-Replace All) in order to perform calculations in Excel. The data set was altered to only show readings from when the measuring started (for example 9.30 am instead of 9 am) up until the same time the following day. The rows and values before and after these times were deleted, leaving 8640 readings.

A line chart with fixed axes values was produced to give consistency when comparing the graphs from area and personal exposure as well as data from different households. The charts were exported as picture files (.png) to be used as presentation material.

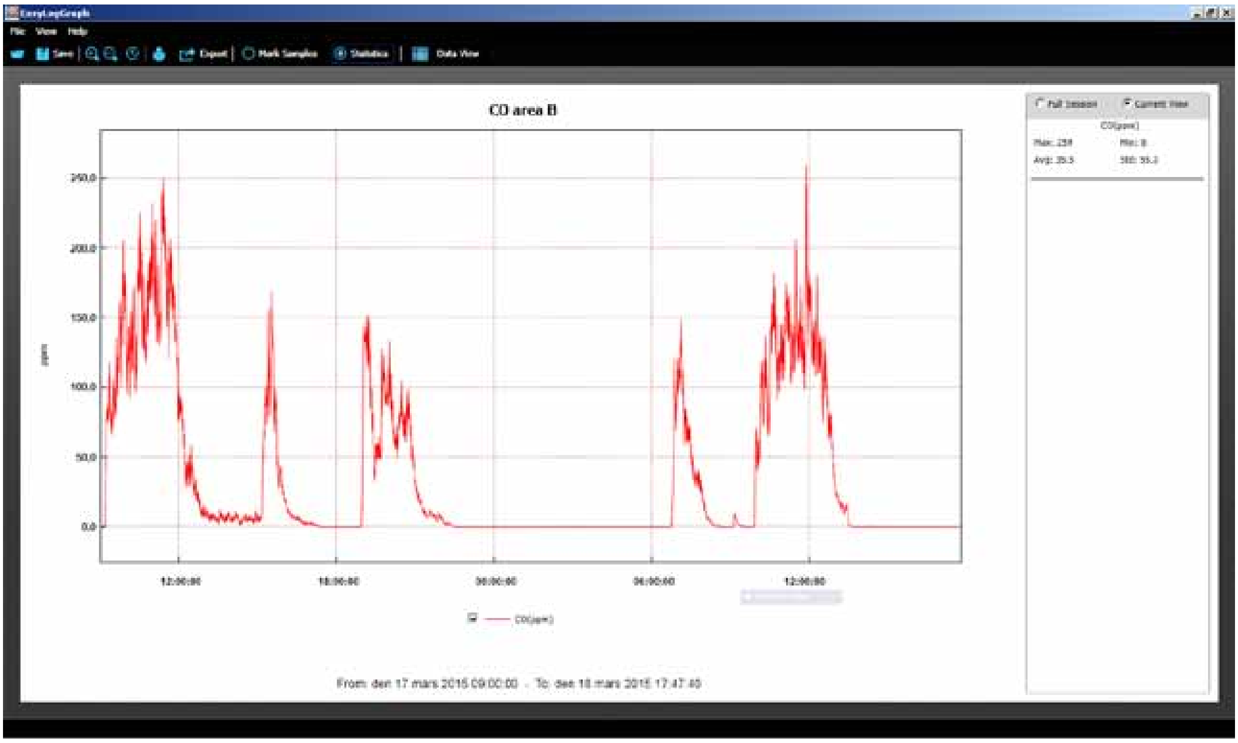


FIGURE 64. *LASCAR EASYLOG SOFTWARE*
The software used to set-up, manage and extract data from the USB-loggers is user-friendly and gives the possibility to view the result from the measurments directly in the program as a graph. The workflow of simple set-up, program start-time and measuring intervals worked flawless.

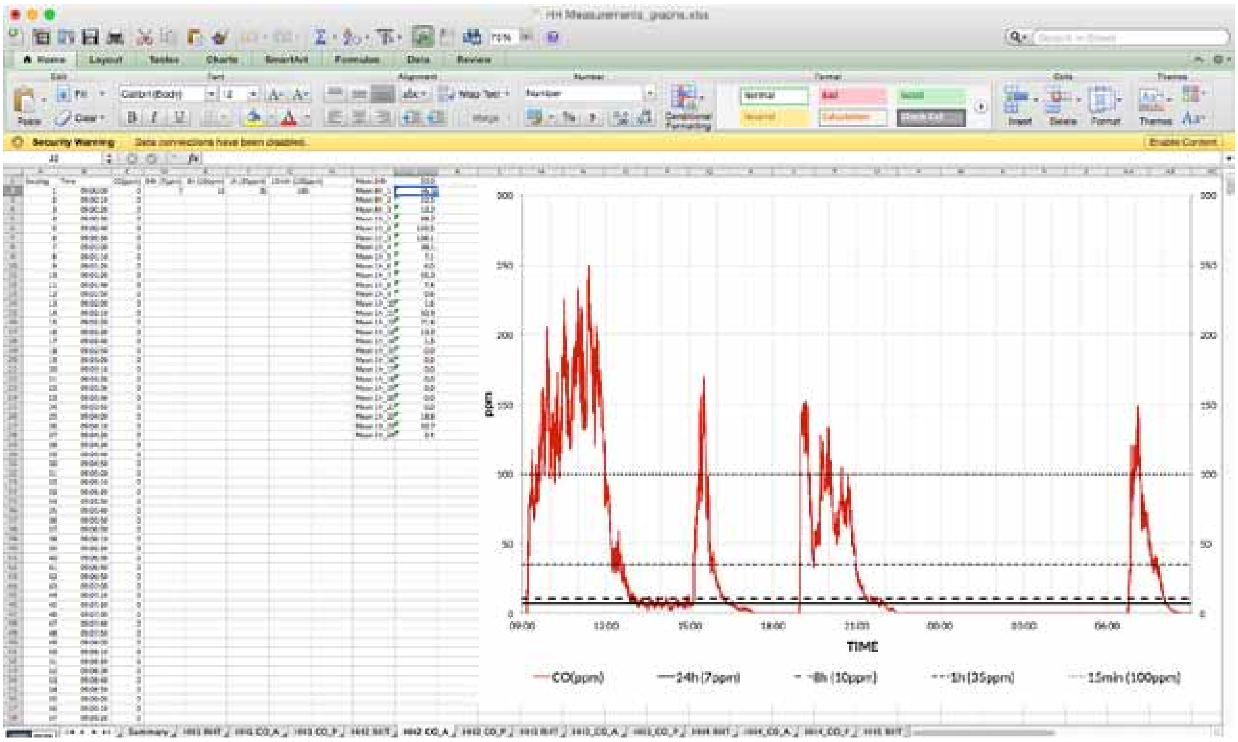


FIGURE 65. *MICROSOFT EXCEL*
Since the graph produced in the Lascar software adapted the scale of the chart to the data instead of user-defined values, it was a bit hard to visually compare the result from different households. Therefore and also to make it easier to calculate mean values, data was imported into Microsoft Excel.

Part from this the data were used to calculate the following:

- Mean 24h exposure (all readings)
- Mean 8h exposure (reading 1-2880, 2881-5760, 5760-8640)
- Mean 1h exposure (reading 1-360, 361-720, 721-1080 etc.)

AUTODESK REVIT ARCHITECTURE

Sketches and measurements from the field were translated into model lines in a plan view in Autodesk Revit Architecture. These lines were used for placing walls and later windows and doors.

The models were made as simple as possible with low detail level. Custom Revit-families for doors and windows were produced.
Presentation material, plans and sections were saved as PDFs.

In selected case study model, phases were used to represent different interventions and alternate designs.

From a 3D-view showing all model information for current situation (current phase) the model was opened in Simulation CFD from the Add-Ins tab. (This step was repeated for all phases resulting in 5 designs in Simulation CFD)

AUTODESK SIMULATION CFD

CFD stands for Computational Fluid Dynamics and is software to calculate and visualie flows of fluids or gases in a model. CFD-software can also be used to calculate heat transfer and mixing of fluids (contaminant and emissions tracking). The software makes it possible to do virtual testing of a design before building.

Traditional emission models with manual culculations have been used for more than 30 years. The single zone model assumes that the pollutant emitted into room air is uniformly mixed throughout the space. Concentrations is determined by emission rate and a number of other factors including duration of combustion, room volume and air exchange rate. The three zone model divides the room into three zones - a plume rising above the combustion device; warm air within a given distance from the ceiling; and the rest of the room. It is assumed that uniform mixing occurs in each zone. The computational fluid dynamics model consider multiple forces involved in transporting air and pollutants within a room, by dividing the space into a large number of small units. (Johnson, Edwards, Marawska, & Smith, 2014)

Historically CFD has been difficult, resource intensive and expensive. It also took a lot of time. But now, with enablers like more computing power, better 3D-modeling software and more user friendly CFD-software it is more accessible and should be possible to apply in more projects.

Pre-processing: Autodesk Simulation CFD is closly integrated with other Autodesk Software like Autodesk Revit. In theory a model created in Revit can be opened up in CFD with correct categorising and material applied. And reduce set-up time compared to a traditional workflow.

In CFD you start with a design (a model geometry), and a scenario. In the scenario materials are applied Fig. 71). Then boundary conditions are applied to surfaces and volumes to give the correct information and input for the simulation (Fig. 72). Finally a mesh is defined (Fig. 73).

Processing: Soliving - The solver use the inputs, parameters and conditions applied to the model to ”solve” the flow calculations (Fig. 74).

Post-processing: Results visualisation (Fig. 75).

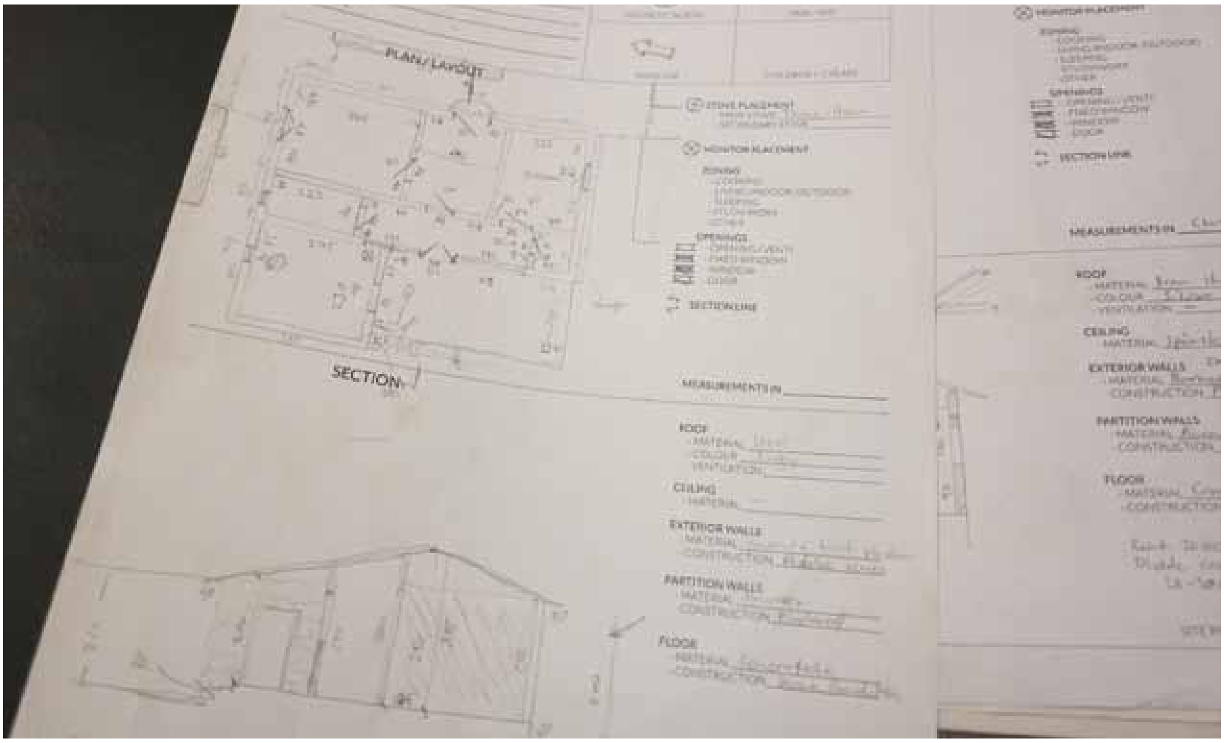


FIGURE 66. *SKETCHES TRANSFERRED TO REVIT ARCHITECTURE*
Sketches produced in the field were manually transferred into revit as lines. These lines were used as references for walls, roof, floor etc.

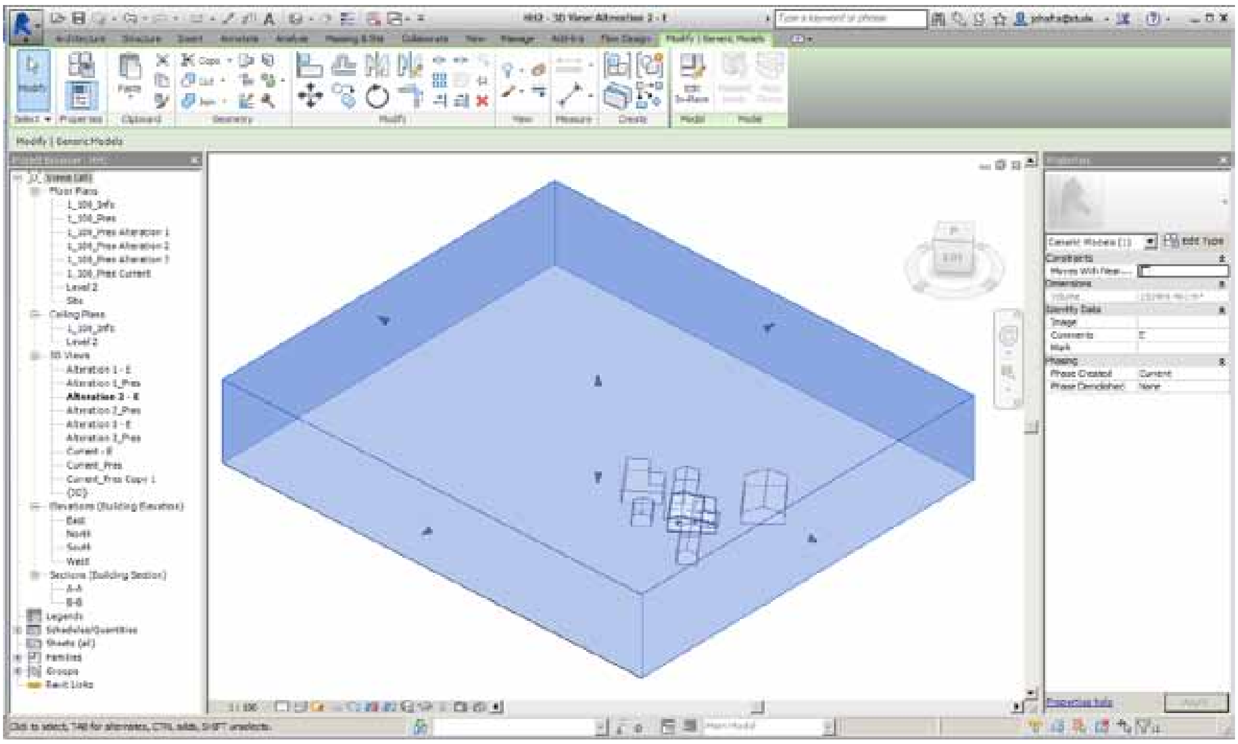


FIGURE 67. *SIMPLE REVIT MODEL*
All houses visited in Part II were modeled in Revit as simple models without unnecessary detailing. These models were used to produce presentation material. One case study house was later elaborated to be used in Simulation CFD. The blue box (generic model) in the model shown above represent the exterior air-space and is rotated to correspond to the wind direction the day of the visit.

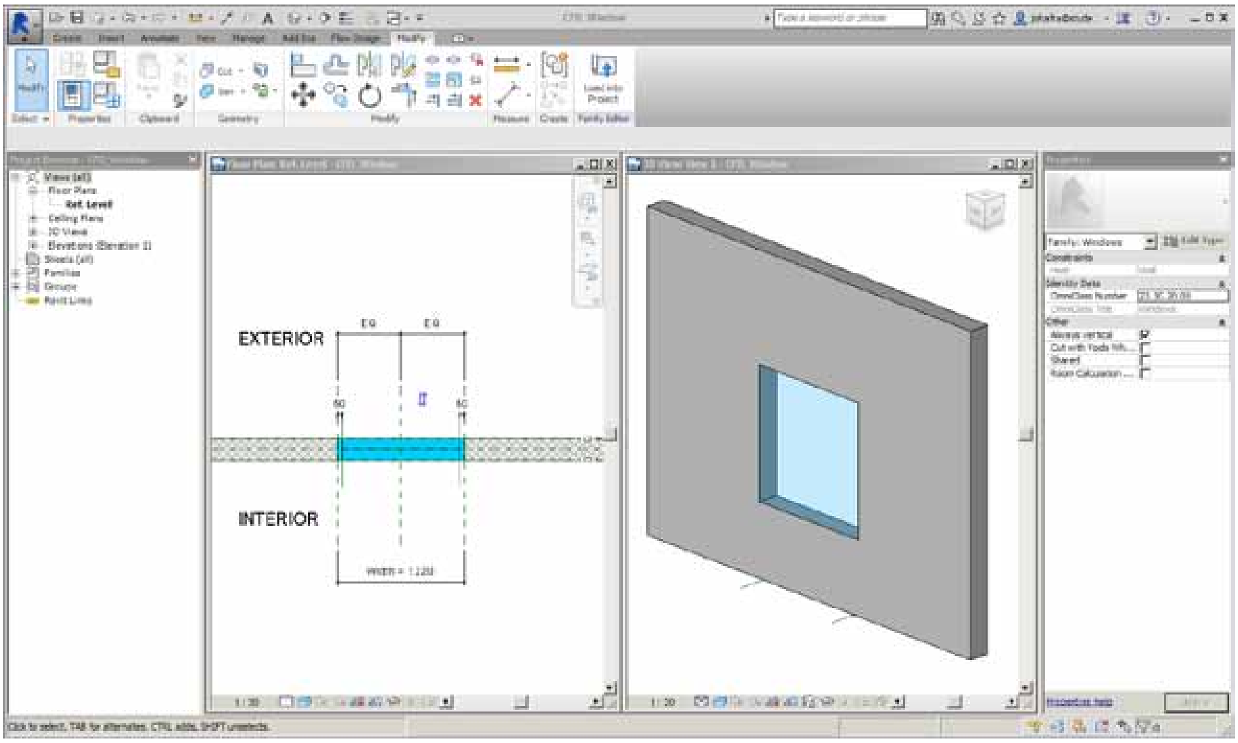


FIGURE 68. *CREATION OF SIMPLE REVIT FAMILIES*

Simplified Revit ”families” (component files imported into projects), were created to minimise the amount of unnecessary geometry in the project. To much detail would substantially increase the time for set-up and simulation in Simulation CFD.

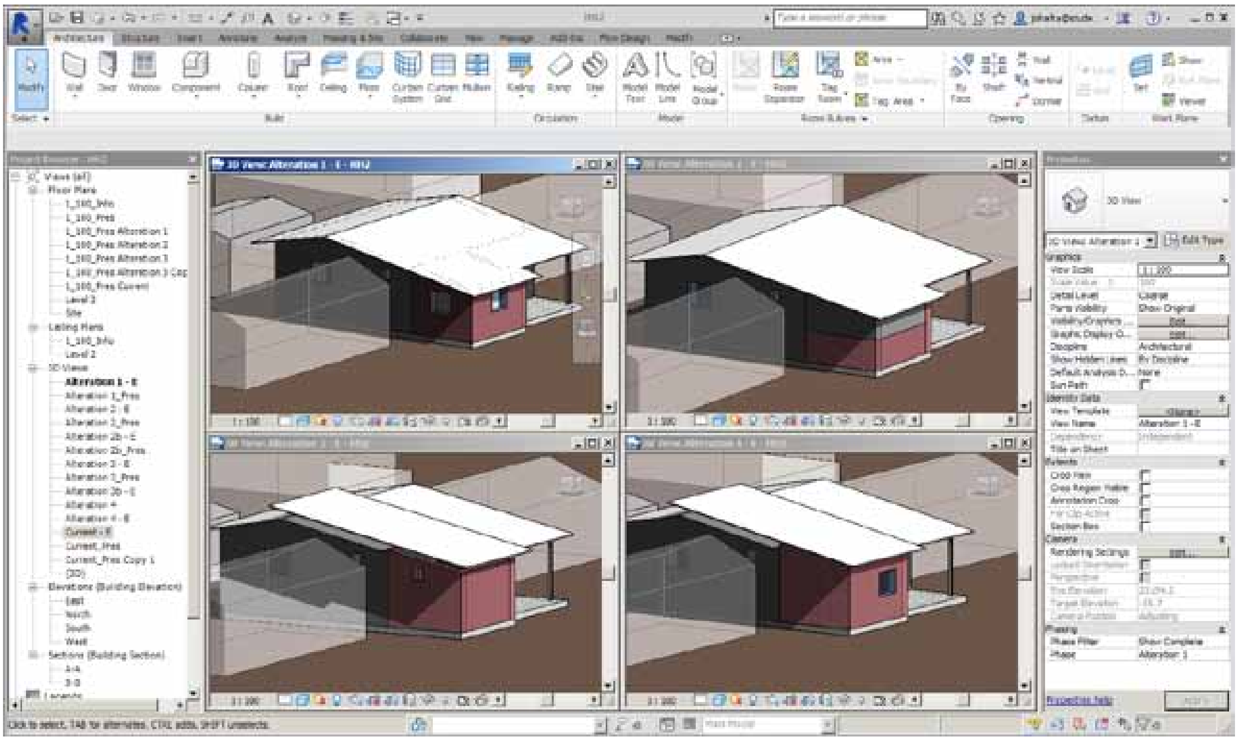


FIGURE 69. *MULTIPLE DESIGNS WITHIN REVIT*

By using ”phases” in Revit, additional 4 alternate designs were modeled. These design are better described in the case study in the result chapter later in this thesis. Individial views were created for each design, both in plan, section and 3d.

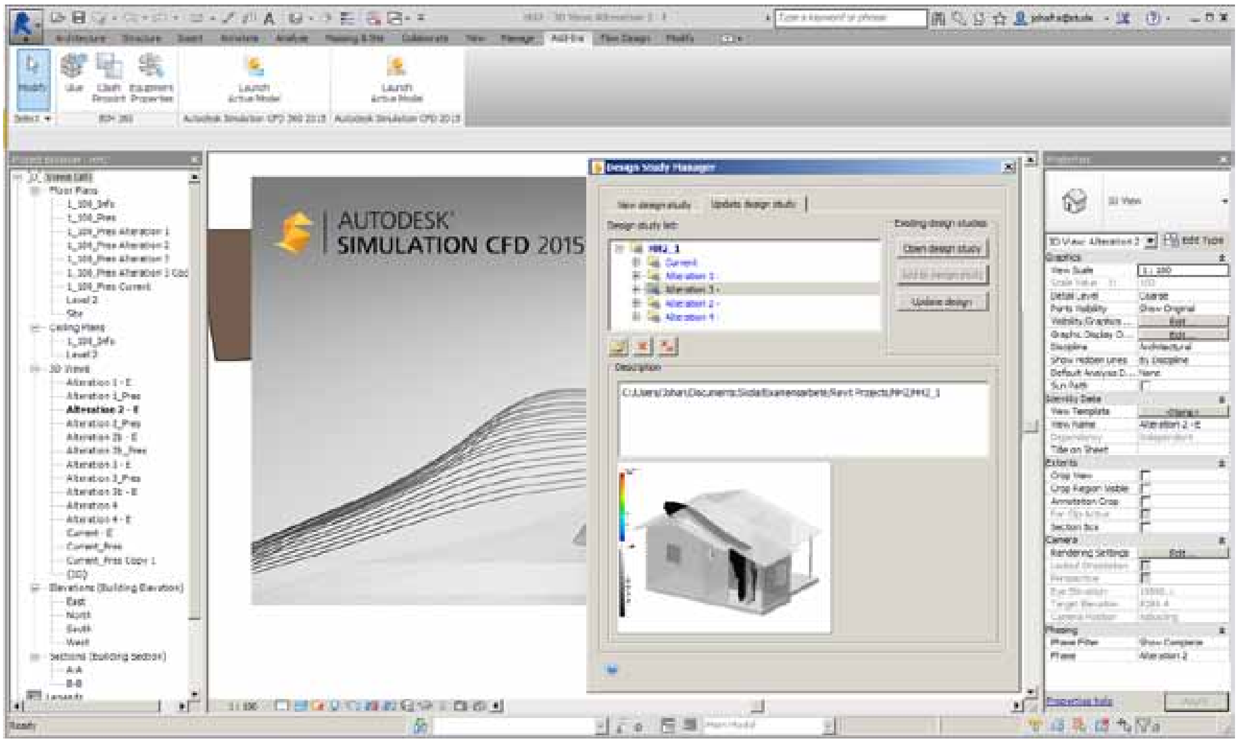


FIGURE 70. *OPEN MODEL IN SIMULATION CFD*
When having a 3D view open with all geometry wanted in the CFD model, the active model is opened in Autodesk Simulation CFD through the Revit plugin. After initial set-up in Simulation CFD, the CFD design was ”cloned” and the alternate design in Revit was added to the new cloned design study in Sim CFD.

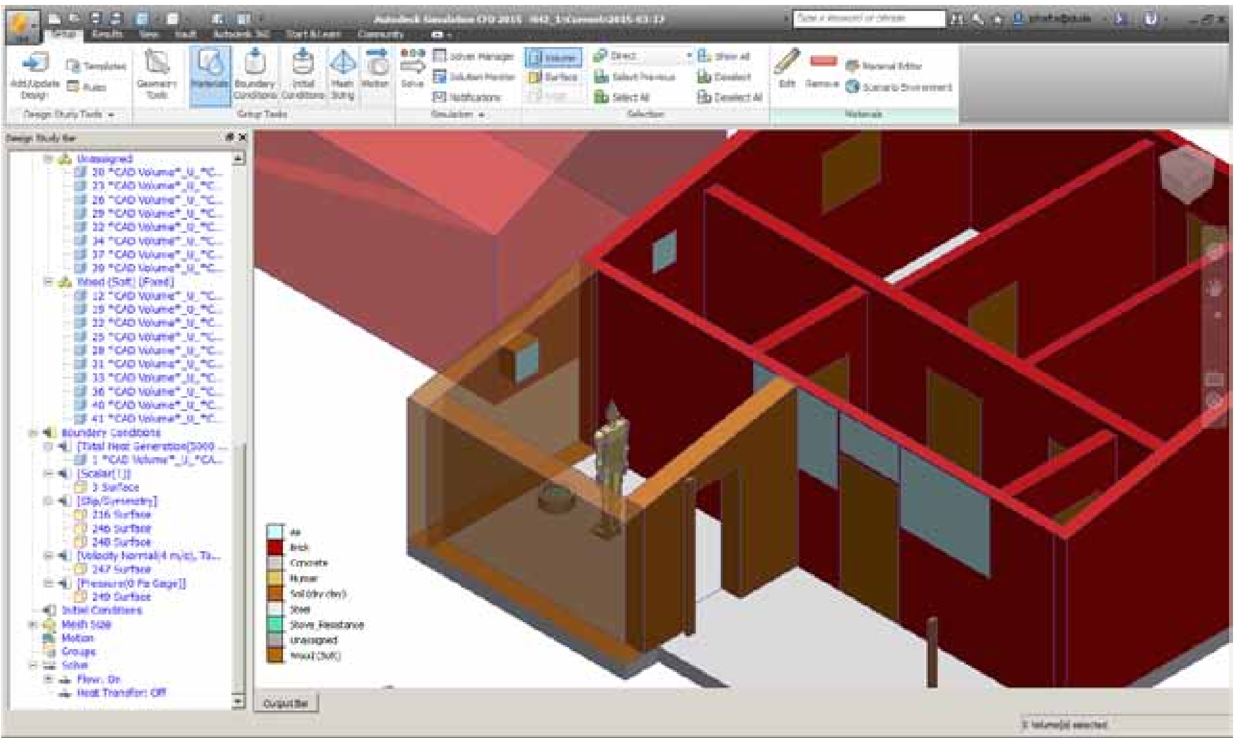


FIGURE 71. *SIMULATION CFD SET UP - MATERIALS*
Many materials and materials parameters are available in the software. And materials are added to the cad-volumes as fluid, solid or resistance materials. The ”open windows” are modeled as ”air”. The stove is modeled as resistence material that releases heat into the environment.

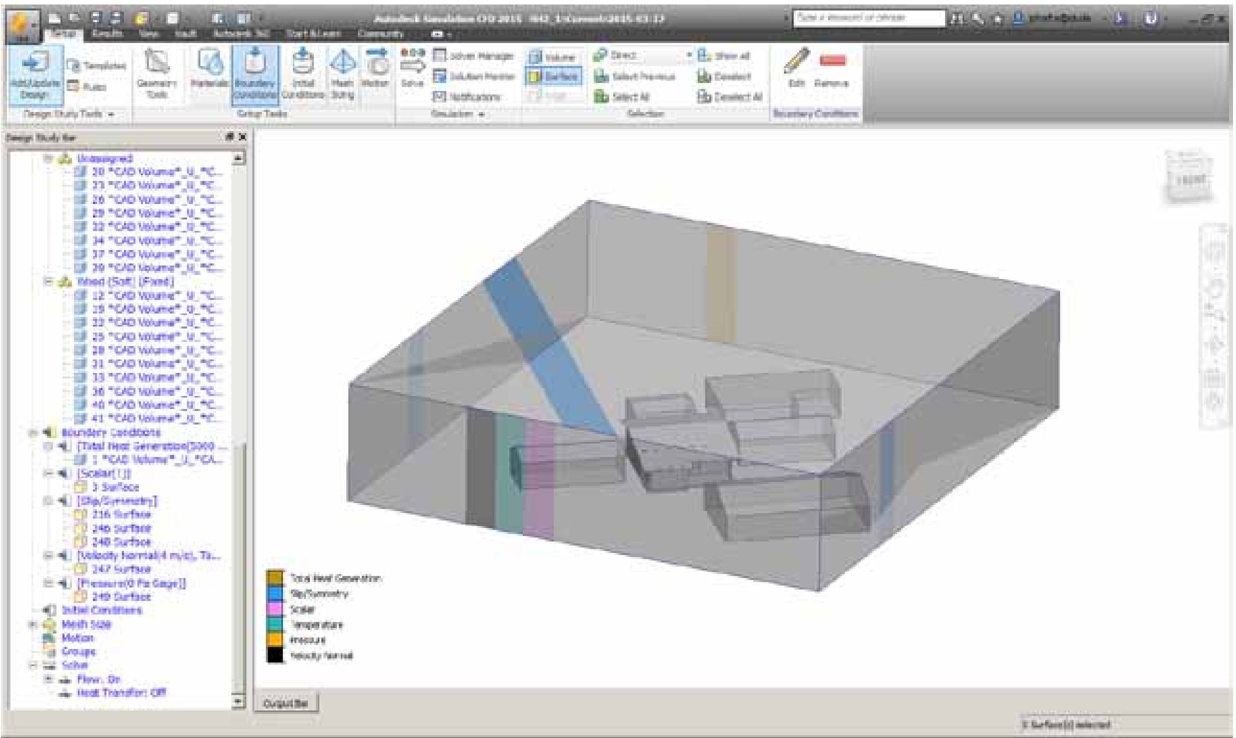


FIGURE 72. *SIMULATION CFD SET UP - BOUNDARY CONDITIONS*
In order for the software to make realistic simulations it is important to add the correct input values, as initial conditions, and boundary conditions. Boundary conditions are added to the exterior air-mass in this model with information of the wind speed, air temperature, pressure etc.

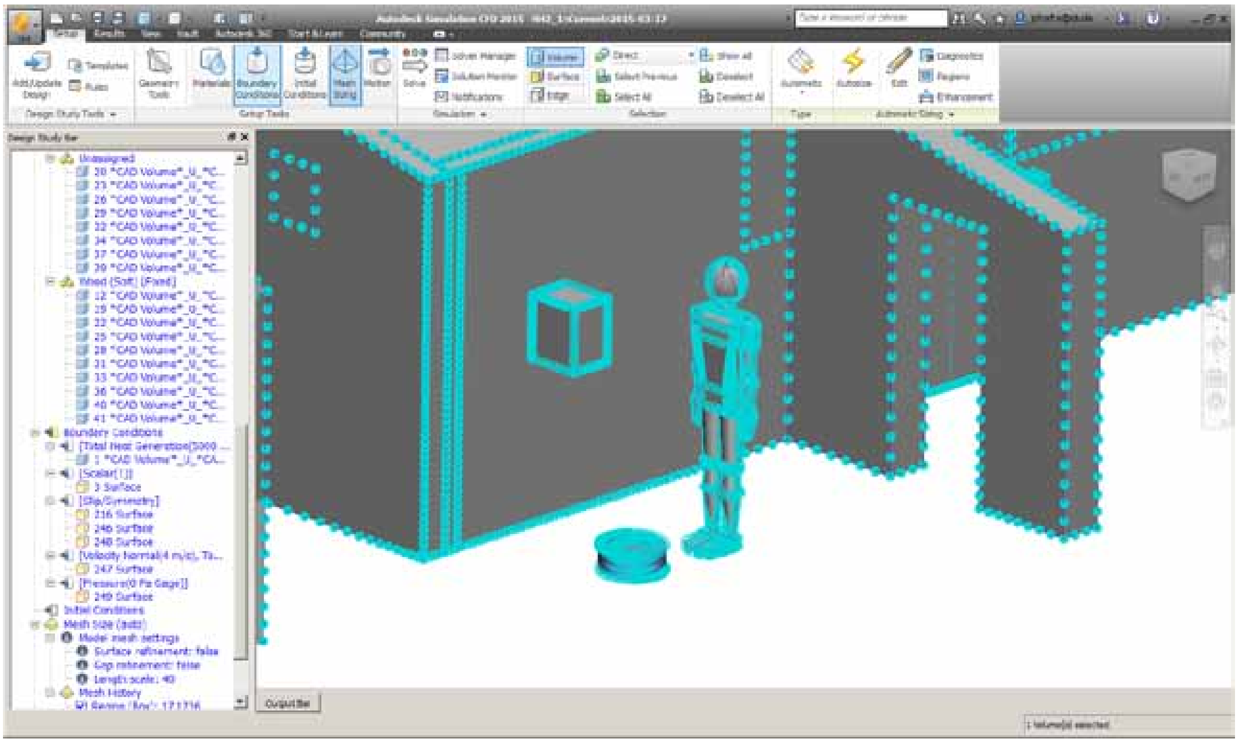


FIGURE 73. *SIMULATION CFD SET UP - MESHING*
Meashing is the process of breaking up solid domains to many smaller regions to improve solving. The mesh size and the model complexity affect the solving time but also the accuracy of the result. Smaller goemetry get a finer mesh than large geometry.

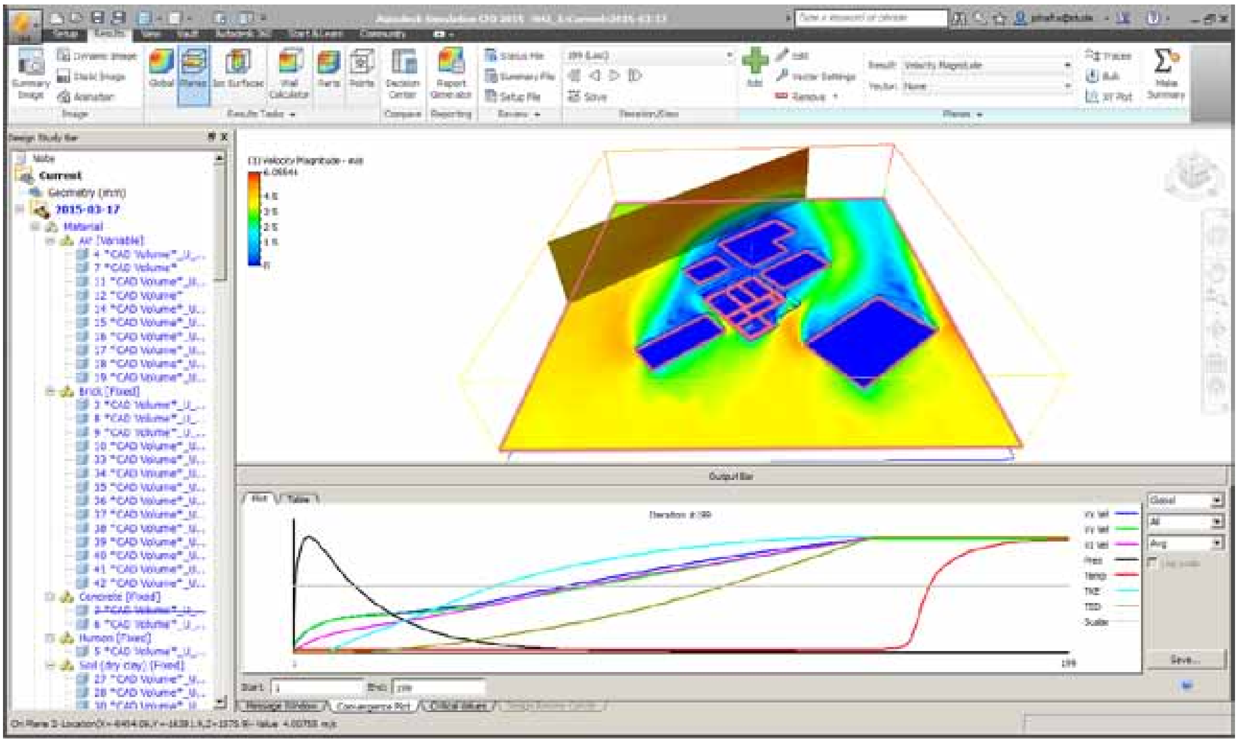


FIGURE 74. *SIMULATION CFD - SOLVING*
The solution time vary based on factors as hardware capability and model complexity, but also on the number of "iterations". The number of iterations has to be enough for the simulation to reach convergence. The possibility to use cloud-solving can make it possible to run multiple design alternatives simultaneously.

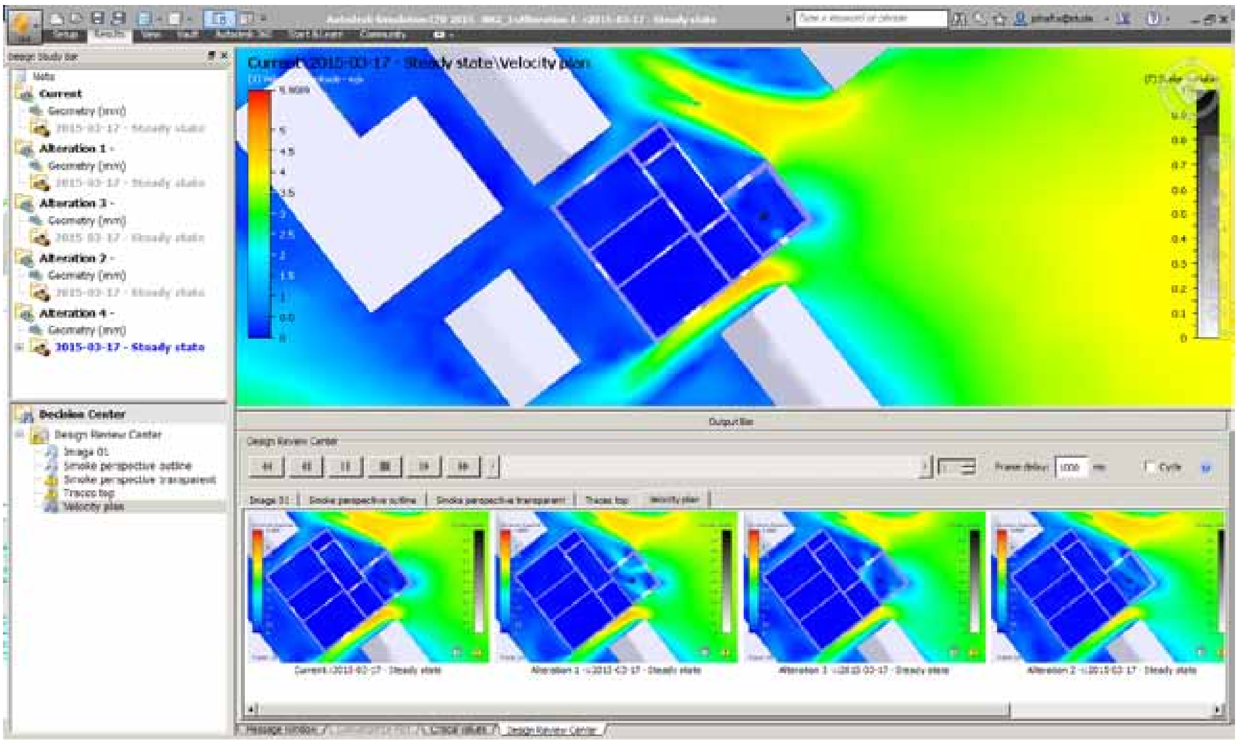
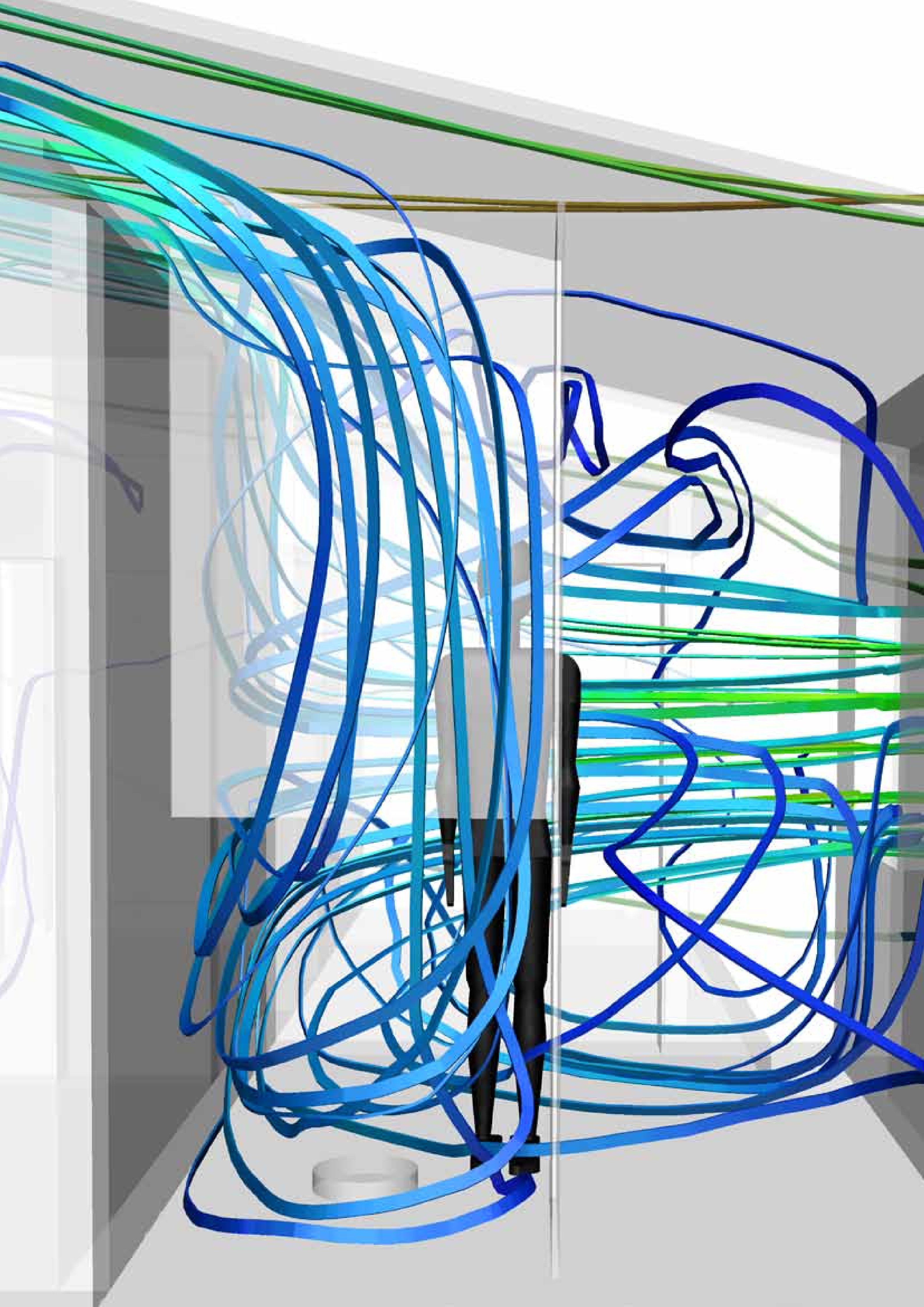


FIGURE 75. *SIMULATION CFD - RESULT*
The objective of every simulation is to understand design performance, and to be able to present the result in an appealing and understandable way. The software makes it possible to compare different designs and scenarios side-by-side for visual review.



RESULT

In this chapter the result from the quantitative and qualitative part of the field study is presented (Part I and II).

The focus of this thesis was to investigate a method for analysing interventions through computer simulations using site specific data. This information was collected during houshold visits and is presented for Household I-VI.

In the end of the chapter the result from applying the method of simulating different design interventions to a case study house is presented.

PART I – QUANTITATIVE STUDY

Questionnaire answers from a total of 213 interviews have been summarised in tables 6-8, where the study population characteristics are presented. The results from questions about household energy, cooking location and building construction are presented in tables 9-11.

CHILD		Frequency	Percent
Gender	Girl	102	47.9
	Boy	111	52.1
Age	1-6 months	70	32.9
	7-12 months	82	38.5
	13-18 months	44	20.7
	19-24 months	17	8
Breastfeeding	Yes	196	92
	No	17	8
Current respiratory symptoms*	Yes	116	54.5
	No	97	45.5
Antibiotic used last 3 months	Yes	137	64.3
	No	76	35.7
Fully vaccinated for age	Yes	213	100
	No		

**chills, rapid or difficulty breathing, cough, running nose, sore throat - with or without fever*

TABLE 6. *STUDY POPULATION CHARACTERISTICS - CHILD*
A majority of the children had some respiratory symptoms the day of the interview, a large part of the population had used antibiotics the last 3 months and all were fully vaccinated for their age.

FAMILY		Frequency	Percent
Education level	Primary school	242	58.3
	Secondary school	144	34.7
	University	13	3.1
	Occupational training	11	2.7
	No education	5	1.2
Employment status	Self employed	260	61.6
	Unemployed	84	19.9
	Employed	78	18.5
Family size	> 3	145	68.1
	≤ 3	68	31.9
Smoking	No	186	87.3
	Yes	27	12.7

TABLE 7. *STUDY POPULATION CHARACTERISTICS - FAMILY*
Most of the parents had finished primary school and most were self employed. The unemployed were mainly mothers who stayed at home taking care of the child/children.

HOUSE		Frequency	Percent
Type of house	Multi-family house	150	70.4
	Single-family house	50	23.5
	Semi-detachted house	13	6.1
Number of rooms	1	81	38
	2	54	25.4
	3	26	12.2
	>3	52	24.2
>1 stove in household	Yes	188	88.3
	No	25	11.7
Access to mobile phone	Yes	201	94.4
	No	12	5.6

TABLE 8. *STUDY POPULATION CHARACTERISTICS - HOUSEHOLD, HOUSE AND KITCHEN*
Over 70% of the families lived in a multi-family house. Almost 90% used more than one stove/fuel for cooking. Only 5.6% lacked access to a mobile phone.

HOUSEHOLD ENERGY		Frequency	Percent
Most important fuel for cooking	Charcoal	103	48.4
	Kerosene	64	30.0
	Wood	29	13.6
	LPG (Gas)	16	7.5
Secondmost important fuel for cooking	Kerosene	85	39.9
	Charcoal	69	32.4
	LPG (Gas)	25	11.7
	Wood	8	3.8
Most important fuel for lighting	Electricity	155	72.8
	Kerosene	41	18.8
	Solar	16	7.5
	Batteries	1	0.5
Secondmost important fuel for lighting	Kerosene	74	34.7
	Wax Candle	38	17.8
	Solar	27	12.7
	Batteries	3	1.4

TABLE 9. *HOUSEHOLD ENERGY*
81% of the population used charcoal for cooking as most, or secondmost important fuel. The percentage for kerosene was 70%. 17% used firewood and 19% used LPG. 72% had electricity and 17% had solar.

COOKING LOCATION	Frequency	Percent
Outside	113	53.1
Part of main living area	104	48.4
Separate building	44	20.7
Enclosed area inside (kitchen)	30	14.1
Separate room attached to main house	12	5.6
Semi-open area	4	1.9

TABLE 10. *COOKING LOCATION*
Many people cook in different locations during different times and when using different stoves/fuels. In general, the people who cook inside the main living area also cooks outside. For sketches, see Appendix F.

KITCHEN, MATERIALS AND VENTILATION		Frequency	Percent
Ceiling in cooking area	No	125	58.7
	Yes	88	41.3
Material of the walls in cooking area	Burned bricks	87	40.8
	Concrete blocks	55	25.8
	Plastered	26	12.2
	Adobe blocks	18	8.4
	Wood	9	4.2
	Iron sheets	8	3.7
	Wattle-and-daub	5	2.3
	Cardboard	1	0.5
	No walls	4	1.9
Ventilation in cooking area	Window	184	86.4
	Venti	108	50.7
	No walls	4	1.9
	Chimney	1	0.5

TABLE 11. *BUILDING CONSTRUCTION*
100% of the interviewees had iron sheet roofing. Plastered walls are probably made up of bricks, stabilized compressed earth blocks (CEB), concrete blocks or adobe blocks.

A summary of the result found by the medical student is presented in Tables 12-15, (Appendix O), it shows the correlations between different household characteristics and the health of the child.

If we compare the results from Part I with the statics from 2012 (Table 2, Table 4), we can conclude that generally, people in Moshi are better off than the rural/urban average in Tanzania, and in Kilimanjaro region.

PART II – QUALITATIVE STUDY

Of the 213 participants, 166 agreed to home visits. 18 households were selected, of which 13 were contacted. Since several participants were not reachable on given number and for logistical reasons, a total of 6 homes were visited. Four homes were single-family houses, one home was a multi-family house and one was a single-family apartment.

Three homes used firewood as fuel. Five used charcoal as most or second most important fuel. Kerosene was used in three homes, for small meals like tea, milk and porridge. 5 of 6 homes had at least two different stoves. 4 of 6 homes were connected to the national grid.

Outside cooking took place in two homes. Two homes had an enclosed area used for cooking attached to the main home. One cooking location was a separate room inside. One household had a separate building for cooking. In total 24 meals were prepared. Of these, nine were Ugali.

The examined children were between 3 months and five years old. 2 of 10 were auscultated with for age increased vital parameters.
4 out of 6 children aged below 2 were nasopharyngeal carriers.
The mothers were between 18 and 40 years old.

5 out of 6 thought smoke could have negative effect on health and 5 of 6 would like to use LPG gas.

In this section the 6 household visits are presented and summarised in text, pictures and drawings.

HOUSEHOLD I

MARCH 16

HOUSING TYPE:	Single family - $40m^2$
NUMBER OF ROOMS:	4
HOUSEHOLD MEMBERS:	7
CHILDREN UNDER 5:	3
COOKING LOCATION:	Outside, Inside when rain
COOKING FUELS:	Firewood, Charcoal
MEANS OF LIGHTING:	Kerosene lantern, Solar lamp

FIELD NOTES
South of Moshi Urban, this young mother and her two children are living with her parents. Her husband lives quite close, but since thieves have stolen all their furniture it is better for the mother and children to stay with the grandparents, otherwise they will have to sleep on the floor.
The mother is 18 years old, married since one and a half year. She has one child from before who has lived with the grandparents since birth. When the situation gets better and the husband can provide better housing for his familiy, they will move back. Her husband is a carpenter, self-employed. Her father is now retired and her mother sells Maandazi (deep fried buns) in the mornings.

She shares bedroom with one of her sisters and her child. Two of her brothers live in the old house 20 meters away. In total they are twelve brothers and sisters, some live in Dar.

Both she and her mother are responsible for cooking. They cook on a traditional three-stone fire using firewood. The cooking place is outside with low brick partition walls. When it is raining they cook inside the old house on a similar stove.
When she is cooking she lifts the pot by hand or sometimes using a stick. When preparing the food and when cooking she sits on a small stool close to the stove. The youngest child is inside the house during cooking, while the older boy sits next to her and the three-stone fire, playing with a strainer.

On the plot they have a latrin and a water tap, but also a shallow well that was dry on the day of our visit.

Behind the old house the familiy keep goats in a small enclosure. They are moved inside to a separate room during the nights.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83.

FIGURE 84. *SITE*

WEATHER

33/17°C
MAX / MIN

NNE
3-8m/s

BUILDING MATERIALS

ROOF
Iron sheets - Good condition
No ceiling

EXTERIOR WALLS
Burned bricks - Interior concrete plaster

PARTITION WALLS
Burned bricks - Concrete plaster

FLOOR
Concrete

LEGEND

- North
- Stove placement
- Monitor placement
- Movement
- Water
- Preparing food
- Cooking
- Dining / sitting room
- Washing up
- Bedroom
- Storage
- Latrine

FIGURE 85. *PLAN*
Observed activities and movements.

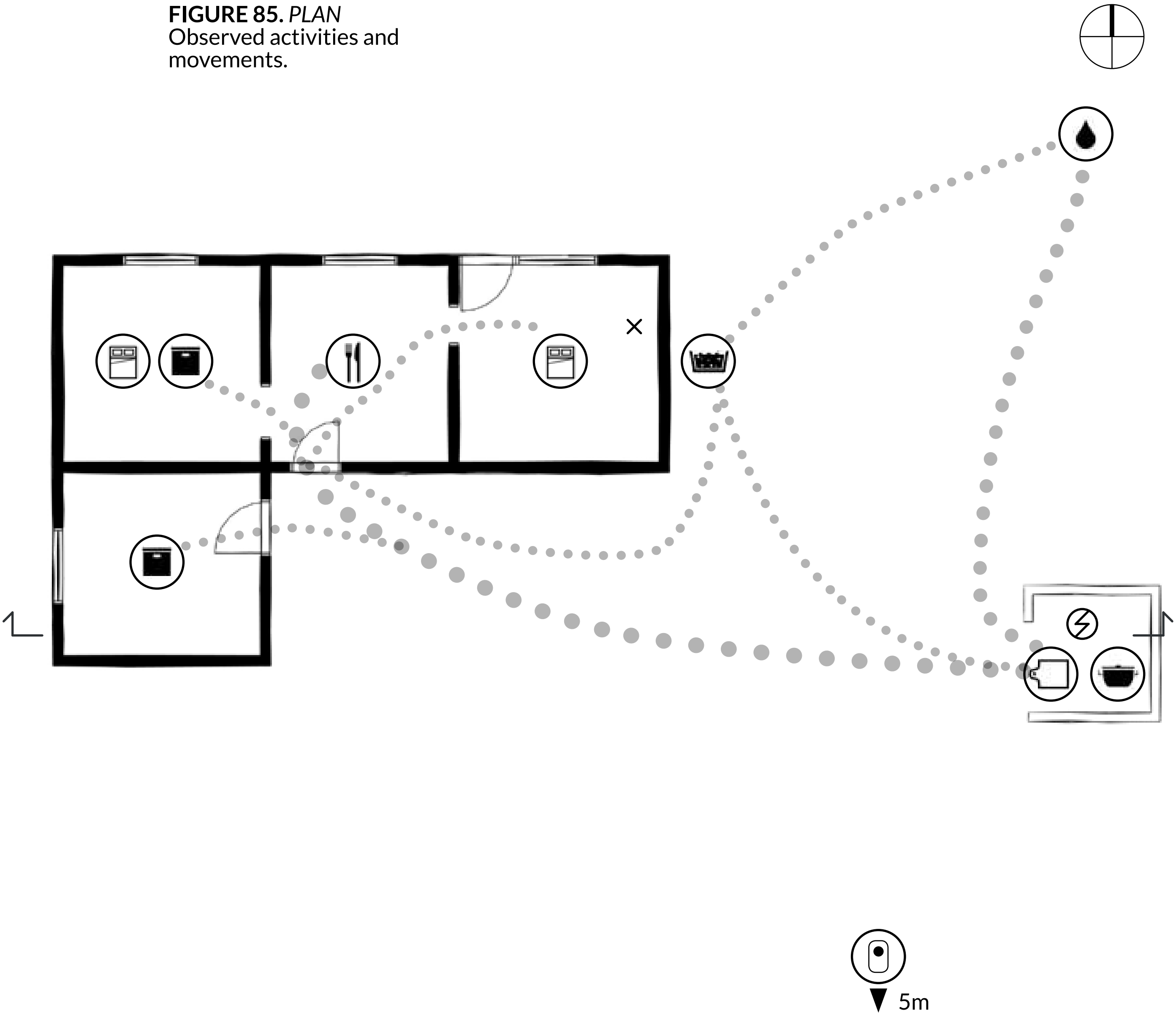
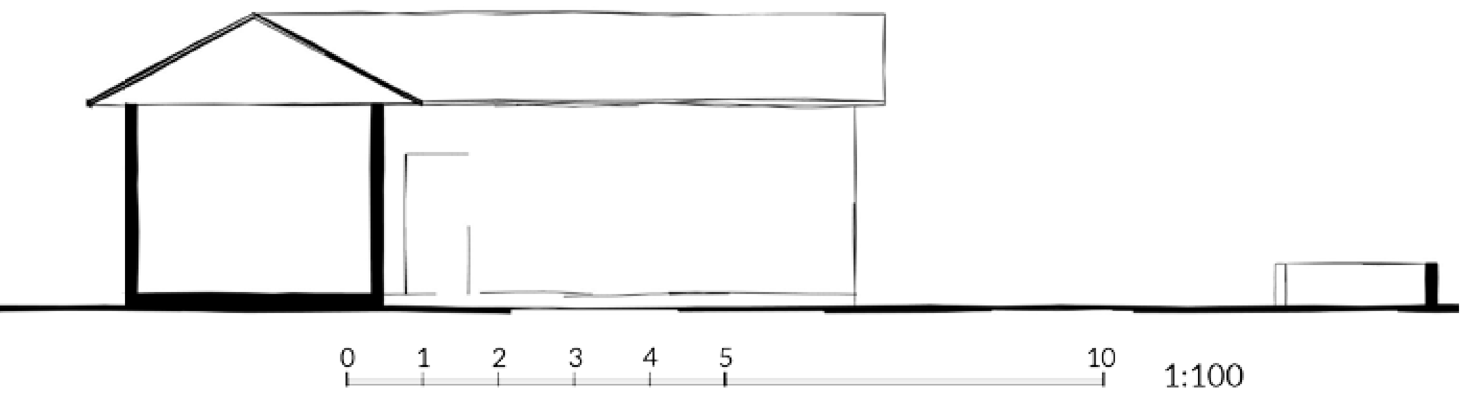


FIGURE 86. *SECTION*



HEALTH STATUS

The mother is sometimes troubled with breathlessness when cooking. Her eyes have been watery the last year and it happens even if she does not have a cold. When she cooks in the sun she sometimes gets strong headaches. Both children have had cough and rapid breathing the last two weeks. Nobody in the familiy has used antibiotics the last year.

YOUNGEST CHILD	
ARI LAST 3 MONTHS:	No
RUNNING NOSE LAST MONTH:	No
NASOPHARYNGEAL CARRIGE:	Yes

CO-LEVELS

Since the household had a space for cooking outside we were not able to place the monitors for area measurements in close proximity to the stove and fire. Instead we placed the stand in one of the bedrooms in the main house. These measurements shows no indication of carbon monoxide area exposure.

Even though the personal exposure measurements show some peaks high above WHO-recommendations, the mean values for 24h, 8h, 1h, and 15min respectively are below the recommended exposure, with a 24h mean value of 1.4 ppm and a highest 1h mean value of 15.6 ppm.

During our visit we observed that the mother was close to the fire 2/3 of the time when she was cooking. The older child (4 years) was close to the fire most of the time both when mother and grandmother were cooking.

CONCLUSION

This household had an outside ”kitchen” and because of this there was no ventilation issue with extracting the smoke. Though the situation when cooking inside during rain, we assume is much worse. Since the cooking area was outside with no roof or walls, all utensils, foodstuff and stools etc. had to be collected, moved back and forth from different storing locations. Both in sleeping rooms, and the old house. In the new house, one out of four rooms was used as storage of building materials, a bicycle and wooden frames. This room could be made into a kitchen with possible cross ventilation and space for storing and preparing food. Though, if using firewood, and without a proper stove, chimney or smoke hood, the situation and indoor air quality would be terrible since there is no ceiling and the smoke would spread to all rooms.

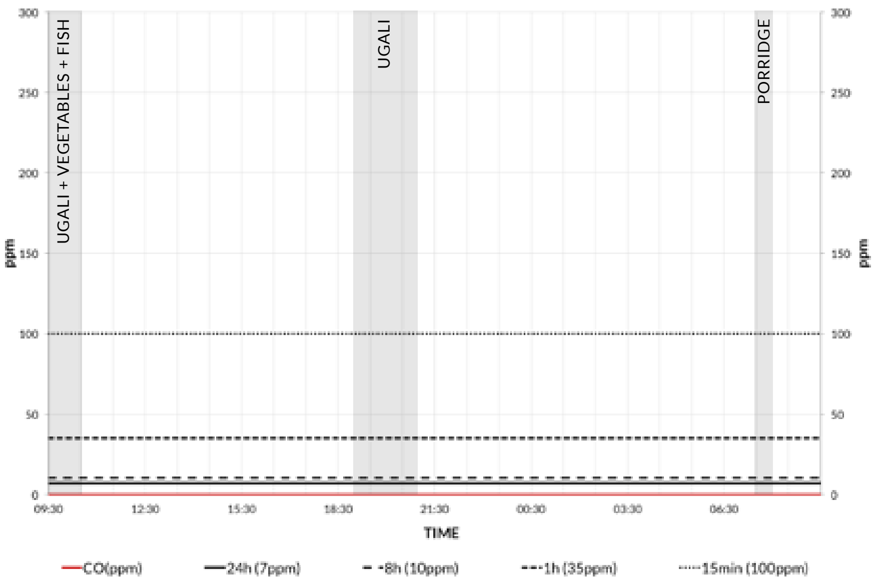


FIGURE 87.
AREA EXPOSURE
First activity observed. Information about other activities and estimated time and duration requested at re-visit.

For monitor placement, see plan on previous spread.

Horisontal lines represent WHO guidelines for mean values of Carbon Monoxide exposure for different time intervals.

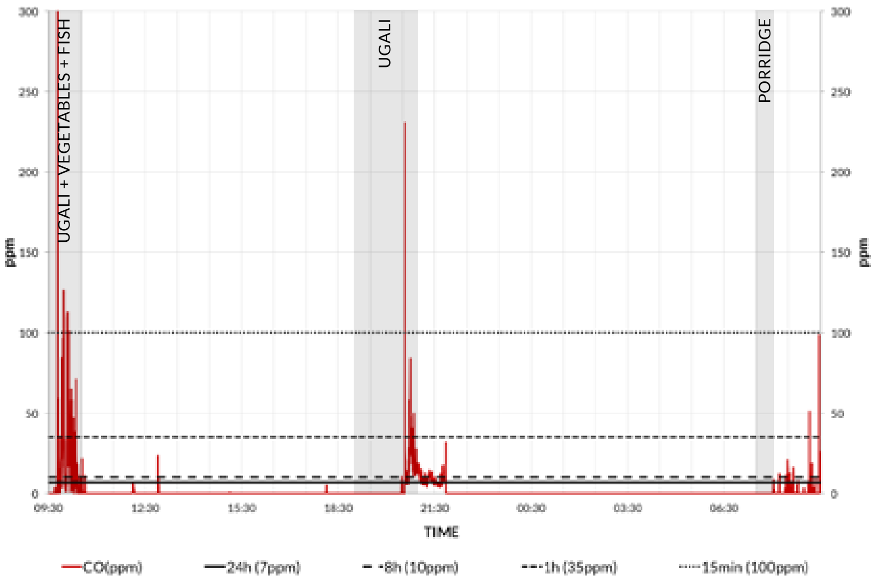


FIGURE 88.
PERSONAL EXPOSURE
First activity observed. Information about other activities and estimated time and duration requested at re-visit.

Horisontal lines represent WHO guidelines for mean values of Carbon Monoxide exposure for different time intervals.

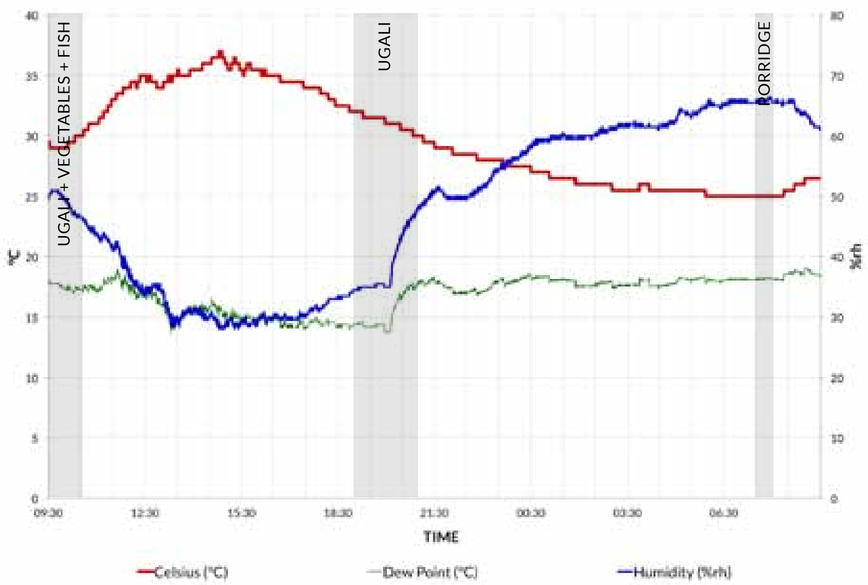


FIGURE 89.
INDOOR ENVIRONMENT
Temperature and relative humidty during the time of measuring.

For monitor placement, see plan on previous spread.

HOUSEHOLD II
MARCH 17

HOUSING TYPE:	Single family - 43m^2
NUMBER OF ROOMS:	4
HOUSEHOLD MEMBERS:	9
CHILDREN UNDER 5:	3
COOKING LOCATION:	Separate room attached to main house
COOKING FUELS:	Firewood
MEANS OF LIGHTING:	Kerosene lantern

FIELD NOTES
This house is a multi-generational home. The mother of six lives with her husband and their two youngest children in one room and her mother in law (who owns the house) lives in a second room with two more children. They use the same kitchen and do all the cooking together. Their two oldest children live just round the corner - one is in secondary school and one is working as a car mechanic. They come home to eat with the family every day.

While the mother is preparing food for the day, the grandmother is sitting on the ground, sorting maize to make ugali for the next day. The children in the area are playing together between the houses. The youngest child moves from person to person and is being breastfed in the smoky kitchen while the mother is cutting onions.

In the smoky kitchen the eyes get sore. The clothes smell of smoke. It is hard to see inside the kitchen because of the smoke and the limited amount of light from the small opening above the three-stone fire. The mother sits on a stool, seemingly unaffected.

In the household the mother is responsible for getting fuel. To do that, she first helps someone at a farm, earns money and after that she buys firewood. If she works 2-3 days, she can buy firewood for a whole week. 10 pieces of wood cost 700 Tsh and last for one day. Sometimes she collects the fuel herself. If collecting from morning til 2pm, they have fuel for three days. But it depends on the season. This time of the year, there is lots of work with preparing the fields. During rainy season it is hard to find good firewood. Her husband is self-employed and works as a carpenter.

Hens are tip-toeing around the plot and goes in and out of the house and kitchen. Out the back in an old building they keep goats.

Her brother in law is building a house for his family on the same plot, but it is far from finished. This structure has a latrine that is used by the household.


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FIGURE 98. *SITE*

WEATHER

33/17°C
MAX / MIN

E
3-9m/s

BUILDING MATERIALS

ROOF
Iron sheets - Bad condition

EXTERIOR WALLS
Burned bricks - Concrete plaster
Kitchen - Mud bricks

PARTITION WALLS
Burned bricks - Concrete plaster

FLOOR
Earth

LEGEND

- North
- Stove placement
- Monitor placement
- Movement
- Water
- Preparing food
- Cooking
- Dining / sitting room
- Washing up
- Bedroom
- Storage
- Latrine

FIGURE 99. *PLAN*
Observed activities and movements.

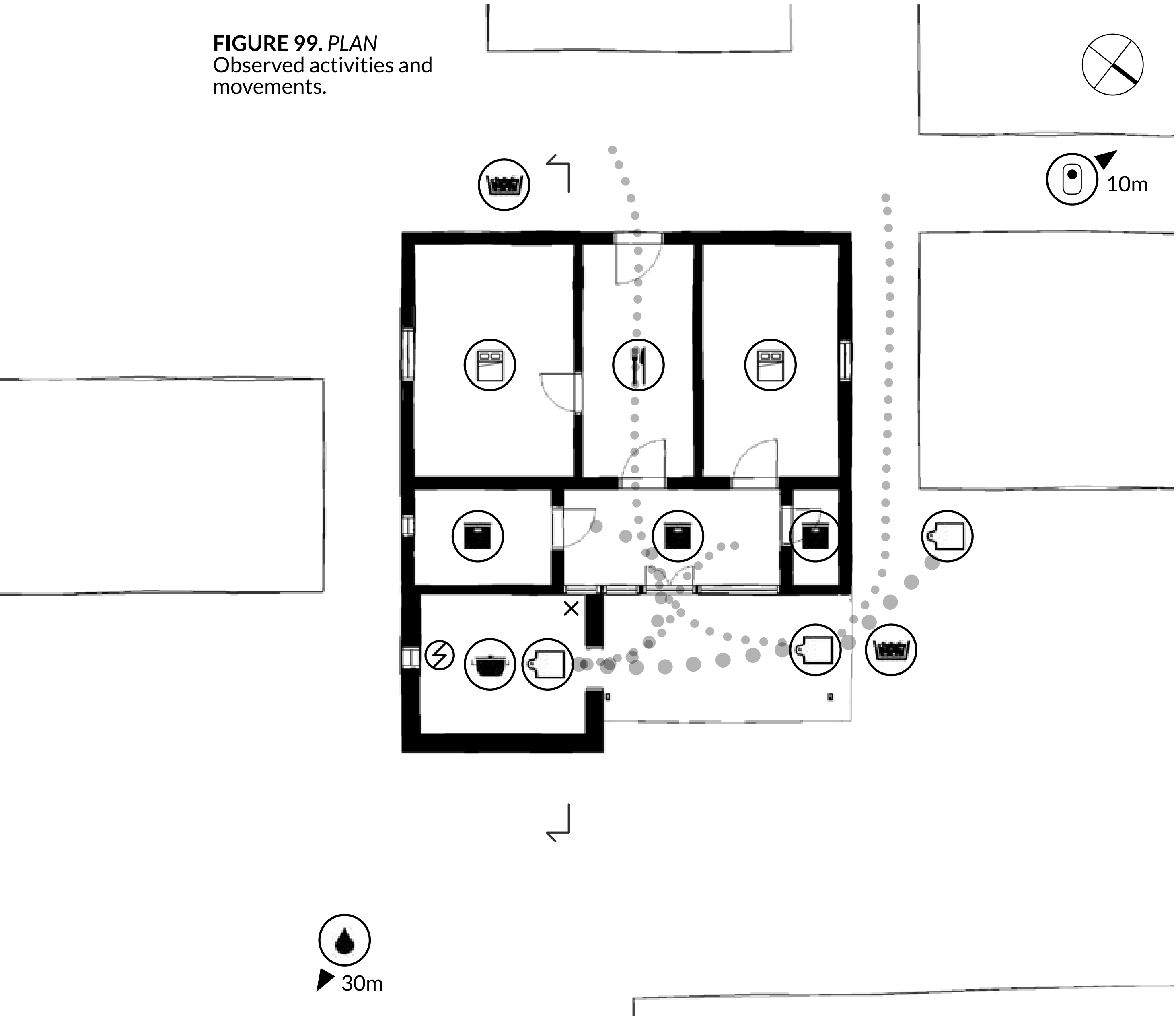
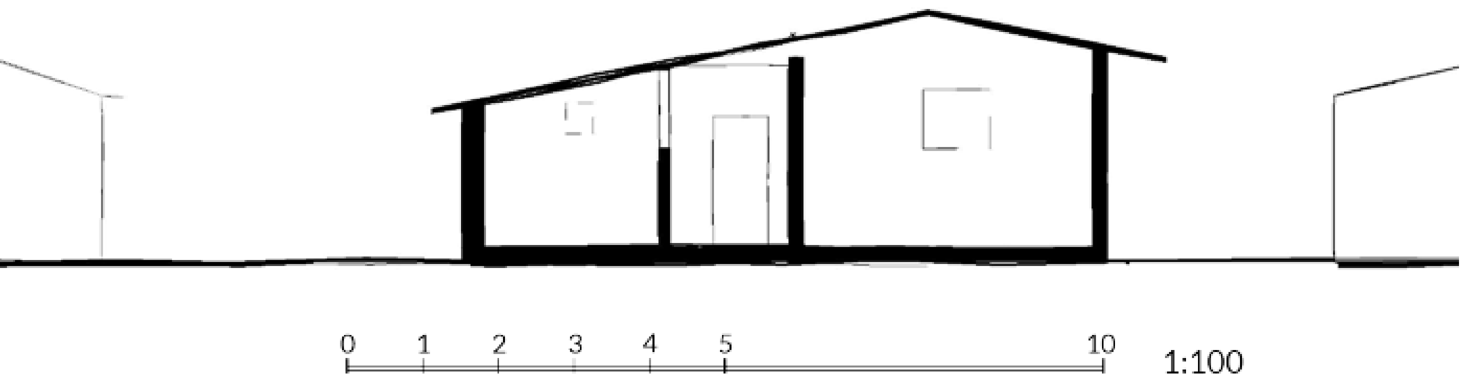


FIGURE 100. *SECTION*



HEALTH STATUS

The mother does not meantion respiratory health problems. Nobody in the family has used antibiotics the last year and the children have not had any episodes with cough or rapid or difficulty breathing.

YOUNGEST CHILD	
ARI LAST 3 MONTHS:	No
RUNNING NOSE LAST MONTH:	No
NASOPHARYNGEAL CARRIGE:	Yes

CO-LEVELS

In this house, the kitchen is an extension added to the main building. We placed the stand with the monitors for area exposure in a corner of the kitchen. The measured values for CO-area exposure far exceeds the recommendations set by WHO. The mean 24h value was 33ppm in relation to the recommended maximum of 7ppm. The values for all three 8h periods exceeded the recommendations of 10ppm, with 66, 22 and 10.2ppm. The 1h mean values in this kitchen exceeded the recommended value of 35ppm 8 out of 24 hours, with up to 4.8 times reaching a mean value of 168ppm.

Even though the area exposure exceeded almost all recommended maximum values, the 24h mean personal exposure was below the recommended 7ppm with a value of 3.7ppm. The mean values for 8h, 1h, and 15min respectively was below the recommended exposure, with a highest mean 1h value of 34.2ppm the third hour of measuring.

CONCLUSION

The rooms were very dark and the walls and roof construction dirty from smoke and dust. The kitchen was also dark and the smoke made it almost unbearable for us to stay there for a longer time. In the same corner of the kitchen where we placed the stand with the sensors there was a metal mesh window that was connected to the inside corridor. Through this opening smoke from the stove and kitchen finds its way into the main living area. Since there was no ceiling the smoke can reach the whole house.

With the current placement of openings in the kitchen and the prevailing winds coming from the east, it is very likely that instead of ventilating the kitchen, the wind pushes the smoke inside the kitchen area.

This house is selected as case study example and interventions will be simulated to find the best solution for this household to make it smokeless.

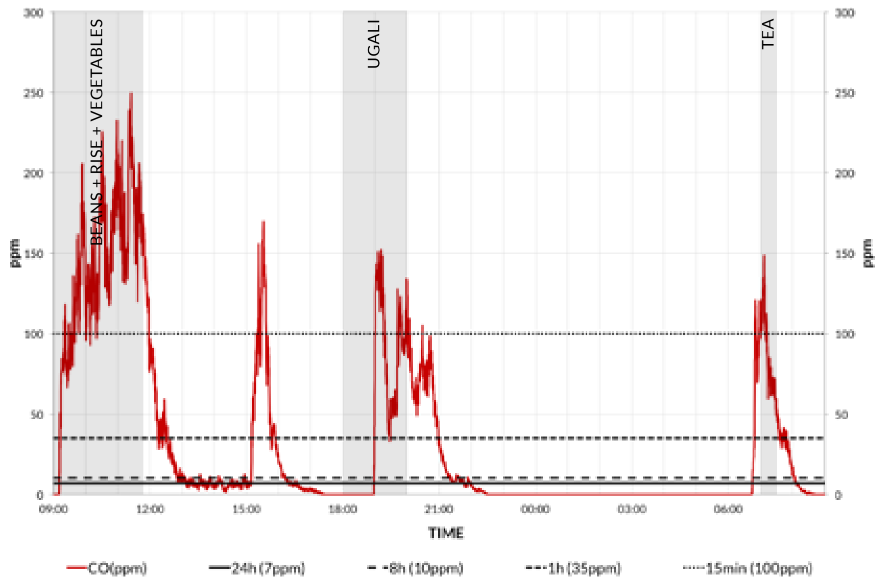


FIGURE 101.
AREA EXPOSURE
First activity observed. Information about other activities and estimated time and duration requested at re-visit.

For monitor placement, see plan on previous spread.

Horisontal lines represent WHO guidelines for mean values of Carbon Monoxide exposure for different time intervals.

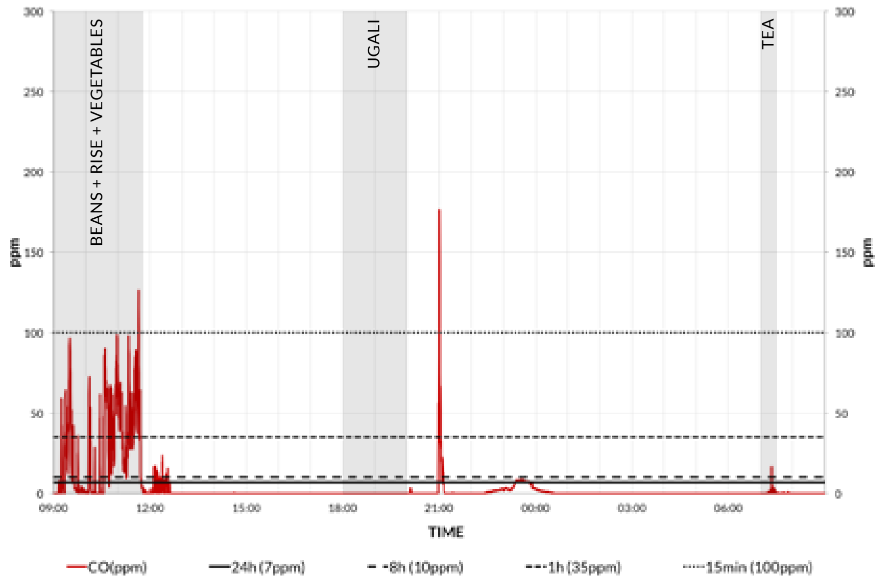


FIGURE 102.
PERSONAL EXPOSURE
First activity observed. Information about other activities and estimated time and duration requested at re-visit.

Horisontal lines represent WHO guidelines for mean values of Carbon Monoxide exposure for different time intervals.

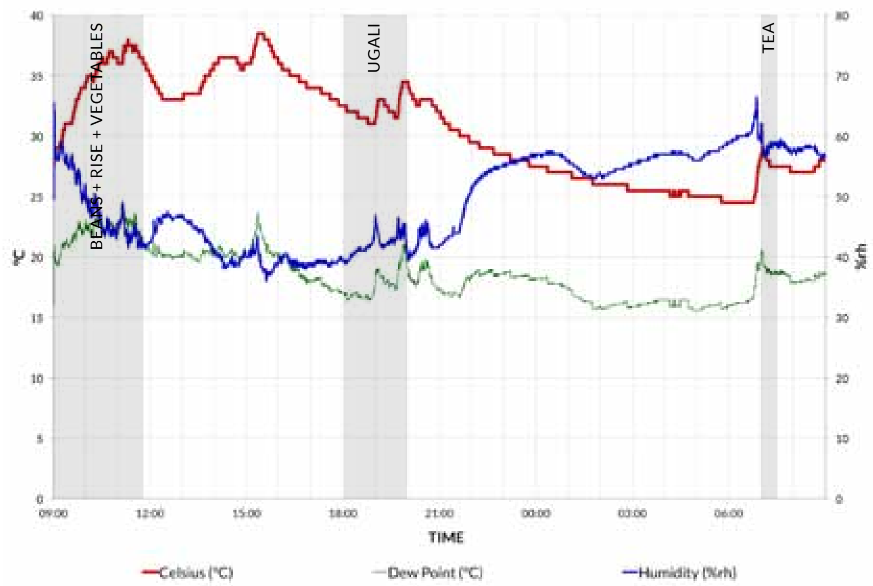


FIGURE 103.
INDOOR ENVIRONMENT
Temperature and relative humidty during the time of measuring.

For monitor placement, see plan on previous spread.

HOUSEHOLD III
MARCH 18

HOUSING TYPE:	Single family - 45m^2
NUMBER OF ROOMS**:**	4
HOUSEHOLD MEMBERS:	5
CHILDREN UNDER 5:	2
COOKING LOCATION:	Separate structure, detached from house
COOKING FUELS:	Charcoal, Firewood
MEANS OF LIGHTING:	Electricity, Kerosene lantern

FIELD NOTES
This young mother and her two children, 9 months and 4 years old, live in her parents house. She has two older sisters who are married and live in the neighbourhood. The small family lives in one room and sleeps on a big mattress on the floor. Her mother wants her to move out, but the father of her children can not afford to support the family at the moment. She wants to marry him when possible.

The mother stays at home and does the cooking and cleaning in the house. Sometimes her daughter (9 months) is with her in the kitchen and sometimes she is left inside. The mother likes to cook with charcoal, but the grandmother prefers firewood.

She has finsished secondary school and speaks good english. Now she is at home but would like to have a work- does not matter what kind of work. She would like to be able to pay the school fee for her son. In pre-school it is 70 000 Tsh each year. This year the grandparents pay the fee, they are self-employed.

A small bag of charcoal costs 10 000 Tsh and lasts for 1 month. 10 piescies of firewood costs 700 Tsh and lasts for about 2-3 days.

On this small triangular plot there is an old house that is falling apart. The new house is about 10 years old. The familiy have prioritised decorative stucco ceilings and a television set, but the main house lacks both kithcen, toilet and running water. The outside latrine has no doors nor roof.

This kitchen is in a separate wooden structure. The structure has many small gaps and openings all around. Utensils, pots and foodstuff are stored in a corner of the sitting room behind a sofa.


104.


105.


106.


107.


108.


109.


110.


111.

FIGURE 112. *SITE*

WEATHER

32/15°C
MAX / MIN

ESE
3-10m/s

BUILDING MATERIALS

ROOF
Iron sheets - Good condition

EXTERIOR WALLS
Burned bricks - Interior concrete plaster
Kitchen - Wood

PARTITION WALLS
Burned bricks - Concrete plaster

FLOOR
Concrete
Kitchen - Earth

LEGEND

- North
- Stove placement
- Monitor placement
- Movement
- Water
- Preparing food
- Cooking
- Dining / sitting room
- Washing up
- Bedroom
- Storage
- Latrine

FIGURE 113. *PLAN*
Observedactivities and movements.

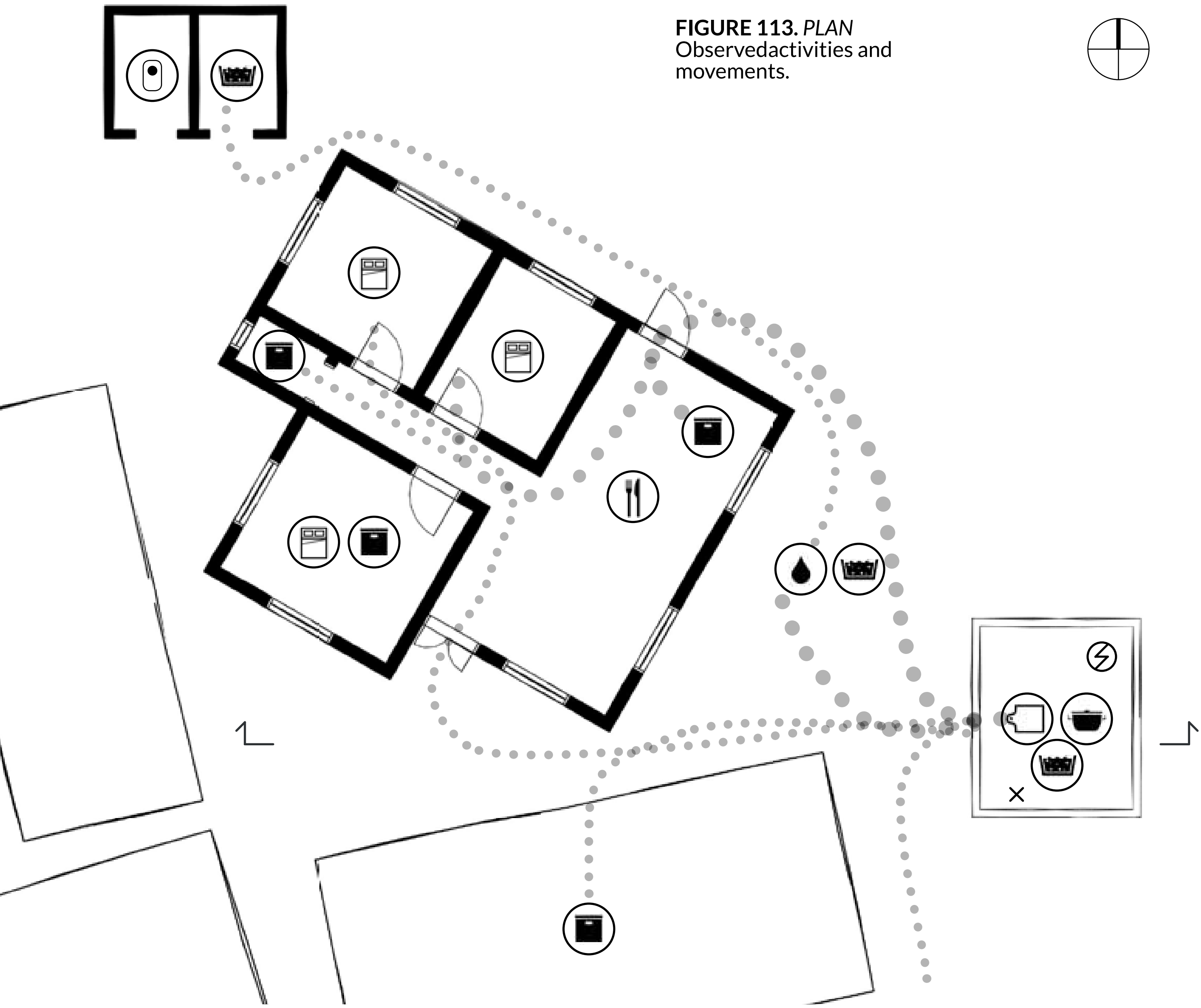
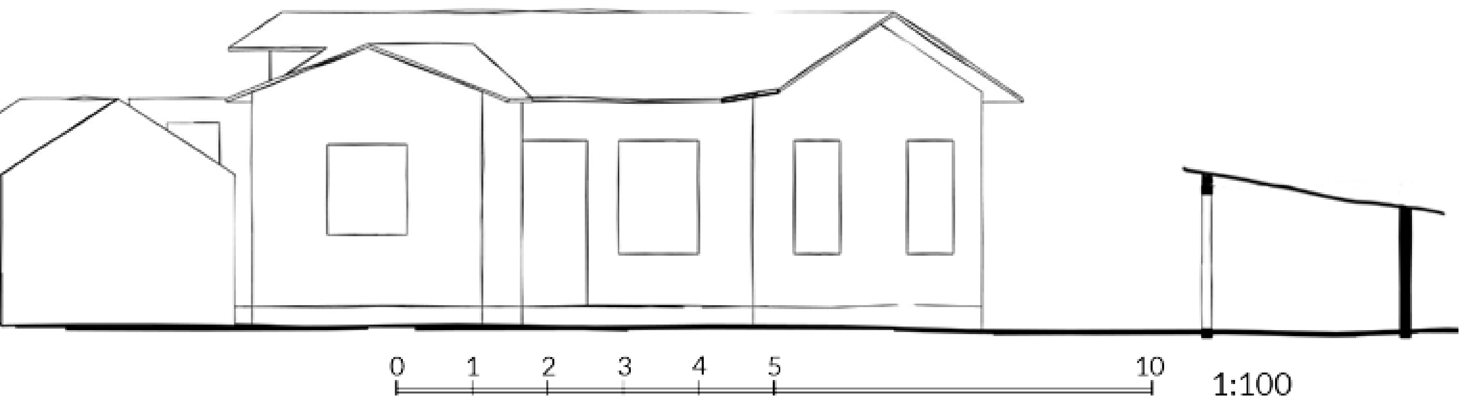


FIGURE 114. *SECTION*



HEALTH STATUS

The mother does often have cough and running nose, but each episode does not last more than two weeks. She has a mild weekly headache, it comes when she feels tired. Both children have had illness with cough during the last two weeks, with affected breathing. All familiy members have used antibiotics the last year.

According to the mother, the family uses Amoxicillin (antibiotics) when coughing, Paracetamol when fever and Codril (cough medicine) when running nose. They buy medicine in the pharmacy, but have also visited dispensary and health centre for treatment.

YOUNGEST CHILD	
ARI LAST 3 MONTHS:	Yes
RUNNING NOSE LAST MONTH:	Yes
NASOPHARYNGEAL CARRIGE:	Yes

CO-LEVELS

We placed the stand with the monitors for area exposure in a corner of the outdoor kitchen. These measurements show values below the recommendations set by WHO.

Even though the personal exposure measurements show some peaks high above WHO-recommendations, the mean values for 24h, 8h, 1h, and 15min respectively are below the recommended exposure, with a 24h mean value of 1.5 ppm and a highest 1h mean value of 12.7 ppm.

During our visit the mother was close to the fire 2/3 of the time when she was cooking. The child was inside sleeping most of the time.

CONCLUSION

The levels of carbon monoxide was low for area exposure and below recommendations for personal exposure. Though, placement of the sensors in combination with cooking location and wind direction might have affected the result. A less windy day, or when cooking on the second stove (firewood), the levels might be higher.

This home was a good example of the kitchen and sanitary spaces being neglected even in new development. This familiy rather prioritise decorative interior and tv-set, instead of a decent toilet or kitchen.

The old house, that now is falling apart, could be torn down compleatly and instead a better kitchen and toilet could be built. There would be possible to have storage and kitchen closer to each other and the ergonomics could be improved. Based on the housing standard in general, our guess is that it would be economically possible to use LPG for cooking instead of charcoal or firewood.

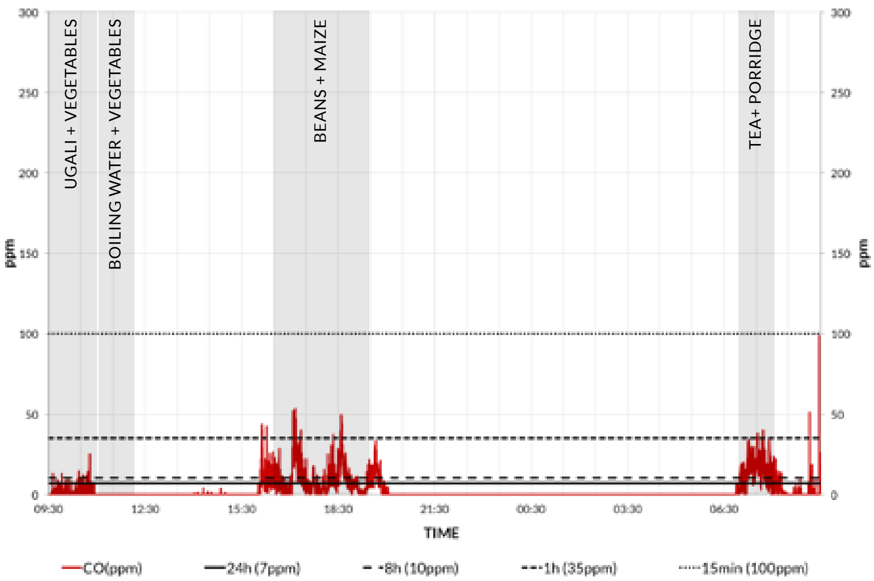


FIGURE 115.
AREA EXPOSURE
First and second activity observed. Information about other activities and estimated time and duration requested at re-visit.
For monitor placement, see plan on previous spread.

Horisontal lines represent WHO guidelines for mean values of Carbon Monoxide exposure for different time intervals.

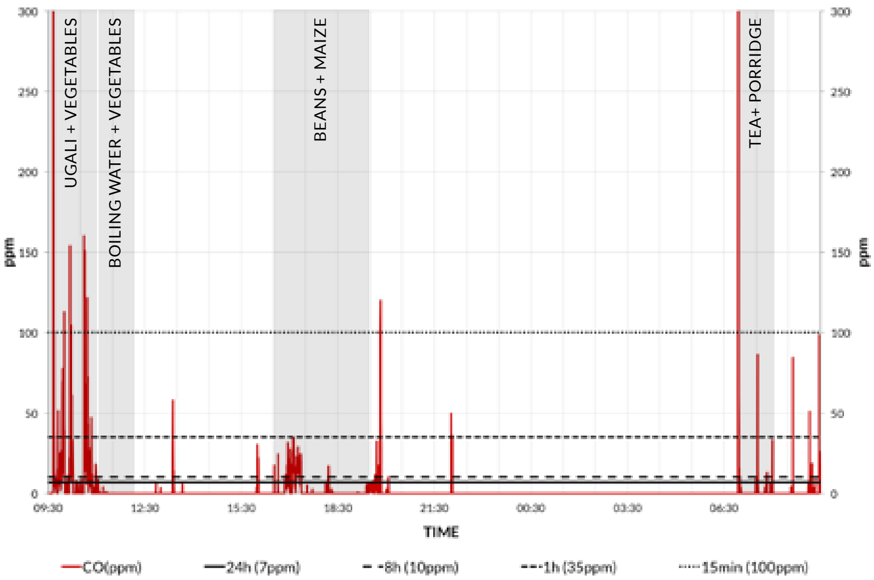


FIGURE 116.
PERSONAL EXPOSURE
First and second activity observed. Information about other activities and estimated time and duration requested at re-visit.

Horisontal lines represent WHO guidelines for mean values of Carbon Monoxide exposure for different time intervals.

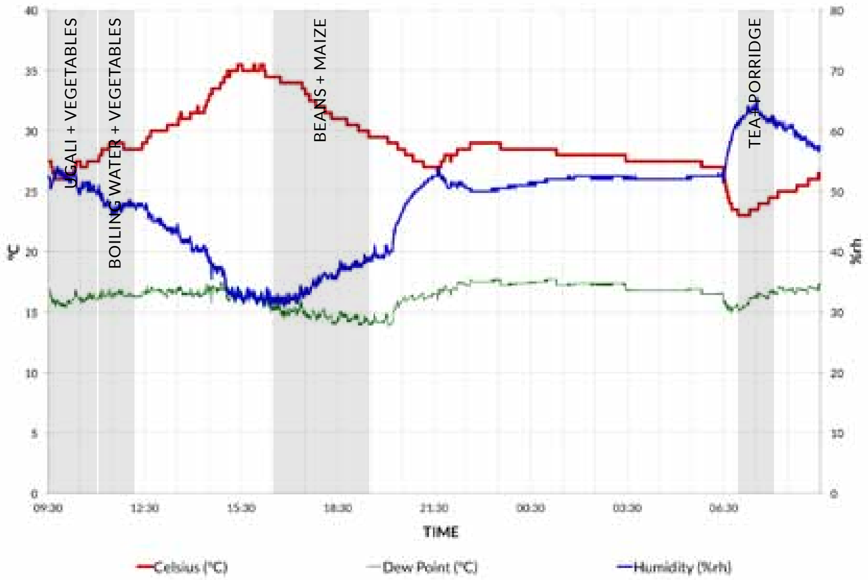


FIGURE 117.
INDOOR ENVIRONMENT
Temperature and relative humidty during the time of measuring.

For monitor placement, see plan on previous spread.

HOUSEHOLD IV
MARCH 19

HOUSING TYPE:	Multi family
NUMBER OF ROOMS**:**	1 ($9m^2$)
HOUSEHOLD MEMBERS:	3
CHILDREN UNDER 5:	1
COOKING LOCATION:	Outside corridor, Kerosene inside when rain
COOKING FUELS:	Charcoal, Kerosene
MEANS OF LIGHTING:	Electricity, Kerosene lantern

FIELD NOTES
This is a small family renting a room in a multi-family house. The house is divided into eight apartments, most of them have one room. One of the families own the building. The rent for the familiy we are visiting is 20 000 Tsh a month. When the bill from the water consumption comes, the households split it. All have access to electricity but choose if they want to be connected or not. In total, they are 29 people living in the building. They share water tap, toilet and shower. Outside the house there is a small ditch, and on the other side, cows and goats are grazing.

Washing lines are mounted across the courtyard and during the morning time they are filled with new-washed clothes making it hard to pass. All activities take place on the corridor, the raised platform that runs around the small courtyard. All are sitting on the raised platform or standing, bending forward working with something on the ground. There are no specific workspaces designated to different tasks. Women are doing the dishes, feeding their children and washing clothes. Two cookstoves are lit.

While the mother goes around the corner to buy tomatoes and charcoal, the child is left on the corridor looked after by the neighbours around. They all cook and wash separately, with their own stoves and utensils.

Both mother and father are self-employed and are working in the market. The room in which they stay has a bed, a small sofa, a table and a television set. The utensils, foodstuff, clothes and other possessions are stacked along the walls.

Their main fuel is charcoal, and she buys a daily amount to cover their needs. It costs about 500 Tsh. She also use kerosene for cooking and lighting. Since kerosene is easier to control, she use it when the child needs her attention. It takes about 30 min to cook porridge using kerosene. With charcoal it takes about 60 min.


118.


119.


120.


121.


122.


123.


124.


125.

FIGURE 126. *SITE*

WEATHER

33/15°C
MAX / MIN

ESE
2-8m/s

BUILDING MATERIALS

ROOF
Iron sheets - Good condition
Ceiling

EXTERIOR WALLS
Burned bricks - Concrete plaster

PARTITION WALLS
Burned bricks - Concrete plaster

FLOOR
Concrete

LEGEND

North
Stove placement
Monitor placement
Movement
Water
Preparing food
Cooking
Dining / sitting room
Washing up
Bedroom
Storage
Latrine

FIGURE 127. *PLAN*
Observed activities and movements.

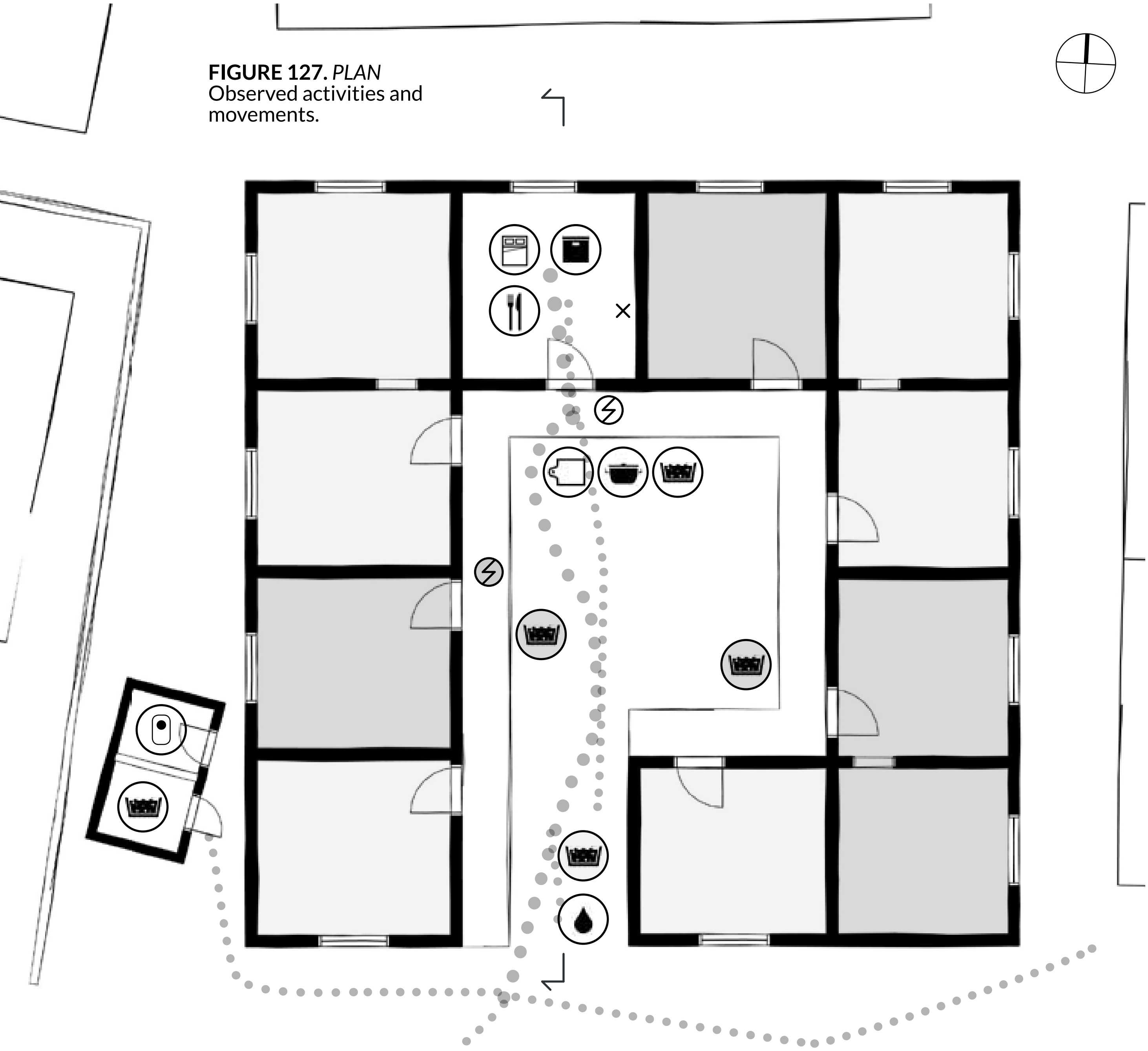
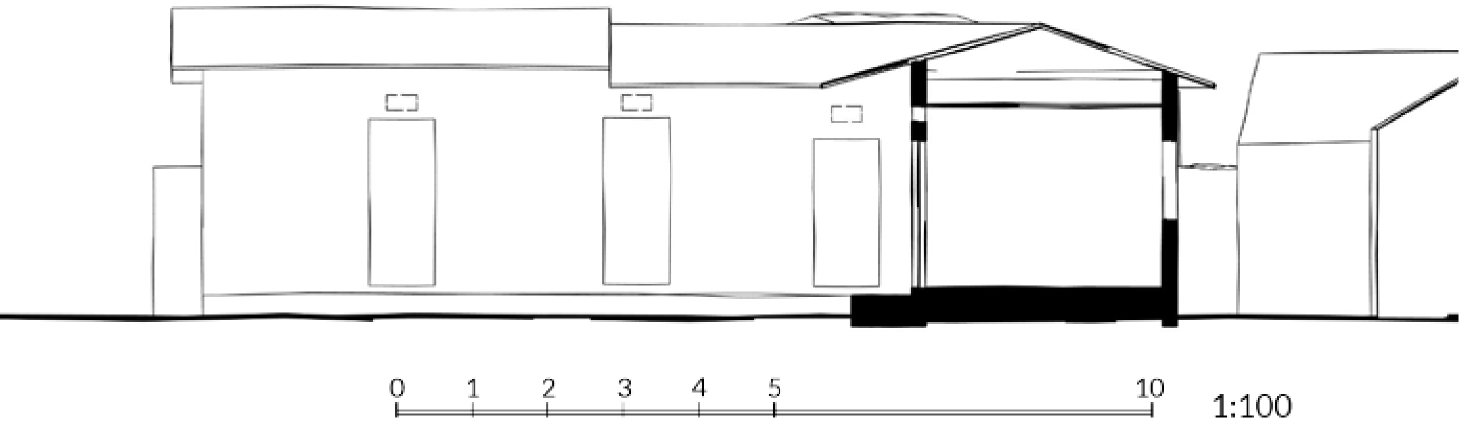


FIGURE 128. *SECTION*



HEALTH STATUS

The mother does not mention any respiratory health problems. She seldom has headaches. The child has had cough and colds the last year, but not severe. The child has used Codril (cough medicine). Neither she or any other family member have used antibiotics the last year.

YOUNGEST CHILD	
ARI LAST 3 MONTHS:	No
RUNNING NOSE LAST MONTH:	No
NASOPHARYNGEAL CARRIGE:	Yes

CO-LEVELS

In this multi-familiy housing all families are cooking outside on raised walkway or platform that runs around the enclosed courtyard. The stand was placed inside the room of the household we visited, quite close to the door. The door was open all the time during our visit.

All families and the children playing in the courtyard are exposed to ambient air pollution from each other stoves, but during the day of measuring the values for area exposure inside was below the recommended mean values set by WHO.

The mother had a 24h mean exposure value of 2.4ppm. And a highest 1h mean value of 19.2ppm.

During our visit we observed that the mother was close to the fire 2/3 of the time when she was cooking. The child was close to the fire half of the time.

CONCLUSION

These families live close together and the activites taking place in the courtyard affect all. There is no or little space for storage, and the system of washing and drying clothes, blocks and restricts the movement to and from the own home.

The risk of communicable diseases exist since so many people share toilet and washing area.

If improving the situation in this multi. familiy housing, all famlies must benifit. We think that it would be physically possible to arrange for a joint workspace for different activities, in or around the courtyard. This workspace could be combined with personal storage of equipment and utensils

It would also be benificial to arrange for different spaces for the activities taking place on the corridor. As it is, there is a risk of slipping, continamation and burns.

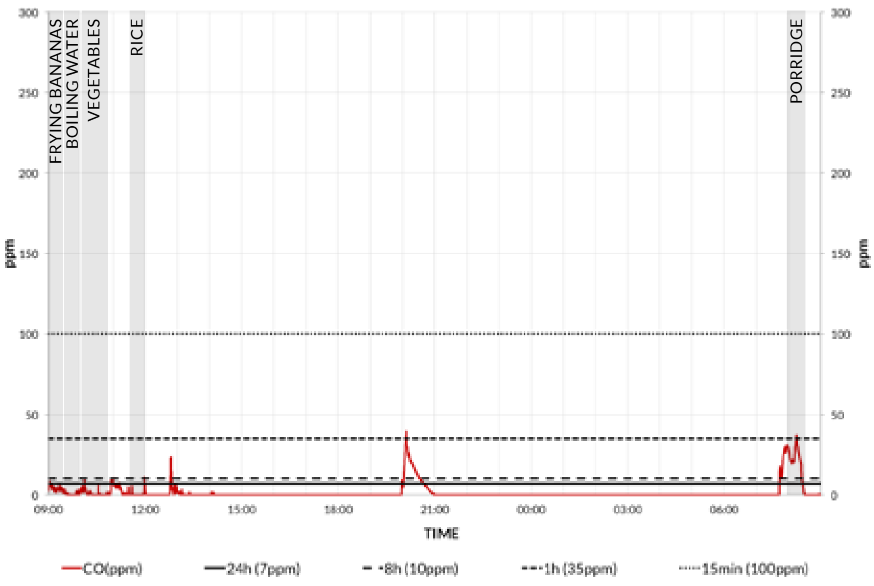


FIGURE 129.
AREA EXPOSURE
First four activities observed. Information about other activities and estimated time and duration requested at re-visit.

For monitor placement, see plan on previous spread.

Horisontal lines represent WHO guidelines for mean values of Carbon Monoxide exposure for different time intervals.

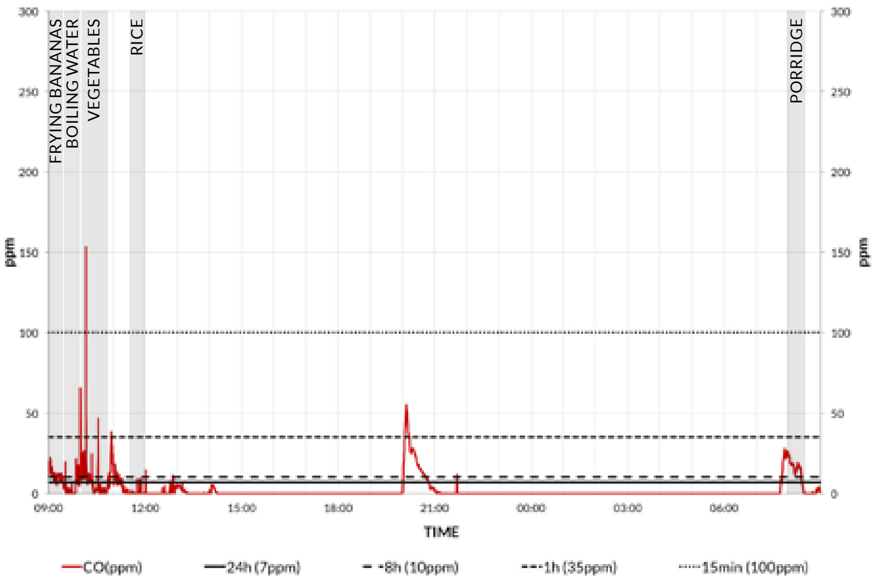


FIGURE 130.
PERSONAL EXPOSURE
First four activities observed. Information about other activities and estimated time and duration requested at re-visit.

Horisontal lines represent WHO guidelines for mean values of Carbon Monoxide exposure for different time intervals.

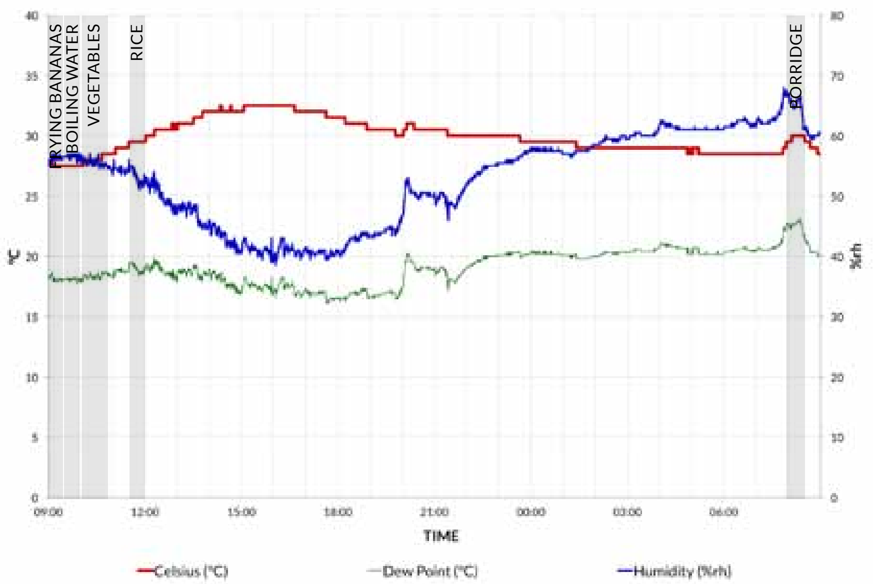


FIGURE 131.
INDOOR ENVIRONMENT
Temperature and relative humidty during the time of measuring.

For monitor placement, see plan on previous spread.

HOUSEHOLD V
MARCH 23

HOUSING TYPE:	Single family - 85m^2
NUMBER OF ROOMS**:**	6
HOUSEHOLD MEMBERS:	5
CHILDREN UNDER 5:	1
COOKING LOCATION:	Separate room inside
COOKING FUELS:	Charcoal, Kerosene
MEANS OF LIGHTING:	Electricity, Kerosene lantern

FIELD NOTES
This household consists of five people. They started to build their house in year 2009 and moved in December 2014, but it is an ongoing project. Before, they lived in one of the older houses behind their new house. They now rent out the rooms in the backyard to three families.

Except mother, father and two children, 9 months and 6 years old, there is a housemaid living with them. She is 18 years old and helps with cooking and taking care of the children in the weeks.
The housemaid has only lived with the famliy for two months, but has worked in another family before where they used charcoal, kerosene and gas. In this house, they use kerosene for small things like tea and milk. Charcoal is used when cooking larger meals.

Both mother and father are self-employed and are working in the market from 7am-12pm every day. They earn about 100 000 Tsh each month. They get an additional 75 000 Tsh in rent from the families in the backyard.

The mother can not tell how much it has cost them to build the new house, they do it step by step.
Next thing on their list is to put in a celing which might cost 5 000 000 Tsh. The house is sparesely furnished and the kitchen has no storage facilities or workspaces, nor running water. The toilet and bathroom are not finished yet and the household use the same latrine as the three other families in the back. Since the house is located along one of the main roads in the area, they plan to open up a shop in one of the rooms towards the street.

The visit was short since the mother had to return to the market and work.


132.


133.


134.


135.


136.


137.


138.


139.

FIGURE 140. *SITE*

WEATHER

31/17°C
MAX / MIN

ESE
2-8m/s

BUILDING MATERIALS

ROOF
Iron sheets - Good condition
No ceiling

EXTERIOR WALLS
Burned bricks - Concrete plaster

PARTITION WALLS
Burned bricks - Concrete plaster

FLOOR
Concrete

LEGEND

- North
- Stove placement
- Monitor placement
- Movement
- Water
- Preparing food
- Cooking
- Dining / sitting room
- Washing up
- Bedroom
- Storage
- Latrine

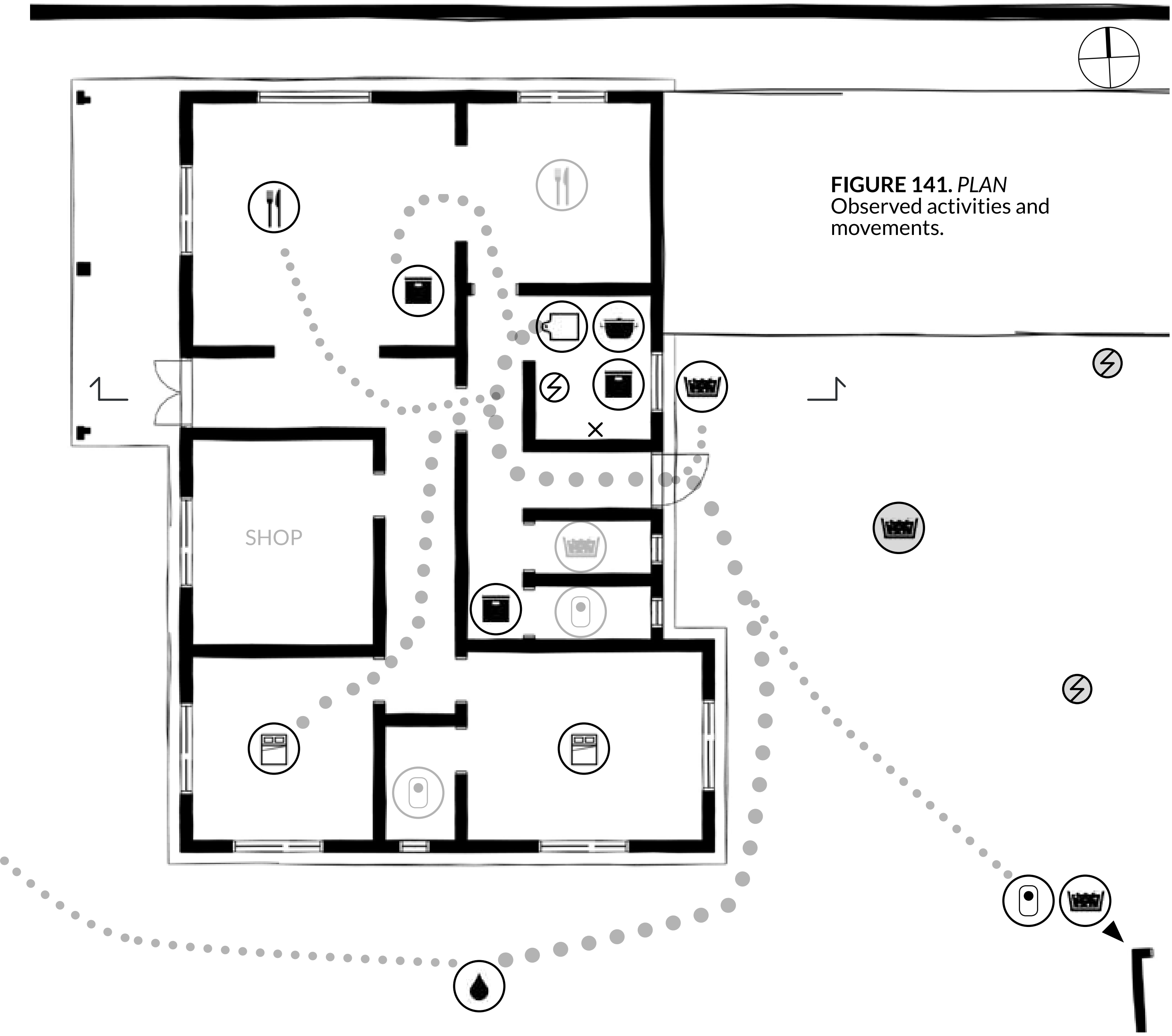
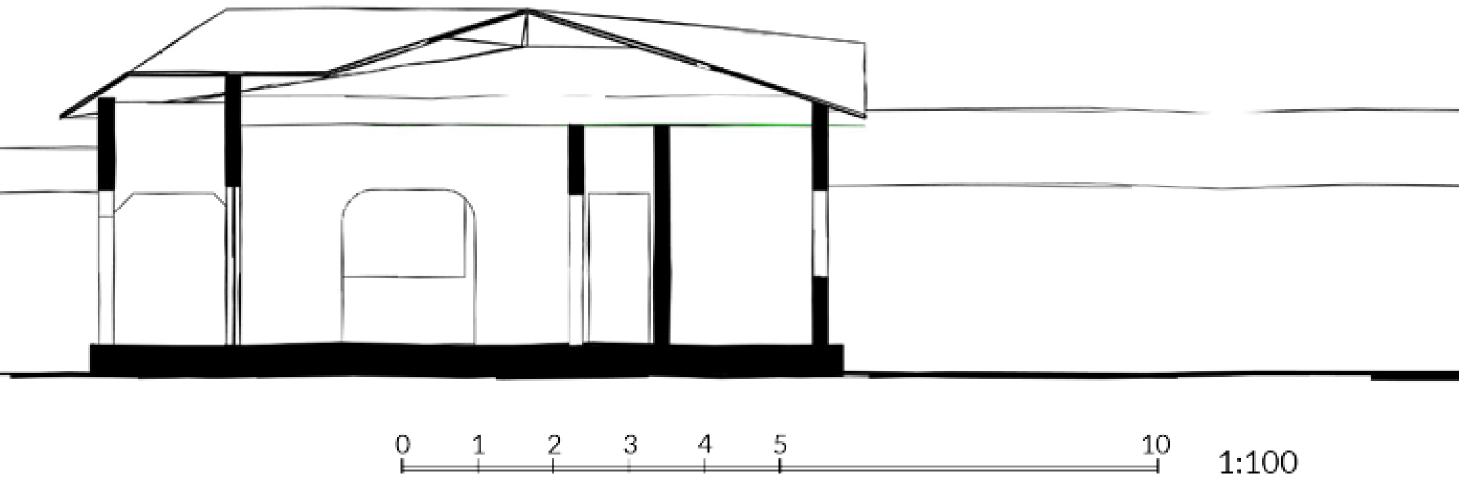


FIGURE 141. *PLAN*
Observed activities and movements.

FIGURE 142. *SECTION*



HEALTH STATUS

Neither the mother, the housemaid or the children have experienced respiratory health problems the last year. The youngest child has used Amoxicillin (antibiotics) once the last 3 months, because of running nose.

YOUNGEST CHILD	
ARI LAST 3 MONTHS:	Yes
RUNNING NOSE LAST MONTH:	Yes
NASOPHARYNGEAL CARRIGE:	No

CO-LEVELS

In this household the mother did some of the cooking in the mornings and evenings as well as during weekends. But most of the time the housemaid was the one responsible for cooking. Therefore, she was the one carrying the sensor for measuring personal exposure. The stand for measuring area exposure was placed in the kitchen, by a wall, about 1m away from both stove and window. The porridge in the morning was cooked by the mother using kerosene.

The 24h mean value for area exposure was 11.1ppm and exceeds the recommended 7ppm. The first 8h mean value for area exposure was three times higher than recommended.

The measured mean value for personal exposure was 3.4ppm for 24h, with the highest 1h mean value of 32.4ppm. These values are below the recommended maximum set by WHO.

CONCLUSION

This familiy had improved there living conditions the past 6 years and had the ambition to expand there business and through it be able to be more stationary and earn more money. They had a separate room for cooking, but it had no door or ceiling, therefore the smoke was noticable (smelled) in all rooms of the house.

With the ambition and long-term economic plan of this family, we believe that a shift to LPG could be a feasible alternative to reduce the smoke exposure. In the short term, ceiling and door to the kitchen would at least stop the smoke from spreading to all rooms.

A joint outside workspace for cooking and washing could be built in the backyard to improve the situation for the other families.

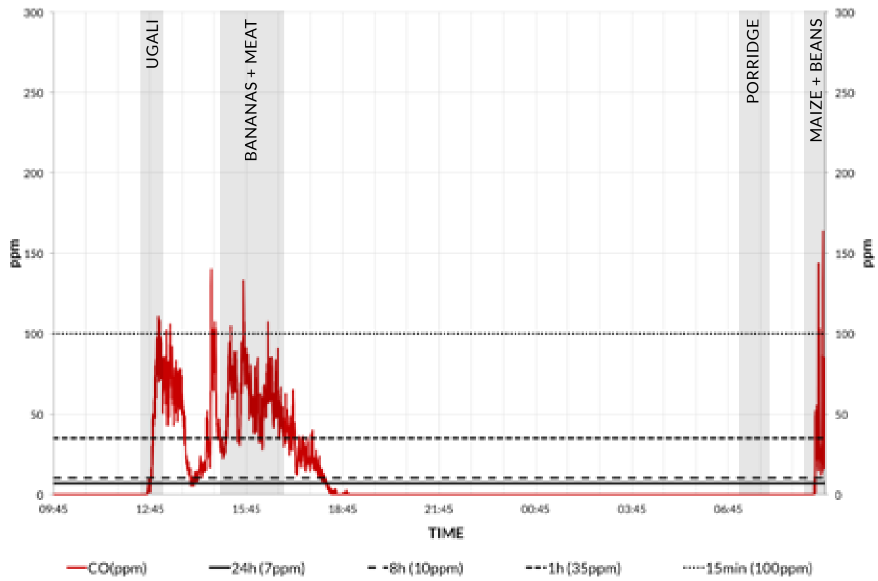


FIGURE 143.
AREA EXPOSURE
First activity observed. Information about other activities and estimated time and duration requested at re-visit.

For monitor placement, see plan on previous spread.

Horisontal lines represent WHO guidelines for mean values of Carbon Monoxide exposure for different time intervals.

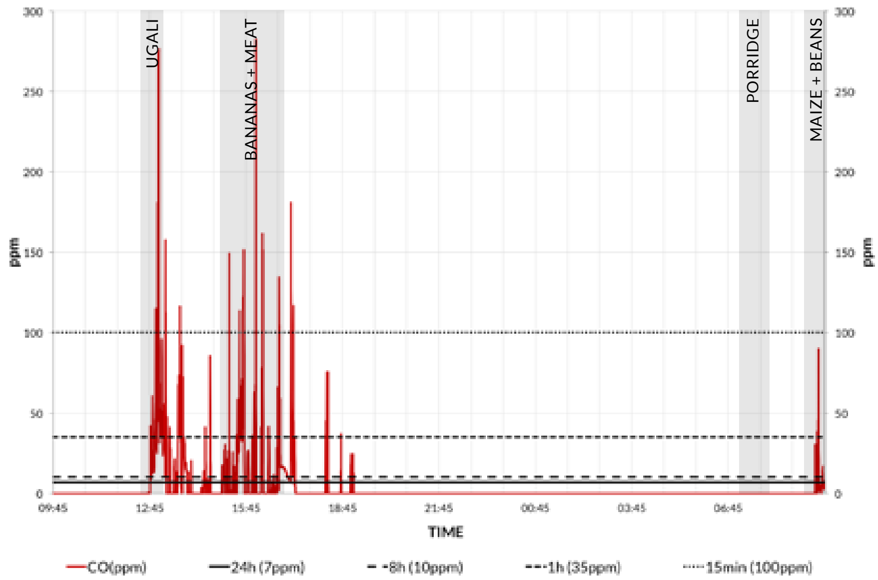


FIGURE 144.
PERSONAL EXPOSURE
First activity observed. Information about other activities and estimated time and duration requested at re-visit.

Horisontal lines represent WHO guidelines for mean values of Carbon Monoxide exposure for different time intervals.

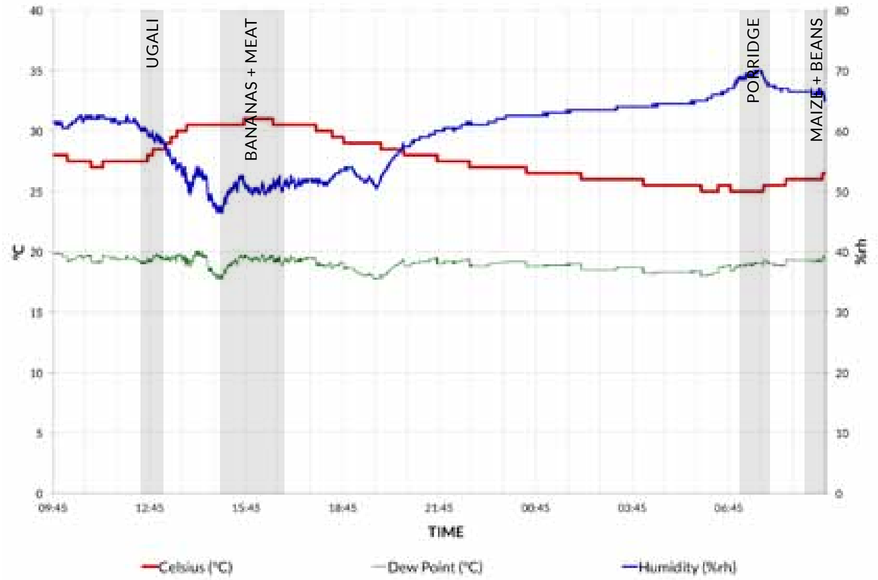


FIGURE 145.
INDOOR ENVIRONMENT
Temperature and relative humidty during the time of measuring.

For monitor placement, see plan on previous spread.

HOUSEHOLD VI
MARCH 24

HOUSING TYPE:	Single family apartment - 36m^2
NUMBER OF ROOMS**:**	3
HOUSEHOLD MEMBERS:	3
CHILDREN UNDER 5:	1
COOKING LOCATION:	Outside lunchtime, Inside when rain
COOKING FUELS:	Charcoal, LPG, Kerosene
MEANS OF LIGHTING:	Electricity, Solar lantern

FIELD NOTES
This small familiy lives in an apartment located in a building that also contains some shops and a beauty salon. There is only one apartment.
They have a bathroom with shower and toilet with running water. This is also where the mother does the laundry.
Usually she cooks outside at lunch and inside the kitchen in the evenings and when raining. She always lights the fire outside, and when using charcoal she has a cylinder shaped "fire starter" with a hole (like a small chimney) to light the fire faster. She does not spend more time then nessessary in the kitchen. There is a window available, but she never use it for ventilation.

The doors are quite heavy and when the mother is washing, the daughter is outside on the veranda. She communicates with sounds to which the mother responds. So they can keep track of eachother.
The child is seldom in the kitchen.

The mother seemed a bit nervous during the visit. She also mentioned it in some ways. It felt like her daily routine was interrupted. When starting cooking at 12.15 she explained that she usually starts to cook earlier.

The father is employed and works in a photo studio. He works six days a week and has the Sundays off. The mother is now at home; before the child came she worked in a factory.
The rent is 100 000 Tsh per month, water and electricity included.

When they buy charcoal, they buy a bag for 15 000 Tsh, which lasts for a month. They also use LPG and a 6kg refill cylinder costs 20 000 Tsh and also lasts a month, if used exclusively. Kerosene is used for smaller tasks and 0.5 litres costs 500 Tsh and lasts for 2 days.

During our visit the television was on, showing a Korean game show.


146.


147.


148.


149.


150.


151.


152.


153.

FIGURE 154. *SITE*

WEATHER

	30/16°C	ESE
	MAX / MIN	2-7m/s

BUILDING MATERIALS

ROOF
Iron sheets - Good condition
Ceiling

EXTERIOR WALLS
Burned bricks - Concrete plaster

PARTITION WALLS
Burned bricks - Concrete plaster

FLOOR
Concrete

LEGEND

- North
- Stove placement
- Monitor placement
- Movement
- Water
- Preparing food
- Cooking
- Dining / sitting room
- Washing up
- Bedroom
- Storage
- Latrine

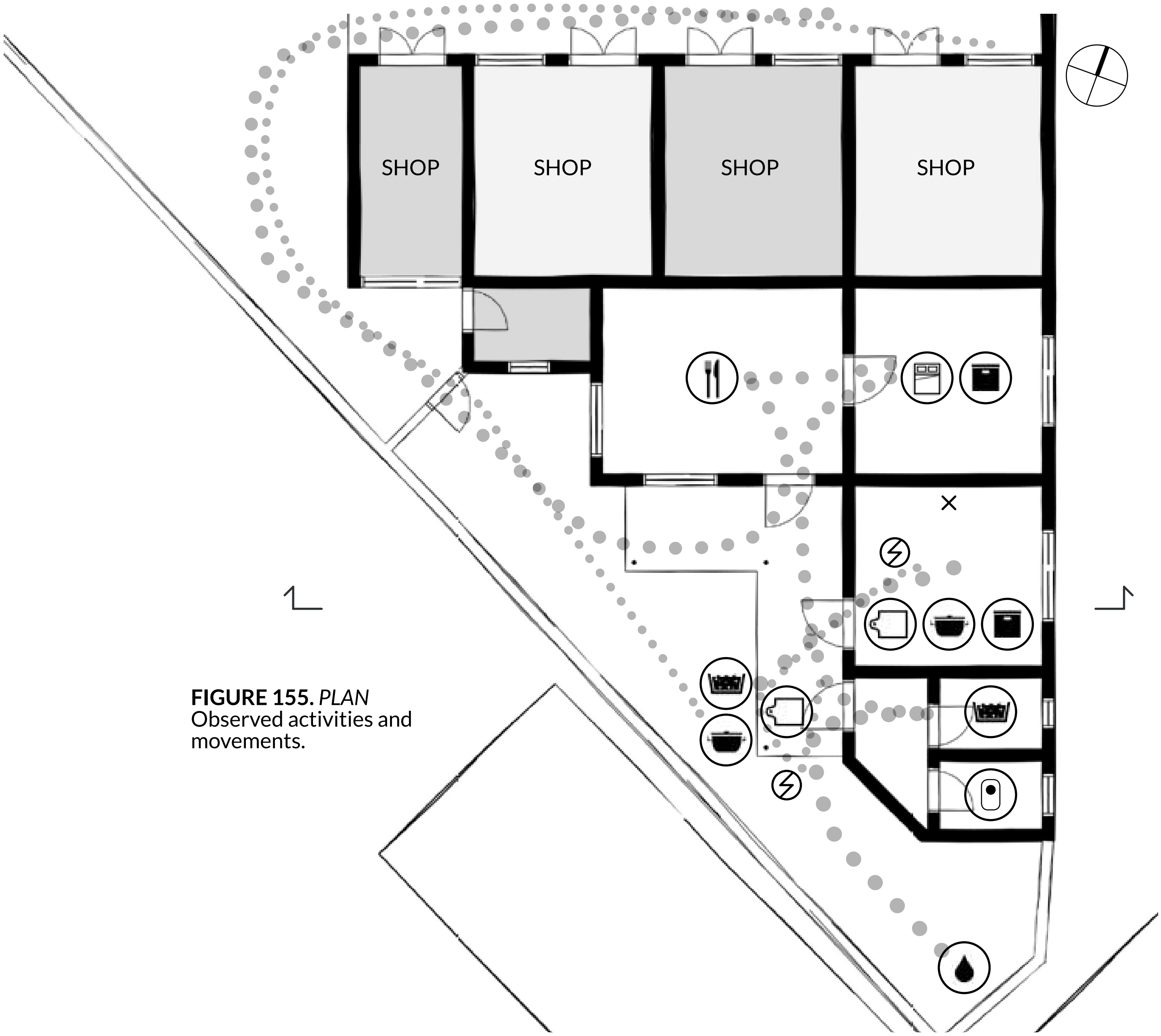


FIGURE 155. *PLAN*
Observed activities and movements.

FIGURE 156. *SECTION*

HEALTH STATUS

The mother wakes up with nasal congestion every day and it lasts for two hours. She uses antihistamines (allergy medicine) as treatment. The child has had illness with cough the last two weeks, but not severe. They have visited dispensary for respiratory health problems the last year and one in the family has used antibiotics.

YOUNGEST CHILD

ARI LAST 3 MONTHS:	No
RUNNING NOSE LAST MONTH:	Yes
NASOPHARYNGEAL CARRIGE:	No

CO-LEVELS

This household has a separate kitchen and uses charcoal, kerosene and LPG for cooking.

The stand was placed in the kitchen, by a wall, about 1m away from both stove and window. The 24h mean value for area exposure was 31.3ppm and exceeds the recommended 7ppm. The second and third 8h-period mean value for area exposure were above the recommended levels, with 69.7ppm and 20.9ppm. As the graph shows, the values between 8pm and 11pm are very high with a peak 1h mean of 264ppm.

The measured mean value for personal exposure was 3.9ppm for 24h, below the recommendations, but exceed the recommended values for 1h, and 15min exposure at several times.

CONCLUSION

This family was quite well-off and it is a good example of stacking and the use of different cooking technologies, both basic and modern fuels when reaching a ”higher” socio-economic status. This familiy used both charcoal, kerosene and LPG.

The kithcen was quite big and had room for all equipment, utensils and foodstuff needed for cooking. But the kitchen and cooking was not a priority when improving the home. All activities took place on the ground or at ground level.

The mother made the dishes on the outside corridor and washing of clothes in the shower/washing room.

Even though the kitchen had both a openable window and a door to allow for cross ventilation, the mother never opened the window. This small behavioral change would probaly improve the situation significantly when cooking with charcoal inside.

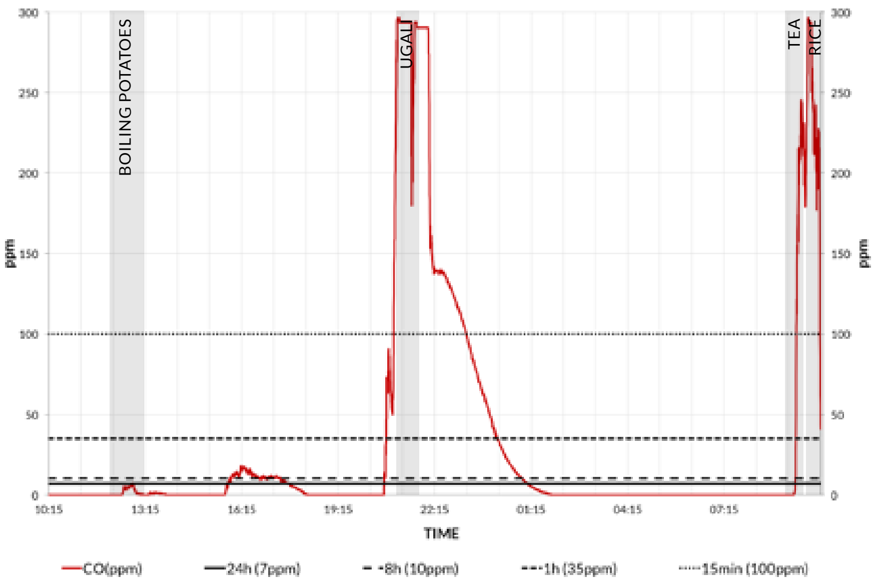


FIGURE 157.
AREA EXPOSURE
First and last activities observed. Information about other activities and estimated time and duration requested at re-visit.

For monitor placement, see plan on previous spread.

Horisontal lines represent WHO guidelines for mean values of Carbon Monoxide exposure for different time intervals.

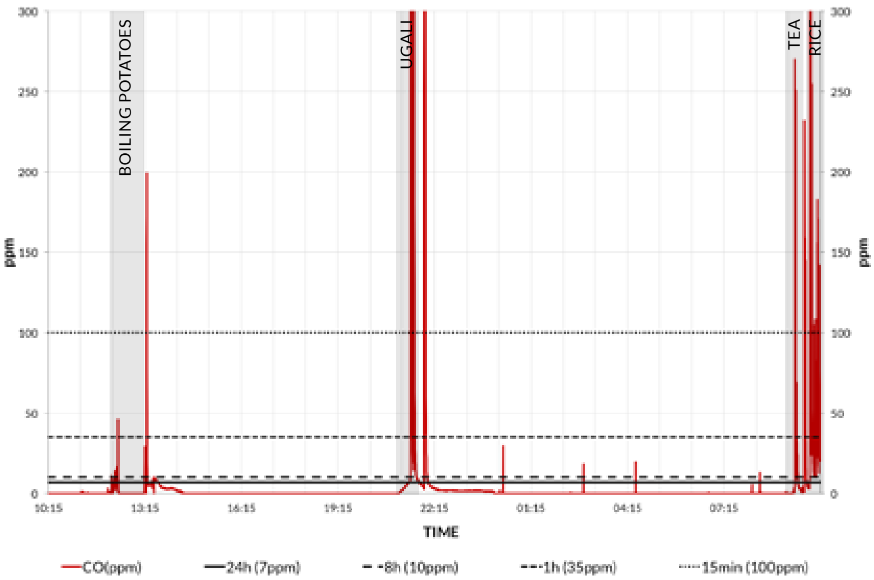


FIGURE 158.
PERSONAL EXPOSURE
First and last activities observed. Information about other activities and estimated time and duration requested at re-visit.

Horisontal lines represent WHO guidelines for mean values of Carbon Monoxide exposure for different time intervals.

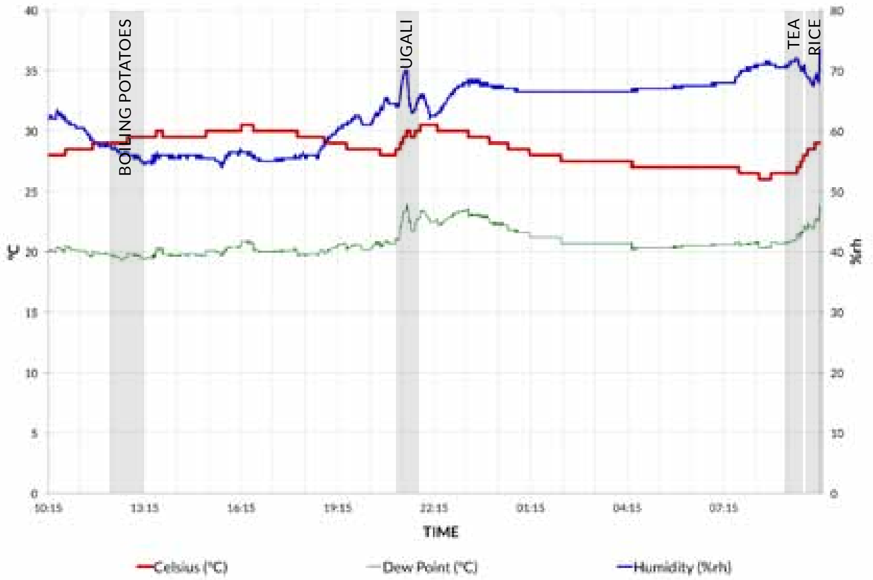


FIGURE 159.
INDOOR ENVIRONMENT
Temperature and relative humidty during the time of measuring.

For monitor placement, see plan on previous spread.

CASE STUDY
HOUSEHOLD II

Household II was selected as case study based on the high levels of smoke measured during the household visit. The site conditions, the use of solid fuels for cooking and the bad conditions regarding smoke and light as well as the materials used in the "kitchen" made it representative for the area (based on field study observations).

Data from the household visit was planned to be entered into a computer model in order to first compare model performance in relation to measured values. Then new data or model alterations (interventions) would be added to new designs in order to evaluate which intervention could be the most effective when it comes to reduction of smoke exposure. Because of various factors this was not possible to do (See Discussion).

Instead the models were limited to analysing wind speed and direction and how the wind interacts with smoke from a stove. First the current situation was set up and analysed in Revit and Simulation CFD.

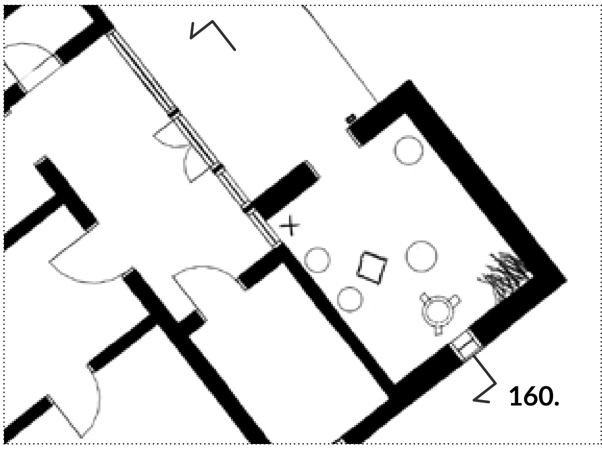
Then 4 alterations were modeled and simulated (Alteration A, B, C and D).

CURRENT SITUATION

This kitchen was built after the main house and the materials are adobe blocks, metal sheets and earth floor. There is only one small window with a wire mesh and the kitchen has no door.

Little wind comes through the small window and if it does it is more likely to keep the smoke in the kitchen instead of ventilating it. It is a dark house and kitchen with little natural light and no electricity.

The main fuel is firewood and they cook using a three-stone-stove.



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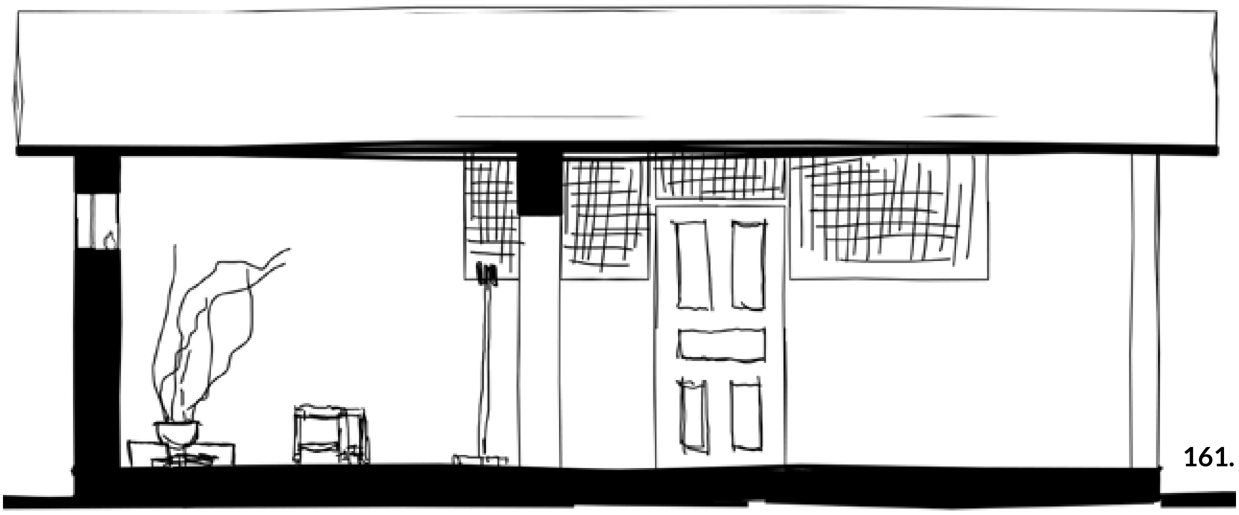

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CURRENT SITUATION

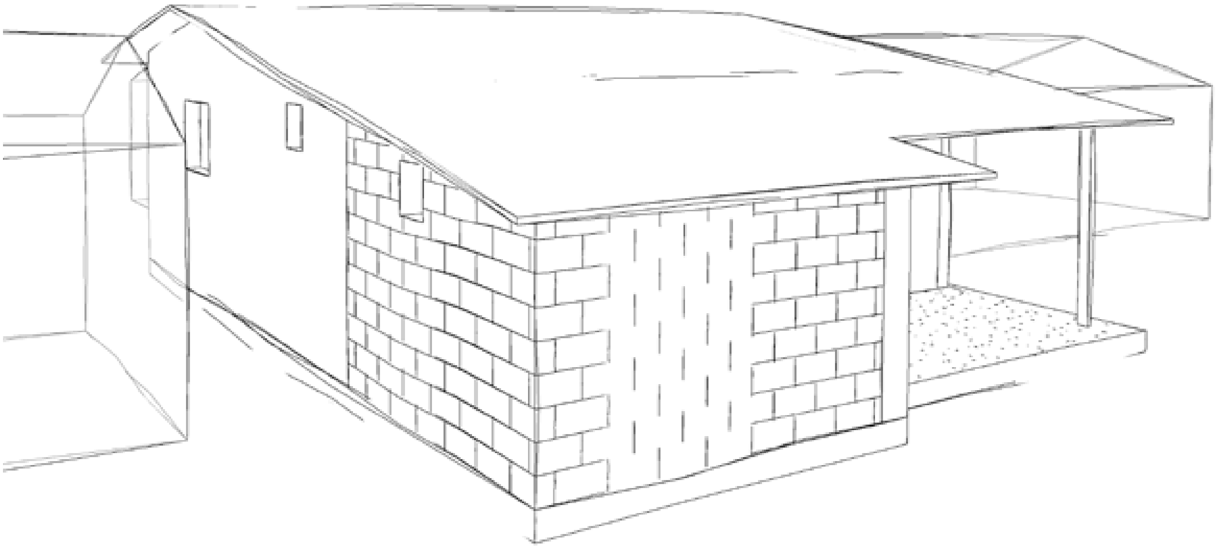


FIGURE 170. *DESIGN*
The current design and position of the kitchen in relation to the house might be good when looking at the social context and activities related to cooking. The front porch is facing the shared space between the houses. This is where the children play and most people pass.

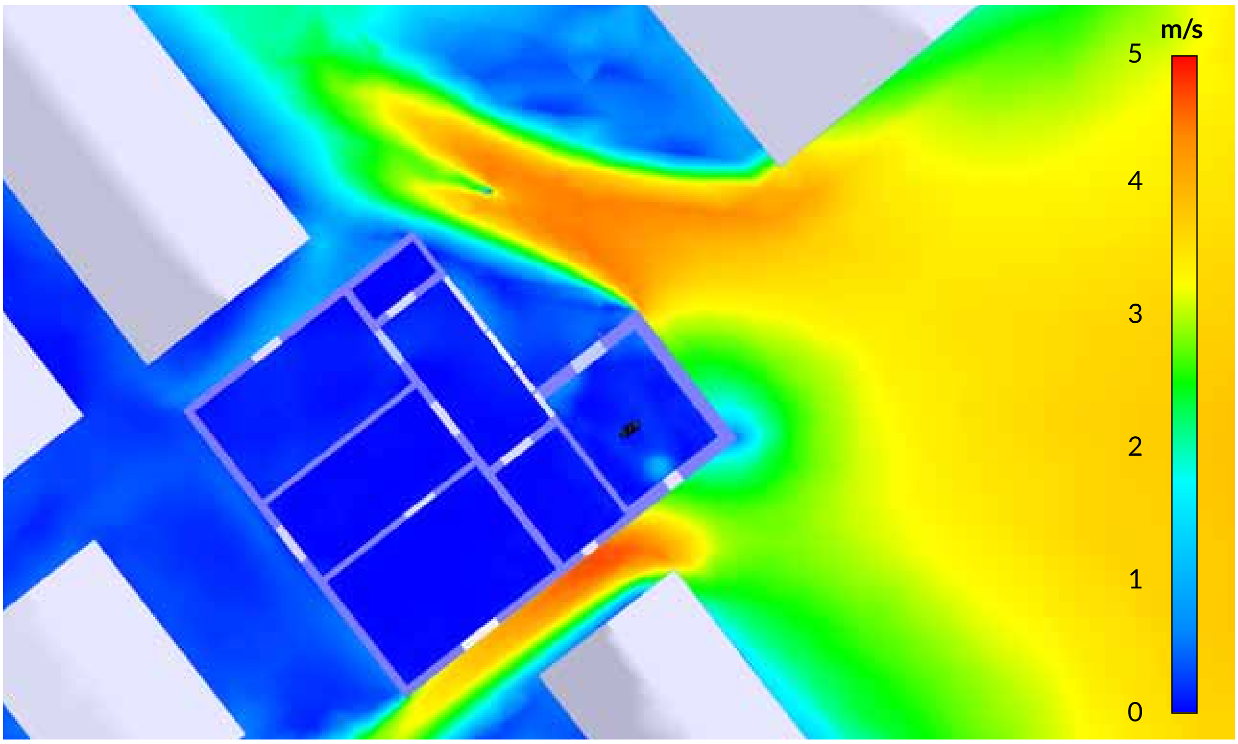


FIGURE 171. *AIRFLOW*
The position of the kitchen on the windward side of the house has the consequence that whatever smoke ventilated from the kitchen may spread into the main living area. The narrow spaces between the buildings increase the airflow in some areas and creates ”pockets” with stagnant air on the leeward side of the house.

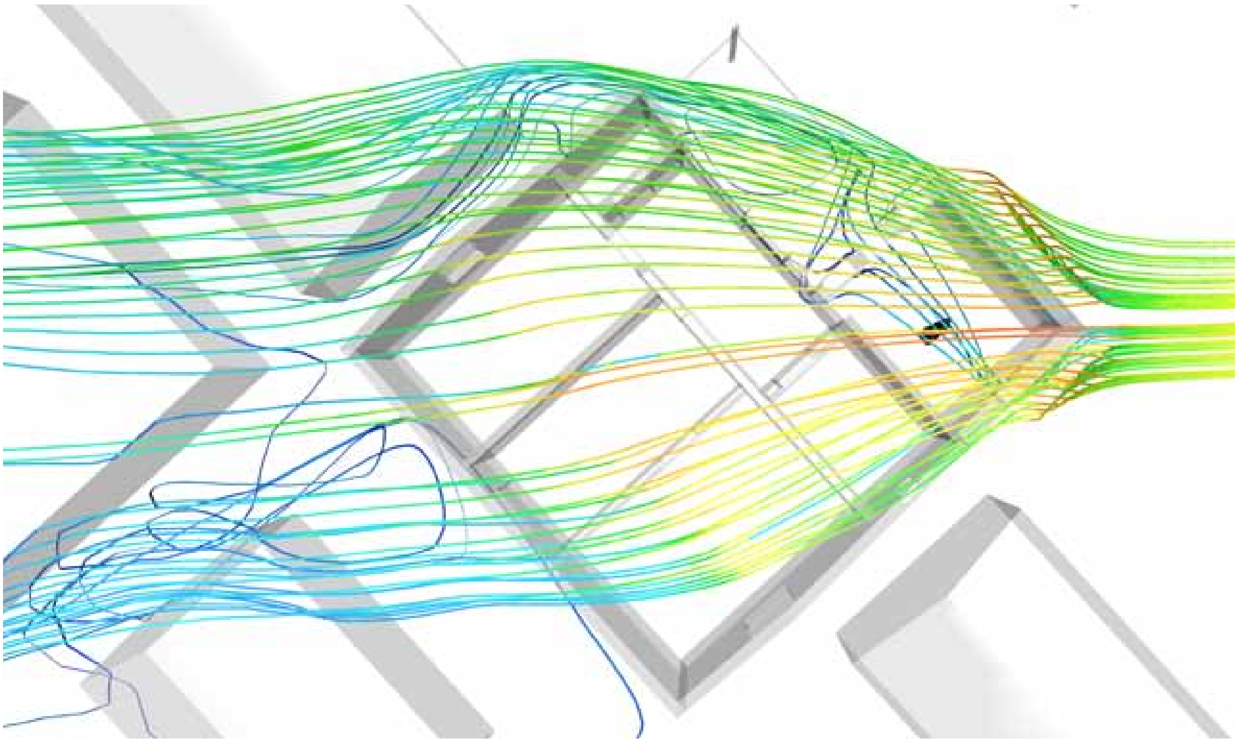


FIGURE 172. *TRACES*
This picture simulates ”trace particles”, the path of randomly selected points along a plane downwind from the house. The paths shows the wind speed and path through these selected points.

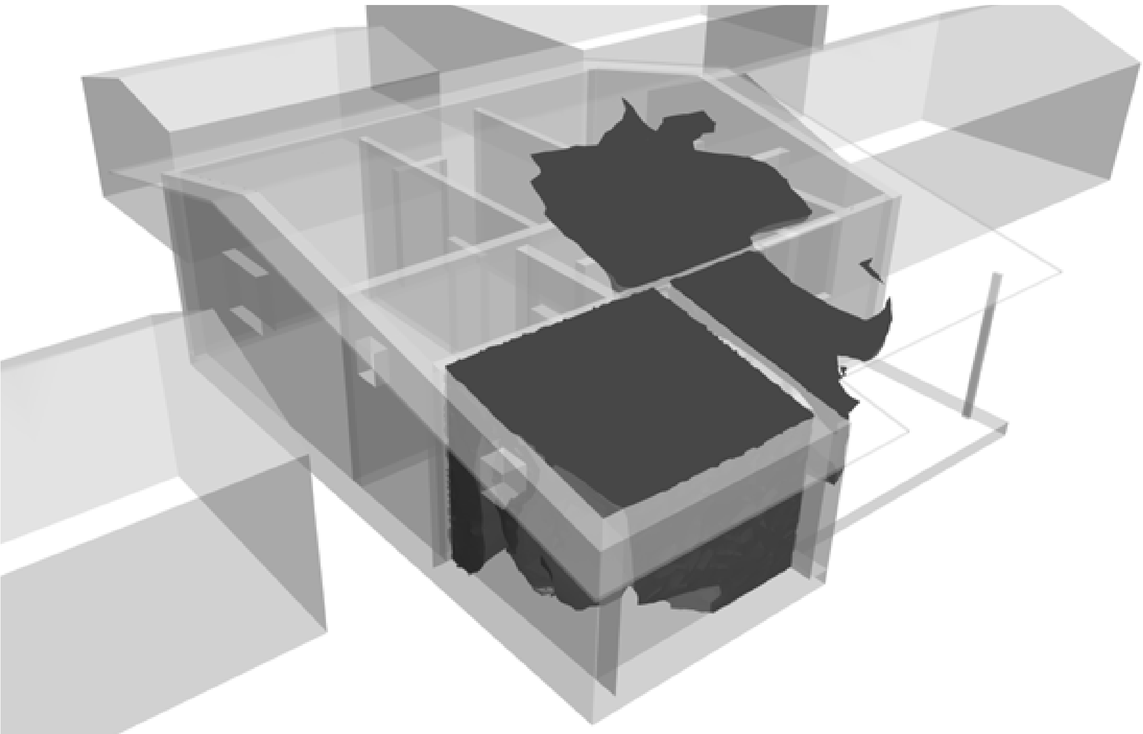
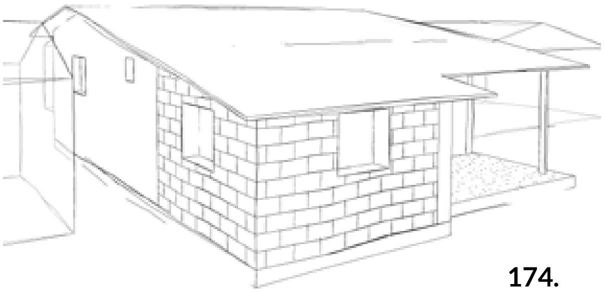


FIGURE 173. *SMOKE DISTRIBUTION*
With the current design with a small window facing south-east, no door and a wire-mesh window between the kitchen and indoor corridor, the smoke first ”fills” the room and then exit through the door or spreads to the indoor corridor through the wire-mesh window. Since there is no ceiling, to smoke can then spread to all other rooms in the house. The smoke in this picture represent an air-mixture with 5% smoke particles.

ALTERATION A

The first design change is to fill the opening between the kitchen and the indoor corridor to reduce the amount of smoke that can spread into the main living area.

The second change is to enlarge the existing opening to south-east and to add a new window to the north-east to improve cross-ventilation. There is still no door to the kitchen.



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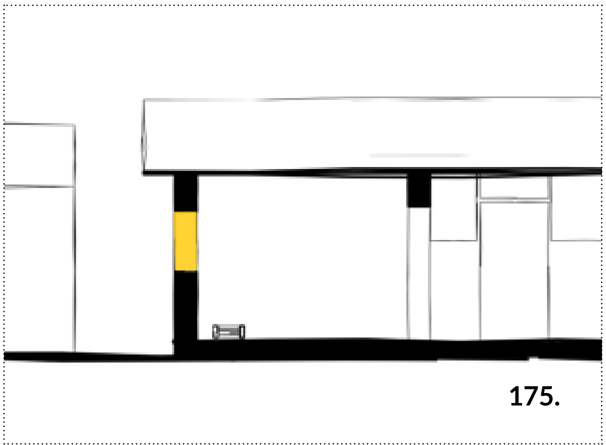

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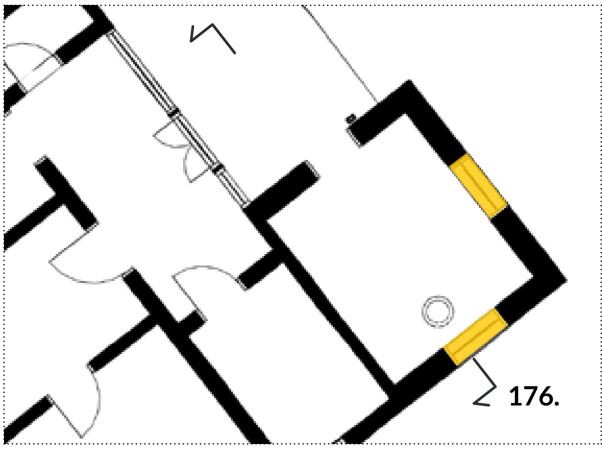

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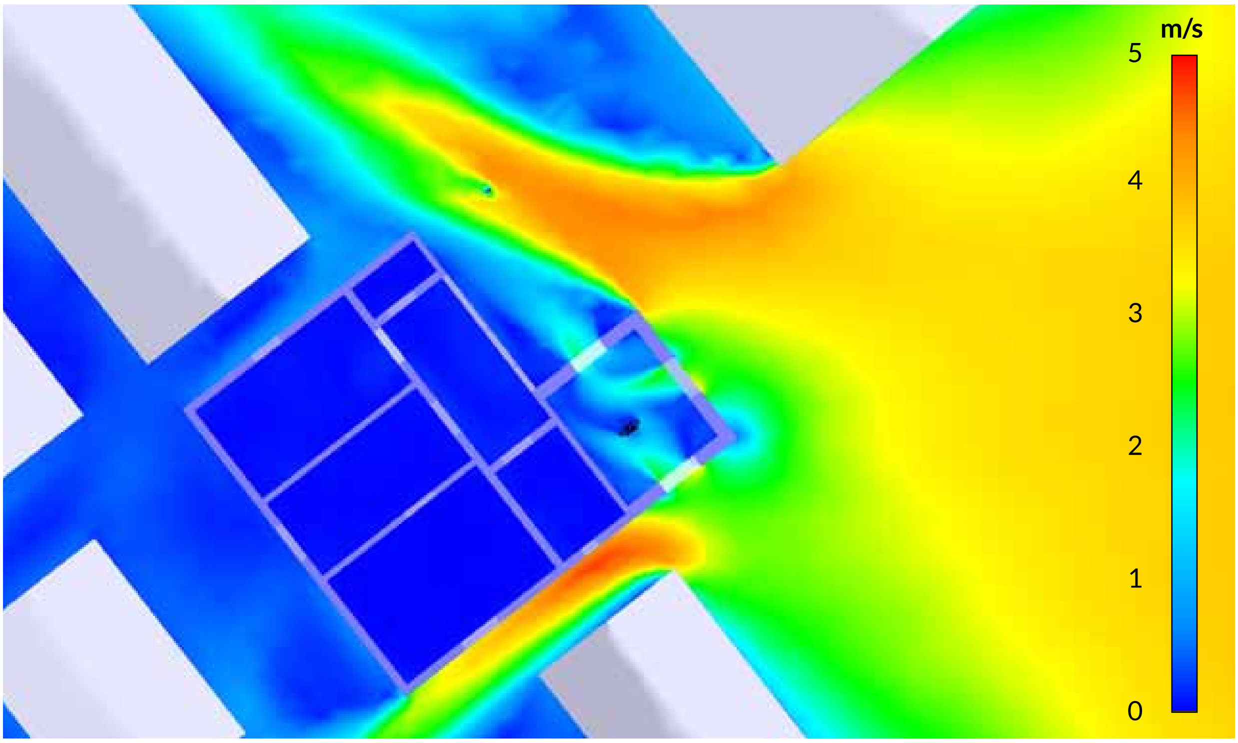


FIGURE 177. *AIRFLOW*
With two bigger windows the airflow through the kitchen is greatly improved. Though without a door to the kitchen the smoke will be ventilated out of the kitchen to the front porch where it might re-enter the home through the wire-mesh windows (Figure 169).

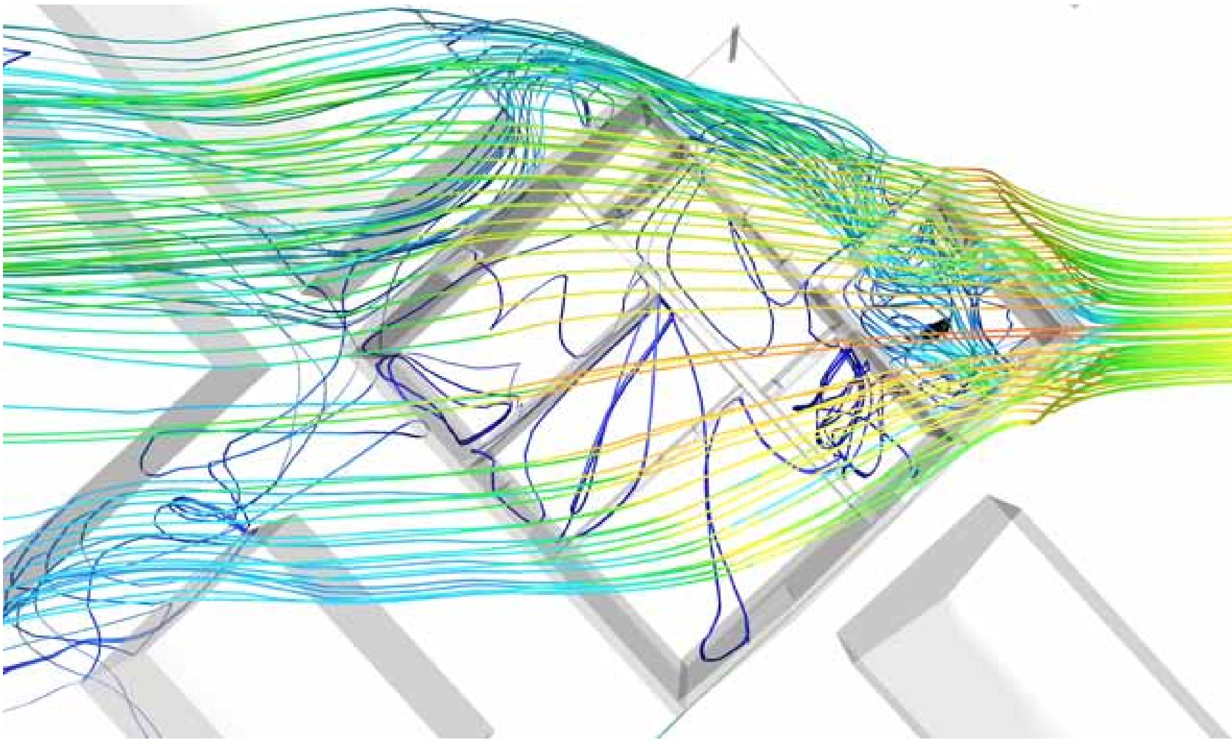


FIGURE 178. *TRACES*
This picture simulates ”trace particles”, the path of randomly selected points along a plane downwind from the house. The paths shows the wind speed and path through these selected points. In comparison with the current design there is more airflow through the kitchen but some traces lead into the main living area.

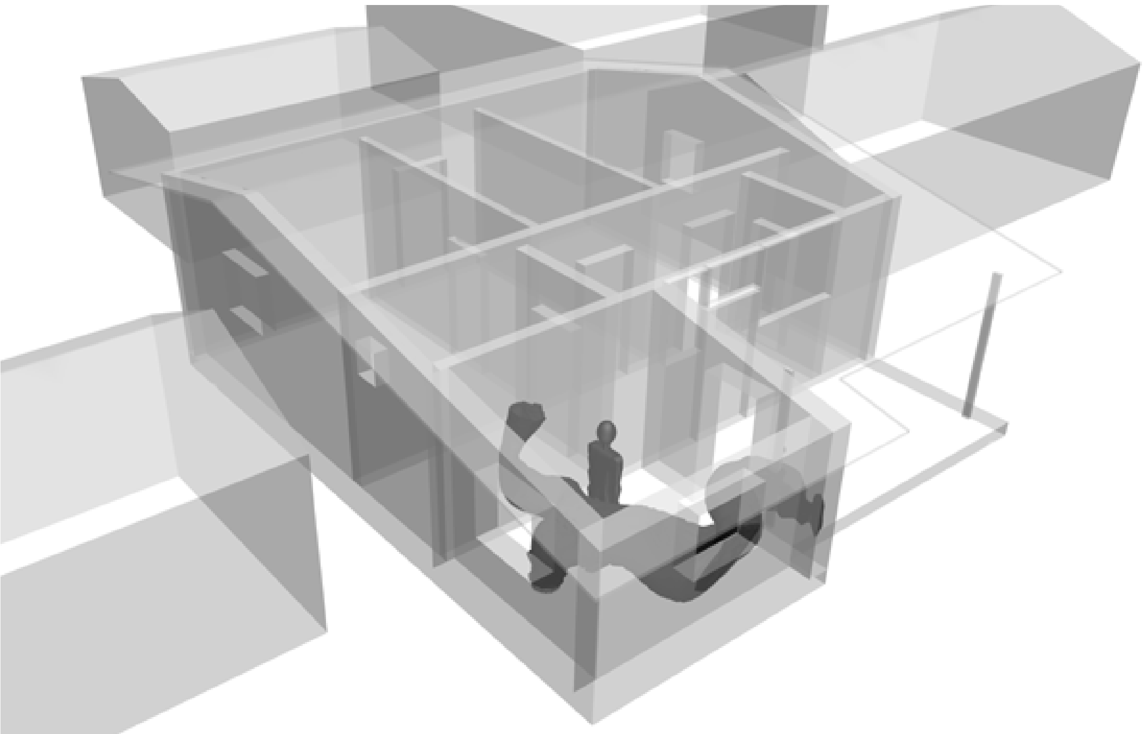
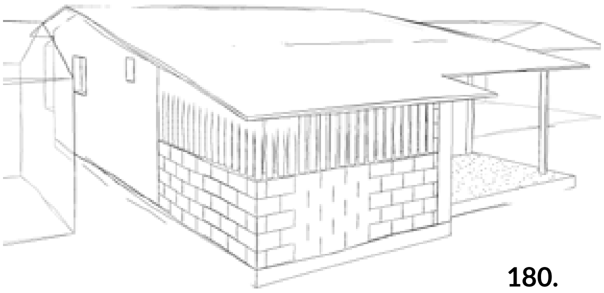


FIGURE 179. *SMOKE DISTRIBUTION*
The smoke from the stove is better ventilated an ”spread” faster which possibly would lead to less smoke.

ALTERATION B

In this second alternative, two of the walls towards south-east are altered. The lower part of the adobe-block walls is kept solid while the upper part of the walls consists of vertical bamboo- or wood-sticks. In the simulation this diffuse ventilation is model by assigning a ”resistence material” with 50% open area to the upper part of the walls.

Opening from kitchen to corridor is covered.



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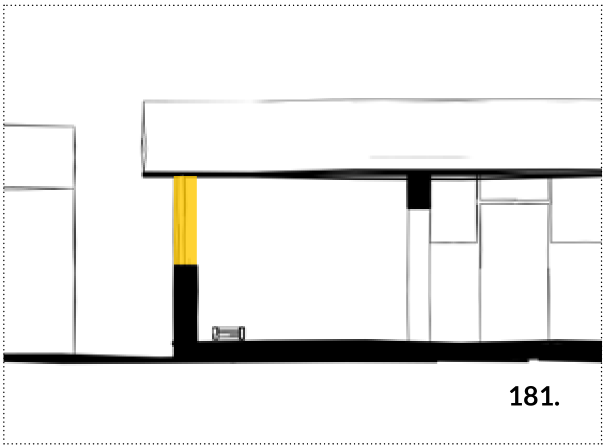

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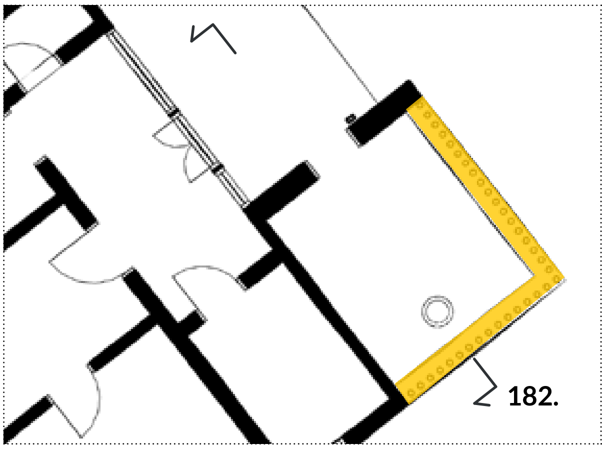

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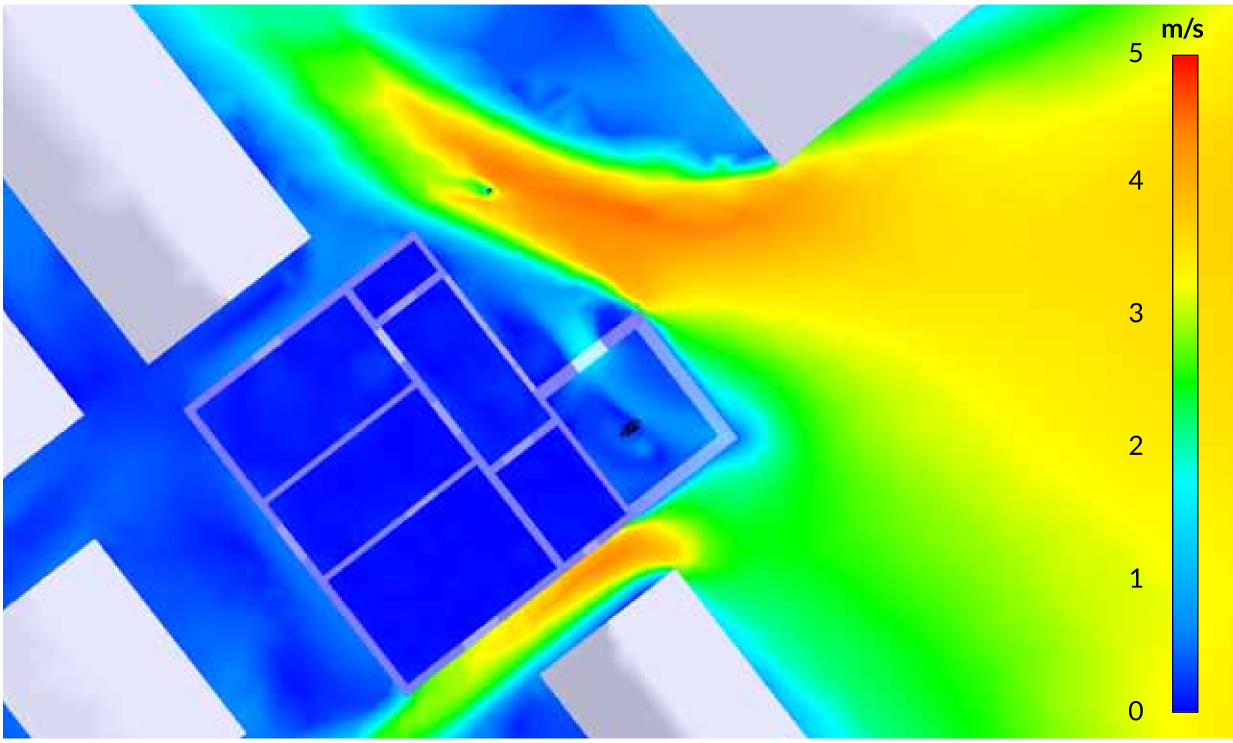


FIGURE 183. *AIRFLOW*
In this picture we can see that the airflow in the kitchen is approximately half the speed of the airflow on the windward side of the house. The air is channeled through the doorway. Adding a door-panel would re-direct the airflow.

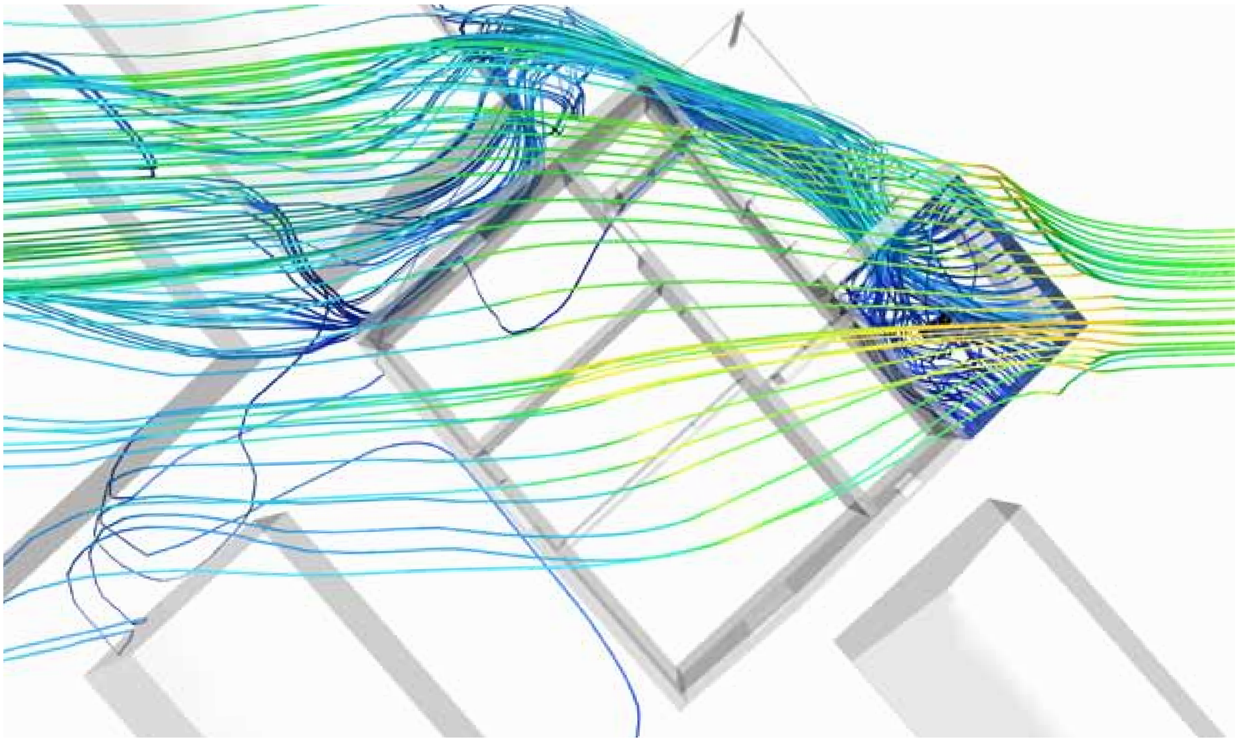


FIGURE 184. *TRACES*
This picture simulates ”trace particles”, the path of randomly selected points along a plane downwind from the house. The paths shows the wind speed and path through these selected points.

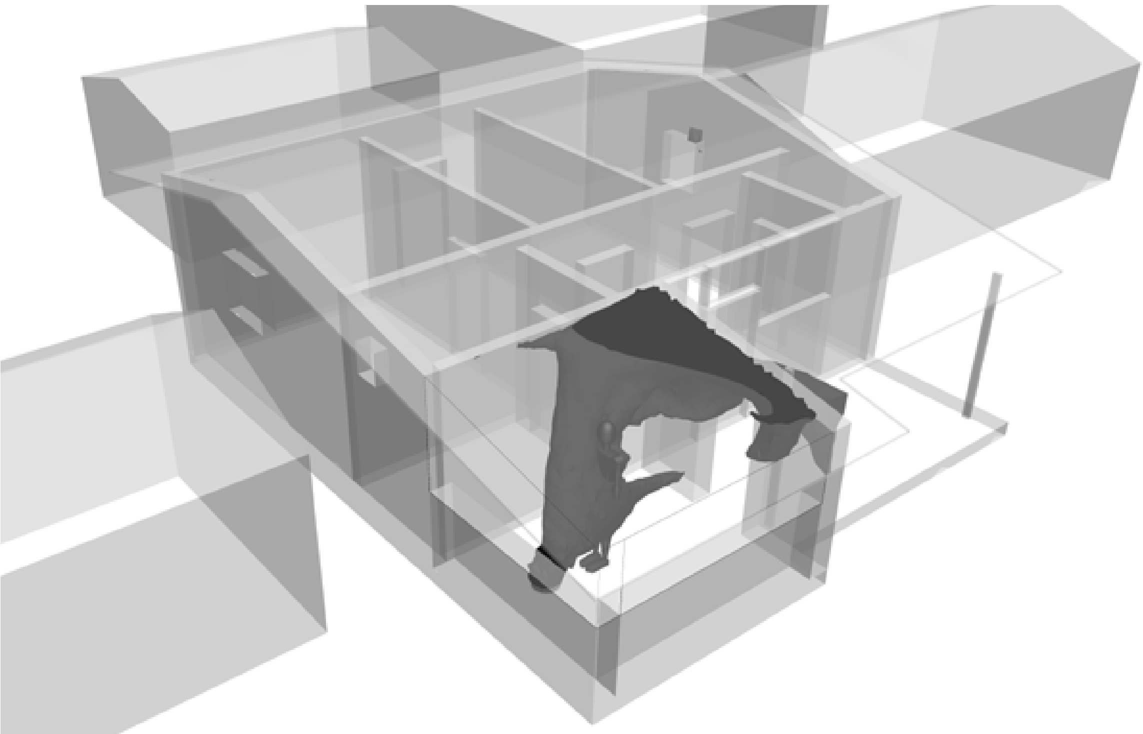
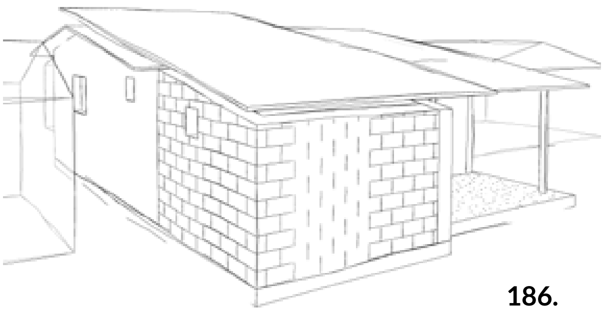


FIGURE 185. *SMOKE DISTRIBUTION*
With a steady wind coming from the east, no smoke leaves the kitchen trough the permeable walls. Instead the smoke that does not get ventilated through the doorway rises to the roof and is pushed directly towards the person responsible for cooking.

ALTERATION C

This design tries to evaluate the effect on only raising the roof. Leaving 30 cm eave space between the top of the walls and the roof. The opening from the kitchen to the indoor corridor is still covered, and there is no door-panel. In a simulation considering solar radiation the result might have looked different. With the sun heating the air between the upper and lower roofs, creating a draft lika a solar-chimney.



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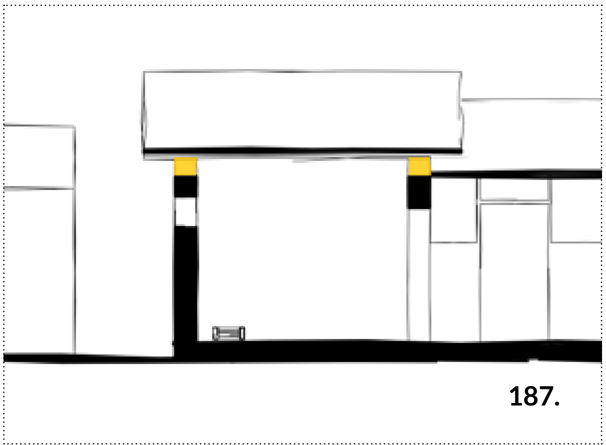

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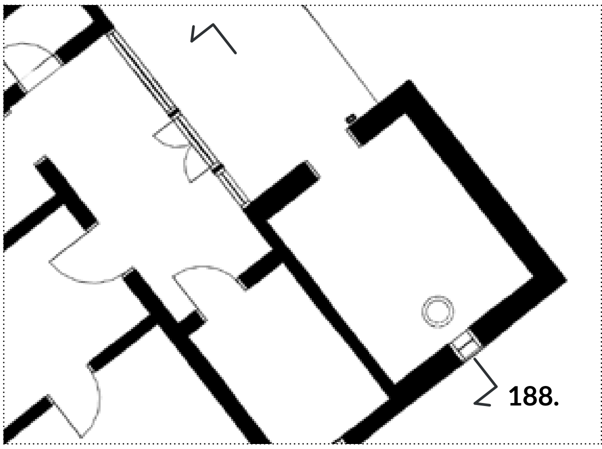

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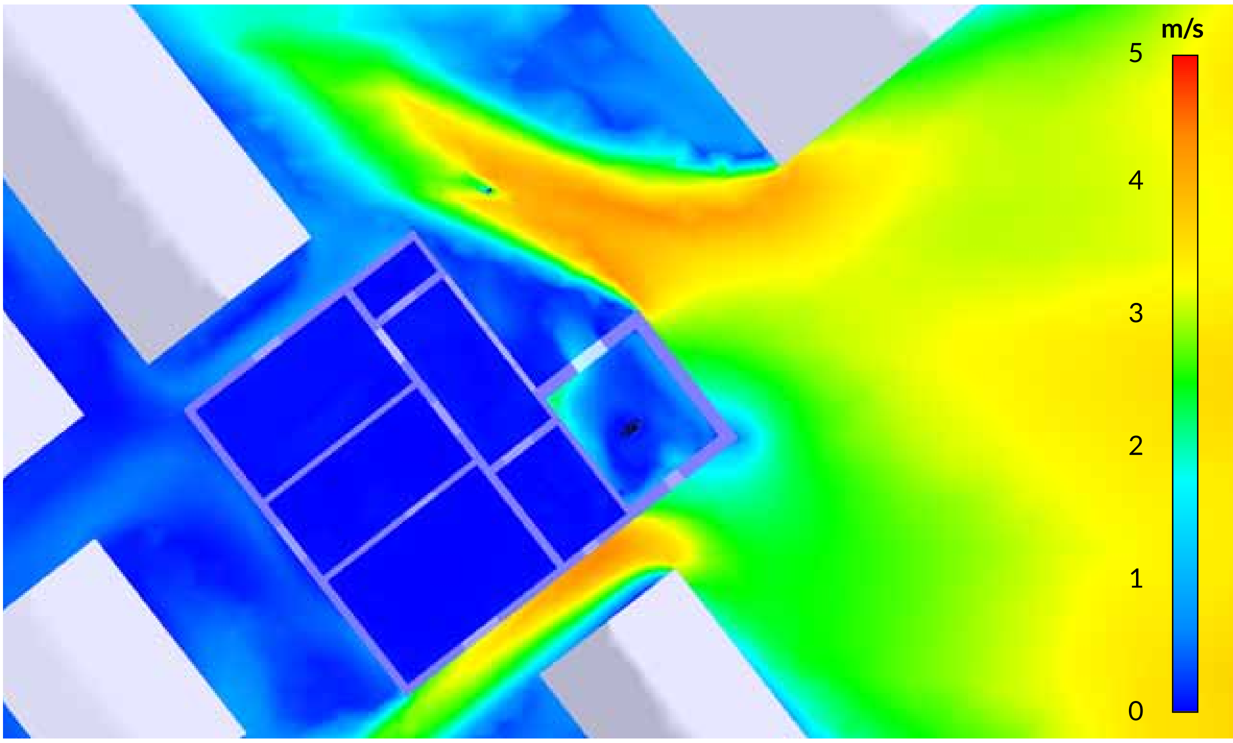


FIGURE 189. *AIRFLOW*
The air entering the kitchen through the eaves-spaces circulates in the room and leaves quite still air in the centre. And with wind coming in from the existing small window creating some turbulence.

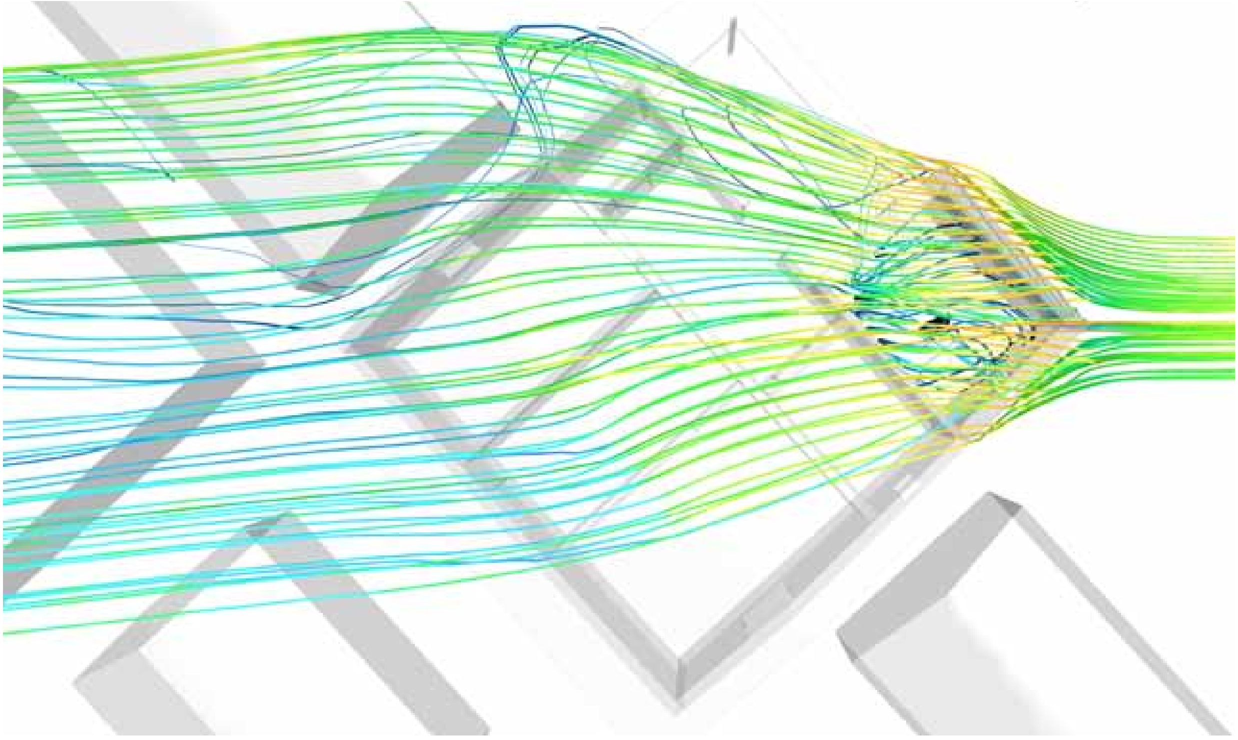


FIGURE 190. *TRACES*
This picture simulates ”trace particles”, the path of randomly selected points along a plane downwind from the house. The paths shows the wind speed and path through these selected points. Very little air leaves the room through the space between the roofs, instead it exits through the doorway.

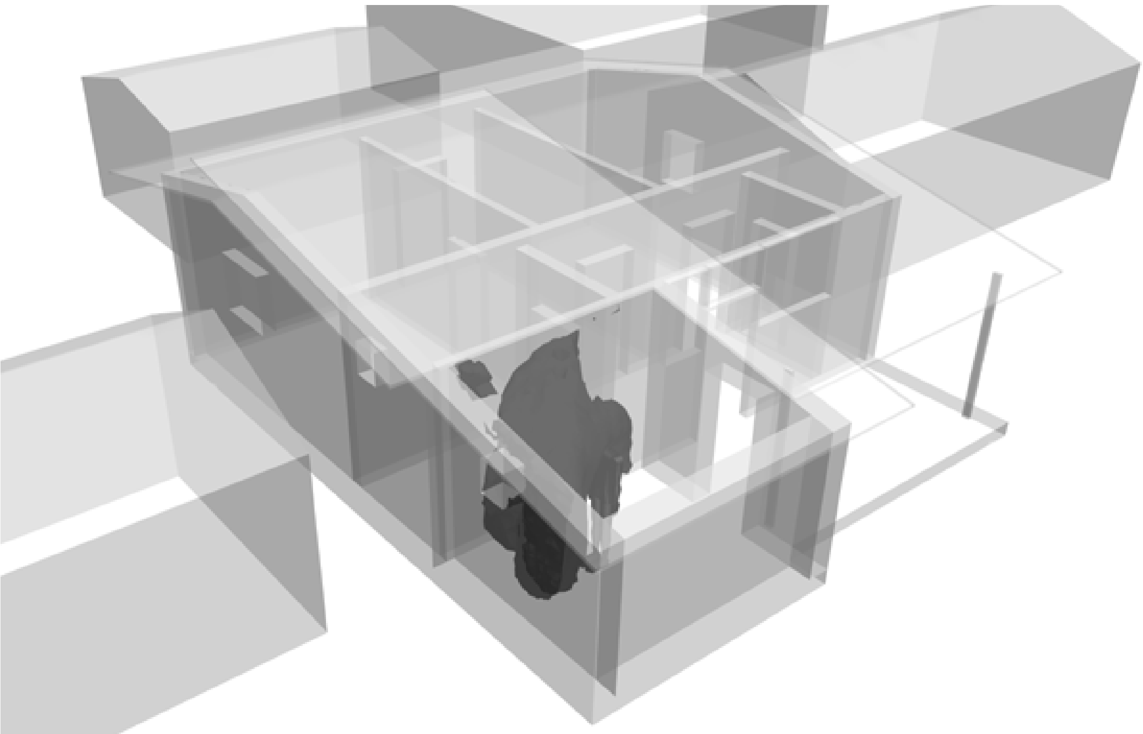
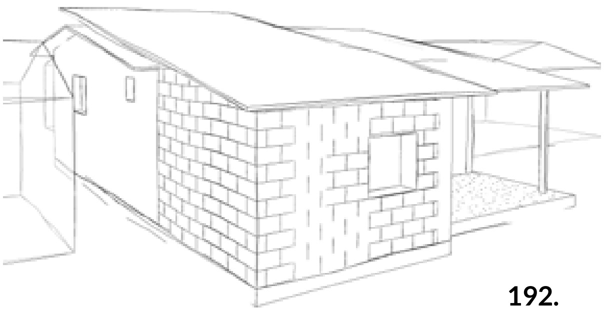


FIGURE 191. *SMOKE DISTRIBUTION*
With better airflow, the smoke is better ventilated. But with a steady wind entering through the eaves spaces and circulates down into the room, the smoke is circulated in the room instead of rising to the roof and exiting through the eaves spaces.

ALTERATION D

This last alteration gives the most controlled environment. The roof is raised, leaving a gap between a new and existing roof to the west. There is a new window and a door panel (door closed in simulation). The stove is also moved to the corner and a smoke hood is modeled around it.



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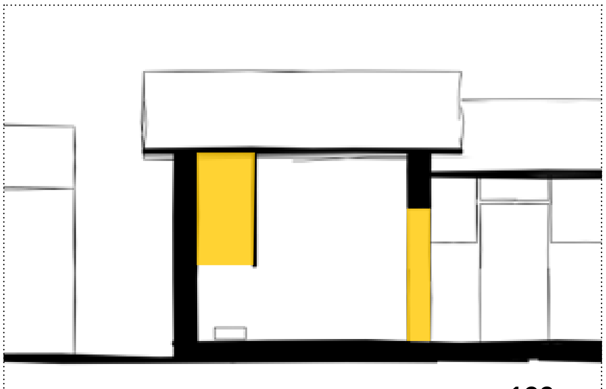

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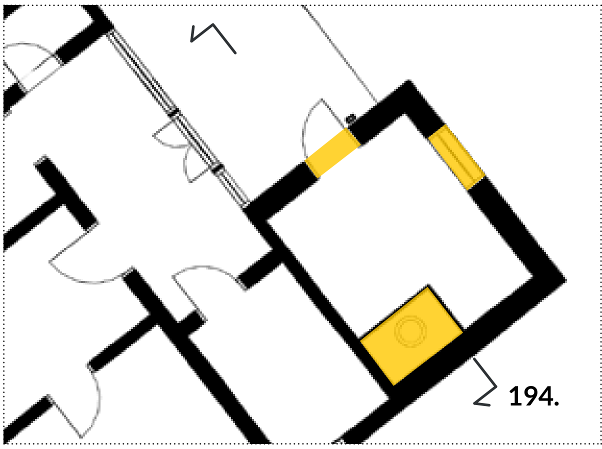

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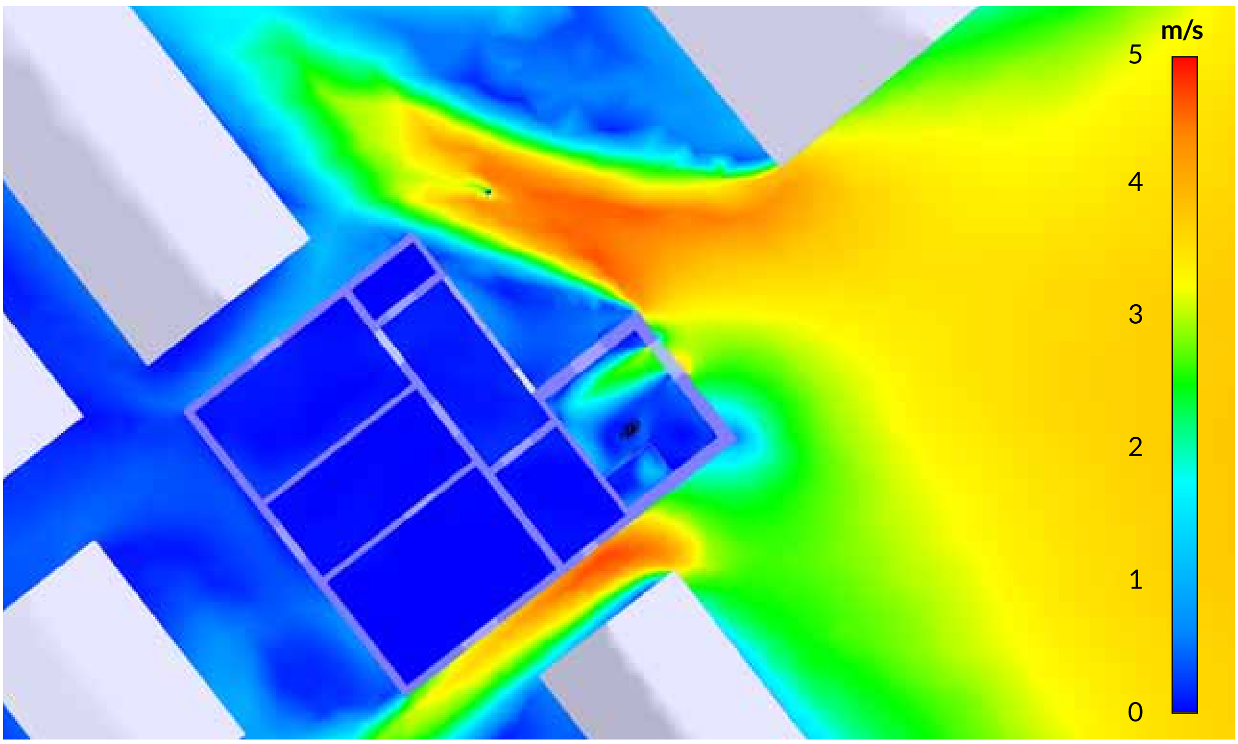

FIGURE 195. *AIRFLOW*
This design creates a very controlled airflow and the smoke hood, closed door and placement of the window makes the air around the stove quite still, while there is good airflow in the other part of the room.

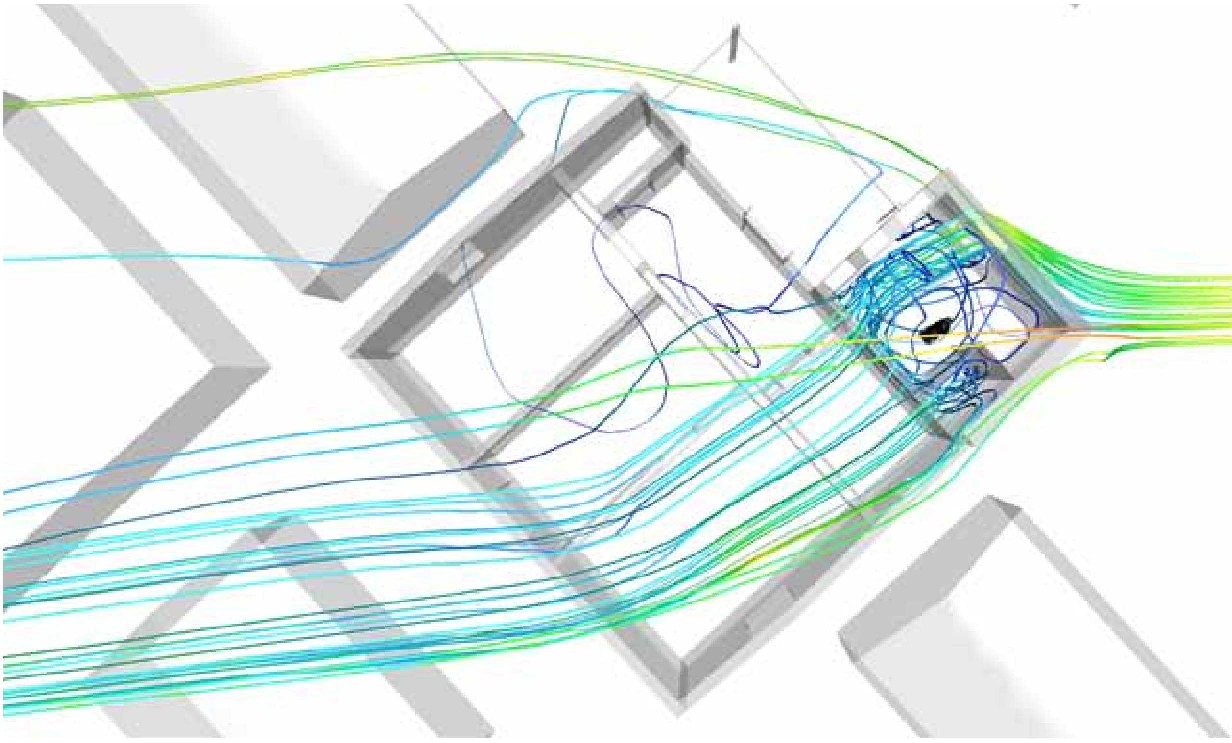

FIGURE 196. *TRACES*
This picture simulates ”trace particles”, the path of randomly selected points along a plane downwind from the house. The paths shows the wind speed and path through these selected points. The wind enters the space through the window and exits through the space by between the new and the existing roof.

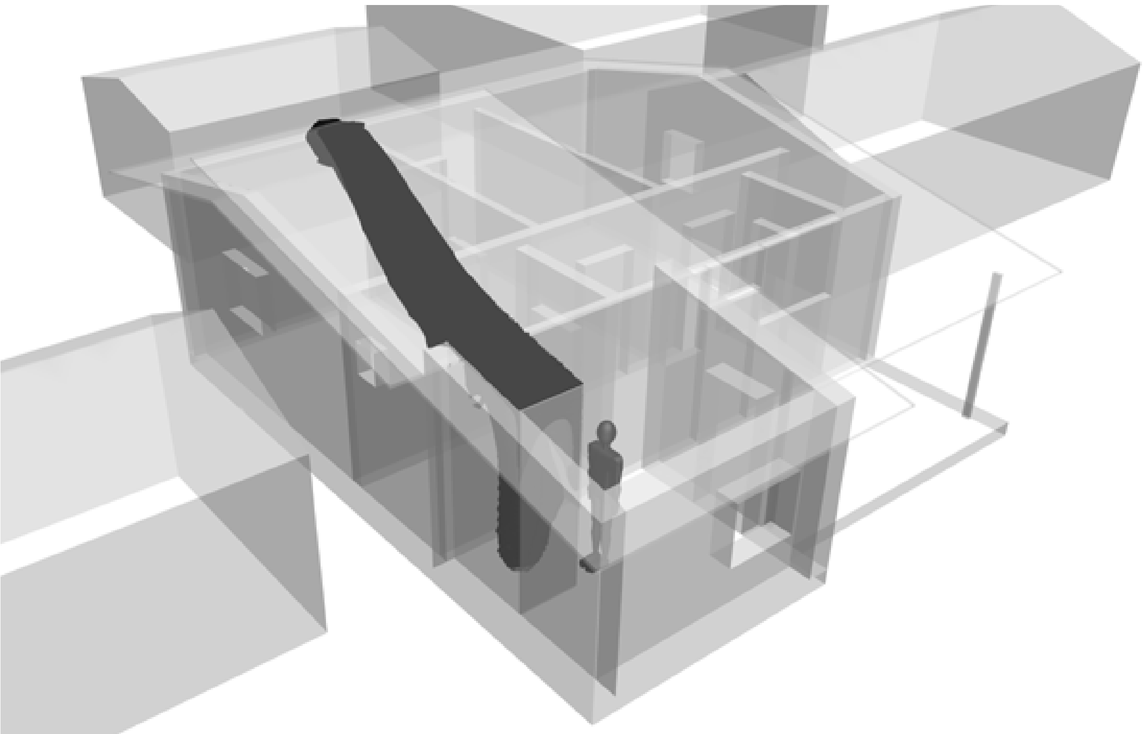

FIGURE 197. *SMOKE DISTRIBUTION*
Being sheltered on two sides and placed in the corner the warm smoke rises straight into the smoke hood and exits between the two roofs. The kitchen is practically smokeless.

CASE STUDY CONCLUSION

There are many strategies and principles on how to improve natural ventilation: open structures and permeable walls or roofs; direct ventilation through openings, doors and windows (cross ventilation): utilise the stack effect etc. (Figures 38-43).

If these principles would guide the design when building, the situation regarding household air pollution would be significantly better in many homes.

Through analysing the site, sun-pattern and prevailing winds, good design choices can be made regarding placement and positioning of both house and kitchen in order to benefit from the site's conditions.

In this case study house, the kitchen was built on the windward side of the main house, resulting in a situation where some of the smoke ventilated outside is more likely to re-enter the living quarters compared to a design where the kitchen is placed on the leeward side of the building.

Apart from changing cooking technology, stove or fuel, my conclusion is that the best solution for this home under current circumstanses would be to add a smoke hood and to make it possible to close the door and/or window to control the airflow. A door would also make it possible to store foodstuff and utensils in the kitchen without risking theft.

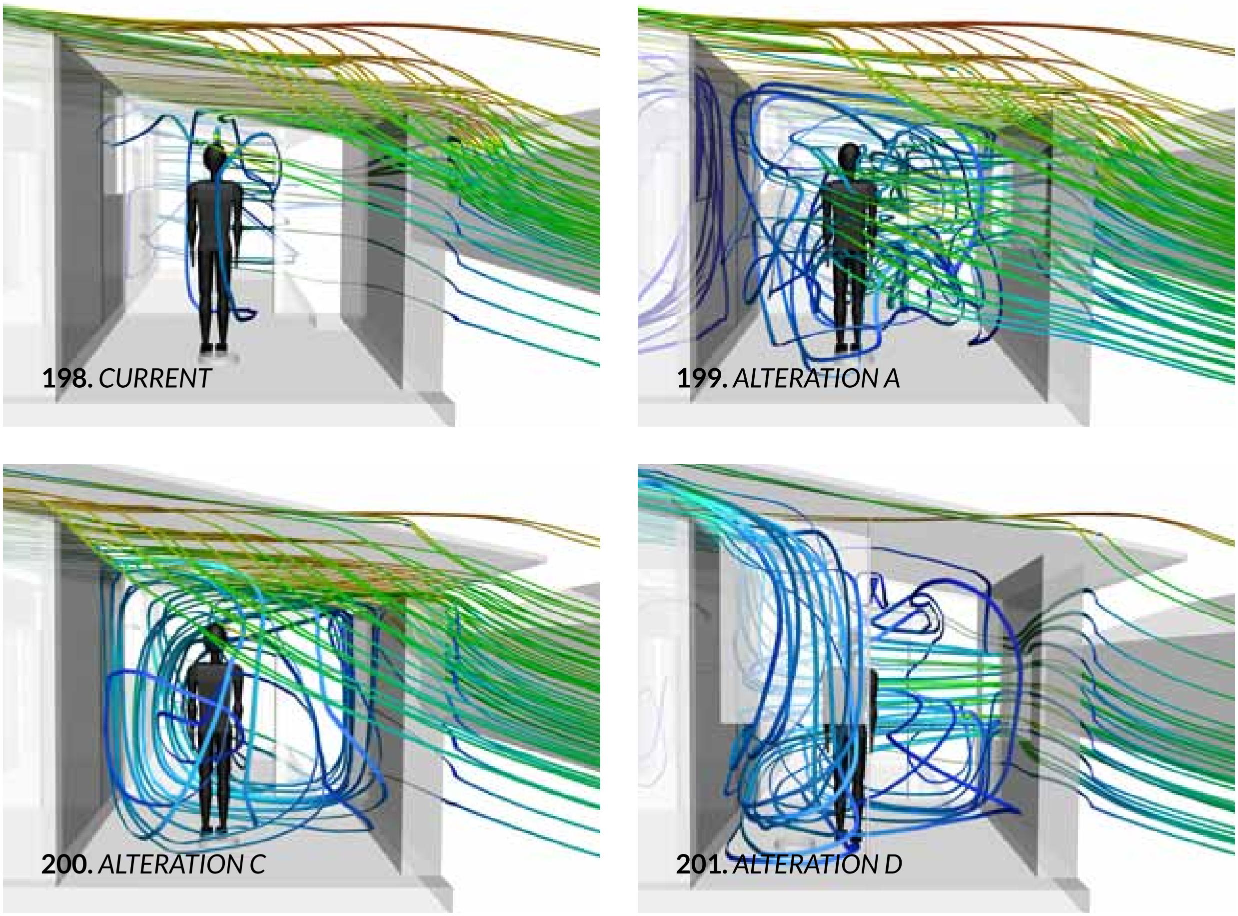

FIGURE 198-201 *SECTION PERSPECTIVE TROUGH KITCHEN*
The traces in the pictures above show the different wind movements in the kitchen in the current design and in design alteration 1, 3 and 4.

DISCUSSION

In this chapter I will discuss the result from Part I and Part II, why we came up with this result and in what way it is different from what we had expected on beforehand.

Then I will discuss the methods and tools used with a focus on Part II and on the case study workflow.

How and why was it different from the planned workflow?

How well did we live up to the project aim?

What is the positive and negative aspects of an interdisciplinary project like this?

RESULT

> *"In research projects, learning what is wrong is almost more important than finding out the good things."*
>
> - Practical Action (2007)

PART I

When we left for Tanzania, we had read a lot about household air pollution and its effects globally. Even though we knew that we were going to a town and that Moshi was probably better off than many other places, I think we thought that the situation regarding household air pollution would be worse.

The result from Part I is based on interviews conducted at three different health facilities within Moshi municipality. The participants were parents or caretakers of a child below two years of age, visiting the health facilities for different reasons. The facilities were chosen by supervisors at KCMC and the population served by these facilities may not represent the situation in Moshi municipality as a whole. Visiting facilities in rural areas and in more places in Moshi might have resulted in a more diverse study population that could giva a more representative result for Moshi, and for Kilimanjaro region. The facilities we visited were located in the southern parts of Moshi urban, and many participants came from unplanned "poor" areas. Still, most of them had access to electricity, but no one used electricity for cooking. Without going into depth trying to define what is 'urban' or 'peri-urban' in this context one could see that difference in fuel-use correspond quite well with the location of the home, being close to town or in the outskirts.

PART II

Out of 213 participants in Part I, 166 were willing to participate in Part II. This was more than we had expected.

The household visits, conducted during 2 weeks in March 2015, went better than expected. We were able to do all tests and collect all the information that we had planned.

Our aim when contacting families to visit was to find different homes with different characteristics and socio-economic status to experience and witness different environments to map and measure differences and similarities.

Even though the homes were quite different regarding employment and socioeconomic status, they had one thing in common: the kitchen envionment was neglected.
The household priorities were directed elsewhere. In all homes, the women (wife, doughter, housemaid) were responsible for cooking, cleaning and washing.

HAP
During the time of household visits the weather was nice and there was no rain. And since most homes cooked outside when using charcoal or firewood, the levels of CO in the indoor air was below the recommended mean values for most time periods during our 24-hour measuring.

For personal exposure, we measured high spikes of CO, but most women did not spend more time than necessary close to the fire, resulting in mean values below the recommended.

It is hard to predict what the result would have been if we had measured for a longer time period, if the weather had been worse, or the families had used a different fuel.

One should also note that we only measured carbon monoxide exposure. And even though several studies suggest that CO is a good marker for other pollutants, it is possible that levels of particulate matter exceeds the recommended limits in the homes we visited.

CASE STUDY
The result from the case study simulations shows the spread and distribution of smoke from a fire in four different alternate designs with the aim to improve ventilation, compared to the current situation. In this thesis the improvement and change is purely visual and it is not possible to accurately say how much lower the CO-levels would be in the different scenarios.

Some could argue that the results from the simulations produced are redundant and unnecessary, and to some extent I would agree. With basic knowledge of the site, weather conditions and natural ventilation principles one could predict the air movement without using computer simulations in this case.

Though, the result shows the importance of being able to control the air movement and to place the kitchen and stove on the leeward side of the house in order to reduce the amount of smoke entering the living quarters.

METHOD

One of the project aims was to evaluate methods for quantitative and qualitative studies to be conducted in a larger scale or in a different context. This evaluation is done through external documents and discussions. In this section I will present a general summary of the different parts of the study and methods used.

PART I
Conducting the quantitative study at health care centres was effective in the way that participants who fitted the study population description set up for the study could easily be recruited with help from the local nurses. The downside of this was that only participants who have access to, and who seeks care are included in the study.

The interview was based on a questionnarie compiled by us before going to Moshi. The questions were gathered from a questionnaire used in a previous study in Moshi and was complemented with questions from other studies conducted in East Africa to include information on household, house and kitchen.

An interview took on average 15 minutes. If limiting the amount of questions or asking them in another way, this time could be reduced in order to have more people included in the study.

PART II
The household visits were conducted as a pilot study to test different tools, tests and methods, to evaluate what data to collect, and how to collect it. The aim was never to gather enough data to be used

in a statistical analysis. This being said, the results from Part II contain many confounding factors. The biggest of these is our presence during measuring. We asked the participant to ignore us and carry out his or her daily activities like a normal day. But our precence, questions, tests and data collection might have changed the everyday life and activites, and when and whare they took place.

When deciding what data to collect and how, one should consider the different characteristics of the project: type of research, intervention, scale, financial and human resources and time.

The data analysis from only six household visits was very time-consuming. Mostly because the data had to be formatted, exported, imported and prepared to be presented in this thesis report. One should question the need for detailed drawings of the building, or the importance of presenting the CO-measuring in tables preparred in Microsoft Excel.

CASE STUDY

One case study house was chosen to explore a workflow and method of using site specific data to compare different interventions. The focus was not to get the most accurate result but to evaluate the method to see if it is feasible to use this workflow and tools when planning and designing for house improvements with the goal to reduce smoke exposure.

As mentioned in the introduction, there is a need for knowledge that interventions make a difference, there is also a need for enhanced methods for testing of emissions in normal use.

INTENDED WORKFLOW

At an early stage when planning this project I started outlining a workflow. My idea was to explore computer software to map a case study building, create a 3D BIM model, run energy analysis based on model characteristics and site specific weather data. Then to open that 3D-model in simulation-software to add data from research on smoke from different stoves and fuels, add material parameters and information about solar radiation, wind direction and speed etc.

One of the key benefits of this workflow would be that most softwares in the chain have cloud-solving capabilities. In theory, this means that it would be possible to perform advanced analyses through web-services on a remote server, without the need for expensive hardware locally. Below I will descirbe the different softwares, the intended workflow, what did not work and why.

RECAP 360

Recap 360 is a web-based software from Autodesk that has a desktop equivalent in Recap pro. It is a software for reality computing, a software to capture and process ”the reality”. Through laser-scanning an object or building is captured,

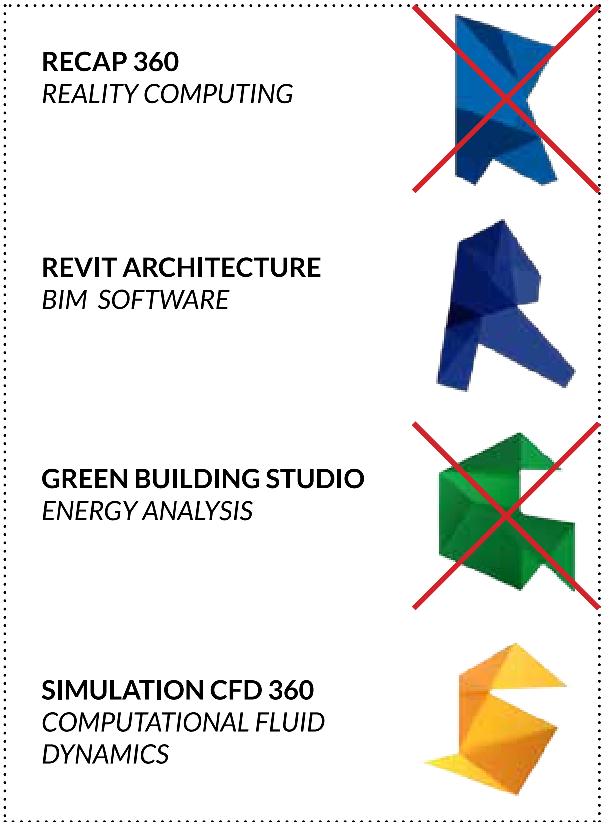

FIGURE 202. *WORKFLOW*

and results in a dense 'point-cloud' that can be used for reconstruction projects or for, quick energy analysis. Another process is called 'photogrammetry'. Multiple overlapping pictures taken around an object, are processed in a software that creates a 3D mesh model that can be downloaded as a point-cloud or 3D-object.

My intention was to use photogrammetry to quickly capture and create accurate models of the houses we visited in Moshi.

I tested the method on several houses but came to the conclusion that it was not as quick and easy to use as I had hoped. In order to get a accurate model, the light conditions have to be the same around the object (the high sun in Moshi resulted in hard shadows and high contrast in images). The images have to be sharp and there has to be many overlapping images to create a good model (100-200).

Uploading these pictures to the web-server took a lot of time using a mobile usb-dongle and 3G network.

For bigger reconstruction projects photogrammetry and laser scanning can still be viable for producing "quick" and accurate models of the exterior or interior for energy simulation and remodeling purposes.

Sketching and manual measurements as a method was far easier to use in these conditions, dense areas and small buildings.

REVIT ARCHITECTURE

Revit is a building information modeling software (BIM) from Autodesk, in which one can create 3D models that can contain a huge amount of information. Not only dimension, but materials, cost, location etc.

Revit is the 'hub' in this planned workflow, containing the basic information about the object, site conditions, materials etc.

GREEN BUILDING STUDIO

This is a cloud-based energy-analysis software from Autodesk. A new project can be set-up from Revit and using location set in Revit. Green building studio (GBS) creates detailed energy analysis and produce weather graphs from virtual weather stations (that are compiled from a variety of valid sources). It is also possible to pick local weather stations available in the Autodesk database. Unfortunately, the closest weather stations to Moshi, virtual or local, where located in the Indian Ocean or in Malawi more than 700 km away. Through different third party software, conversion tools and with help from autodesk support channels, I tried to find and apply local weather-data from Moshi Airport to use in an energy analysis. After a week I had to conclude that this was not possible, feasible or relevant to do in this project.

SIMULATION CFD 360

Computational fluid dynamics software has historically been difficult, resource intensive and expensive. Autodesk, with Simulation CFD 360, claim to have made it possible for more people to make advanced analysis (you do no longer need a PhD in programming or physics to use the software). Integration with Revit also makes it possible to shorten the set-ups time for different designs and scenarios substantially by mapping materials and paramters in Revit to settings in Simulation CFD. The possibility of using the cloud-solving capabilities in Simulation CFD 360 also makes it possible to run multiple designs and scenarios simultaneously.

Unfortunately, even though there is a lot of material from Autodesk on how to get started with Simulation CFD, the software is still complicated to use. A lot of data has to be entered manually, which requires an extensive knowledge about different parameters and units.

Integration with Revit was not seamless and I did not get the data added to the building components to map over into Simulation CFD. I do not know why this did not work.

On top of this, Autodesk decided to remove the possibility for students to use the CFD cloud-solving capabilities as of 9 April, 2015.

Instead of running several simulations simultaneously in the cloud, I had to run them on my own computer. One simulation took more than 8 hours to complete. This, together with problems of combinging solving capabilities for natural ventilation, smoke distribution and solar radiation limited the simulations to only handle wind and smoke interaction in different designs with the same initial conditions.

CONCLUSION

Of course there are similarities between different homes. But in the same time, no two are alike in all aspects, and household air pollution exposure is linked to many different factors.

There is a need for a good understanding about the local context and the household situation in order to propose the appropriate intervention or house improvement for that family.

The household visits gave us a better understanding of the situation and the CO-measurments provided us with hard facts on the situation. Even though the CO-concentration was below recommendad levels in several homes during the 24-hours of measuring, it is clear that the issue of household air pollution exists even in urban areas in Moshi. It is likely that the situation during another time would be worse, and that there can be harmful concentrations of other pollutants in the homes we visited.

PURPOSE AND AIM

The main purpose of this project was to collect data about the situation in Moshi regarding health and household air pollution though interviews, observations and measurements. The project was conducted as a pilot study to evaluate quantitative and qualitative research methods.

We believe that we have met this objective, though one should question if the data collected during the study is representative for Moshi as a whole.

We managed to carry out all planned parts and tests during the field study. But maybe not to the extent we thought we would.

The aim of this thesis to use a web-based workflow for evaluating and testing different types of interventions failed in some parts. But this ”failure” rather gave an insight of how the tools can and should be used, and the potential in different contexts.

INTERDISCIPLINARY WORK

The kitchen and the household is a potential hub for interdisciplinary research as described in this thesis. And the complexity of the issue of HAP requires an interdisciplinary approach.

But what are the benefits and downsides of conducting a field study involving different professions?

In this field study we were restricted to the research permission given to Kilimanjaro Christian Medical College (KCMC) as receiving institution. This limited the research to be conducted within the geographical and administrative borders of Moshi municipality.

The interview questionnaire used in Part I contained questions about both health, the household and house and kitchen. A shorter qusestionnaire could have resulted in a greater number of interviews.

The collaboration with Sahlgrenska Academy opened up for personal contacts at KCMC and their logistic capacity.

Being from different academic background, we observed and noticed different things both during Part I and Part II.

Another aim of the project was to spread knowledge about the issue of HAP and increase awareness on how to improve the situation or reduce exposure on a household level. We felt that it was useful to have different views and perspectives of the issue, its helth effects and interventions when discussing the project with participants or people interested in the project.

It was also positive to be two, both when planning the study, reading about the issue, collecting and analysing data. And coming from different departments, we had full confidence in each other about our knowledge regarding different topics connected to our respective fields.

The interdisciplinary approach can also be positive when spreading the knowledge about the issue in different sectors.

Different professions can also highlight various factors and need for interventions, incentives, standards or regulations when developing housing, products or upgrading residential areas.

MY ROLE

I think that my role as an architect in a project like this can be to widen the perspective to include more factors and to point out the complexity of the situation to better understand what has to be considered when working with this issue.

With skills ranging from sketching to project management, the architect can play an important role througout a project like this. From research and analysis of the local context and site conditions, to design, implementation and evaluation.

If involved at an early stage of planning and designing I believe that an architect or person with insight and knowledge about building characteristics, material properties, climatic conditions and principles for natural ventilation, can save lives, energy, material and money.

RECOMMENDATIONS

We hope that the field study has served a purpose by creating greater awareness about the issue of HAP. We also hope that method evaluations can help when planning new studies in Moshi or in another context.

As mentioned earlier in the discussion, one have to thouroughly go trough what to monitor and how, and what the data will be used for. The amont of data collected should correspond to the scale of the research, available financial and human resources.

When visiting households there are limits on what data can be collected. Involving too many professions in a study could have negative effects on the willningness to participate. For getting a better understanding of the household activities, we think it would be important to stay and observe for a longer time, possibly the whole day. Air pollution monitoring could maybe be done for a longer time period, or at serveral times to account for confounding factors. Indoor air pollution is interesting to measure when looking at the interventions related to the physical structure or ventilation, but for evaluating the health effects of smoke it is more important and relevant to measure personal exposure.

As an alternative to on-site observations, the participants could be asked to fill out a cooking-journal or activity-journal.

The intended workflow did not turn out

as expected, but I would still argue that HAP modeling and computer simulations could potentially be of help when planning and developing solutions to reduce HAP exposure.

Measuring and modeling can be used to identify a problem, measure impact, develop solutions, implement solution and to evaluate the impact.

I believe that CFD have greater potential when used by organisations and governments when developing and evaluating different interventions for differnt contexts, instead of being used as a tool to evaluate the most effective intervention for individual homes.

It is clear that every home is unique and the best intervention for all homes might not be a more efficient stove, and if it is, a stove might not be enough. Therefor we have to work on all scales.

There is no simple answer or quick solution to the complex issue of household air pollution, and I think it is important to work together with different professions, and vital to work with the local community when looking for answers and implementing solutions.

Together we can all help to raise the status of the kitchen and the women and children affected by household air pollution in developing countries by demanding clean energy for all and by creating a greater awareness about the issue ■

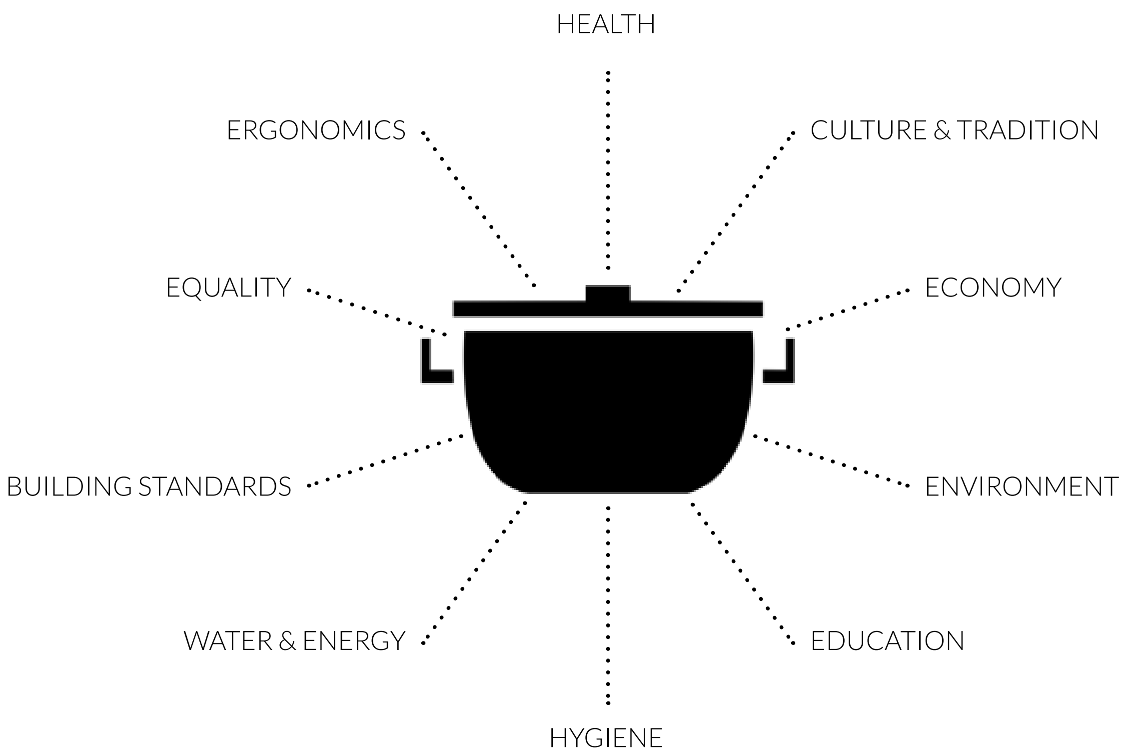

FIGURE 203. *THE KITHCEN AS A HUB FOR INTERDISCIPLINARY RESEARCH*

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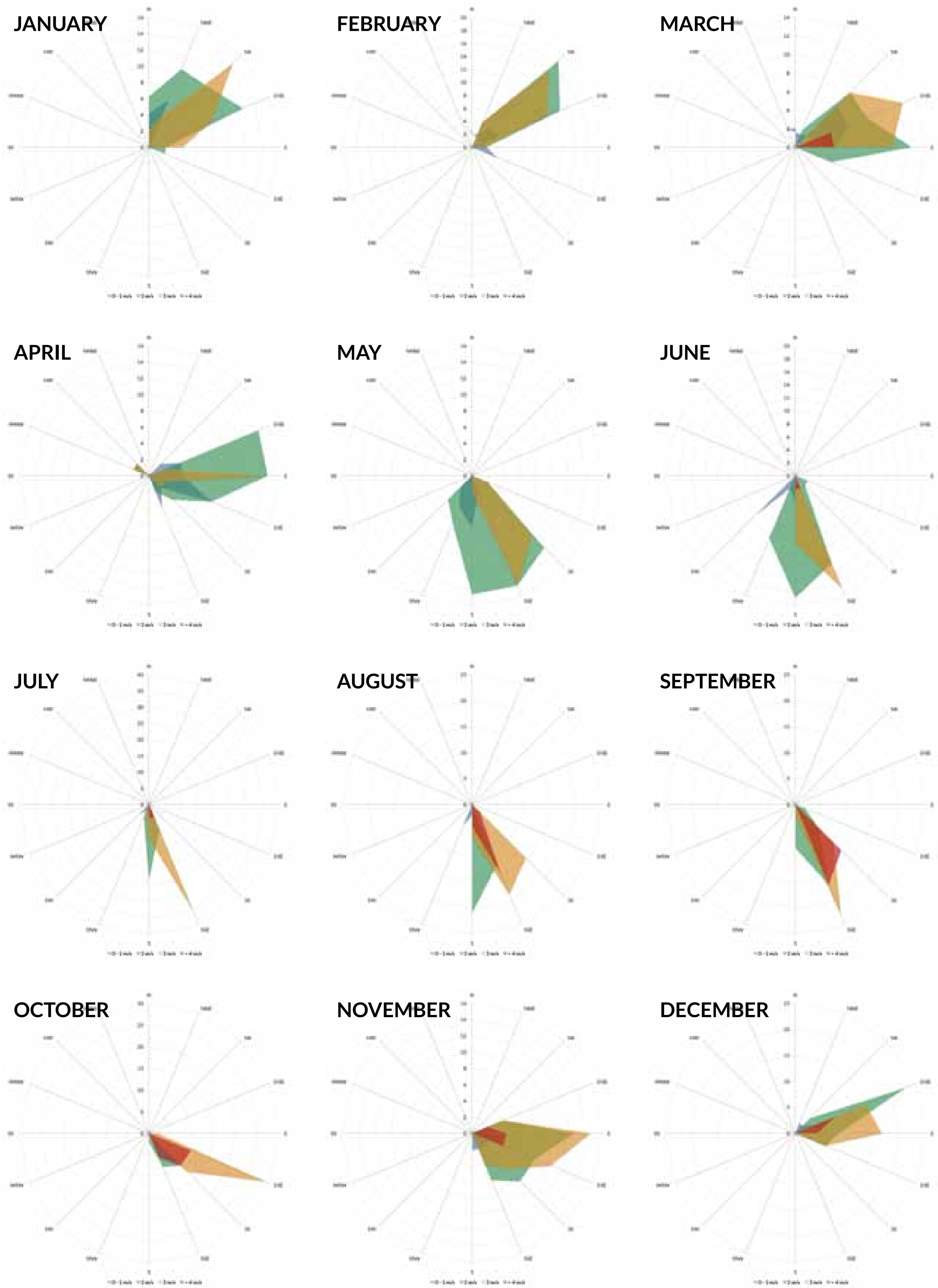
WIND DIAGRAMS FOR MOSHI, TANZANIA

WIND DIRECTION, SPEED AND DISTRIBUTION JAN-DEC

Based on conditions during the first day of each month year 2000-2012



Appendix B

TUMAINI UNIVERSITY MAKUMIRA

KILIMANJARO CHRISTIAN MEDICAL UNIVERSITY COLLEGE
P. O. Box 2240, MOSHI, Tanzania

RESEARCH ETHICAL CLEARANCE CERTIFICATE

No. 809

Research Proposal No. 693

Study Title: Effect of pneumococci vaccine (PCV 13) and indoor pollution on carriage and symptomatic infection with Streptococcus pneumonia among children aged < 2 year attending PHC facilities in Moshi,Tanzania

Study Area: Moshi Municipality

P. I Name: Drs. Sia Msuya and Balthazari Nyombi

Institution (s): Kilimanjaro Christian Medical University College

Funding Agency:

The Proposal was approved on: 3rd February,2015

Duration of Study: One Year

From: 3rd February,2015 **to** 3rd February,2016

This certificate is valid for one year only

Beatrice Temba

Secretary – CRERC

Prof. Mramba Nyindo

Chairman – CRERC

MOSHI MUNICIPAL COUNCIL

(All correspondence be addressed to the Municipal Director)

MUNICIPAL DIRECTOR: +255-027-2752344
ALL OFFICE: +255-027-2754371/4
FAX : +255-027- 2752906
E-MAIL: director.moshi@gmail.com
WEB SITE: www.moshimc.go.tz
blog-manispaayamoshi.com
TELEGRAPHIC ADDRESS: MANISPAA

MUNICIPAL HALL,
P.O. BOX 318,
MOSHI.

Ref. No. MMC/HO/7008/Vol.V/2 **Date:** 17/02/2015

1. Dr. Sia Msuya,
2. Dr. Balthazari Nyombi,

Kilimanjaro Christian Medical University College,
MOSHI.

RE: PERMISSION TO CONDUCT RESEARCH

Refer your ethical clearance with No. 809 and which is valid from 3rd February, 2015 to 3rd February, 2016 permitting you to conduct a research on "Effect of pneumococci vaccine (PCV 13) and indoor pollution on carriage and symptomatic infection with streptococcus pneumonia among children aged <2 year attending PHC facilities in Moshi, Tanzania".

The permission to conduct research in Moshi Municipality has been granted.

You will also be required to share the final report and publication with the DMO's office.

Sincerely.

Dr. Boaz J. Mwakugile
FOR: **MUNICIPAL DIRECTOR**
MOSHI MUNICIPAL COUNCIL

Copy to: Dr. incharges
MOSHI MUNICIPAL COUNCIL HEALTH FACILITIES.

PART 2 - Information sheet

Nasopharyngeal carriage of pathogenic bacteria in relation to household air pollution among Tanzanian children

WHAT WE WANT TO DO?

- ***Household visit > From 9am – To about 13pm***
- *Observations - Learn*
- *Questions - Learn*
- *Spirometry > Breathing test*
- *Sketches > House*
- *Pictures > House*
- *Measurements > House*
- *Measurements > Smoke exposure > 24h*

WHEN?

- *Only if your family is willing to participate!*
- *We will only visit 5-15 households*
- ***Selection > Variety of homes > Logistic reasons***
- *Within a month from this date*
- *Contact through telephone 1 or 2 days before visit*
- ***Visit Day 1 > Setting up sensor for smoke measurement***
- ***Day 2 > Sensor measure for 24h > We return to retreive sensor***

WHY?

- ***Students - Master's thesis project, observations and tests, <u>not treatment</u>!***
- *Here to learn, you are experts!*
- ***Voluntary participation**!*
- ***Won't effect your services at PHC/Dispensary**!*
- *No rewards for participation*
- ***No interventions***
- *Confidentiality*
- ***Free to refuse or withdraw from study***
- *Published as thesis in Sweden and available from KCMC through contact to be announced later*

Interview Questionnaire *Dodoso*

Nasopharyngeal carriage of pathogenic bacteria in relation to household air pollution among Tanzanian children

ID				
ID	**Number of participant** *Namba ya utafiti ya mtoto*			
1	**Name of facility** *Jina la kituo*			
2	**Level** *Ngazi*			
	1. Health Centre *Kituo cha afya*			
	2. Dispensary *Dispensari*			
3	**Main reason for attending at health facility** (Mark the appropriate, multiple answers possible) *Sababu ya kumleta mtoto katika kituo cha afya leo? (Jibu zaidi ya moja linaruhusiwa)*			
	1. Vaccination of the child *Chanjo*			
	2. Growth monitoring *Kumpima mtoto maendeleo- uzito*			
	3. OPD clinic (child is sick) *Mtoto ni mgonjwa nimemleta kwa matibabu taja dalili za ugonjwa alizo nazo motto*	3.1	Symptoms	
	4. CTC clinic (parent is sick) *Kliniki ya watoto wenye wazazi walio na maambukizi*			
	5. Other Nyingine tafadhali taja	3.2	Specify	
4	**Date of filling questionnarie** *Tarehe ye kujaza dodoso*			
5	**Name of person filling the questionnaire** *Jina la anayejaza dodoso*			
	5.1	Person answering questions – (Relation to child)		
	PART 1 - HEALTH			
6	**Date of birth of the child** *Tarehe ye kujaza dodoso*	6.1	Age in months (Started)	
7	**Birth weight of the child** *Uzito wa kuzaliwa(Kgs)*			
8	**Current weight** *Uzito (Kgs)*			
9	**Current length** *Urefu (cm)*			
10	**Gender** *Jinsia*			
	1. Girl *Kike*			
	2. Boy *Kiume*			
11	**Is the child still breastfeeding?** *Je mtoto bado ananyonya?*			
	1. No *Hapana*	11.1	When did you stop? *Umri alioacha*	
	2. Yes *Ndiyo*	11.2	1. Exclusive *Maziwa ya mama pekee*	
			2. Mixed *Ameanza kupewa vyakula vingine*	
12	**Does the child have any of the following symptoms for respiratory tracts today?** *Je mtoto ana dalili zifuatazo leo? Tiki kila kipengele panapohusika. Kama ana dalili jaza muda aliokaa na dalili kwa namba za siku*			
	1. Fever *Homa*			
	2. Chills *Kutetemeka kwa baridi*			
	3. Rapid or difficulty breathing *Kupumua kwa shida/haraka*			
	4. Cough *Anakohoa*			
	5. Running nose *Ana mafua*			
	6. Sore throat *Anaumwa na koo au tezi*			
	7. Other *Dalili nyinginezo taja*	12.1	Specify	
13	**Has the child used any antibiotics in the past?** *Mtoto amewahi kutmia dawa eg ampicilin*			
	1. No *Hapana*			
	2. Yes, Past 7 days *Ndiyo Siku 7 zilizopita*			
	13.1	Prescribed *Aliandikiwa na daktari?*	1. No *Hapana*	2. Yes *Ndiyo*
	13.2	Type *Aina ya dawa aliyotumia*	13.3	Indication *Sababu*
	3. Yes, Past month *Mwezi mmoja uliopita*			
	13.4	Prescribed *Aliandikiwa na daktari?*	1. No *Hapana*	2. Yes *Ndiyo*
	13.5	Type *Aina ya dawa aliyotumia*	13.6	Indication *Sababu*
	4. Yes, Past 3 months *Mwezi 3 iliyopita*			
	13.7	Prescribed *Aliandikiwa na daktari?*	1. No *Hapana*	2. Yes *Ndiyo*
	13.8	Type *Aina ya dawa aliyotumia*	13.9	Indication *Sababu*

14	**Has the child had any of the following respiratory tract infections the past 3 months:** cough with fever, rapid breathing, difficulty when breathing, pneumonia? *Je katika kipindi cha miezi mitau iliyopita, mtoto ameshapata au kutibiwa kwa ajili ya; kukohoa kulikoambatana na homa, kupumua kwa shida/haraka, pneumonia?*			
	1. No *Hapana*			
	2. Unknown *Sijui*			
	3. Yes *Ndiyo*	14.1	How many times? *Taja ameugua mara ngapi*	
		14.2	Antibiotic treatment given *Alitibiwa na dawa gani*	
15	**Has the child ever been treated for the following** *Je mtoto ameshawahi kutibiwa magonjwa yafuatayo*			
	1. Asthma *Pumu*			
	2. Gastrointestinal infections *Kuharisha*			
	3. Measles *Surua*			
	4. Malaria *Malaria*			
	5. HIV *UKIMWI*			
	6. Lung tuberculosis *Tuberculosis*			
	7. Heart disease *Ugonjwa wa moyo*			
	8. Other *Nyingine*	15.1	Specify	
	15.2	Symptoms, duration, treatment, number of times, medical verification		
16	**Has the child been hospitalized since one month of age?** *Je mtoto ameshawahi kulazwa tangu alipokuwa na umri wa mwezi mmoja*			
	1. No *Hapana*			
	2. Yes *Ndiyo*	16.1	When? *Umri aliolazwa*	
		16.2	Why? *Sababu ya kulazwa*	
17	**Is the child vaccinated?** *Je mtoto wako amepata chanjo zifuatazo?*			
	1. No *Hapana*			
	2. Yes *Ndiyo*	17.1	PCV-13	[1][2][3][4.Unknown]
		17.2	Heptavalent	[1][2][3][4.Unknown]
		17.3	OPV	[At birth][1][2][3][4.Unknown]
		17.4	BCG	[At birth][2.Unknown]
		17.5	Measles	[1][2][3.Unknown][4.Child < 9 months]
		17.6	Rota vaccine	[1][2][3.Unknown]
PART 2 - HOUSEHOLD				
18	**Where do you live?** *Unaishi wapi? Wilaya, kata na mtaa*			
	18.1	District *Wilaya*		
	18.2	Type *Eneo*		
		1. Rural area *Kijijini*		
		2. Peri-Urban area *Mji mdogo*		
		3. Urban area *Mjini*		
19	**Does this child live with both parents?** *Je mtoto anaishi na wazazi wote wawili?*			
	1. Yes both *Wote wawili*			
	2. Single parent *Mama mwenyewe*			
20	**Parents level of education** *Elimu ya wazazi*			
	20.1	Mother *Mama*		
		1. No education *Hajasoma*		
		2. Primary school *Elimu ya msingi*		
		3. Secondary school *Elimu ya sekondari*		
		4. Occupational training *Ufundi*		
		5. University *Chuo kikuu digrii/diploma*		
		6. Unknown *Sijui*		
	20.2	Father *Dada*		
		[1][2][3][4][5][6]		

21	**Parents employment status: employed with regular monthly salary** *Je wazazi wameajiriwa sehemu wanayolipwa kila mwezi*	
	21.1	Mother *Mama*
		1. Employed *Mwajiriwa*
		2. Self employed *Kujiajiri*
		3. Unemployed *Ajira*
		4. Unknown
	21.2	Father *Dada*
		[1][2][3][4]
22	**How many siblings does this child have?** *Namba ya watoto wako ukimuweka huyu uliyemleta kliniki?*	
23	**How many people live in your household?** *Namba ya watu wanaoishi nyumbani kwako?*	
	23.1	How many are under 5 years of age? *Wangapi wana umri chini ya miaka 5*
24	**Number of people sleeping in the same room as this child** (Child not included) *Namba ya watu wanaolala chumba kimoja na mtoto*	
25	**Do you keep any animals inside the house?** *Mnakaa na wanyama nyumbani*	
	1. No *Hapana*	
	2. Hen *Kuku*	
	3. Goat *Mbuzi*	
	4. Cow *Ng'ombe*	
	5. Other *Nyingine*	25.1 Specify
26	**Do any of the adults in the household smoke?** *Kuna mtu anavuta sigara nyumbani*	
	1. No *Hapana*	
	2. Yes *Ndiyo*	
PART 3 – HOUSE AND KITCHEN		
27	**How do you live?** (See sketches on separate paper) *Aina ya nyumba unayoishi ni (angalia picha na utiki panapostahili)*	
	1. Multi-family housing *Ghorofa*	
	2. Semi-detached house *Mbili zimeunganika*	
	3. Single family housing *Ya familia moja*	
28	**Total number of rooms in your home** *Namba ya vyumba nyumbani kwako*	

FUEL	1. Wood *Kuni*	7. Solar *Jua*
	2. Charcoal *Mkaa*	8. Grid electricity *Umeme wa Tanesco*
	3. Kerosene (Paraffin) *Mafuta ya taa*	9. Batteries *Betri*
	4. LPG (Gas) *Gesi*	10. Wax candle *Mishumaa*
	5. Dung *Kinyesi cha wanyama*	11. Other (specify) *Nyinginezo*
	6. Agricultural residues *Magunzi*	

29	**What types of fuel do you use for cooking?** (Incl. Drinks) *Mnatumia nini kupikia*	
	29.1	Most important fuel *Muhimu zaidi*
	29.2	Secondmost important *Linalofuata*
30	**What types of fuel do you use for lighting?** *Mnatumia nini kuwasha taa*	
	30.1	Most important fuel *Muhimu zaidi*
	30.2	Secondmost important *Linalofuata*
31	**What types of fuel do you use for electrical equipment?** *Mnatumia umeme gani*	
	31.1	Most important fuel *Muhimu zaidi*
	31.2	Secondmost important *Linalofuata*

S T O V E	1. Three-stone fire	6. Kerosene stove
	2. Shielded mud stove	7. LPG (Gas) stove
	3. Wood-burning ceramic stove	8. Solar cooker
	4. Metal stove	9. Grid powered electric stove
	5. Improved charcoal stove	10. Other *Nyinginezo*

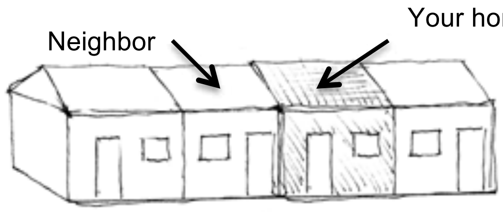
32	**What type of stoves do you use in your household?** (See sketches on separate paper) *Aina gani la jiko mnatumiga nyumbani kwa kupikia? (Angalia picha na utiki panapostahili)*			
	32.1	Main stove *Jiko linalotumika mara nyingi*		
	32.2	Secondary stove *Linalofuata*		
33	**Where do you cook your food?** (Multiple answers possible, see sketches on separate paper) *Wapi kupika chakula chako? (Jibu zaidi ya moja linaruhusiwa, angalia picha na utiki panapostahili)*			
	1. Enclosed area (Kitchen)			
	2. Semi-open area			
	3. Part of main living area			
	4. Separate room attached to main house			
	5. Separate building (If '*Yes*' = Question 34-37 will be about this building)			
	6. Outside			
	33.1	Details, reason for different locations, time of year etc.		
34	**How is the roof constucted?** *Paa la jiko likoje?*			
	1. Sloped without ceiling *Mteremko bila dari*			
	2. Sloped with ceiling *Mteremko na dari*			
	3. Flat without ceiling *Gorofa bila dari*			
	4. Flat with ceiling *Gorofa na dari*			
	5. Other *Nyinginezo*	34.1	Specify	
35	**What is the material of the roof?** *Paa la jiko limeezekwa na*			
	1. Thatch *Nyasi*			
	2. Tiles *Tiles*			
	3. Iron sheets *Mabati*			
	4. Other *Nyinginezo*	35.1	Specify	
36	**What is the material of the walls?** (See sketches on separate paper) *Kuta za jiko zomejengwa kwa (Angalia picha na utiki panapostahili)*			
	1. Adobe/earth blocks *Udongo/tofali za udongo*			
	2. Wattle and daub *(kusuka) Vijiti na udongo*			
	3. Iron sheets *Mabati*			
	4. Burned bricks *Matofali ya kuchoma*			
	5. Concrete *Saruji*			
	6. Other *Nyinginezo*	36.1	Specify	
37	**Types of ventilation / smoke extraction.** (Multiple answers possible, see sketches on separate paper) *Je moshi unatotewaje kwenye jiko. (Jibu zaidi ya moja linaruhusiwa, angalia picha na utiki panapostahili)*			
	1. Permanent holes in roof			
	2. Eaves spaces			
	3. Chimney			
	4. Smoke hood			
	5. Windows/openings in area used for cooking			
	6. Other (example: fan or air-condition)	37.1	Specify	
38	Willingness to participate in part II (Inform about Household visit)			
	1. No *Hapana*			
	2. Yes *Ndiyo*			

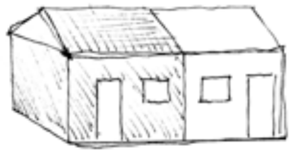
Thank you for participation!
Asante kwa kushiriki

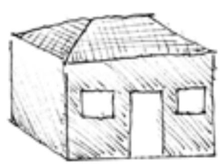
Interview Questionnaire – Sketches

Nasopharyngeal carriage of pathogenic bacteria in relation to household air pollution among Tanzanian children

27. How do you live?



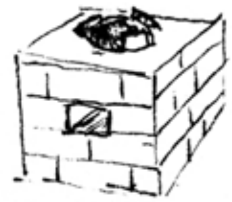




1. Multi-family housing 2. Semi-detached house 3. Single family house

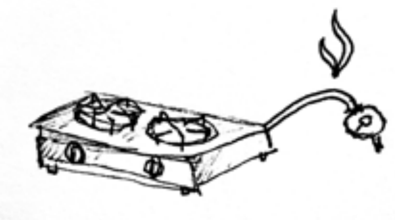
	1. Wood *Kuni*	7. Solar *Jua*
F	2. Charcoal *Mkaa*	8. Grid electricity *Umeme wa Tanesco*
U	3. Kerosene (Paraffin) *Mafuta ya taa*	9. Batteries *Betri*
E	4. LPG (Gas) *Gesi*	10. Wax candle *Mishumaa*
L	5. Dung *Kinyesi cha wanyama*	11. Other (specify) *Nyinginezo*
	6. Agricultural residues *Magunzi*	

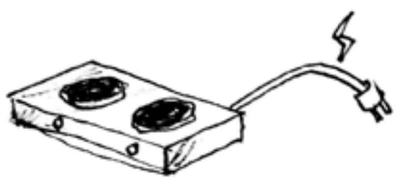
32. What type of stoves do you use in your household? *(General sketches, real stove might look different)*



1. Three-stone fire 2. Sheilded mud stove 3. Wood-burning ceramic stove

4. Metal stove 5. Improved charcoal stove 6. Kerosene stove

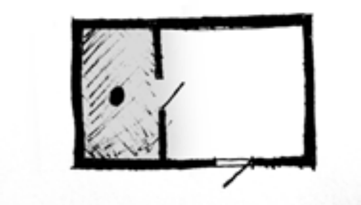


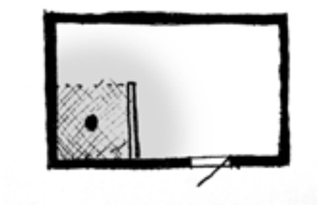


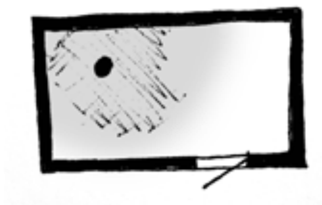
7. LPG (Gas) stove 8. Solar cooker 9. Grid-powered electric stove

10. OTHER

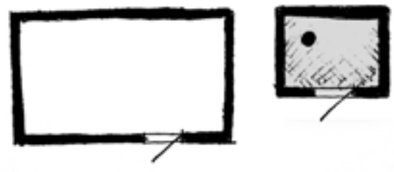
33. Where do you cook your food? *(<u>Multiple answers possible</u>, general sketches - floor plan representation)*

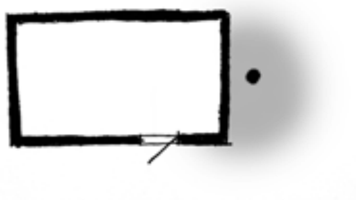

1. Enclosed area (Kitchen)


2. Semi-open area


3. Part of main living area


4. Separate room attached to main house


5. Separate building


6. Outside

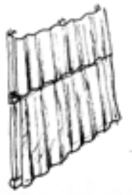
34. How is the roof constructed?

1. Sloped without ceiling
2. Sloped with ceiling
3. Flat without ceiling
4. Flat with ceiling

36. What is the material of the walls?


1. Adobe/earth blocks
Udongo/tofali za udongo


2. Wattle and daub
(kusuka) Vijiti na udongo

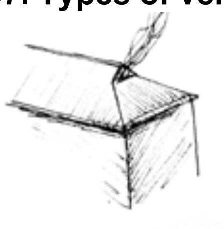

3. Iron sheets
Mabati


4. Burned bricks
Matofali ya kuchoma

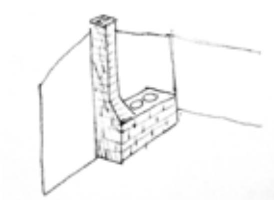

5. Concrete
Saruji

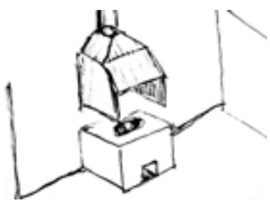
6. OTHER

37. Types of ventilation / smoke extraction


1. Permanent holes in roof *(Not chimeny)*


2. Eaves spaces *(Space between wall and roof)*


3. Chimney *(with or without stove)*


4. Smoke hood

5. Windows / openings in area used for cooking
6. OTHER *(Example: fan or air-condition)*

Appendix G

Interview Questionnaire – Datasheet

Nasopharyngeal carriage of pathogenic bacteria in relation to household air pollution among Tanzanian children

ID										
1										
2	1	2								
3	1	2	3	4	5					
	3.1									
	3.2									
4	2015 / /									
5			5.1							
PART 1 - HEALTH										
6	20 / /		6.1	Months:						
7	Birth weight *(Kgs)*:									
8	Current weight *(Kgs)*:									
9	Current length *(cm)*:									
10	1	2								
11	1	2	11.1					11.2	1	2
12	1	2	3	4	5	6	7	12.1		
13	1	2	13.1	1	2	13.2				
			13.3							
		3	13.4	1	2	13.5				
			13.6							
		4	13.7	1	2	13.8				
			13.9							
14	1	2	3	14.1			14.2			
15	1	2	3	4	5	6	7	8		
	15.1									
	15.2	*(Details)*								
16	1	2	16.1			16.2				
17	1	2	17.1	1	2	3	4			
			17.2	1	2	3	4			
			17.3	Ab	1	2	3	4		
			17.4	Ab	1					
			17.5	1	2	3	4	5		
			17.6	1	2	3				
PART 2 - HOUSEHOLD										
18	18.1				18.2	1	2	3		
19	1	2								
20	20.1	1	2	3	4	5	6			
	20.2	1	2	3	4	5	6			
21	21.1	1	2	3	4	21.2	1	2	3	4
22										
23			23.1							
24										
25	1	2	3	4	5	25.1				
26	1	2								
PART 3 – HOUSE AND KITCHEN										
27	1	2	3							
28										
29	29.1				29.2					
30	30.1				30.2					
31	31.1				31.2					
32	32.1				32.2					
33	1	2	3	4	5	6				
	33.1	*(Details)*								
34	1	2	3	4	5	34.1				
35	1	2	3	4	35.1					
36	1	2	3	4	5	6	36.1			
37	1	2	3	4	5	6	37.1			
38	Willingness to participate in part II				1	2				

Informed Consent Form *(Information sheet)*

This Informed Consent Form is for men and women who we are inviting to participate in research on the health effects of air pollution in the household.

Salamu. Jina langu naitwa Sofie Johansen toka Chuo kikuu cha Gothenburg Sweden. Ninafanya kazi ya utafiti nikishirikiana na hospitali ya rufaa ya KCMC, Chuo Kikuu Kishiriki cha KCMU College na Idara ya afya ya manispaa ya Moshi. Utafiti tunaoufanya unahusu kuangalia athari za moshi utokanao na matumizi ya nishati za kupikia mfano mkaa na kuni katika afya ya watoto na watu wengine wa familia.Zaidi tunaangalia kama kuna athari kwenye mapafu na magonjwa yanayoathiri mfumo wa kupumua.

Tumeomba familia na akina mama wenye watoto chini ya miaka miwili kushiriki kwenye utafiti huu. Huduma za jamii na pamoja na huduma za hospitali hazitaathirika kwako na kwa familia iwapo usingependa kushiriki. Kushiriki kwenye utafiti ni hiari yako bila kulazimishwa.

Utafiti utahusisha kuja nyumbani kwa muhusika mara mbili. Siku ya kwanza watafiti watakuja nyumbani na kuuliza maswali machache kuhusu nishati inayotumika kupikia na kuhusu afya. Wataangalia mahali mnapotumia kupikia na mtaalamu mmoja wa afya atakupima mapafu kwa kutumia chombo kinachoitwa ‘’spirometry’’. Vilevile watachukua kipimo kupima bacteria toka puani. Wataacha kifaa ambacho wewe mama kama mpishi na mtoto mtakishikisha kwenye nguo ili kupima kiasi che gesi inayodhuru ambayo inatokana na nishti ngumu za kupikia kama mkaa na kuni. Ni muhimu kukivaa kifaa hiki mchana na usiku kama inavyoshauriwa. Watafiti watarudi siku inayofuata ili kukichukua kifaa na kwenda kupima kiasi cha gesi ya ‘’karbon monoxide’’

Majibu ya hali ya mapafu utayapata hapo hapo. Majibu ya kipimo cha puani na wingi wa gesi yataletwa baadae na wataalamu toka KCMC.

Habari zote na majibu unayotupa katika huu utafiti yatahifadhiwa kufuatana na sheria za utafiti na hayatapewa kwa mtu yeyote mwingine nje ya utafiti. Majina hayatatumika ni namba tu katika dodoso na fomu za kukusanyia takwimu.

Tunategemea majibu ya utafiti huu yatasaidia kuona athari za nishati mbalimbali katika afya ya binadamu na kuona nchi ifanyeje kubadili hali hiyo.

Je una swali lolote la kuniuliza?

Mshiriki: Nimesoma/ au nimesomewa madhumuni ya utafiti, utakavyofanyika na faida na madhara yake. Nimeruhusiwa, kuuliza maswali na nimeridhika na majibu. Ninakubali kushiriki katika utafit huu

Sahihi ya mshiriki	*Tarehe*
………………………………..	…………………………..
Sahihi ya mtafiti	*Tarehe*
………………………………..	…………………………..

Salaam. My name is Dr Sia Msuya/ Dr Balthazar Nyombi/ Reaserchers from KCMC and KCMU-College. We represent the Department of Public Health and Clinical Microbiology Lab at KCMC/KCMU-Co. We are conducting a study in cooperation with the DMO of Moshi Municipality and the University of Gothenburg, Sweden.

This study is looking at health effects of air pollution in the household. In Tanzania most people use solid fuels (such as firewood and charcoal) for cooking. This produces smoke that can affect the health of small children and adults who are responsible for cooking. We are investigating if exposure to smoke is causing symptoms of respiratory disease, if smoke affects the presence of microorganisms (virus and bacteria) in the airways that may cause disease, or if defence against microorganisms is affected.

We are inviting all families with children under 2 years of age who have attended Pasua Health Centre to participate in this study on smoke and respiratory health. Your participation in this study is entirely voluntary. Whether you choose to participate or not, all the services you receive at the Health Centre or hospital will continue and nothing will be changed. You can anytime and without explanation interrupt your participation in the study without affecting your contacts with any health care facilities in the future.

Procedures for adults responsible for cooking: This research will involve two visits of the research team in your household. The first day the research team will stay in your household to see where you are cooking. The research team will also ask some questions about your health and cooking habits. One medically trained researcher will perform a simple health examination of your lungs and heart. He/she will also help you to test the function of your lungs, ‘spirometry’. To look for virus and bacteria, a sample will be taken from your nose. Before the research team leaves they will leave two measuring instruments, one for you and one for your youngest child. The instrument will measure smoke that is produced during burning, it is important that you and your child carry this small instrument both day and night. The research team will come back for a short visit the next day to collect the measuring instruments.

If you agree to participate all information about you, your children and your household will be handled with confidentiality. We guarantee that your name or the name of your child will never appear in any data or report. Our hope is that the result of this study will help us to better understand the health affects of smoke and help to bring up cleaner fuels for the benefit of the people of Tanzania.

Informed Consent Form *(Certificate of Consent)*

This Certificate of Consent is for men and women who we are inviting to participate in research on the health effects of air pollution in the household.

Participant:
I have been invited to participate in the research on smoke and respiratory health. I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions that I have asked have been answered to my satisfaction. I consent voluntarily to participate as a participant in this research.

Signature of Participant ___________________

Date ___________________________
Day/month/year

Researcher:
I have accurately read out the information sheet to the potential participant, and to the best of my ability made sure that the participant understands that the following will be done:

1. Two visits will be made by the research team in the participant's household. The research team will make observations and ask questions about the health and cooking habits of the participant.
2. A clinical examination and spirometry will be performed on the participant, a sample will also be taken from the nose.
3. A small measuring instrument will be carried by the participant for 24 hours.

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

A copy of this ICF has been provided to the participant.

Signature of Researcher /person taking the consent__________________________

Date ___________________________
Day/month/year

Information

This Information is for families who have been part of the research on the health effects of air pollution in the household.

Swahili:

Hii ni taarifa kwa akina mama na familia walioshiriki katika utafiti wa kuangalia athari itokanayo na nishati za kupikia katika afya. Familia nyingi Tanzania hata hapa Moshi zinatumia mkaa, kuni au mafuta ya taa kwa ajili ya kupikia. Nishati hizi zinaweza kuto gesi zenye kemikali zinazoweza kuathiri afya kama ‘’kaboni monoxide’’

Utafiti wetu uliangalia kama moshi unaotokana na nishati zinazotumika kupikia zinaleta dalili za magonjwa ya kifua na magonjwa mengine yanayo athiri mfumo wa kupumua

Tulipotembelea nyumbani tuliacha vifaa viwili vya kupima kiasi cha moshi au gesi kinachotokana na nishati mnayotumia kwa kupikia hapo nyumbani.

Tunategemea majibu tuliyoyapata kutokana na ushirikiano wako yatasaidia kujua madhara ya gesi inayotokana na nishati ngumu kwenye afya ili yaweze kuchangia kuleta maendeleo kwa watu wa Moshi na Tanzania kwa ujumla Shirika la afya la dunia (WHO) limeweka viwango vya gesi inayokubalika kwa afya kutokana na nishati ngumu zinazotumika katika kupima

Katika nyumba nyingi tulizopita na ya kwako tumekuta kiwango cha moshi (‘’kaboni monoxide’’) kimezidi kiwango kilichowekwa na shirika la afya duniani (WHO).Moshi unakemikali zingine hatari ambazo hatujaweza kuzipima, Lakini itakuwa vizuri ukiweza kupunguza atari za (‘’kaboni monoxide’’) moshi hii kwa njia zifuatazo; kwanza jaribu kupikia nje wakati wote ili moshi (‘’kaboni monoxide’’) zenye kemikali zisibaki ndani hasa mnapolala na mnapotumia muda mwingi kukaa,pia usipende kukaa kwa muda mrefu karibu na moshi.Mkaa,kuni na mafuta ya taa zinatoa kemikali hatari na zinaweza kuwa na madhara makubwa kwa afya.Mbili kama itawezekana jaribu kutumia nishati zisizotoa moshi (‘’kaboni monoxide’’) nyingi mfano gesi.

Kama utataka kujua zaidi kuhusu majibu tuliyoyapata tutakuomba uende kituo cha afya Pasua na umuone nesi ambaye atakupa majibu.

Kwenye ukurasa unaofuata kuna ripoti kutoka kwenye nyumba zenu. Picha ya kwanza inaonyesha kifaa cha kupima kiwango cha moshi kilichowekwa kwenye chumba na picha nyingine kifaa cha kupima kiwango cha moshi kilichokuwa kimeshikizwa karibu na shingo.
Asante kwa kukubali kushiriki!

SMOKELESS ARCHITECTURE
- DATA COLLECTION MATRIX FOR HOUSEHOLD VISITS

Building components	**Specific research questions**	**Data required**	**Data collection method**	**Data collection / analytical instrument**
Roof	Form Material (why?) Colour Air outlet - eaves	Shape Material properties (U-value, density) Cost of material Cost of building	Observations Survey data In-depth interviews Litterature study	Survey Photographs Sketches
Walls	Material (why?) Structure Openings	Dimensions Material properties Cost of material Cost of building	Observations Survey data In-depth interviews Litterature study	Survey Photographs Sketches Measurements
Floor	Material (why?) Foundation Flood protection	Material properties Cost of material Cost of building	Observation In-depth interviews Litterature study	Survey Photographs Sketches
Windows	Material Construction Light Wind Safety	Dimensions Placement Material properties Cost of material Cost of building	Observations Survey data In-depth interviews Litterature study	Survey Photographs Sketches Measurements
Doors	Material Construction Light Wind Safety	Dimensions Placement Material properties Cost of material Cost of building	Observations Survey data In-depth interviews Litterature study	Survey Photographs Sketches Measurements
Interior properties	**Specific research questions**	**Data required**	**Data collection method**	**Data collection / analytical instrument**

Air - volume	Air mass	m^3 - Volume of different rooms, total volume of building	Observations	Measurements Photogrammetry
CO-level	Concentration of CO in the indoor air	(mg/m^3) Mean value during cooking / 24-hours average	Observations Household visits	CO-data-logger
Temperature	Temperature at different heights and places Heat input from different sources: Stoves, fires, animals, people, sun	Degrees Celcius (°C)	Observations Household visits	Temperature-Relative humidity - Data logger
Humidity	Humidity in different places	Relative humidity (%)	Observations Household visits	Temperature-Relative humidity - Data logger
Floor plan	Layout of building Areaplan		Observations Mesurements Household visits	Photogrammetry Sketches
Interior walls	Material Height Openings		Observations Survey data In-depth interviews	Photographs Sketches
Zoning	Coooking Living indoor/outdoor Sleeping Study/work		Observations Survey data In-depth interviews Litterature study	Photographs Sketches
Exterior properties	**Specific research questions**	**Data required**	**Data collection method**	**Data collection / analytical instrument**
Location	Coordinates Area (neighbourhood) Altitude Building position on site	Longitud/Latitude? Height / Altitude Cardinal	Internet service	GPS (phone) Compass Sketches

Sun	Solar study Solar radiation Surface exposure	Location Time	Internet service	Computer model Sketches
Temperature	Outdoor temperature	Degree celcius	Weather data	?
Wind	Wind direction Wind speed	Cardinal (m/s)	Weather data Interviews	?
Surrounding buildings	Site plan Neighbours		Household visits Internet service Maps	Computer model Sketches Photographs
Kitchen	**Specific research questions**	**Data required**	**Data collection method**	**Data collection / analytical instrument**
Stove	Stove types Cost Efficiency Use	Combustion efficiency Heat transfer efficiency? Consumption, turn-down ratio, speed of cooking, user satisfaction, emissions, cost	Household visits Survey data Stove tests reports etc.	Notes, Photographs
Smoke extraction	Natural ventilation Mechanical ventilation Chimney Smoke hood	Cost Efficiancy	Intervention reports Info from manufacturer Household visits Survey data	Notes Photographs
Fuel	Type Cost time/money Seasons Lasting for how long?	Type of fuel Consumption / per capita Cost / Time / per capita? Seasonal changes	Household visits Survey data Interviews National/regional statistics	Household visits Survey data Interviews Statistics
Cooking equipment	Pots and pans, tradition, wishes, dreams		Interviews	Photographs, sketches, notes
Meals	What meals?	Time	Observations	Photographs

	At what times? Preperation time? Cooking time? Eating Cleaning up	(Exposure)	Interviews	Sketches Notes
Storage	Purchases Durability/sustainability/shelf-life Preparation of food	Expenditure (day-to-day)	Observations Interviews	Photographs Sketches Notes
Hygiene	Cleaning - Personal hygiene - Clothes - Cooking equipment - Indoor cleaning	Health risk factors	Observations	Notes
Safety	Risk of burns etc. Robbery etc.		Observations Interviews	
Water	Flow schedule - Water used for what activities?	Health risks, time spent on water collection, resource efficiency	Observations Interviews	Photographs Sketches Notes
Household	**Specific research questions**	**Data required**	**Data collection method**	**Data collection / analytical instrument**
People	Age Gender Occupation		Survey data Interviews	Notes
Health	History Current status Risk factors	-		
Economy	Total income Total spendings on kitchen/housing/fuel	Feasability assessment	Interviews (survey?)	Notes (ananymity)

HOUSEHOLD VISIT __

DATE: 20 - -

AREA:

DATA FILES:

COarea _

COpersonal _

RH Temp _

Spirometri _

Pictures: -

___:___ TIME	WEATHER
MAGNETIC NORTH	___/___°C MAX / MIN
WIND DIR	CHILDREN < 5 YEARS

PLAN / LAYOUT

STOVE PLACEMENT
- MAIN STOVE ____________________
- SECONDARY STOVE ______________

MONITOR PLACEMENT

ZONING
- COOKING
- LIVING (INDOOR /OUTDOOR)
- SLEEPING
- STUDY/WORK
- OTHER

OPENINGS
- OPENING / VENTI
- FIXED WINDOW
- WINDOW
- DOOR

SECTION LINE

MEASUREMENTS IN ________________

SECTION

ROOF
- MATERIAL ______________________
- COLOUR ________________________
- VENTILATION ___________________

CEILING
- MATERIAL ______________________

EXTERIOR WALLS
- MATERIAL ______________________
- CONSTRUCTION___________________

PARTITION WALLS
- MATERIAL ______________________
- CONSTRUCTION___________________

FLOOR
- MATERIAL ______________________
- CONSTRUCTION___________________

SITE PLAN / SKETCHES

HOUSEHOLD VISIT __

DATE: 20 - -

AREA:

DATA FILES:

COarea _

COpersonal _

RH Temp _

Spirometri _

Pictures: -

PERSON RESPONSIBLE FOR COOKING
- AGE________________
- GENDER______________

EMPLOYMENT STATUS
- ADULT 1_______________
- ADULT 2_______________
~INCOME_______________

NUMBER OF PEOPLE IN THE HOUSEHOLD

GENERAL NOTES:

NUMBER OF CHILDREN BELOW 5 YEARS OF AGE

TYPES AND USES OF HOUSEHOLD FUEL

FUEL	USE	COST/TIME/EVERY WEEK, DAY MONTH ETC.

TYPES OF FOOD AND DRINKS PREPARED

ACTIVITY	TIME OF DAY	DURATION	NUMBER OF PEOPLE / COMMENT

LOCATION OF PERSON RESPONSIBLE FOR COOKING AND CHILDREN

TIME	ADULT NEAR STOVE						CHILD IN SAME AREA AS STOVE					STOVE CHARACTERISTIC
	0	1/4	1/2	3/4	1/1		0	1/4	1/2	3/4	1/1	
8												
9												
10												
11												
12												
13												
14												

NOTES

Health questionnaire - Household cook

ID. Identifying household and cook			
ID1	Household number (1, 2, 3…)		
ID2	Name of interviewer		
ID3	Identifier for Household Cook (1a, 2a, 3a…)		
ID4	Date of interview		
ID5	Age of Household Cook		
A. Cough (Kohoa)			
A1	Over the last 12 months, have you usually had a **cough** first thing in the morning, or at other times of the day?	No (go to B1) Yes	1 2
A2	Do you usually **cough** like this on most days?	No Yes	1 2
A3	For how many months, in total, in the last year have you **coughed** like this?	9 or more months 5 - 8 months 3 - 4 months 1 – 2 months less than 1 month	1 2 3 4 5
A4	For how many years have you **coughed** like this?	Years:	
B. Phlegm (Kohozi)			
B1	Over the last 12 months, have you usually brought up **phlegm** from your chest (deep down in your lungs) first thing in the morning, or at other times of the day?	No (go to C1) Yes	1 2
B2	Do you usually bring up **phlegm** like this on most days?	No Yes	1 2
B3	What colour is the **phlegm** usually?	Clear or white Yellow or green Brown or black Red (streaked)	1 2 3 4
B4	For how many months, in total, in the last year have you brought up **phlegm** like this?	9 or more months 5 - 8 months 3 - 4 months 1 – 2 months less than 1 month	1 2 3 4 5
B5	For how many years have you brought up **phlegm** like this?	Years:	
C. Episodes of cough and phlegm			
C1	Over the last 12months, have you had episodes of both (increased*) **cough** and **phlegm** together lasting for 3 weeks or more? **Increased if already have* ***cough*** *and/or* ***phlegm***	No (go to section WH1) Yes	1 2
C2	How many such episodes did you have in the last year?	Number:	
C3	For how many years have you had at least one episode per year like this?	Years:	

D: Health of under-five children as rated by mother *Respiratory health problems to include all upper (**coughs**, colds, etc) and more severe respiratory problems including **coughs** going onto chest, with fever, etc.*				
D1	How many children under five years of age do you have?		Number of children under 5	
D2	Have any of your under-five children had an illness with a **cough** at any time in the last two weeks?		No (go to D6) Yes	1 2
D3	If yes, did they breathe very noticeably faster than usual with short, rapid breaths? *(if more than one child with cough, discuss youngest)*		No Yes	1 2
D4 D5	How old is the child with the **cough**? *(if more than one child with cough, discuss youngest)*		Years Months	
D6	What (other) respiratory health problems, if any, have your under-five children experienced in the last year? **Do not prompt!**	None (go to D8) Coughs and colds More serious illness with difficulty breathing Other (specify)		1 2 3 4
Burns and scalds (Ungua na Kichomo)				
D7	How many times have **burn**s or **scald**s occurred to any of your under-five children in the last year? (if none, insert '0' and go to next section)		Number of times:	
D8 D9	What was age of that child at the time? *If more than one child – discuss youngest*		Years Months	
D10	For the most severe occasion in the last year, how severe was this **burn**?		No scar (go to next section) Small scar ≤2 cm Large scar >2 cm	1 2 3
D11	Where did this **burn** or **scald** occur?		Your kitchen Not in your kitchen	1 2
D12	How did this **burn** or **scald** occur? **Do not prompt!**		Fell into fire Touched hot object **Scald**ed when pot fell over Clothes caught fire Other (describe)	1 2 3 4 5
D13	Is there anything else you would you like to say about the health of your children under 5 at the present time?			
TM: Treatment for respiratory health problems				
In the last 12 months have you or your family visited any of the following health providers for respiratory health problems?				
TM1	Dispensary		No Yes	1 2
TM2	Health Centre		No Yes	1 2
TM3	Hospital		No Yes	1 2
TM4	Traditional Healer		No Yes	1 2
TM5	Other		No Yes	1 2

TM6	How many in the family have used antibiotic the last 12 months?	Number of people:	
AT. Attitudes and awareness			
AT1	Why do you think you and your children sometimes have respiratory symtoms?		
AT2	Do you think household air pollution can affect you and your childrens health?	No (go to AT4) Yes	1 2
AT3	If yes, in what way?		
AT4	Would you like to use some other fuel for cooking than what you are using now?	No (go to AT7) Yes	1 2
AT5	What kind of fuel would you like to use instead?		
AT6	Why would you like to change fuel?		
AT7	What are the main benefits with the fuel you are using now? (faida)		
IN. Inhaling pollutant *(this is needed for analysing breath-CO tests)*			
IN1	How long ago (in hours) did you last cook using a stove?	Hours ago	
IN2	Which fuels/stoves have you used during the last day?		
IN3	Over the last day, have you sat close to your own or a neighbours fire, when the fire was burning brightly?	No (go to **IN4**) Yes	1 2
IN4	How many hours ago did this happen?	Hours ago	
IN5	Do you smoke, or have you ever smoked, cigarettes? Answer 1: Go to **IN9** Answers 2 & 3: Go to **IN8**	Never Gave up more than year ago Gave up during last year Yes	1 2 3 4
IN6	Average smoked per day	Less than 5 per day 5 – 9 per day 10-19 per day 20 or more per day	1 2 3 4
IN7	How many hours since you smoked your last cigarette?	Hours ago	
IN8	[Current and ex-smokers] For how many years have you smoked (or did you smoke) cigarettes?	Years:	

WH. Wheezing (Koroma)			
WH1	Over the last 12 months, has your chest (your lungs) sounded **wheezy** or **whistling**	No (go to BR1) Yes	1 2
WH2	Has this happened when you have a cold?	No Yes	1 2
WH3	Has this happened at other times when you do not have a cold?	No Yes	1 2
WH4	For how many years has this wheeze been present (whether or not when you have a cold)?	Years: (Put '1' if less than one year)	
BR. Breathlessness			
BR1	Do you ever feel troubled by breathlessness?	No (go to H1) Yes	1 2
BR2	If yes, specify: Breathless when hurrying or walking up a slight hill Has to stop for breath when walking in own pace on level ground Stops for breath after a few minutes/100 meters on level ground Breathless when dressing/undressing		 1 2 3 4
H. Headaches (Maumivu ya kichwa)			
H1	Over the last 12 months, have you tended to get **headaches?**	No (go to E1) Yes	1 2
H2	How often do you have **headaches**?	Every day Most days Few days per week Once per week Less often	1 2 3 4 5
H3	How strong are the **headaches** usually?	Very strong Fairly strong Mild	1 2 3
H4	What do you think usually causes these **headaches**? **Do not prompt!**	Smoke Having a cold Weakness of sight Other	1 2 3 4
H5	If 'other' please specify		
E. Eyes (Macho)			
E1	Over the last 12 months have your eyes been draining?	No (do to O1) Yes	1 2
E2	Has it happened when you have had a cold?	No Yes	1 2
E3	Has it happened at other times when you do not have a cold?	No Yes	1 2
O. Other factors			
O1	Do you have animals inside your house?	No Yes	1 2

IN9	Does your neighbor smoke?	No Yes	1 2
IN10	Have you, in the last 24 hours, spent more than about half an hour in the same room as someone smoking cigarettes?	No (end interview) Yes	1 2
IN11	How many hours ago?	Hours ago	
EX. Experience			
EX1	How has this day been?		
EX2	How did you find it to wear the CO-monitor?		
EX3	Would you say that this day has been representative for a usual day in your home?		

Clinical examination - Household Cook

ID, date and examinator				
ID of Household Cook				
Date of examination				
Name of examinator				
HW. Height and weight				
Height (if known)				
Weight (if known)				
L. Lungs				
L1	Breathing count		Breaths/min:	
L2	Use of accessory breathing muscles		No Yes	1 2
L3	Lung sounds	Vesicular (normal)	No Yes (go to HE1)	1 2
L4		Crackles (fine)	No Yes	1 2
L5		Crackles (coarse)	No Yes	1 2
L6		Wheeze	No Yes	1 2
L7		Rhonchi	No Yes	1 2
L8		Other	No Yes	1 2
HE. Heart				
HE1	Heartbeat		Beats/min:	
HE2			Irregular heartbeat Regular heartbeat	1 2
HE2	Heart murmurs		No Yes	1 2
OS. Other symptoms noted during examination				
OS1	Cough		No Yes	1 2
OS2	Cough and phlegm		No Yes	1 2
OS3	Breathlessness		No Yes	1 2
OS4	Eye draining		No Yes	1 2
OS5	Other		No Yes	1 2

Clinical examination – Children under 5 years of age

ID, date and examinator				
ID of Child				
Date of examination				
Name of examinator				
L. Lungs				
L1	Breathing count		Breaths/min:	
L2	Use of accessory breathing muscles		No Yes	1 2
L3	Chest indrawings		No Yes	1 2
L4	Lung sounds	Vesicular (normal)	No Yes (go to HE1)	1 2
L5		Crackles (fine)	No Yes	1 2
L6		Crackles (coarse)	No Yes	1 2
L7		Wheeze	No Yes	1 2
L8		Rhonchi	No Yes	1 2
L9		Other	No Yes	1 2
HE. Heart				
HE1	Heartbeat		Beats/min:	
HE2			Irregular heartbeat Regular heartbeat	1 2
HE2	Heart murmurs		No Yes	1 2
OS. Other symptoms noted during examination				
OS1	Cough		No Yes	1 2
OS2	Runny nose		No Yes	1 2
OS3	Fever		No Yes	1 2
OS4	Other		No Yes	1 2

RESULT PART I

PNEUMOCOCCAL NASOPHARYNGEAL CARRIAGE (NPH) AND ACUTE RESPIRATORY TRACT INFECTION (ARI) AMONG CHILDREN IN MOSHI

EXPECTED RISK FACTORS

In total 53 isolates were found in the 213 samples, thus 25% of the children were pneumococcal carriers. As shown in Table 12, factors such as low birth weight, crowding and education level of the parents, are not related neither pneumococcal carriage nor acute respiratory tract infection (ARI) the last 3 months. A significant association is found between antibiotic use and ARI. Among the 150 children who had had an ARI the last 3 months, 80% had used antibiotics during the same period. Only 12% (17/137) who had used antibiotics the last 3 months had not had an ARI.

	Children with NPH carriage			Children with ARI last 3 months*		
	No n=160 (%)	Yes n=53 (%)	*p* value	No n=63 (%)	Yes n=150 (%)	*p* value
Birth weight						
<2500 g	38 (24)	15 (28)	0.58	15 (24)	38 (25)	0.86
≥2500 g	122 (76)	38 (72)	0.58	48 (76)	112 (75)	0.86
Crowding						
≥3 siblings	18 (11)	8 (15)	0.47	7 (11)	19 (13)	0.82
≥3 persons sleeping in the same room as the child**	63 (39)	19 (36)	0.75	22 (35)	60 (40)	0.54
Current ARI*	86 (54)	30 (57)	0.75			
Antibiotics in the past						
Last 7 days	41 (26)	13 (24)	1	2 (3)	52 (35)	<0.001
Last month	71 (44)	25 (47)	0.75	12 (19)	84 (56)	<0.001
Last 3 months	101 (38)	36 (68)	0.62	17 (27)	120 (80)	<0.001
Education level of mother						
Primary school or lower	102 (64)	33 (62)	0.87	40 (64)	95 (63)	1
Secondary school	52 (32)	18 (34)	0.85	21 (33)	49 (33)	1
Post-secondary school	6 (4)	2 (4)	1	2 (3)	6 (4)	1
Education level of father						
Primary school or lower	85 (53)	27 (51)	0.87	31 (49)	81 (54)	0.55
Secondary school	56 (35)	18 (34)	1	24 (38)	50 (33)	0.53
Post-secondary school	13 (8)	3 (6)	0.77	6 (10)	10 (7)	0.57
Unknown	6 (4)	5 (9)	0.15	2 (3)	9 (6)	0.51
Smoking	19 (12)	8 (13)	0.63	11 (17)	16 (11)	0.18

* *acute otitis media, chest pain, cough, breathing problem, cough+fever, cough+running nose, running nose+fever*
***child not included*
**** acute otitis media, chills, cough, rapid or difficulty breathing, running nose, sore throat - with or without fever*

TABLE 12. *PNEUMOCOCCAL NASOPHARYNGEAL CARRIAGE (NPH) AND ACUTE RESPIRATORY TRACT INFECTION (ARI) AMONG CHILDREN IN MOSHI, IN RELATION TO EXPECTED RISK FACTORS.*

FUEL

The participants were asked to grade the most and the second most important fuel used for cooking and in Table 13 answers from these questions are merged. There are no discrepant findings when analysing the questions separately. Ninety-two percent of the households used firewood, charcoal or kerosene as most important fuel for cooking. Kerosene usage tends to be more common among children without pneumococcal carriage. No apparent correlations between charcoal users and carriage or ARI the last 3 months are found. Although no association between pneumococcal carriage and usage of firewood can be shown, there is a significant association between use of firewood and an episode of ARI the last 3 months.

	Children with nasopharyngeal carriage			Children with ARI last 3 months*		
	No n=160	Yes n=53	*p* value	No n=63	Yes n=150	*p* value
Firewood	25 (16)	12 (23)	0.30	4 (6)	33 (22)	0.005
Charcoal	131 (82)	41 (77)	0.55	53 (84)	119 (79)	0.45
Kerosene	117 (73)	32 (60)	0.086	45 (71)	104 (69)	0.87
LPG (gas)	31 (19)	10 (19)	1	15 (24)	26 (17)	0.34

* *acute otitis media, chest pain, cough, breathing problem, cough+fever, cough+running nose, running nose+fever*

TABLE 13. *PNEUMOCOCCAL NASOPHARYNGEAL CARRIAGE (NPH) AND ACUTE RESPIRATORY TRACT INFECTION (ARI) AMONG CHILDREN IN MOSHI, IN RELATION TO FUEL USED FOR COOKING.*

BUILDING CHARACTERISTICS

The material of the walls mainly concerned the main house. If the cooking took place in a separate building (21%) the material of the kitchen building was requested.

As shown in Table 8, no clear results are found between nasopharyngeal carriage and materials of the walls.

Roof without ceiling tends to be associated with ARI the last 3 months. Among them without ceiling, 75% (94/125) had had an ARI the last 3 months. There is a significant correlation between ARI the last 3 months and burned bricks as material. Among the houses made from burned bricks, 67 % had a roof without ceiling. The opposite correlation is found between ARI the last 3 months and concrete and among the houses made from concrete only 35% did not have ceiling. When concrete and burned bricks are added as high thermal mass, no correlation is found.

	Children with nasopharyngeal carriage			Children with ARI last 3 months*		
	No n=160 (%)	Yes n=53 (%)	*p* value	No n=63	Yes n=150	*p* value
Roof						
Without ceiling	93 (58)	32 (60)	0.87	31 (49)	94 (63)	0.093
With ceiling	67 (42)	21 (40)	0.87	32 (51)	56 (37)	0.093
Material of the walls						
*Lower thermal mass***	18 (11)	9 (17)	0.34	5 (8)	22 (15)	0.26
*High thermal mass****	142 (89)	44 (83)	0.34	58 (92)	128 (85)	0.26
Adobe	14 (9)	4 (7.5)	1	5 (8)	13 (9)	1
Wattle Daub	2 (1)	3 (6)	0.1	2 (3)	3 (2)	0.63
Iron Sheets	6 (4)	2 (4)	1	0	8 (5.3)	0.11
Burned Bricks	62 (39)	25 (47)	0.33	19 (30)	68 (45)	0.047
Concrete	45 (28)	10 (19)	0.21	23 (36.5)	32 (21.3)	0.026
Plastered	21 (13)	5 (9)	0.63	11 (17.5)	15 (10)	0.17
Other	10 (6)	4 (7.5)	0.75	3 (5)	11 (7.3)	0.76

** acute otitis media, chest pain, cough, breathing problem, cough+fever, cough+running nose, running nose+fever*
*** iron sheets, wattle and doube, other e.g. wood*
**** adobe, burned bricks, concrete, plastered*

TABLE 14. *PNEUMOCOCCAL NASOPHARYNGEAL CARRIAGE (NPH) AND ACUTE RESPIRATORY TRACT INFECTION (ARI) AMONG CHILDREN IN MOSHI, IN RELATION TO BUILDING CHARACTERISTICS.*

COOKING AREA

The participants were asked about where they cook their food. It could be an enclosed area to enter from another room or an enclosed area connected to the main house but entered from outside. The stove could also be used in the main living area, in some cases the same area as sleeping. Another option was a separate building, often a shed. The stove could also be used outside, either put on the ground or put on the corridor (veranda with/without roof) just outside the door. It was possible to give multiple answers. Common combinations were to cook with charcoal outside and use kerosene inside or to use charcoal outside but inside when raining.

As shown in Table 15, between ARI the last 3 months and cooking in a separate building, the association is significant. Eighty-six percent (38/44) of the children cooking in a separate building had had an ARI the last 3 months.

When looking at Table 15, to cook in the main living area is significant associated with lower carriage rate. Since the majority of those who answered that they cook inside in the main living area used charcoal outside, one should not emphasis on the finding that cooking in the main living area can prevent carriage, because the feared fuel is used outside.

When making a predicted ”high risk exposure” group in SPSS (household that cooked with firewood or charcoal as most important fuel in the main living area), it was no longer protecting to cook in part of main living area.

	Children with nasopharyngeal carriage			**Children with ARI last 3 months***		
	No n=160 (%)	**Yes n=53 (%)**	***p* value**	**No n=63 (%)**	**Yes n=150 (%)**	***p* value**
Enclosed area, kitchen	22 (14)	8 (15)	0.82	10 (16)	20 (13)	0.67
Part of main living area	89 (56)	19 (36)	0.017	35 (56)	73 (49)	0.37
Separate room attached to main house	9 (6)	3 (6)	1	6 (10)	6 (4)	0.19
Separated building	29 (18)	15 (28)	0.12	6 (10)	38 (25)	0.009
Outside	90 (56)	23 (43)	0.11	34 (54)	79 (53)	0.88

**acute otitis media, chest pain, cough, breathing problem, cough+fever, cough+running nose, running nose+fever*

TABLE 15. *PNEUMOCOCCAL NASOPHARYNGEAL CARRIAGE (NPH) AND ACUTE RESPIRATORY TRACT INFECTION (ARI) AMONG CHILDREN IN MOSHI, IN RELATION TO COOKING LOCATION.*