Improved Cook Stoves Assessment and Testing

ICS Taskforce Tanzania

April 2013

About ICS Taskforce

Facilitated by SNV, the ICS Taskforce of Tanzania was created in 2011, with the Ministry of Energy and Minerals (MEM) as the Chair and the Tanzania Renewable Energy Association (TAREA) elected as the secretariat. The ICS Taskforce was initiated with the aim to increase coordination in the Improved Cook Stove (ICS) sector, for stakeholders to better understand and develop the sector through multi-stakeholder processes, while doing the necessary studies to come to a joint way forward for further ICS market development in the country. This document, elaborated by Dr. H.M. Rajabu and A.E. Ndilanha from the University of Dar es Salaam, is one of the resulting documents of the ICS Taskforce. Other documents include: market intelligence studies for ICS in different regions of the country, ICS policy analysis, and a Country Action Plan for Clean Cookstoves and Fuels.

Authors of this study: Hassan Rajabu and Arfaxad Ndilanha, University of Dar es Salaam

Coordination and editing: Francis Songela, Finias Magessa & Martijn Veen, SNV Tanzania

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Disclaimer

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Abbreviations

AREED	African Rural Energy Enterprise Development
ARTI	Appropriate Rural Technology Institute
BEDOKO	Benny and Dominic Komba
C	Carbon
CAMARTEC	Centre for Agricultural Mechanization and Rural Technology
CBOs	Community Based Organizations
CCFAT	Clean Cookstoves and Fuels Alliance of Tanzania
CCT	Controlled Cooking Test
CH4	Methane
CNSL	Cashew Nut Shell Liquid
CO	Carbon Monoxide
CO2	Carbon Dioxide
COSTECH	Tanzania Commission for Science and Technology
CRR	Crop-to-Residue Ratio
ENVOTEC	Environment Technology
GACC	Global Alliance for Clean Cookstoves
GDP	Gross Domestic Product
GHGs	Green House Gases
GTZ	Deutsche Gesselschaft fuer Teknische Zussammenarbeit
GWh	Giga Watt Hour
IAP	Indoor Air Pollution
ICS	Improved Cook Stoves
ISO	International Standards Organization
ITDG	Intermediate Technology Development Group
IWA	International Workshop Agreement
KCJ	Kenya Ceramic Jiko
KIDT	Kilimanjaro Industrial Development Trust
KJ	Kilo Joules
KPT	Kitchen Performance Test
LPG	Liquefied Petroleum Gas
M&R ATECO	Mzobora and Rweyemamu Appropriate Technology Company
MCDA	Multiple Criteria Decision Analysis
MEM	Ministry of Energy and Minerals
MIGESADO	Miradi ya Gesi ya Samadi Dodoma
MNRT	Ministry of Natural Resources and Tourism
MRHP	Mwanza Rural Housing Programme
MSTHE	Ministry of Science, Technology and Higher Education
N	Nitrogen
N2O	Nitrogen Oxide
NAFCO	National Agriculture and Food Corporation
NBS	National Bureau of Statistics
NGOs	Non Government Organizations
NORAD	Norwegian Agency for Development Co-Operation
NOx	Nitrogen Oxides
NSGRP	National Strategy for Growth and Reduction of Poverty
PAHs	Polycyclic Aromatic Hydrocarbons
PCA	Philippine Coconut Authority
PCBs	Polychlorinated biphenyls
PCIA	Partnership for Clean Indoor Air
PfD	Partners for Development
POPC	President's Office Planning Commission
ProBEC	Programme for Basic Energy and Conservation
PRR	Product-to-Residue Ratio

PRSP	Poverty Reduction Strategy Paper
PRSR	Poverty Reduction Strategy Review
R&D	Research and Development
REA	Rural Energy Agency
REF	Rural Energy Fund
SACCOS	Savings and Credit Cooperative Society
SADC	Southern African Development Community
SIDA	Swedish International Development Cooperation Agency
SME	Small and Medium Enterprises
SNV	Netherlands Development Organisation
SOx	Sulphur Oxides
SVOCs	Semi-Volatile Organic Compounds
TAFORI	Tanzania Forestry Research Institute
TaTEDO	Tanzania Traditional Energy and Environment Development Organization
TBS	Tanzania Bureau of Standards
TFCT	Timed Fuel Consumption Test
TIRDO	Tanzania Industrial & Research Development Organization
TLUD	Top-lit Updraft
TPC	Kilimanjaro Sugar Factory
TREE	Technologies for Renewable and Efficient Energy
TVOC	Total Volatile Organic Compounds
UNICEF	United Nations Children's Fund
UDSM	University of Dar es Salaam
US EPA	United States Environmental Protection Agency
USA	United States of America
USDA	United States Department of Agriculture
VOCs	Volatile Organic Compounds
VPO	Vice President’s Office
WB	World Bank
WHO	World Health Organization

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- Ms. Shigela for hosting the CCT and participating in the test; Ms. Mwajuma and Ms. Anasteria for participating in the CCT in Mwanza;
- Mr Fraten, a food vendor in Mwanza for hosting and participating in the TFCT on Charcoal Stoves for Vendors in Mwanza;
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- All other people who contributed to this work in one way or another since it is practically impossible to name each and everyone here.

All their ideas, information, guidance and comments have great significance to this study.

Executive Summary

Background

In January 2011, SNV Tanzania facilitated the formation of ICS Task Force; and supported the Task Force and Tanzania Renewable Energy Association (TAREA) to work with key actors to develop a commercially viable sub-sector through supply and demand sides strengthening, research and development, resource mobilization, evidence based technological and market intelligence and enhanced public policy dialogue.

Lack of information on R&D and performance of existing ICS is one of the challenges the ICS Task Force wanted to address. Additionally, many findings (including SNV, 2011) revealed that rural wood stove programmes have not been sustainable due to a number of reasons including poor dissemination approaches, inexistence of ICS models that can be commercialized. In this regard, SNV Tanzania and ICS Task Force planned to evaluate existing ICS (local and imported) and develop household wood stove models that can be commercialized in rural and sub-urban areas of Tanzania. The Task Force intended to make use of the findings from the assessment for the development of an impact oriented, private-sector led, commercially viable, and sustainable ICS sub-sector in Tanzania.

Objectives and Methods for this Assignment

Objectives of this assignment are:

- To collate R&D findings on ICS in Tanzania
- To assess current ICS technologies in Tanzania,
- To evaluate locally produced ICS
- To assess various feed stocks (alternative to wood and charcoal) suited for ICS.
- To test 4 domestic wood stove designs in the Lake Zone

Methods used to obtain data and information and for assessment of ICS includes: review of published reports and literature on previous interventions on ICS; interviews with key stakeholders in the ICS sector; Survey using structured questionnaires; stove testing on ICS models and tradition stoves; A Multiple Criteria Decision Analysis (MCDA) method in assessment of ICS for up-scaling; and feedback and information sharing from the Workshop on Cookstoves Standard held in Dar es Salaam on 17th – 18th, December 2012.

Findings from the Assessment of ICS

Specific findings, conclusions and recommendations from the assessment are presented below according to the respective tasks of this assignment:

(a) General

With exception of ceramic-lined metal charcoal stove models, most of other introduced ICS models have generally failed to penetrate the market to reach a critical mass production stage. The majority of cookstoves makers are in the informal sector with localized sales, substandard quality, and little consistency in stove quality. Previous studies on the ICS sector in Tanzania have identified many reasons and/or challenges which can be linked to the failure in the dissemination of ICS. Among them include:

i. Low awareness and lack of knowledge to majority of targeted end-users on fuelwood saving from ICS. This is especially critical in families which still fetch fuelwood for cooking (free fuelwood)
ii. Low awareness and lack of sensitization on the effects of harmful emissions in the smoke to the cooks and babies
iii. High cost of ICS compared to tradition stoves
iv. Lack of business skills, promotion, marketing strategies, and chain actors in the ICS sector
v. Lack of access to finance to establish proper stove production facilities

vi. High material and production costs which lead to high product cost
vii. Mismatch or inappropriate stove designs which does not fit cooks preferences and culture.
viii. Lack of clear-cut integrated policy from the government that provides incentives for the commercialization of the ICS sector specifically
ix. Lack of large- and medium-scale stove makers and promoters
x. Donor-dependence of existing organizations and NGOs which mainly operate on donor's program requirements.

It is difficult to have an ICS model which will fit the preferences of all users across the country or even in a region. This is due to the differences in cultures, staple foods and preferences. Hence it is important to first ***identify groupings of users with similar cooking preferences, etc.,*** which is very likely to coincide with the geographic areas. The appropriate ICS can then be identified and ***modified if needed by involving women in that particular culture to set specifications and versions of the stove such as: two or more sizes of the stove; multiport; portable and fixed versions; etc.***

Most households especially in urban and suburban areas have two or more stoves which use different types of fuels to enhance energy security and cooking preferences. In most multi-stove and multi-fuel households, a stove which is preferred for cooking staple foods is normally the *main stove* and is used more frequent than the other stoves. ***An ICS is more likely to have an impact (fuelwood saving, etc), if it is preferred for cooking staple foods. Hence, the usability of the ICS has to be an improvement of the tradition stoves on aspects which are liked by the cooks in order to be preferred for cooking staple foods.***

It is further recommended that new cooking technologies such as gasification stoves which can use fuel pellets made from agricultural waste be promoted ***in areas with acute scarcity of fuelwood.*** Advantages of a gasifier stove over conventional ICS include:

- Very clean burning hence can be used indoors
- Use a wider variety of biomass fuels (husks, shells, grass,)
- Higher efficiency
- Makes charcoal during the process

(b) Research, Development and Promotion of ICS Technologies

The following have been observed in research, development and promotion of ICS:

i. Sector policies reveals adequate coverage and emphasis on efficient and use of clean cooking technologies by encouraging R&D efforts and promotion of clean household energy options especially in the rural communities where biomass is the main source of energy.
ii. Lack of emphasis in sector policies on reducing Indoor Air Pollution (AIP) which is affecting many households that are using biomass energy for cooking.
iii. Despite the many players in the Government, there is no clear coordination and documentation mechanism or media which will enable all players to share information on what others are doing at the local and national levels. Each actor plans, implements, documents and disseminates information in-house, which creates possibilities of duplicating efforts and resources.
iv. Lack of linkage between research institutions due to their locations under different Ministries leading to lack of coordination which is important for sharing research findings and resources such as expertise, equipment, etc. Furthermore, lack of human capacity, finance and equipment hinders research and operational activities of the institutions.
v. There are many NGOs, CBOs, and other ICS stakeholders, but there is no coordinating mechanism to share information and experience to create an enabling environment for all stakeholders to contribute effectively to policy influencing strategies to increase awareness, ICS market, reduce costs, and other aspects to improve their ICS businesses.
vi. Inadequate budget from the Government to research institutions for R&D in general.
vii. Some private institutions who are interested in financing ICS technologies exist. These include Savings and Credit Cooperative Society (SACCOS), E+CO, AREED, Tujijenge Bank, and Tanzania Private Foundation Sector.
viii. Establishment of Rural Energy Fund (REF) under Rural Energy Agency (REA) provides grants, capacity building, technical assistance and promotion for renewable energy technologies.

ix. Most ICS entrepreneurs do not have sufficient training to meet carbon finance

x. In the interim, there is no standard and mechanism in place to protect customers from sub-standard ICS in the market. The international stove community has recently started to address the issue of lack of internationally agreed standards for stoves.

xi. Review of successful ICS programmes reveals that:
  - Research and development and training to artisans and consumers are important steps in ICS programmes.
  - Involvement of Government and non-government institutions from national to village levels is essential for raising awareness to achieve wider markets for ICS.

It is recommended that TAREA and CCFAT be supported to take leading roles as official platforms to represent the interest of actors in the ICS sector including users.

(c) Testing of Ceramic ICS Models for Household and Food Vendors

The following can be concluded from the tests conducted in Mwanza:

i. *Matawi-Y* and *Matawi-Portable* are the most efficient stoves from the CCT conducted in Mwanza, but overall the Matawi-Y stove is the best stove among the stoves tested in Mwanza

ii. All *Matawi* stoves have comparable cooking times with 3-stone fire

iii. The *Matawi*-Portable stove is not an appropriate "first choice" stove in households using fuelwood for cooking, as is not safe and is difficult to operate.

iv. The charcoal ICS for food vendor suggests fuel saving of over 40%.

More tests are recommended for charcoal ICS for food vendors to confirm the potential saving from the tradition vendor stove and its durability. The test should cover at least 3 food vendors and should last for at least one week to cover both "normal" and "abnormal" days.

(d) Survey of Imported ICS

Imported ICS which have been available in the market in Tanzania have mainly come through carbon projects. The design characteristics of these stoves can be summarized as follows:

- They are made from metal fabrication with ceramic inserts at combustion chamber
- They are portable and lightweight
- Good appearance with good quality finish
- Not easy to repair locally
- Have small combustion chamber

A survey conducted for the Envirofit imported stove in the sub-urban area of Arusha town reveals the following operational characteristics of the Envirofit stove:

i. The Envirofit stove (G-3300) is small and not suitable for bigger pots
ii. Only small fuelwood size can be used
iii. Need more attention (to tend fire) because small fuelwood burnout fast
iv. The fuelwood does not leave charcoal after the flames have extinguished
v. Fuelwood has to be dry for the stove to work well
vi. Not suitable for foods which require heavy stirring such as *ugali*
vii. Give smoke and cannot be used indoors
viii. Deposit soot on pots
ix. Cooks fast
x. Save fuel
xi. Fire too strong and hence not suitable to cook certain foods

(e) Assessment and Evaluation of ICS Technologies Available in Tanzania

A *Multiple Criteria Decision Analysis (MCDA)* is used for assess and recommend ICS models for promotion to mass-scale production. The criteria selected for evaluations are: *Manufacturability and scalability*; *Fuel saving; Usability; Durability; Maintainability; Portability; Cost/affordability; Safety-1 (stability, hot surfaces, sharp edges); Safety-2 (smoke, emissions); Weight and space; Looks and cultural aspects*.

Each criterion is assigned a weight between 0 – 5, zero (0) for "not important" and 5 for "very important" criterion based on the goals of the assessment to reflects the importance or priority of criterion on up-scaling (or commercialization), acceptance by users, and meeting other ICS usual expectations. Each ICS model is given a score between 0 – 10 for each criterion. Zero (0) for poor, and ten (10) for excellent. The criterion score is then multiplied by respective *criterion importance (%)* to get *Total Score* in each criterion. The *Overall Score* for each ICS model is the sum of the Total Scores of all criteria. The Tables below show the results of the evaluations with assigned weights, criterion importance, and score of each criterion for available ICS technologies in Tanzania. Higher ratings have been assigned to the criteria which are important in acceptance (market) and ease in quality low-cost mass production.

From the Tables the results of evaluation of the ICS indicate that ***Fixed ceramic stove (1st), Portable Ceramic stove (2nd), and Metal-clad Rocket (3rd)*** *are* appropriate models for promotion to commercial scale production.

For the case of non-fuelwood stoves ***metal-clad charcoal (1st)*** and ***gasification stove (2nd)*** have emerged above metal and clay charcoal stoves for promotion to commercial scale. It has to be cautioned that ***there will never be a clear winner*** in a MCDA where the criteria are assigned different weights and in some criteria the scores are subjective.

Evaluation results for fuelwood stoves

Criterion	Weight or rating (0-5)	Criterion importance (%)	Fuelwood Stoves									
			Mud -Normal		Mud-rocket		Clay-fixed		Clay-portable		metal-clad rocket	
			Point score	Total score	Point score	Total score	Point score	Total score	Point score	Total score	Point score	Total score
Manufacturability and scalability	5	12%	5	0.60	4	0.48	7	0.83	8	0.95	6	0.71
Fuel saving	5	12%	4	0.38	6	0.57	6	0.57	6	0.57	9	0.86
Usability	3	7%	6	0.71	4	0.48	8	0.95	7	0.83	4	0.48
Durability	5	12%	2	0.19	2	0.19	6	0.57	4	0.38	8	0.76
Maintainability	2	5%	8	0.57	8	0.57	8	0.57	4	0.29	5	0.36
Portability	5	12%	0	0.00	0	0.00	0	0.00	10	0.71	6	0.43
Cost/affordability	4	10%	9	1.07	8	0.95	8	0.95	8	0.95	4	0.48
Safety-1 (stability, burns)	3	7%	8	0.76	8	0.76	8	0.76	4	0.38	7	0.67
Safety-2 (emissions)	3	7%	4	0.29	8	0.57	6	0.43	6	0.43	9	0.64
Weight and space	5	12%	5	0.48	5	0.48	7	0.67	8	0.76	7	0.67
Looks and cultural aspects	1	2%	8	0.38	8	0.38	9	0.43	9	0.43	7	0.33
OVERALL SCORE	**41**	**100%**		**5.43**		**5.43**		**6.74**		**6.69**		**6.38**
		RANKING	**4**		**4**		**1**		**2**		**3**	

Evaluation results for charcoal and gasification stoves

Criterion	Weight or rating (0-5)	Criterion importance (%)	Charcoal and Gasifier Stoves							
			Clay Charcoal		metal clad-charcoal		All metal-charcoal		Gasifier stove	
			Point score	Total score	Point score	Total score	Point score	Total score	Point score	Total score
Manufacturability and scalability	5	12%	8	0.95	9	1.07	9	1.07	7	0.83
Fuel saving	5	12%	9	1.07	9	1.07	4	0.48	10	1.19
Usability	3	7%	6	0.43	9	0.64	9	0.64	4	0.29
Durability	5	12%	2	0.24	8	0.95	5	0.60	6	0.71
Maintainability	2	5%	4	0.19	4	0.19	6	0.29	4	0.19
Portability	5	12%	10	1.19	10	1.19	10	1.19	10	1.19
Cost/affordability	4	10%	9	0.86	9	0.86	10	0.95	5	0.48
Safety-1 (stability, burns)	3	7%	7	0.50	8	0.57	5	0.36	8	0.57
Safety-2 (emissions)	3	7%	5	0.36	5	0.36	5	0.36	9	0.64
Weight and space	5	12%	8	0.95	9	1.07	9	1.07	9	1.07
Looks and cultural aspects	1	2%	9	0.21	8	0.19	6	0.14	4	0.10
OVERALL SCORE	**41**	**100%**		**6.95**		**8.17**		**7.14**		**7.26**
		RANKING	**4**		**1**		**3**		**2**	

(f) Alternative Fuel Feedstock for ISC

The current situation on fuelwood scarcity in some areas of the country calls for immediate interventions on alternatives for fuelwood and charcoal to alleviate the problem. Briquettes are attractive alternatives because they can be used in the same stoves (tradition and ICS) which have been developed for fuelwood and charcoal. A quick assessment of biomass waste resource revealed good potential of utilizing the wastes for briquetting projects, however, area-specific and residues-specific information need to be gathered on the alternative uses and their availability for making fuel briquettes. Due to the small-scale and scatter nature of most residues, promotion of small- and medium-scale briquetting projects is recommended.

Apart from briquettes which can be used in tradition stoves and conventional ICS, it is recommended to promote stove technologies such as the semi-gasifier sawdust stove which can utilize small-particle biomass waste. The full gasifier stove needs fuel particles of a certain size range to work properly by natural draft. Smaller particles like rice and coffee husk requires a fan which will need electricity source to drive the small fan. Hence, pelletization of smaller particle to appropriate size for natural draft gasifier stove will make the gasifier stove to have an impact in fuel scarcity areas. Pilot trials of *Jiko Bomba* gasifier stove with rice husk pellets in the villages in Singida, Arusha, and Shinyanga regions has recorded good acceptance of the stove.

The seasonal availability of residues and the form which they appear (foreign matter, wetness, size, etc) are important in examining the feasibility of briquetting projects. Some residues such as sawdust and rice husk are available almost throughout the year. Other residues are available during post-harvest period which could complicate the feasibility of using such residues for fuel. In areas with paddy farming and brick making activities, rice husk residues are completely unavailable for free, and it will be difficult for briquetting project to compete for rice husk.

Other important issues for assessing biomass waste for fuel include the following:

i. Studies should be carried out to determine the possible effects of an increased use of field (farm) residues on soil conservation and degradation
ii. Promotion of the use of residues for a new application such as briquetting will not only put a value on the residues but may also deprive a part of the population (often the poorest) which use residues as fuel.
iii. There are large regional variations for particular residues according to farming and crop production patterns in the country. Hence development of a tool for assessing agricultural residues generation and inventory of amount of residues generated in different crops in different parts of the country.
iv. Identifying the major uses of crop residues and comparative assessment of their competing uses.
v. Assessing and characterizing the quality of crop residues and their suitability for fuel application.

1. INTRODUCTION

1.1 What is an Improved Cooking Stove (ICS)

Improved Cooking Stove is a relative concept which depends on the desired improvement from the *tradition stove.* The improvement can be on fuelwood saving, reduction in emissions, convenient and usability, fast cooking, etc. Depending on the region or country, tradition stoves are also different. However, in Tanzania context, and for the purpose of this task, *traditional cookstoves* are referred to three-stone fire and single-walled metal charcoal stove designs as shown in Figure 1.1.

The term ICS is mainly associated with *fuel saving* because when cookstove programs started in developing countries in 1980s the drive was on forests conservation and energy saving in general. The recent increase in awareness on the deaths cause by indoor air pollution (AIP) from biomass cookstoves has made reduced emissions from cookstoves an additional requirement for a stove to be considered an ICS. Despite the performance improvements of ICS relative to tradition stoves there is still no international consensus for the degree of improvements that are necessary for the stove to be categorized an ICS, though efforts by International ICS community is currently working on appropriate mechanism to rate ICS on fuel saving, emissions, and safety.

Three-stone fire

Single-walled metal charcoal stove

Figure 1.1 Tradition stoves used in Tanzania

1.2 Status of ICS Sector

It is estimated that about 8 million households in Tanzania cook with firewood and/or charcoal on traditional cookstoves. This presents a health risk to users, mainly women and children. The World Health Organization (WHO) estimates that about 18,900 deaths in Tanzania are attributable to indoor air pollution (IAP) annually. However, there is almost no awareness of the health risks of IAP in the general population.

In addition to the health problems associated with current cooking practices in Tanzania, rising fuels prices and increasing pressure on natural resources have increased the price of fuels and decreased the accessibility of wood and charcoal fuels. This means that the market for more efficient stoves, which use less fuel, is becoming more and more appealing to consumers, and poor families who have to walk long distances to fetch fuelwood. It is estimated that the adoption of ICS technologies in Dar es Salaam city with about 800,000 households is about 40%; whereas in other urban centers in the regions is about

20%; and less than 3% of households at national level (more than 8,000,000 households) are using ICS[1].

At present the manufacturing of cookstoves in Tanzania takes place primarily in the informal sector with localized sales, substandard quality, and little consistency in stove quality. However, ICS manufacturers have started to emerge in Tanzania, but sales are limited by low demand and higher prices due to low scales of production.

A survey conducted on rural agricultural households in 20037/08[2] revealed that the most prevalent source of energy for cooking is fuelwood, which was estimated at 94.5% of all rural agricultural households, followed by charcoal (3.9%), and crop residues (0.7%) as shown in Figure 1.2.

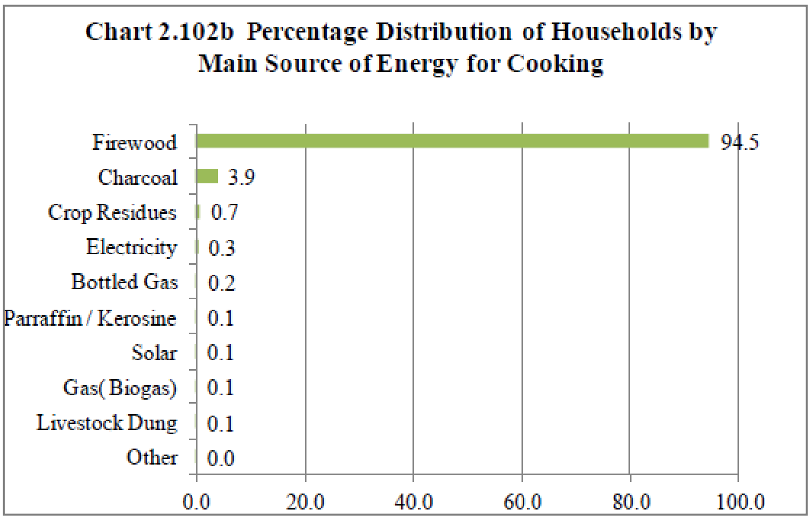

Figure 1.2 Percentage distribution of households by the main energy for cooking[3]

1.3 Background to the Task

In January 2011, SNV-Tanzania facilitated the formation of ICS Task Force; and supported the Task Force and Tanzania Renewable Energy Association (TAREA) to work with key actors to develop a commercially viable sub-sector through supply and demand sides strengthening, research and development, resource mobilization, evidence based technological and market intelligence and enhanced public policy dialogue.

Lack of information on R&D and performance of existing ICS is one of the challenges the ICS Task Force wanted to address. Additionally, many findings (including SNV, 2011) revealed that rural wood stove programmes have not been sustainable due to a number of reasons including poor dissemination approaches, inexistence of ICS models that can be commercialized. In this regard, SNV Tanzania and ICS Task Force planned to evaluate existing ICS (local and imported) and develop household wood stove models that can be commercialized in rural and sub-urban areas of Tanzania. The Task Force intended to make use of the findings from the assessment for the development of an impact oriented, private-sector led, commercially viable, and sustainable ICS sub-sector in Tanzania.

[1] Finias Magesa. EAC Strategy to Scale-up Access to Modern Energy Services by, May 2008
[2] National Sample Census of Agriculture. Small Holder Agriculture. Vol II. 2012
[3] National Sample Census of Agriculture. Small Holder Agriculture. Vol II. 2012

1.4 Objectives, Scope, and Methods

The objectives of the assignment are:

- To collate R&D findings on ICS in Tanzania
- To assess current ICS technologies in Tanzania,
- To evaluate locally produced ICS
- To assess various feed stocks (alternative to wood and charcoal) suited for ICS.
- To test 4 domestic wood stove designs in the Lake Zone

Scope of the assignment is defined as follows;

- To collate R&D findings on ICS in Tanzania. The study to collate the available research and developments on ICS done to date in Tanzania,
- To review current ICS technologies in Tanzania and evaluate the technologies in order to recommend few ICS models which should be promoted for commercialization.
- Specifically compare Tanzanian ICS products with imported products. The study should compare the performances of local and imported ICS,
- Assess existing feed stocks suited for ICS and multi-purpose stoves. The study should examine cooking energy options (limited to biomass briquettes and pellets), their calorific values and energy conversation efficiencies of the feed stocks subject to the ICS and multipurpose stoves,
- Recommend R&D plan for ICS and potential feed stocks
- Undertake stove testing, data collection and recording of the results (for 4 stove models) in the Lake Zone (Mwanza) as per agreed testing standards/producers, in consultation with SNV, International Consultant (hired by SNV), TSAEE (local NGO based in Misungwi) and local stove producer in Misungwi
- Analyse and document the results gathered into a comprehensive report which provides recommendations on the choice of household stove(s) to be promoted in the Lake Zone,
- Present study findings to the stakeholders including the ICS Task Force.

Methods used to obtain data and information and for assessment of ICS includes: review of published reports and literature on previous interventions on ICS; interviews with key stakeholders in the ICS sector; Survey using structured questionnaires; stove testing on ICS models and tradition stoves; A Multiple Criteria Decision Analysis (MCDA) method in assessment of ICS for up-scaling; and feedback and information sharing from the Workshop on Cookstoves Standard held in Dar es Salaam on 17th – 18th, December 2012.

1.5 Limitations of the Assignment

Since 1980s there have been many projects on ICS on aspects which any new product intended for the market need to go through to be accepted. Many of these efforts and interventions are not documented and many more ICS models never reached the market. The key players in the interventions include Government and academic institutions, local and international organizations and NGOs, social communities, and private companies.

This assignment will only report findings and observations from:

- Tests and surveys which were conducted as parts this assignment
- Published and/or official documented information from other sources including public domain.

Furthermore, only ICS which were designed to use solid biomass fuels will be dealt with in the task to assess, evaluate and recommend ICS models for up-scaling.

2. PROMOTION, RESEARCH, AND DEVELOPMENT ON ICS TECHNOLOGIES

Improved Cook Stove (ICS) technologies were introduced in Tanzania in early 1980s. Initially, the objective of the Government for introducing ICS programmes in the country was to mitigate deforestation[4] Later, the Government supported development, research and promotion of ICS technologies for mitigating deforestation, managing efficient use of biomass energy and improving the health of users by improving kitchen environment.

ICS technologies have a long run social-economic contribution to achieving sustainable development of the Nation in terms of environment conservation through efficient use of biomass energy resources; improvement of health to the majority of the people particularly women and children through reduced harmful emissions; and creation of employment and income generation opportunities through production, marketing and use of ICS, just to mention a few. Accumulations of these impacts will contribute in achieving broad objectives of the Tanzania Development Vision 2025 of having a population with high quality of life by 2025.

In this assignment, research, development and promotion of ICS in Tanzania are analyzed by looking in the following areas:

a) Enabling policy frameworks;
b) Institutional Framework on R&D Initiatives and Promotion on ICS in Tanzania;
c) Lessons learned from previous ICS in Tanzania;
d) Lessons learned from successful ICS projects
e) Financial mechanisms; and
f) Code of standards for ICS.

2.1 Enabling Policy Frameworks

Enabling policy frameworks include policies and acts that form the basis for implementing ICS programmes in the country. Government Policies are divided in 4 main categories including: Economic Sector Policies; Cross-cutting Sector Policies; Key Development Policies/Strategies; and Other Sector Policies. Compositions of policies in each category are shown in Appendix I.

ICS technologies convert solid biomass energy particularly charcoal and firewood efficiently into useful heat for cooking and productive use compared to tradition stoves. Biomass energy is consumed by the majority of the population in Tanzania to meet their basic energy needs particularly cooking and agro-processing activities. Government policies that involve energy issues in one way or another were selected to analyze Government strategies on Research, Development and Promotion of ICS. These include:

a) Economic Sector Policies;
- The National Energy Policy; and
- The National Investment Promotion Policy.

b) Key Development Policies/Strategies;
- National Strategy for Growth and Reduction of Poverty (NSGRP).

c) Cross-cutting Sector Policies:
- The National Science and Technology Policy for Tanzania; and
- National Environmental Policy.

[4] Boiling point issue no.29; Article by Tom Otiti on Household energy Development in Southern and East Africa.

d) *Other Sector Policies;*
- The National Research and Development Policy
- Policy on women and gender development in Tanzania

2.1.1 National Energy Policy (2003)

The National Energy Policy was prepared by the Ministry of Energy and Minerals in 2003. The policy overall objective is to ensure availability of reliable and affordable energy supplies and their use in a rational and sustainable manner in order to support national development goals**.** The policy statements in the sectors of Household; Commerce; Renewable Energy Technologies; Rural Energy; Energy Efficiency; Environment and Health; and Research and Development reflects Government support on promotion, research and development on ICS:

Key Policy Statements

a) *Household Sector:*
- Promotion of efficient end-use technologies and good household practices,
- Wider application of alternative sources of energy for cooking, heating, cooling, lighting and other applications,
- Safe utilization of household energy appliances through regulation of safety standards.

b) *Commerce Sector*
- Encourage efficient use of alternative energy sources.

c) *Renewable Energy Technology Sector:*
- Promotion of efficient biomass energy conversion technologies to save resources; reduce deforestation and minimize threats on climate change.

d) *Rural Energy Sector:*
- Application of alternative energy sources other than fuelwood and charcoal.
- Promotion of entrepreneurship and private initiative in the production and marketing of products and services for rural and renewable energy*.*

e) *Energy Efficiency and Conservation Sector:*
- Enhancement of Energy efficiency and conservation initiatives in all sectors

f) *Environment and Health Sector:*
- Promote development of alternative energy sources and end-use efficient technologies

g) *Research & Development Sector:*
- Supporting research and development in renewable energy technologies and rural energy.
- Promotion of Regional and International cooperation on research and development of energy forms and related innovative environmentally sound energy technologies.

Strategy Areas

The Energy Policy (2003) established strategic areas that can support promotion, research and development of ICs sector. These include:

a) *Market Forces:*
- In this area the strategy requires supply of energy products and services to be market-oriented.

b) *Regulatory Regime:*
- To ensure that the market functions without distortion, the strategy requires the establishment of a regulatory regime with varying regulatory mandates in the different energy sub-sectors that is anchored in legislation. The regulator for Energy and Water Utilities (EWURA) is already operational.

c) *National Interest versus Market Forces:*
- The strategy requires the Government to regulate or deregulate the market in order to protect the economically weaker communities and groups by applying transparent fiscal (taxes, duties, levies) and non-fiscal (fees, subsidies, concessional credits, guarantees) measures to direct market forces and, when necessary, correct market failures. Under this strategy Rural Energy Act was formulated in 2005 that resulted in the establishment of the Rural Energy Agency and Rural Energy Fund in 2005. Rural energy agency was operational since October 2007 to

facilitated access to modern energy services in rural areas where the majority are using biomass energy for cooking.

d) *Appropriate Technologies:*
- The strategy requires scaling up and commercializing some of the appropriate technologies already in place while continuing with research and ongoing pilot testing.

e) *Energy Conservation and Efficiency:*
- The strategy is putting high priority on Energy conservation and efficiency issues.

f) *Gender Issues:*
- The strategy emphasizes on putting incentives to encourage more active participation of women in energy issues at all levels from decision to utilization.

g) *Legal Interventions:*
- The strategy emphasizes the need of updating existing legislation and laws in order to put in place missing ones and replacing outdated ones that do not reflect recent developments.

2.1.2 National Investment Policy (1996)

In relation to ICS technologies, the National Investment Policy under President's Office Planning Commission (POPC) encourages investments in:
- The development of all possible commercial and alternative sources of energy with emphasize on utilizing domestic resources as well as reducing dependence on biomass fuels,
- Promoting adoption of energy systems which are efficient and not detrimental to the environment, and
- Promoting sub-regional and regional cooperation and collaboration in the energy sector.

2.1.3 National Strategy for Growth and Reduction of Poverty (NSGRP) (2005)

NSGRP under the Vice President's Office is a national organizing framework for putting the focus on poverty reduction high on the country's development agenda. The NSGRP builds on the Poverty Reduction Strategy Paper (PRSP), the Poverty Reduction Strategy Review (PRSR), the Medium Term Plan for Growth and Poverty Reduction and the Tanzania Mini-Plan Tiger 2020 that emphasizes the growth momentum to fast-track the targets of Tanzania Development Vision 2025.

The NSGRP strategies provide a great opportunity for ICS technologies to contribute in achieving broad outcomes of the NSGRP in clusters I and II. These strategies include:
- Preventing the negative impacts on the environment and peoples' livelihood,
- Promoting R&D and patenting proven technologies including support to R&D institutions,
- Providing reliable, affordable and efficient energy and alternative rural energy schemes,
- Developing and promoting utilization of indigenous energy resources and diversification of energy resources,

2.1.4 National Science and Technology Policy (1996)

The Policies and strategies in National Science and Technology Policy under the Ministry of Science, Technology and Higher Education (MSTHE) which encouraging research and development in the area of ICS include:
- Development of new and renewable energy sources,
- Developing and sustaining training and research institutions,
- Where possible industries should establish R &D units for development and improvement of their products and d link them with academia,
- Development of special talents,
- Dissemination and utilization of already available research findings,
- Reducing the drudgery of women and children through promotion of appropriated technologies that have been designed in consultation with women,

- Strengthening mechanisms for diffusion, extension and commercialization of technologies that are relevant to the needs of the people, especially in rural areas in order to reduce the chores of drudgeries of life

2.1.5 National Environmental Policy (1997)

Environment impact of actions in one sector is often felt in other sectors. In that regard, the National Environment Policy under Vice President's Office (VPO) internalizes environment considerations in other sector policies and programmes and coordinates them in order to achieve sustainable development.

The National Environment Policy encourages:

- Minimization of woodfuels consumption through the development of alternative energy sources and increasing woodfuels energy efficiency
- Promotion of sustainable renewable energy resources,
- Assessment and control of development and use of energy, and
- Energy efficiency and conservation,

2.1.6 Other Sector Policies

Other sector policies which address the energy sector include:

- The National Research and Development Policy
- Policy on women and gender development in Tanzania

2.1.7 Observations on policy frameworks

Observations on policy framework are:

- There is adequate coverage and emphasis on efficient and use of clean cooking technologies by encouraging R&D efforts and promotion of clean household energy options especially in the rural communities where biomass is the main source of energy.
- There is no emphasis on reducing Indoor Air Pollution (AIP) which is affecting many households that are using biomass energy for cooking.

2.2 Players, R&D and Promotion of ICS in Tanzania

2.2.1 Sector Players

Since introduction of ICS in Tanzania in 1980s, various players including International Organizations (such as WB, Sida, NORAD, SNV, etc); Government institutions (CAMARTEC, TIRDO, etc); community organizations (NGOs, CBOs, Individuals); private companies, have contributed either through funding in R&D, or promotion or dissemination of ICS programmes.

Government Institutions

Almost all programmes which have been introduced through the government have been implemented under different Ministries. The Ministry of Industry and Trade have ICS programmes at CAMARTEC, TBS, TIRDO, TEMDO and SIDO; other ICS programmes are under the Ministry of Energy and Minerals; Ministry of Natural Resources and Tourisms; Ministry of Community Development, Ministry of Science and Technology (COSTECH), Women and Gender; Prime Minister's Office, and under the Vice President's Office. ***Despite the many players under the Government, there is no clear coordination of biomass energy and ICS programmes in particular.***

Research Institutions

Research institutions such as TIRDO, and Universities which are involved in research and testing of ICS prototypes are under different Government ministries. TIRDO is under the Ministry of Industry and Trade while Universities are under the Ministry of Science, Technology and Higher Education. ***The scatter of institutions under different ministries lead to lack of linkage which is important for sharing research findings and resources such as expertise, testing equipment, etc. Furthermore, lack of human capacity, finance and equipment hinders research and operational activities of the institutions***.

NGOs, CBOs and Private Companies

Many NGOs, CBOs and private companies are actively involved in ICS programmes in the areas of development, manufacturing and promotion of ICS, and most of the efforts have been taken by individual organizations through the assistance of Government institutions and International donors. ***However, there is no popular coordinating mechanism to share information and experience to create an enabling environment for all stakeholders to contribute to policy influencing strategies to increase the market, reduce production costs, access to finance, and other aspects which will strengthen their ICS businesses***.

TAREA (Tanzania Renewable Energy Association), formerly known as TASEA (Tanzania Solar Energy Association), was founded in the year 2000 for the goal of bringing together actors in the renewable energy sectors to promote the accessibility and use of renewable energies in Tanzania. The initial focus of TAREA was solar energy, but of recent TAREA has been involved with promotion of other types of renewable energy, including biomass and it has been working with the rural communities in the promotion of renewable energy technologies through capacity building, technology awareness raising, energy policy advocacy and end user protection.

One of the recommendations at the East Africa Stakeholder Consultation and Strategic Planning Workshop organized by the Global Alliance for Clean Cookstoves (GACC) held in Nairobi in April 2012 is for countries to create coordinating mechanism or platform for ICS stakeholders. A result of which is the formation of an alliance, the Clean Cookstoves and Fuels Alliance of Tanzania (CCFAT). The mission of the alliance is to facilitate the increased innovation in design, production, marketing and use of clean cookstoves and fuel through better government policies, increased public awareness, micro-finance opportunities and capacity building through information sharing, training and campaigning. The objectives of CCFAT are:

- To strengthen partners' collective concerns on issues of clean cookstoves and fuels for the creation of appropriate policies, implementation strategies and regulatory frameworks
- To facilitate the transfer of local and global knowledge and skills on clean cookstoves and fuels to all stakeholders
- To enhance demand, strengthen supply and build an enabling environment for the clean cookstoves and fuels market.

To date, the Alliance is still not registered but it is in the final stages for registration in the Ministry of Home Affairs

2.2.2 R&D Initiatives and Promotion of ICS in Tanzania

All players mentioned in section 2.2.1 are involved with R&D and promotion in varying degrees. The important stages for ICS programme involve:

Development stage:	Designing work and in-house testing of prototypes to confirm on efficiency, cooking time, smoke emissions, stability, etc
Field testing stage:	Prototypes are tested in selected households which represents the target group to assess on acceptability of the stove

Promotion stage: The ICS model is promoted for mass dissemination.

Appendix II describes various ICS programmes which have been introduced and promoted in Tanzania showing indicative cost, advantages, disadvantages and development status. A previous study by GACC on Tanzania ICS sector mapping estimated the cost of various ICS technologies as shown in Figure 2.1

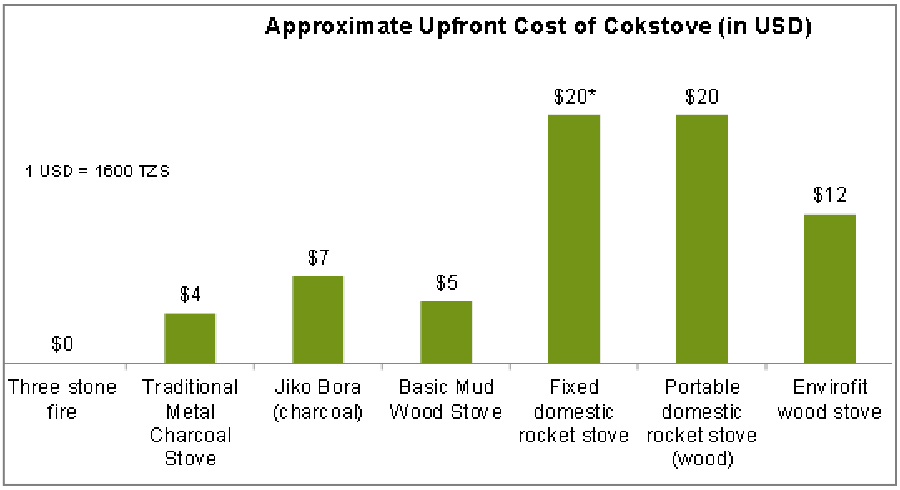

Figure 2.1 Costs of local and imported stoves in 2011[5].

2.2.3 Observations on Players, R&D and Promotion of ICS

The following are observations from players, R&D and promotion:

a) Despite the many players in the Government, there is no clear coordination and documentation mechanism or media which will enable all players to share information on what others are doing at the local and national levels. Each actor plans, implements, documents and disseminates information in-house, which creates possibilities of duplicating efforts and resources.
b) The scatter of research institutions under different ministries lead to lack of linkage which is important for sharing research findings and resources such as expertise, testing equipment, etc. Furthermore, lack of human capacity, finance and equipment hinders research and operational activities of the institutions.
c) There are many NGOs, CBOs, and other ICS stakeholders, but there is no coordinating mechanism to share information and experience to create an enabling environment for all stakeholders to contribute effectively to policy influencing strategies to increase awareness, ICS market, reduce costs, and other aspects to improve their ICS businesses. However, the formation of CCFAT, if succeeds, will create a platform to enhance information sharing unified voice to communicate with the Government.

2.3 Lessons from Past ICS Projects in Tanzania

Many lessons have been learned and documented on the failures and successes from previous efforts on ICS projects to replace tradition stoves. It has proved in many places that the traditional three-stone fire, is difficult to be replaced since the components to make it are readily available, no special skills or tools are required for its assembly, it can burn a wide variety of types and sizes of fuel, flexible to the pot size, stable, and it is free.

[5] GVEP International. Global Alliance for Clean Cookstove. Tanzania Market Assessment-Sector Mapping

With exception of ceramic-lined metal charcoal stove models, most of other introduced models have generally failed to penetrate the market to reach a critical mass production stage. Previous studies on the ICS sector in Tanzania have identified many reasons and/or challenges which are linked to the failures, among the reasons in Tanzania include:

- Low awareness and lack of knowledge to majority of targeted end-users on fuelwood saving from ICS. This is especially critical in families which still fetch fuelwood for cooking (free fuelwood)
- Low awareness and lack of sensitization on the effects of harmful emissions in the smoke to the cooks and babies
- High cost of ICS compared to tradition stoves
- Lack of business skills, promotion, marketing strategies, and chain actors in the ICS sector
- Lack of access to finance to establish proper stove production facilities
- High material and production costs which lead to high product cost
- Mismatch or inappropriate stove designs which does not fit cooks preferences and culture.

Other challenges and/or reasons reported in the SNV/Round Table Africa Desk Study[6] include the following:

- Lack of clear-cut integrated policy from the government that provides incentives for the commercialization of the ICS sector specifically
- Lack of large- and medium-scale stove makers and promoters
- Donor-dependence of existing organizations and NGOs which mainly operate on donor's program requirements.

The SNV/Round Table Africa Desk Study further recommended the following to be given priority by ICS stakeholders:

- Quality control, standardization and after sale service
- Identification of suitable stove designs and publication of their socio-economic and technical performances
- R&D for new technologies
- Production capacity and supplier relations
- Improving distribution networks
- Provision of market information and baseline data
- Household and market surveys
- Technical training programs and connection to vocational training institutes
- Business management training and coaching
- Micro credit, start-up facilities and other incentives for small entrepreneurs
- Establishing producer organizations
- Monitoring and researching market developments (charcoal sector, carbon finance)

2.4 Lessons from Successes in Commercialization of ICS

Important lessons can be learned from successful programmes within the country and in other countries with similar demographics to Tanzania. Good examples of successful ICS projects include those of *Kenya Ceramic Jiko or Jiko Bora* in Tanzania, and Sri Lanka's successful commercialization of ICS, particularly the *Anagi stove*.

2.4.1 Kenya Ceramic Jiko and Tanzania's Jiko Bora

The *Kenya Ceramic Jiko (KCJ),* which is made of metal casing and inner ceramic liner shown in Figure 2.2, is a modification of both Thai charcoal stove (Thai Bucket) and traditional metal charcoal stove used in Kenya and many other parts of Africa, including Tanzania. The KCJ experience offers an excellent example to other countries with similar demographics of a successful technology transfer venture, and

[6] Household Improved Cook Stove Sector in Tanzania. Desk Study. Joint SNV and Round Table Africa. February 2000.

unsurprisingly the Tanzania version of KCJ, *Jiko Bora*, is also the most successful ICS in the country especially in urban areas in terms of its acceptance and sells volumes.

Figure 2.2 Ceramic lined charcoal stove similar to KCJ and Jiko Bora

In the early 1986 Tanzania's Renewable Energy Development Project Unit under the Ministry of Energy and Minerals launched an initiative aimed at developing and disseminating more efficient cooking technologies. As a starting point, the project adopted the KCJ and modified it to suit the prevailing small-scale production technologies, trained local artisans and potters, whose end result was *Jiko Bora*. Since its inception more than 20 years ago, the market for *Jiko Bora* in the country still looks good, with sales projected at over 60,000 per year in Dar es Salaam region alone and well over half a million annually country-wide. Apart from Tanzania, the Kenya KCJ stove has now been successfully replicated or adopted in Uganda, Rwanda, Sudan, Malawi and Senegal.

Some of the characteristics of the *KCJ* and *Jiko Bora* which made the programmes to succeed include the following:

a) The KCJ was arrived at through a *series of training, research and development steps* which involved artisanal stove producers, potters, interested NGOs, research institutions, and Government Ministries.
b) *Utilization of the existing tradition cookstove production, marketing and retailing systems* to produce and market the new ICS product.
c) The ICS models are *not radical departures from the traditional stoves*, and in reality they are like upgrades from the traditional metal charcoal stove. As such, they are well adapted to the cooking patterns of charcoal stove users which are mainly suburban and urban households.
d) They use *materials that are locally available and can be produced locally* even in small towns.
e) Commercialization of the stove models *did not rely on subsidies and donor funds*.

The cost of the KCJ was initially high compared to the tradition metal charcoal stove when it was introduced in the 1980s. But involvement of private entrepreneurs contributed to competition between producers which reduced the cost of the KCJ significantly thus bringing the stove within the affordability range of most low-income households in Kenya. The expansion of KCJ was rapid, and by 1995, there were more than 200 businesses, artisans, and micro-enterprise or informal sector manufacturers producing over 13,000 KCJ each month, and in overall it was estimated that there were over 700,000 KCJ in use in Kenya, which was over 50% of all urban homes, and roughly 16% of rural homes[7].

The production of the KCJ stove is mainly done by local small scale entrepreneurs, with metal parts (tinsmiths) dominated by male small-scale enterprises, most of whom previously produced traditional

[7] *Walubengo, D. (1995) "Commercialization of improved stoves: The case of the Kenya Ceramic Jiko (KCJ)", in Stove Images: A Documentation of Improved and Traditional Stoves in Africa, Asia, and Latin America, Westhoff, B. and Germann, D. (eds.), (Commission of the European Communities: Brussels, Belgium).*

metal charcoal stoves, whilst the clay liners are often made by women groups, whose members are mainly potters[8]. The use of local artisan ensures local availability of the KCJ and together with the incomes derived from stove sales act as incentives for the producers to promote the stove.

Despite the successes, both KCJ and Jiko Bora entrepreneurs have experienced some operational drawbacks. The main problems include:

a) The need for **close cooperation of potters and tinsmiths** within the localities in terms of standard dimensions, and quality of ceramic liners.
b) Availability of **suitable clay** for making high quality ceramic liners.

2.4.2 Sri Lanka's Anagi Stove

In Sri Lanka, interest in ICS was initially sparked in early 1950s by Indian migrant tea plantations workers. However, the spread of ICS accelerated in 1970s when several ICS projects including the *Anagi* stove were initiated by the Sri Lanka Governmental and non-governmental organizations. The new initiatives were instrumental, as they provided continuous progress towards ICS commercialization by passing through all important steps of design, testing, development, promotion, dissemination, and commercialization of ICS products. Figure 2.3 illustrates the *Anagi* stove.

It is reported that an extensive commercial network was in place for the *Anagi* stove with 185 trained potters spreading over 14 districts. In 1991, about 3 million *Anagi* stoves were commercially produced and marketed throughout the country. Currently, the *Anagi* market is fully established with well established market chains to support it. In most set-ups distributors buy *Anagi* stoves in bulk from production centers and distribute them to retail shops which are spread throughout the country. In some cases small producers living in isolated areas sell their products direct within their village or in nearby towns without using whole sale distributors.


Figure 2.3 Anagi stove

Several studies have identified the following factors to play a major role in the commercialization of *Anagi* stove. Among the important factors for Tanzania ICS sector to learn include the following:

a) *Involvement of both governmental and non-governmental organizations*: The project's wide reach through the utilization of government district offices and a subsidization scheme raised crucial awareness of the ICS movement to donors, the private sector and users.
b) *Program continuity*: Despite the involvement of different organizations led by different objectives and strategies, each phase of development picked up from where the previous one was left without much duplication of effort.
c) *Exposure to international experience and networks*: Through collaboration with international organizations such as ITDG, the program benefited from funding and the international experience of its partners on successful commercialization of products.
d) *Large scale commercialization* of the Anagi stove ensured a constant supply of the product through the main marketing channels, making it a product that poor communities could aspire to obtain.

[8] http://wgbis.ces.iisc.ernet.in/energy/paper/softenergy/cookstove.html

e) *Support the emergence of larger scale producers* in villages and create links to wholesalers and retailer
f) *Strategies to reach the poor* were developed alongside the commercial network to provide credit, establish revolving funds and introduce stoves as an entry point to other health and social concerns.
g) *Flexibility of marketing strategies*: Application of modern marketing strategies while accommodating a variety of socio-economic, cultural, equity factors and aspirations of a traditional society.
h) *Increase quality of stoves from informal potters by delivering prepared clay* to the villages thus allowing small potters, which are mostly women, to work within their own village environment.
i) Unsuccessful attempts at dissemination of previous stove designs demonstrate that *technological performance alone is not sufficient to guarantee product success.*

2.5 Financial Mechanisms

As mentioned previously, financing of most R&D and promotion in ICS is facilitated by International development partners. However, most entrepreneurs and artisans who are involved in fabricating ICS are in the informal sector and very few have limited capital base and capacity to afford loans from Local financing systems which require collateral agreements. Other observations include:

a) Inadequate budget from the Government to research institutions for R&D in general.
b) Some private institutions who are interested in financing ICS technologies exist. These include Savings and Credit Cooperative Society (SACCOS), E+CO, AREED, Tujijenge Bank, and Tanzania Private Foundation Sector.
c) Establishment of Rural Energy Fund (REF) under Rural Energy Agency (REA) provides grants, capacity building, technical assistance and promotion for renewable energy technologies.
d) Most ICS entrepreneurs do not have sufficient training to meet carbon finance

2.6 Standards for Biomass Cookstoves

Tanzania Bureau of Standards (TBS) has developed a standard for only charcoal stove (TZS 473:2010) but there is no enforcement mechanism. Hence, in the interim, there is no mechanism in place to protect customers from sub-standard ICS in the market. The international stove community has recently started to address the issue of lack of internationally agreed standards for stoves. In the past two years there has been a series of meetings and forums to work on the standards for stoves, and so far the agreement is to rate the stoves in *efficiency, emissions,* and *safety* in tiers.

In a meeting convened in February 2011 in The Hague by the Global Alliance for Clean Cookstoves (GACC) and US EPA's Partnership for Clean Indoor Air, and chaired by the International Standardization Organization, more than 90 stakeholders from 23 countries reached a consensus on an International Workshop Agreement (IWA)[9] document. Tanzania was represented by TBS. The agreement represents a significant step in global efforts to scale up clean cookstoves and fuels as it provides guidance for rating cookstoves on fuel saving potential, emissions, and safety performance indicators.

The ISO-IWA provides a framework for rating cook stoves against tiers of performance indicators for: Fuel Use (Efficiency), Emissions (Carbon Monoxide and Particulate Matter 2.5), Indoor Emissions (Carbon Monoxide and Particulate Matter 2.5), and Safety. The proposed tiers (or scale) for performance indicators are:

- Tier-0: No improvement over baseline (tradition stove)
- Tier-1: Measurable improvement over baseline
- Tier-2: Substantial improvement over baseline
- Tier-3: Currently achievable technology for biomass stoves

[9] http://www.pciaonline.org/proceedings/iso-international-workshop-clean-and-efficient-cookstoves

- Tier-4: Stretch goals for targeting ambitious health and environmental outcomes

Future standards to be developed by ISO-IWA will also include:

- Climate impact: What effect will the stove have on the local and global environment?
- Durability: How long will the stove going to last under normal use
- Field testing: How will the stove perform in the field

Figure 2.4 illustrates the stove performance indicator's tier levels[10].

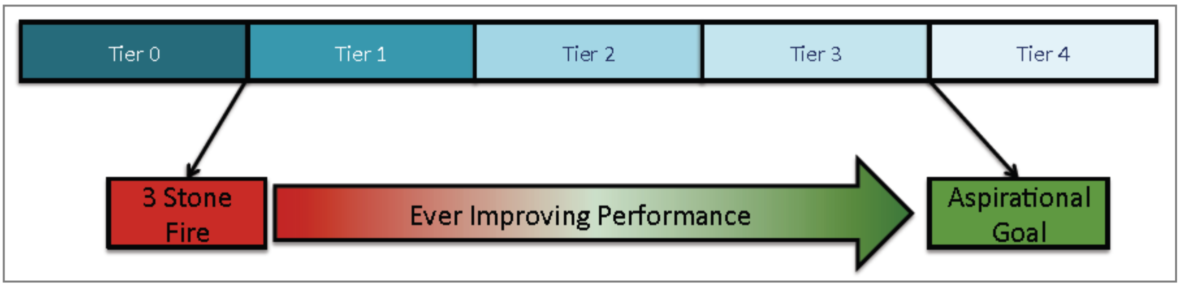

Figure 2.4 Stove performance tier levels

2.7 Concluding Remarks

The following are observations from research, development and promotion of ICS:

a) Sector policies reveals adequate coverage and emphasis on efficient and use of clean cooking technologies by encouraging R&D efforts and promotion of clean cooking options especially in the rural communities where biomass is the main source of energy.
b) Lack of emphasis in sector policies on reducing Indoor Air Pollution (AIP) which is affecting many households that are using biomass energy for cooking.
c) Despite the many players in the Government, there is no clear coordination and documentation mechanism or media which will enable all players to share information on what others are doing at the local and national levels. Each actor plans, implements, documents and disseminates information in-house, which creates possibilities of duplicating efforts and resources.
d) Lack of linkage between research institutions due to their locations under different Ministries leading to lack of coordination which is important for sharing research findings and resources such as expertise, equipment, etc. Furthermore, lack of human capacity, finance and equipment hinders research and operational activities.
e) There are many NGOs, CBOs, and other ICS stakeholders, but there is no coordinating mechanism to share information and experience to create an enabling environment for all stakeholders to contribute effectively to policy influencing strategies to increase awareness, ICS market, reduce costs, and other aspects to improve their ICS businesses.
f) Inadequate budget from the Government to research institutions for R&D in general.
g) Some private institutions who are interested in financing ICS technologies exist. These include Savings and Credit Cooperative Society (SACCOS), E+CO, AREED, Tujijenge Bank, and Tanzania Private Foundation Sector.
h) Establishment of Rural Energy Fund (REF) under Rural Energy Agency (REA) provides grants, capacity building, technical assistance and promotion for renewable energy technologies.
i) Most ICS entrepreneurs do not have sufficient training to meet carbon finance requirements
j) In the interim, there is no standard and mechanism in place to protect customers from sub-standard ICS in the market. The international stove community has recently started to address the issue of lack of internationally agreed standards for stoves.
k) Review of successful ICS programmes reveals that:

[10] The Partnership for Clean Indoor Air and the Global Alliance for Clean Cookstoves. ISO International Workshop Agreement Guidance for Clean Cookstoves. 2011

- Research and development and training to artisans and consumers are important steps in ICS programmes.
- Involvement of Government and non-government institutions from national to village levels is essential for raising awareness to achieve wider markets for ICS.

It is recommended that TAREA and CCFAT be supported to take leading roles as official platforms to represent the interest of actors in the ICS sector including users.

3. TESTING OF ICS MODELS IN THE LAKE ZONE

3.1 Introduction

Controlled Cooking Test (CCT) and Timed Fuel Consumption Test (TFCT) were conducted in Mwanza for three household stove models and ceramic-lined charcoal ICS proposed to be introduced to food vendors in Mwanza. The tradition stoves used for comparisons were 3-stone fire for households and tradition rectangular metal charcoal stove commonly used by food vendors.

The objectives of CCT for domestic stoves (*Matawi)* are:

- To compare the specific fuel consumption of three matawi stove models.
- Compare the cooking times of the three models.
- Inquire and observe to see whether the cooks are comfortable using the models and whether they like how the stove cooks the chosen meal.

The objective of TFCT for food vendor stove was to compare the rate of charcoal consumption of ceramic-lined charcoal ICS with the tradition metal charcoal stove which is commonly used by food vendors.

Description of Household Stoves for CCT

The three clay stove models (*Matawi*) for household are all single-pot stoves with no chimney. Two of the models are fixed versions built into a mud surround inside the kitchen. Both versions (*Matawi-I* and *Matawi-Y)* have a narrow bottom which is specifically designed to conserve fuelwood by limiting the combustion chamber space, however, the narrow bottom makes the portable version to look unstable. All three Matawi models are hand-made but they differ slightly in combustion chamber and fuel door dimensions. The stoves are designed to use fuelwood, but they can also use large-particle agricultural wastes and cow dung.

The built-in versions are heavily insulated which can increase their efficiency when used to cook meals which takes a long time to get cooked. The weight of the inserts used in the fixed stoves range between 4.5 – 5.5 kg. The portable stove used for the test weighs 5.66 kg. Figure 3.1 shows the photos of stove models used in the CCT.

Matawi-I *Matawi-Y* *Matawi-Portable* *Three-stone fire*

Figure 3.1 Matawi stove models and three-stone fire used for CCT

Description of Food Vendor Stoves for TFCT

The charcoal ICS for a food vendor which was tested comprised of three medium sized (20 – 23 cm diameter) ceramic-lined charcoal stoves assembled in a common frame as shown in Figure 3.2. Each stove has its own removable ash drawer at the bottom which also acts as air control to the respective stove. The tradition charcoal stove for food vendor has a firebox which rectangular tradition metal charcoal stove which was used for comparison for the vendor measures 89 cm (length), 25 cm (width), and 8 cm (deep).

 

Figure 3.2 Photos of tradition charcoal stoves (R) and ICS (L) used by food vendors

3.2 Controlled Cooking Test (CCT)

The controlled cooking test (CCT) is one of three standardized cookstove testing protocols commonly used to evaluate and compare introduced cooking technologies. CCT is designed to assess the performance of the improved stove relative to the common or traditional stoves that the improved model is meant to replace. Stoves are compared as they perform a standard cooking task which is closer to the actual cooking. However, the tests are designed in a way that minimizes the influence of other factors related to kitchen management and the environment and allows for the test conditions to be reproduced. The 3-stone stove was used as a tradition stove and a baseline for comparing the performance of the three ICS.

The CCT yields two main quantitative outputs:

- the amount of fuel used per unit weight of meal(s) cooked (or specific fuel consumption)
- and the time required to complete the task of cooking the meal(s) (or cooking time)

SNV selected CCT as the evaluation tool to compare the three designs of fired clay stoves (*Matawi)* which are being developed in the lake zone. However, irrespective of the CCT results, the evaluation of how well the households might accept the ICS stoves had to be measured separately with appropriate indicators related to user acceptability. The CCT conducted in Mwanza followed the established CCT Version 2.0 (2004) which was prepared by Rob Bailis for the Household Energy and Health Programme, Shell Foundation[11].

Kitchen Arrangement for CCT

The two fixed ceramic stoves, Matawi-I and Matawi-Y have been built adjacent to each other in the same kitchen. To minimize errors caused by environment conditions (wind and ambient temperature) it was decided that the experiments for the other two stoves (portable Matawi and 3-stone) also be conducted inside the same kitchen as there was enough space to accommodate one more stove.

Cooks and CCT Sample

The selection of the three local cooks was done by SNV-Mwanza and the local stove maker who was also one of the cooks. For statistical confidence to be established a minimum of 36 cooking runs were proposed to be conducted. In brief, each cook will cook 3 replications in all 4 stoves (3 Matawi models and 3-stone fire).

[11] http://www.pciaonline.org/node/1050

Selection of Food for the CCT

The CCT can be conducted with one type of food or a combination of foods if more extensive testing seems important. For Mwanza CCT it was decided to select only one type of food due to a large number of tests required to achieve significant confidence on the results.

The most common foods in Misungwi and Mwanza in general are *ugali*, rice, beans, fish, and potatoes. Rice was selected to be the food for the CCT because, unlike ugali, pot lid is used during cooking and also it is easy to define the "cooked point" or "doneness" of rice compared to ugali. On the other hand, beans also have a clearly defined cooked point - but it takes too long for the beans to be cooked which will take a long time to complete the minimum required tests.

Supplies and Ingredients used for the CCT

The types of fuelwood normally used in the village were used for the CCT. The fuelwood collected for the CCT were enough to test all stoves for the duration of the tests. A sample of fuelwood used is shown in the photo in Figure 3.3. Adequate rice and other ingredients for the CCT were purchased in the local market a day before the tests. Other items which were used for the CCT include:

- Cooking pots: 2 pots of the same type, dimensions and materials for cooking rice.
- Assorted pots for weighing water, dry rice, and washing and decanting the rice
- Lids for covering the pots during cooking.
- Digital scale (15 kg capacity and 2 gram accuracy).
- Stop watch
- Small shovel/spatula to remove charcoal from stove.
- Flat metal tray to hold fuelwood for weighing.

Figure.3.4 shows some of the equipment and materials used for the tests.

Figure 3.3 Fuelwood used during CCT

Figure 3.4 Equipment used for CCT

Cooking Procedure

Before the tests the cooks agreed on the common preparations and cooking procedure for rice which had to be closely followed by all cooks during the tests. This is important to ensure the cooking task is performed similarly on each stove by all cooks. The tradition cooking practice for rice in *Sukuma*, and many other parts of Tanzania include baking the rice after it has reached the "cooked point" by leaving small amount of glowing charcoal in the stove and spread evenly the rest of glowing charcoal on the pot lid until the time to serve the food. It was agreed that the end of the test (cooked point) should be when the rice is soft and before the baking process begins. This is also because during baking the cook does not attend the stove or the charcoal on top of the lid, or the cooked food, until the time to serve the food.

Table 3.1 shows the quantities of ingredients used for cooking rice. The preparation and procedure for cooking rice for CCT involved the following activities, in that order:

- Sorting and winnowing the rice to remove small stones, foreign matters and light chaffs
- Weighing 1000 g of cleaned rice
- Washing the rice to remove small sand particles, and decanting the water.
- Boiling a measured amount of water (1500 g) in the cooking pot and start boiling (lid on)
- Adding measured amounts of salt and oil
- Stir the mixture gently until boiling resumes
- Add measure amount of washed rice in the boiling mixture of water, salt and oil
- Stir gently to avoid rice sticking and agglomerating at the bottom - until the mixture starts to boil again
- Simmering with lid on
- Turning the rice periodically during simmering. (lid replaced after each stir)
- Adding water if the cook feels the water will dry before the rice is cooked (option)
- Stop when the rice gets soft and the water has dried up (cooked)
- Record the cooking time and weigh the cooked rice

After finishing the CCT run the cook proceed with baking the rice.

Table 3.1 Quantities of ingredients used during CCT

INGREDIENTS USED FOR CCT		
1	Dry rice	1000 g
2	Water	1500 g
3	Salt	10 g
4	Oil	20 – 30 mls

3.3 Timed Fuel Consumption Test (TFCT)

Observations on the operation of charcoal stoves used by most food vendors preparing *chips-mayai* (chips-eggs pancake) revealed the following information:

- Potato chips are prepared and fried in bulk in a separate stove commonly located somewhere at the back. The fried chips are then stored in a glass display to wait for *chips-mayai* orders from customers.
- When an order is placed a portion of chips is put on a frying pan and beaten eggs are sprayed to make an agglomerated mix of chips and eggs called *chips-mayai*.
- The rectangular tradition stove can accommodate up to three frying pans by spreading the glowing charcoal along the length of the rectangular stove, or up to two frying pans and leave a space to roast *mishikaki*.
- Once ignited when the business starts, the rectangular stove is not extinguished until closing time, some 8 hours later. Occasionally, the cook adds fresh charcoal to put the fire alive and in the "ready state" to enable quick service to unpredictable customers.
- When there are no orders, the glowing charcoal is accumulated on one side of the rectangular box to form a pile to conserve charcoal (by limiting the air to the charcoal hence reduce its burn rate)
- The quantities of potatoes and meat for *mishikaki* bought for the day's business is the same in every normal day.
- In a normal day, the stove is ignited in the afternoon and business ends near midnight or when the chips are finished (whichever comes first), however, the busy hours are from 6 pm to 9 pm, and the rest of the time there are no many customers but the stove is kept alive waiting for customers.

From the above observation it was therefore not appropriate to test the vendor's stove using standardized test procedures such as CCT or KPT because most of the time the stove is idle but burning the charcoal away. It was also not practical to give instructions to the vendor to record on the number of the orders served because he buys the same amount of ingredients each day. From the observations on the conduction of the business and the continuous operation of the stove it was decided to conduct a Timed Fuel Consumption Test (TFTC) of the tradition vendor stove and the multi-pot charcoal ICS proposed for the vendors.

Procedure for TFCT

After learning on the activity schedule of the vendor, the tests were planned accordingly and only one stove was tested per day where the following were recorded:

- The times the vendor stove was ignited to start business and business closing time
- The weight of charcoal in the container before business starts and after the business is closed

There was no need to weigh the amount of potatoes and meat because the vendor buys the same amount every normal day, which was 20 kg of potatoes and 1 kg of meat, which gives 45 plates of *chips-mayai* plates and 50 *mishikakis*, respectively.

3.4 CCT Results for Matawi Models

Controlled Cooking Test measures the amount of fuel (gm) or energy (KJ) transferred to the pot to cook 1 kg of food (specific fuel consumption or specific energy consumption), and the time taken to cook the food. The specific fuel consumption (SCF) is calculated from the following relationships[12]:

[12] http://www.pciaonline.org/node/1050

$$SC_F = \frac{f_d}{W_f} * 1000$$

Where f_d is the mass in kilograms of equivalent dry fuel used; W_f is the mass of food cooked. A factor of 1000 in SCF is used to convert kilograms of fuel to grams. Cooking time (□t), is the duration from when the stove is ignited until when the food is cooked.

3.4.1 Percentage Improvement on Fuel Consumption

The data obtained were analyzed using Shell Foundation HEH CCT Calculation Software Version 2.0. The summary of results showing all stoves and cooks are presented in Appendix III. Results reveals that with exception of one cook (Shigela) in Matawi-I stove, all ICS revealed significant confidences (over 95%) on the differences on specific fuel consumption with 3-stone fire for all other combinations of cooks and stoves. ***The most efficient ICS stove is Matawi-Y, followed by Matawi-Portable, Matawi-I, and the least efficient is the 3-stone fire*** as shown in Table 3.2. ***The percentages improvements of the ICS over 3-stone fire are 46%, 45%, and 26%, for Matawi-Y, Matawi-Portable, and Matawi-I, respectively***. Complete Tables of results for each cook are in Appendix-III.

3.4.2 Percentage Improvement on Cooking Time

With exception of Anasteria - Matawi-Y stove combination, ***the cooking times of all other combinations are comparable to the 3-stone fire, i.e all tests failed the 95% confidence test on the difference with 3-stone fire.***

Table 3.2 Summary of CCT Results

Stove Type	Parameter	Cooks			Mean
		Mwajuma	Anasteria	Shigella	(all cooks)
3-Stone	Specific Fuel Consumption (g/kg)	239	193	165	**199**
	Cooking time (min), □t	25	27	22	**24.6**
Matawi-I	Specific Fuel Consumption (g/kg)	151	123	165	**146**
	%-difference with 3-stone	37%	36%	4%	**26%**
	95% Confidence for SC_F	YES	YES	**NO**	
	Cooking time (min), □t	29	27	22	**26**
	%-difference with 3-stone	-14%	-1%	-7%	**7%**
	95% Confidence for □t	NO	NO	NO	
Matawi-Y	Specific Fuel consumption (g/kg)	114	102	101	**106**
	%-difference with 3-stone	52%	47%	38%	**46%**
	95% Confidence for SC_F	YES	YES	YES	
	Cooking time (min), □t	28	19	24	**24**
	%-difference with 3-stone	-11%	27%	-4%	**4%**
	95% Confidence for □t	NO	**YES**	NO	
Matawi-Portable	Specific Fuel consumption (g/kg)	104	110	108	**107**
	%-difference with 3-stone	56%	43%	35%	**45%**
	95% Confidence for SC_F	YES	YES	YES	
	Cooking time (min), □t	23	26	28	**26**
	%-difference with 3-stone	10%	2%	-25%	**-4%**
	95% Confidence for □t	NO	NO	NO	

Table 3.3 Ranking of stoves based on cooking efficiency from CCT results

STOVES RANKING	MOST EFFICIENT	
	g/kg	% Difference to 3-Stones
1	**Matawi–Y (105.6)**	**46%**
2	Matawi-Portable (107.3)	45%
3	Matawi–I (146.3)	26%
4	3-Stone fire (199)	NA

3.5 Observations from the CCT

Cooks

The CCT was conducted in Ms Shigela's kitchen who was also among the cooks for the tests, and in addition she is the fabricator of the *Matawi* stoves. The other cooks were selected by SNV-Mwanza in collaboration with Ms. Shigela to participate in the test. It was evident that Ms. Shigela was more familiar with the Matawi stoves compared to the other cooks especially on starting and managing the fire during cooking. Despite her expertise, data on specific fuel consumption showed very little difference between her and Ms. Anasteria as shown in Table 3.4.

Table 3.4 Ranking of cooks on cooking efficiency

RANK OF COOKS	SPECIFIC FUEL CONSUMPTION (g/kg)				OVERALL
	Matawi-I	Matawi-Y	Matawi-Portable	3-stones	
1	Anasteria (123)	Shigela (101)	Mwajuma (104)	Shigela (165)	Anasteria (132)
2	Mwajuma (151)	Anasteria (102)	Shigela (108)	Anasteria (193)	Shigela (133)
3	Shigela (165)	Mwajuma (114)	Anasteria (110)	Mwajuma (239)	Mwajuma (152)

The decision of using Ms. Shigela kitchen for CCT may have an influence in her results because she was not concentrating as the other cooks during the tests, and was frequently moving in and out of the kitchen attending other household chores. This observation is supported by the standard deviations of specific fuel consumption of the cooks shown in Figure 3.5 which puts Ms. Anasteria as the most consistent of the three cooks, whereas Ms. Shigela has a big standard deviation in Matawi-I stove. This might be due to her inconsistence in tending the fire during cooking, adding water to the food, and turning the food on time.

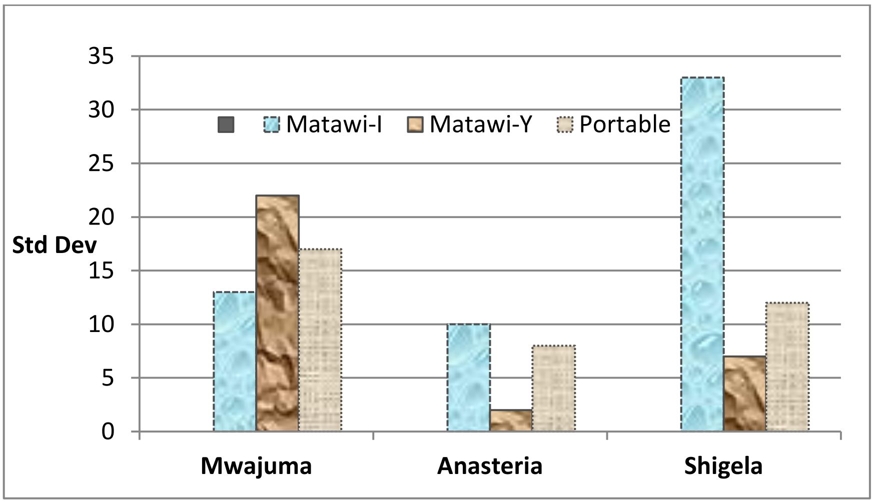

Figure 3.5 Consistency of cooks during CCT – Specific Fuel Consumption data

Stoves

All cooks selected *Matawi-Y* as the best ICS of the three models. The reason cited is that it has "better and consistent fire" throughout the cooking process. Other observations made during the tests include the following:

- The portable ICS is not stable enough. This was evident during cooking as the cooks puts the pot on the floor during turning of the rice as shown in Figure 3.6. This practice was also observed in 3-stone fire and less frequently in built in Matawi stoves.
- Long fuelwood sticks are also not safe for the portable Matawi stove as they can easily topple the stove or spill the food when someone trips or steps on the long fuelwood sticks.
- On the other hand, short fuelwood sticks tends to lift up towards the pot inside the *Matawi* portable stove combustion chamber. The reason which caused the short sticks to lift is the height of the combustion chamber bottom above the kitchen floor. The built-in *Matawi* stoves do not have this problem because the floor of chamber bottom is on the same level to the kitchen floor, whereas the difference is about 3–4 cm above the kitchen floor for the portable version. During the tests it was noted that the two cooks were struggling to arrange the short fuelwood

sticks in the portable stove before Ms. Shigela showed them how she normally do for short sticks in the portable stove, as shown in Figure 3.7.

Figure 3.6 Putting the pot down to turn the rice

Figure 3.7 Raising the fuelwood ends to position the front ends

3.6 TFCT Results from Charcoal Stoves for Food Vendors

Results from the few tests conducted for charcoal stoves used by food vendors suggests a 40% saving on charcoal ICS when compared to the tradition metal charcoal stove as shown in Table 3.5. A follow-up on the vendor by SNV staff in Mwanza revealed that the food vendor has abandoned the tradition stove and he is currently using the charcoal ICS. According to the SNV staff, the vendor realized up to 60% savings in terms of money spent on charcoal compared to when he use the tradition metal stove.

Table 3.5 Results for TFCT for charcoal ICS and tradition food vendor's stoves

	ICS (charcoal)	**Tradition**
Average charcoal consumption rate (kg/hr)	0.535	0.881
%-difference from tradition stove	40.10%	NA

3.7 Concluding Remarks and Recommendation

The following can be concluded from the tests conducted in Mwanza:

- ***The most efficient ICS stove is Matawi-Y, followed by Matawi-Portable and Matawi-I, in that order***. The 3-stone fire is clearly the least efficient of the stoves tested. ***The percentages improvements of the Matawi ICS over 3-stone fire are 46%, 45%, and 26%, for Matawi-Y, Matawi-Portable, and Matawi-I, respectively***.
- ***The Matawi-Portable stove is not an appropriate "first choice" stove*** in households using fuelwood for cooking, as is not safe and is difficult to operate.
- ***Overall the Matawi-Y stove is the best stove among the stoves tested in Mwanza***
- All *Matawi* stoves have comparable cooking times with 3-stone fire
- The ceramic-lined multi-pot charcoal ICS showed 40% saving on charcoal compared to the tradition charcoal stoves used by food vendors.

More tests are recommended for charcoal ICS for food vendors to confirm the potential saving from the tradition vendor stove and its durability. The test should cover at least 3 food vendors and should last for at least one week to cover both "normal" and "abnormal" days.

4. SURVEY OF IMPORTED ICS

4.1 Introduction

Development of carbon markets for ICS has attracted foreign companies to link with local NGOs and stove manufacturers and distributors to generate carbon revenues through sales of ICS. *Envirofit stove* and *StoveTec* are the two imported stoves which have entered the local market through carbon credits hence they are sold at subsidized prices. The Envirofit stove has been distributed by "Energy Through Enterprises", a non-profit organization based in the USA, in collaboration with local companies L's Solution based in Arusha and Zara Solar based in Mwanza. However, the later has withdrawn the sales in 2011 because of logistical problems which caused inconveniences to the company and very small profit margins.

The Envirofit stove is manufactured in China and India and was designed by Envirofit International in close cooperation with Oakridge National Research Laboratory in Tennessee, USA, Colorado State University's Engines and Energy Conversion Laboratory, and the Shell Foundation. The stove has powder coated sheet metal, cast iron cooking top and stainless steel combustion chamber with ceramic inserts and detachable inner and outer fuel grates. The StoveTec stove is a metal rocket stove designed by Aprovecho Research Center (USA), and manufactured in China. The combustion chamber of StoveTec is made of insulating refractory ceramic encased in steel, and has a removable and adjustable pot skirt available in a range of sizes, and some with two fuelwood doors. Figure 4.1 shows the photos of Envirofit and StoveTec imported ICS.

Both imported stoves are claimed to save fuel and reduce emissions compared to tradition stoves[13,14]. A field study[15,16] conducted in Mbolla village in Tabora region in 2010 on three-stone fire, Envirofit and StoveTec stoves rated StoveTec highest in saving fuelwood, followed by Envirofit, and lastly three-stone fire. Both imported stoves cook the food fast compared to the three-stone fire. However, some respondents cited that imported stoves are not suitable to cook foods which require heavy stirring such as *ugali.* Furthermore, imported stoves require more tending of the fuel, and also they are too small for some families. However, nearly half of respondents reported no complaints.

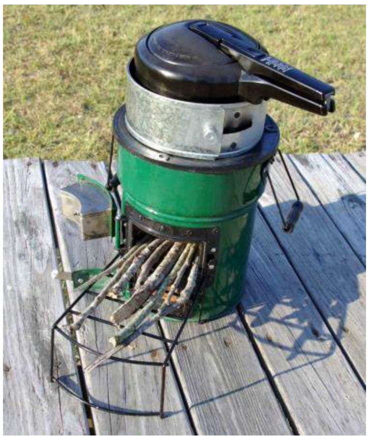

Figure 4.1 Envirofit (L) and StoveTec (R) imported ICS

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[13] www.stovetec.net
[14] www.envirofit.org
[15] Adkins, et. al. Field testing and survey evaluation of household biomass cookstoves in rural sub-Saharan Africa. Energy for Sustainable Development. 2010.

4.2 Survey of Imported ICS Users

In November 2012 a survey of Envirofit stove users was conducted in the households as one of the task in this study. The households selected were located in Arusha suburban villages of *Themi, Mambala, Maji ya Chai, Kikwakwaru, Patandi, Embaseni* and *Njiro* villages. The objectives of the survey were to assess the problems and acceptance of imported stove in local cooking practices. The surveyed villages are typical of Tanzania's sub-urban villages where multi-stove and multi-fuel use is common mainly for the purpose of enhancing energy security in the event of supply shortages.

All households surveyed have more than one type of stove. The highest number of stoves is four (20% of the households), 47% have three other stoves, and 33% have two other types of stoves. The dominant stove types are kerosene, charcoal, and LPG as shown in Figure 4.2.

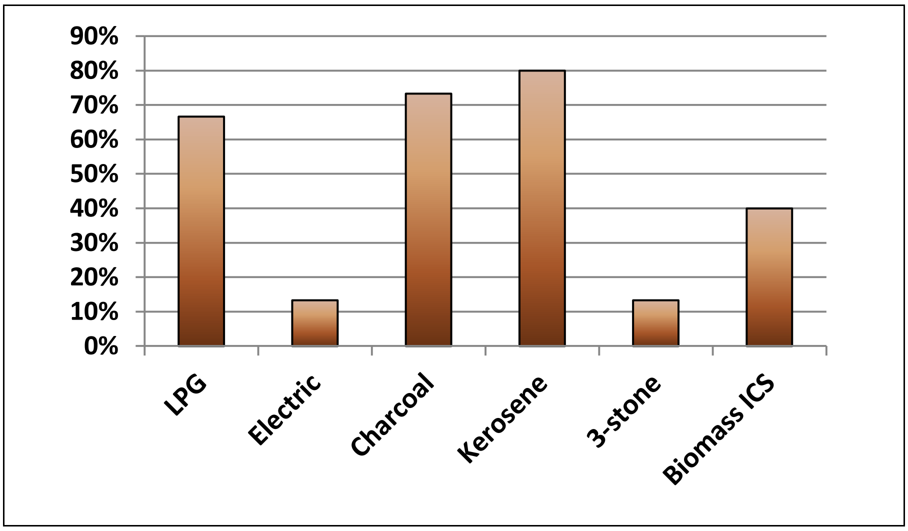


Figure 4.2 Percentages of other stoves used in the households with Envirofit stove

During the survey the Envirofit stove was checked to see if it is used frequently, and the cooks were asked on the following questions on the operation of the Envirofit stove:

- the time family has been using the Envirofit stove (months or years)
- whether it is easier or more difficult to cook with the Envirofit stove, and to give reasons.
- what the cook like most about the Envirofit stove
- and if there is anything that the cook would like it to be changed in the design

Furthermore, the cooks were requested to reply either YES or No to the following common problems associated with ICS:

- if the Envirofit stove is hot to the touch and can cause burns
- If the pots are not stable during cooking
- If the fire turns the pots black (soot)
- If the Envirofit stove makes smoke during cooking
- If the Envirofit stove is hard to start
- If it is difficult to cook certain foods with Envirofit stove, and to mention the foods
- If the Envirofit stove is too small for the size of pots or the family
- Any other problems not mentioned above when using Envirofit stove

Table 4.1 summarizes responses from the questions above.

Table 4.1 Summary of responses from the survey of Envirofit stove users

Question	Results	Remarks
Does the Envirofit stove appear as if it is used frequently	73% Yes 27% No	*(Observation –this question was not asked to the cooks)*
Is it easier or more difficult to cook with the Envirofit stove? Reasons?	87% Easier 13% Difficult	*<u>Reasons easier</u>* *-cook fast* *-easy to manage fire* *-portable* *<u>Reasons difficult</u>* *-stove needs dry fuelwood* *-stove needs small fuelwood* *-smoke (most HH cooks inside)*
What does the cook like about the Envirofit stove?	67% Cook fast 53% Save fuel 6% Less smoke	
Is there anything that needs to be improved on Envirofit stove?	6% Have chimney 20% Fuelwood grates 20% Reduce smoke 20% Be multi-pot 6% Handles 6% Increase size 13% Instructions to use 27% Nothing	
Indicate Yes or No as appropriate:		
The stove is hot to the touch and can cause burns	40% Yes 60% No	
The pots are not stable	0% yes 100% No	
Fire turns the pots black	100% Yes 0% No	
The stove makes smoke	73% Yes 27% No	
Stove is hard to start	13% Yes 87% No	*With fuelwood which is not dry enough*
Difficult to cook certain foods (list the foods)	73% Yes 27% No	*-Chapati (stove too hot)* *-Rice (stove does not make enough charcoal for baking rice)*
Stove is too small	40% Yes 60% No	
Other problems:	-Does not make charcoal -Fuel has to be dry -Cannot be used indoors	

4.3 Concluding Remarks

The general characteristics of imported ICS and Envirofit stove in particular can be summarized as follows:

- Metal fabrication with ceramic inserts at combustion chamber
- Portable and lightweight
- Good appearance with good quality finish
- Use small fuelwood size
- Does not work well with wet fuelwood
- Not easy to repair
- Need more attention (to tend fire) because it uses small fuelwood which burns-off quickly
- Has small combustion chamber
- Not suitable for bigger pots
- Not suitable for foods which require heavy stirring such as *ugali*

The result of the survey in sub-urban Arusha suggests strongly that cooks prefer stoves which cook fast and also save fuel. The unfavourable aspects of the stove include smoke and the fact that the Envirofit stove works well with only certain sizes of fuelwood which has also to be dry. This implies that the cook have to prepare the fuelwood into smaller sizes and make sure that the fuelwood is dry. Another noted aspect is from the recommendations by some of the respondents that the size of the Envirofit stove (G-3300) is small. This recommendation is undoubtedly given by households with big families and use bigger pots for cooking. It is also important to note that the cooks like multi-pot stoves. Typically, the cook needs more than one fire to prepare a meal which normally consists of starch and protein or vegetables. Hence, a multi-pot stove is more practical than to use two stoves to prepare a meal.

All respondents said that the Envirofit stove deposits soot at the pots and 73% reports smoke emission from the stove which makes it not suitable for using indoors like charcoal, kerosene, and LPG stoves. Three-quarters of the respondents mentioned rice and chapati (pancakes) to be difficult to cook with the Envirofit stove. "Fire too strong" was the reason cited for chapati, which suggests that the stove gets too hot and is difficult or not convenient to reduce heat. This might be the case for a well insulated combustion chamber like the one fitted in the Envirofit stove.

Inability of the fuelwood to make charcoal in the Envirofit stove was the reason for some respondent not to prefer Envirofit stove for cooking rice. It has to be noted here that it is customary in many parts of the country to bake the rice by putting glowing charcoal at the pot lid when the rice gets cooked. The reasons for the fuelwood to burn in this mode in the Envirofit stove can be due to any or all of the following reasons:

- the small size of the fuelwood used
- the provision of a grate in the combustion chamber which allows more air to pass under the burning fuelwood which simultaneously consumes the formed charcoal during flaming combustion
- high temperature achieved in the well insulated chamber of Envirofit stove which accelerates charcoal oxidation during flaming combustion

The surveyed villages are typical of Tanzania's sub-urban villages where multi-stove and multi-fuel use is common mainly for the purpose of enhancing energy security in the event of supply shortages. Another study on multiple stove use conducted in Siha, Kilimanjaro region in 2011, which is also a sub-urban area, recorded 81% of households with more than one type of stove[17]

Other reasons of equal importance for households to keep multiple stoves and fuels include:

- preference of type of stove with certain food (e.g. charcoal stove is preferred for cooking beans because it takes long time to cook and charcoal stove require minimum tending)
- some meals require two fires to be prepared effectively
- most cooks prefer to cook two or more foods simultaneously to save time
- for cooking large meals when there are guests, or a function (normally 3-stone fire because it is flexible with pot size)

[17] Grimsby, L.K; Rajabu, H.M; and Treiber, M. Multiple Stoves and Fuels – A Subtle Approach. 2013

- when cooking a quick meal or boiling water for a sick person or a baby at night (normally kerosene stove or LPG because they are quick to start)
- early in the morning or when the cook is very busy with other activities (Kerosene, LPG)

From the observations on multi-stove and multi-fuel practices, it suggests that rather than targeting to substitute existing cooking options completely, the best approach is to treat dissemination of new stove (ICS) as an addition in the household stoves portfolio.

5. EMERGENCE OF GASIFICATION STOVES IN TANZANIA

5.1 Principles of Biomass Gasification Stoves

When fuelwood or biomass is ignited the biomass starts to pyrolyze and give out combustible gases (synthesis gas or wood gas) which escapes upwards (because they are lighter than air) and mix with oxygen in the air and burn with a flame just on top of the decomposing biomass. The flame above the biomass has a feedback effect by radiating some of the heat back to the decomposing biomass underneath causing more and more gases to be released by the charring biomass until the whole (inside) of biomass or fuelwood is charred.

In this mode of combustion (direct combustion) it is not easy to completely eliminate harmful emissions because there is not enough *time* and *space* for the synthesis gases to properly mix with the correct amount of air before they are completely burned. Tradition 3-stone fire and all conventional ICS including rocket stoves which use solid biomass fuels operates through the principle of direct combustion, and it is no wonder there are very few conventional ICS which can completely eliminate harmful emissions.

In gasification stoves the fuel bed of biomass is ignited at the top or bottom but with very limited (primary) air which does not allow direct combustion in the vicinity of the decomposing biomass. This allows the synthesis gas to escape. After escaping the biomass it is then mixed with the (secondary) air and burned away from the biomass underneath. In this way there is no feedback effect of the flame of the burning gases to the decomposing biomass, hence the rate of decomposition of biomass (and release of the gases) is controlled by the amount of (primary) air which is purposely put to sustain decomposition of the biomass (pyrolysis), but not enough to form ignitable mixture with synthesis gas coming out of the fuel. The small amount of primary air can be fed by a small blower (forced draft) or by natural draft, depending on the size of the fuel particle and pressure drop in the fuel bed. Figure 5.1 illustrates the principle of gasifier stove.

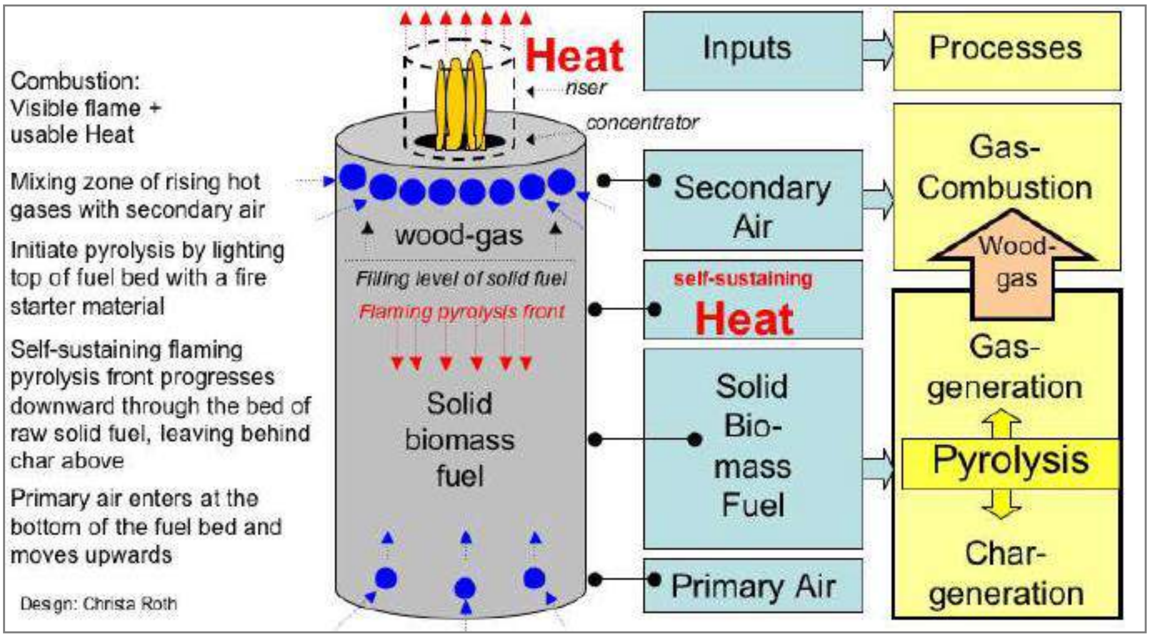


Figure 5.1 Principle of Top-Lit Updraft (TLUD) Gasifier Stove[18]

[18] Crista Roth. Micro-gasification – Cooking with gas from biomass

By separating the combustible synthesis gases from the decomposing biomass, the gases can be mixed thoroughly with (secondary) air and ignited to burn just like a LPG burner. In this mode of combustion (pre-mixed combustion) smoke and harmful emissions from the stove are very much reduced, which is the first main advantage of a gasifier stove. Other advantages of gasification stoves include:

- Very clean burning hence can be used indoors
- Use a wider variety of biomass fuels (husks, shells, grass,)
- Higher efficiency
- Makes charcoal during the process
- Can be used remotely with gas piping

5.2 Fuels for Gasification Stoves

The main disadvantage of gasifier stoves for household is that they only work well with uniform small-particle biomass materials of size between 5 – 15 mm. Bigger particles create big void spaces between them, and hence too much air will be trapped in the fuel bed which will be enough to form a combustible mixture with the released gases and burn within the fuel bed which will cause the whole process to be out of control because the heat added by direct combustion within the fuel bed will accelerate the release of synthesis gases, or in general the fuel in the gasifier will burn in direct combustion mode.

On the other hand, uniform smaller particles with size less than 5 mm will require a fan to push the primary air through the fuel bed, which is also not a good idea as most rural household do not have electricity. Other disadvantages of gasification stove are:

- Complicated design and tight tolerances – hence only metal construction is feasible
- More skill and processes are needed to fabricate gasifiers
- Relatively expensive compared to conventional ICS

Despite using biomass particles of specific size range being a disadvantage, there are huge amounts of naturally occurring agricultural residues which can be constituted to a specific size by pelleting. Agricultural residues are defined as biomass by-product from the agricultural system, which include straws, husks, shells, and stalks. These residues can be categorized into two groups: *field residues*, which remain in the field after harvest, such as, stalks and straws; and *crop processing residues* which are the by-products of the industrial processing of crops, such as, rice husk, coffee husk, nut shells, etc,.

Agricultural residues are attractive feedstock for fuel since they are considered a waste material and therefore have no intrinsic value, and when they are dry the heat of combustion is also similar to fuelwood. Although the potential is very high for field and crop processing residues, quantities which are currently used for fuel are very small. This is mainly because even in areas of fuelwood scarcity, tradition stoves and conventional ICS only use big-particle agricultural waste such as maize cobs, coconut shells, and stalks. Small-particle biomasses such as rice husk are not suitable for direct combustion because they will not allow enough air to pass through and hence stop the combustion process.

5.3 Developments in Gasification Stoves around the World

Recent awareness on cleaner biomass combustion from cookstoves has increased R&D activities worldwide on household gasification stoves. Furthermore, the huge availability of agricultural waste which are considered “difficult” to use in tradition stoves and convention ICS, can be directly used or reconstituted to pellets and burn cleanly in gasifier stoves with the consequence of reducing kitchen pollution, pressure on fuelwood resources, and at the same time solve disposal problems of crop processing waste surrounding the mills located in towns and villages with agricultural activities. Figure 5.2 shows various models of gasifier stoves which have been developed in the World in the past few years.

 Peko-pe (Malawi)	 Vesto (Swaziland)
 Daxu Gasifier Stove (China)	 TN Orient (China)
 Champion (India)	 Oorja Gasifier Stove (India)
 MJ Gasifier Stove (Indonesia)	 Mwoto Stove (Uganda)

Figure 5.2 Models of gasifier stoves developed in other countries

5.4 Gasification Stoves in Tanzania

In 2010, Partners for Development (PfD) a USA-based NGO in Tanzania with funding from the United States Department of Agriculture (USDA), supported and promoted two natural draft gasifier cook stove models which were under development in Arusha by Kiwia and Laustsen Ltd, and Jetcity Stoveworks of USA in collaboration with a local NGO, PAMOJA. The two gasifier stove models namely, *Jiko Mbono (*now *Jiko Bomba)* developed by Kiwia and Laustsen Ltd, and *Jiko Safi of* Jetcity Stoveworks are both natural draft top-lit updraft (TLUD) gasifier stoves, both stoves are fabricated locally using mild steel sheets and channels. Jiko Mbono use pellets as fuel which are made from grounded agricultural waste with jatropha cake binder, whereas Jiko Safi use jatropha whole seeds as fuel. As shown in Figure 5.4, the pellets are cylindrical with approximately 8 mm diameter and approximately 25 mm length.

In 2011, the locally developed gasifier stoves were tested in the Laboratory for efficiency and emissions, and also evaluated in the field in two rural villages and in Bariadi town in Shinyanga region[19]. The main objective of the evaluation is to assess the technical, environmental and socio-economic acceptance of gasifier stoves in rural and town settings. Results obtained indicated that the thermal efficiency of the gasifier stoves is around 30%, which compares well with most conventional ICS. The levels of carbon monoxide (CO) and Total Volatile Organic Compounds (TVOC) from the gasifier stoves were also low compared to air quality standards from World Health Organization (WHO). The level of CO was observed to be around 7 ppm, which is lower than the WHO limit for exposure for CO concentration of 8.7 ppm (10 mg/m^3) for 8 hour exposure time.

The qualitative part of the field test revealed many aspects of gasifier stoves which were liked and disliked by the cooks. The disliked aspects are the poor stability of the gasifier stove and the size of the stove which was small for many families as reported from the field test. Aspects which were liked by the cooks (compared to three-stone fire), include less time to attend fire; fast cooking; and has less smoke and soot deposition on the pot after cooking. Figure 5.3 and 5.4 shows the models of *Jiko Bomba* and *Jiko Safi* and the fuels they use, respectively.

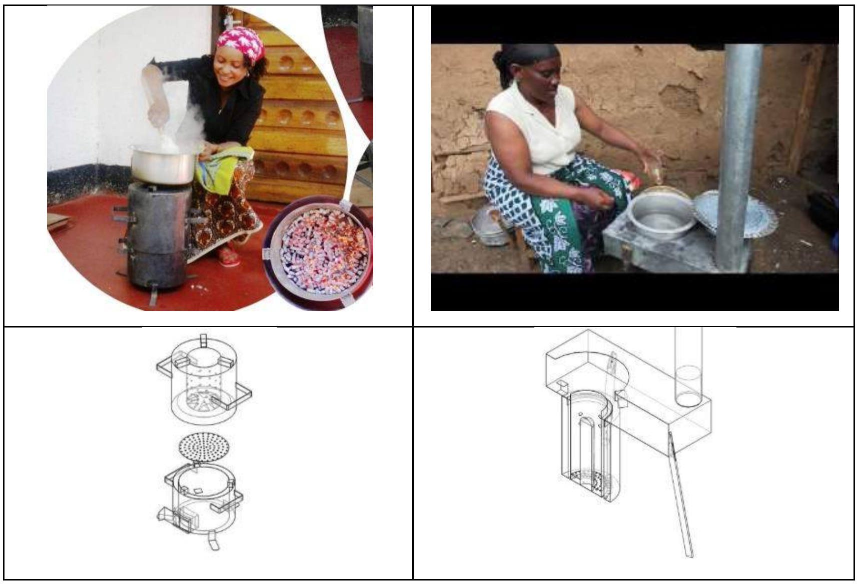


Figure 5.3 Jiko Bomba (left) and Jiko Safi (right) gasifier stoves

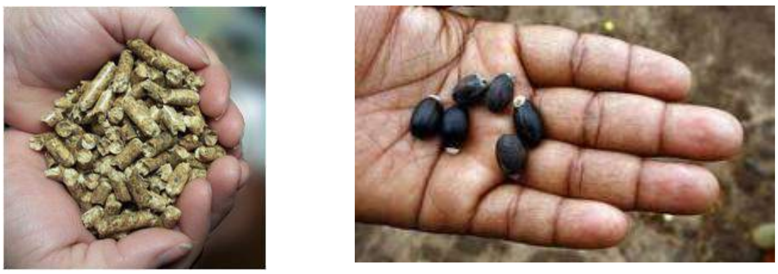


Figure 5.4 Rice husk pellets (L) and jatropha seeds (R) used as fuels in Jiko Bomba and Jiko Safi, respectively

[19] Rajabu, H.M. Evaluation of Jiko Mbono and jiko Safi Gasifier Stoves for Domestic Use In Bariadi. Partners for Development. October 2011.

6. ASSESSMENT AND EVALUATION OF EXISTING ICS TECHNOLOGIES

6.1 Important Characteristics for ICS Technologies Assessment

Stove manufacturing factors and materials to be used have a direct influence on the design of the stove, its efficiency and other characteristics during its lifetime. In this assessment the important characteristics for assessing and evaluating the existing ICS in the country are:

- **Manufacturability and scalability**: Ability to be build with local materials and skills and ease of mass production and on transportation to reach commercial scale
- **Fuel saving:** Efficiency and fuelwood saving compared to tradition stoves
- **Usability:** Ease of use (easy to regulate fire, fast cooking, fuel flexibility, pot flexible, and ability to cook staple meals effectively, require no training or special skills to use)
- **Durability:** The ability of the stove to withstand use over time (at least 2 years) without damage or altering performance
- **Maintainability**: Ease to clean, remove ash, repair, or replace damaged parts
- **Portability:** Lightweight, and be able be carried by one person. This is also an important aspect on stove transportation and distribution to reach remote customers
- **Cost/affordability:** Low initial cost of stove and fuels it uses should be affordable
- **Safety-1:** Stability of stove and pot during cooking, and it should not have very hot external surfaces
- **Safety-2:** Smoke, and specifically carbon dioxide (CO) and particulate emissions
- **Weight and space:** Size of stove and the space it occupies in the kitchen and also when moved (for portable)
- **Looks and cultural aspects:** Stove should look good and as a status symbol.

The characteristics listed above are central for any stove irrespective of the fuel used or location. Non-cooking characteristics such as space heating ability, giving smoke to preserve seeds and thatched roof from insects, and giving light to the room are not included in this assessment. This is because they are location and users specific and they conflicts to the intentions of promoting ICS.

Categories of Existing ICS Technologies

Material of construction of stove is the main factor which determines stove design, its manufacturing processes, quality and dimensional tolerances, lifetime, and its characteristics during the operational lifetime. Hence the characteristics of the existing ICS technologies are reviewed and evaluated based on their materials of construction as:

- Mud stoves
- Fired-clay stoves (or ceramic stoves)
- Metal-clad stoves
- All-metal stoves

6.2 Characteristics of Mud Stoves

Mud-stoves have been used for many years to replace the tradition 3-stone fire in many parts of Tanzania and other parts of Africa and Asia. In general, a simple mud stove is an improvement from the 3-stone fire by filling in the two sides with mud or clay to make a U-shape open hearth leaving one side for feeding fuelwood. This simple modification from the 3-stone fire improves the efficiency of the simple mud stove because it stabilizes the flame under the pot by preventing through-draughts and also insulating the combustion chamber which leads to hotter flame.

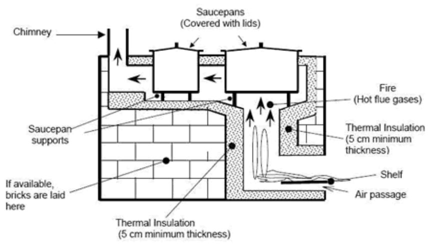
Mud-stoves are mostly fixed stoves and are built primarily for fuelwood, but can also be adapted for charcoal if a seat for charcoal grate is incorporated. The traditional mud stove which has been used in many areas of the country is made by earthen mixture of sand and clay, and sometimes combustible materials such as sawdust is added to the mix to create porosity and hence insulation. Mud stoves can be built in big sizes to accommodate two- or more pots as shown in Figure 6.1. Models which have chimneys have also been built as illustrated in Figure 6.2.

Rocket stoves built of mud have also been built to further improve efficiency and most important reduce smoke without using a chimney. The most popular rocket mud stove is *Lorena* which was first introduced in Guatemala and quickly became popular in other South American countries and later in Africa including Uganda and Kenya.

Figure 6.1 One-pot (L) and multi-pot (R) mud stoves

Lorena 1-Pot mud rocket stove

Lorena 2-Pots mud rocket stove



Schematic of Lorena 2-pots mud rocket stove

Figure 6.2 Lorena Mud Rocket Stoves

Table 6.1 summarizes the characteristics of mud stoves on the important criteria for the assessment of ICS for commercialization in the country. The remarks indicated in each criterion compares mud stoves to other stoves made from ceramic, metal-clad, and all-metal stoves.

Table 6.1 Characteristics of mud stoves

	Criterion	General Characteristics
1	Manufacturability and scalability	-Easier to manufacture locally, though the rocket version requires more skills -Mass production is difficult to achieve (fixed stove), and not transportable
2	Fuel saving	Average to good -the bulkiness of mud stoves makes it absorb a lot of heat during the initial stages (cold start), hence its efficiency gets better when becomes warm. Hence suitable for long cooking times such as beans.
3	Usability	Very good (the resemblance of mud stoves to tradition three-stone fire makes it easier to be used in households which use three-stone fire).
4	Durability	Poor (they crack easily and disintegrate around hot areas require regular repairing of cracks)
5	Maintainability	Very good (easy to repair with minimal skill)
6	Portability	Poor (mostly fixed or built-in. The portable versions will be very heavy and fragile)
7	Cost/affordability	Very good (cheap)
8	Safety-1 (stability, burns)	Very good (mostly fixed or built-in)
9	Safety-2 (emissions)	-Poor (normal version) -Good (rocket version)
10	Weight and space	Poor (normally made bulky in order to have strength)
11	Looks and cultural aspects	Good (complements well in tradition kitchen)

6.3 Characteristics of Fired Clay Stoves (or Ceramic Stoves)

Fired clay stoves or ceramic stoves are similar to mud stoves, but the main difference is that ceramic stoves are fired at high temperatures in a kiln for added durability. Making fired clay stoves requires expertise and they need higher quality clay. Ceramic stoves can be portable or fixed (built-in). The portable version is easy to carry around but can have a disadvantage on stability.

In a fixed version a ceramic lining is placed in a kitchen floor and mud is build around the lining leaving an opening for feeding fuel. The fixed version has added advantages of stability and more insulation from the surrounding mud. Popular types of ceramic stoves include *Upesi/Maendaleo* (Kenya) and *Mulanje* (Malawi) stoves[20], and the newly introduced *Matawi* stove in the lake zone (Tanzania). Figure 6.3 illustrates models of clay stove.

Both *Upesi, Mulanje*, and *Matawi* are one-pot stoves with no chimney and they can be built if both good clay and pottery skills are locally available. The disseminated models can be used with fuelwood or farm waste such as maize stalks and cobs, and animal dung. Charcoal can also be used if a seat for metal or

[20] USAID. Fuel-Efficient Stove Programs in Humanitarian Settings: An Implementer’s Toolkit. 2012.

ceramic grate is incorporated in the design as shown in Figure 6.3. Portable versions have limited flexibility to accommodate bigger or smaller pots than the size range which the model was designed. Ceramic stoves require maintenance (cracking) if poor clay is used, but not to the same degree as mud stoves.

Fixed Ceramic Stove for Fuelwood and Charcoal

Portable Ceramic Stove for Fuelwood

Portable Ceramic Stove for Fuelwood and Charcoal

Figure 6.3 Examples of Ceramic Stoves

Table 6.2 summarizes the characteristics of ceramic stoves on the important criteria for the assessment of ICS for commercialization in the country. The characteristics indicated in each criterion compare clay stoves to other stoves made from mud, metal-clad, and all-metal stoves.

Table 6.2 Characteristics of ceramic stoves

	Criterion	**General Characteristics**
1	Manufacturability and scalability	-Easier to manufacture, though more pottery skill is required compared to mud stoves -Require good quality clay -Good clay is location specific -Mass production is possible through chain actors and modernization of pottery -Transportation to very long distances is not attractive
2	Fuel saving	-Good (insulation characteristics of ceramics).
3	Usability	-Very good for fixed version (resembling tradition three-stone fire) -Good for portable version
4	Durability	-Good for fixed version (cracks can be neglected) -Poor for portable version (cracking, and accidental falls, etc)
5	Maintainability	-Good for fixed version -Poor-average for portable version
6	Portability	-Poor for fixed version -Very good for portable version (light-weight)
7	Cost/affordability	Good (cheap locally, transportation increase cost)
8	Safety-1 (stability, burns)	-Very good for fixed version -Poor for portable version
9	Safety-2 (emissions)	Poor - average

10	Weight and space	Good
11	Looks and cultural aspects	Very good

6.4 Characteristics of Metal-Clad Stoves

Metal-clad stoves are stoves that have ceramic or clay liners enclosed with a metal body. These types of stoves have added advantage of being lightweight compared to mud or ceramic stoves and most are portable and more durable compared to ceramic and mud counterparts. A metal-clad which forms the external body of the stove add strength to the stove, hence the ceramic or mud inserts mainly improves stove efficiency by insulating the high heat from escaping through the stove metal body. Hence, the ceramic/mud layers are made thinner not to absorb too much heat during cold starts. Other important components of the stoves such as pot rests, air control, and legs can also be of metal which can easily be attached to the metal body surrounding the stove which simplifies and strengthen the stove.

Examples of locally available metal clad stoves are improved charcoal stoves (*Sahara, Jiko Bora, Zasawa, CARMATEC*), *Maasai* fuelwood stove, *Envotec,* and *M&R* domestic rocket stoves. Both rocket stoves have outer body made of galvanized sheet. M&R has combustion chamber made of hollow bricks that are made from a mixture of clay and low mass materials such as sawdust or rice husk, whereas ENVOTEC has rectangular combustion made of refractory bricks that are joined by high temperature cement. Figure 6.4 illustrates metal-clad stoves.

Zasawa Charcoal Stove

Maasai Stove

M&R Rocket Stove

Figure 6.4 Examples of metal-clad stoves

Table 6.3 summarizes the characteristics of metal-clad stoves on the important criteria for the assessment of ICS for commercialization in the country. The characteristics indicated in each criterion compares metal-clad stoves to other stoves made from ceramic, mud, and all-metal stoves.

Table 6.3 Characteristics of metal-clad stoves

	Criterion	**General Characteristics**
1	Manufacturability and scalability	-Requires more skills -Metals not readily available in rural areas -Easier to scale-up and transport
2	Fuel saving	Very good (insulation from ceramic inserts)
3	Usability	-Very good for charcoal versions (resemblance to tradition charcoal stoves) -Very good for portable fuelwood version -Pot size restriction for rocket versions
4	Durability	-Good (depends on the bonding of metal and clay liner/inserts

5	Maintainability	-Poor (require skills and availability of materials)
6	Portability	-Good for charcoal and portable rocket -Poor for fixed versions
7	Cost/affordability	Very good for charcoal (very cheap to make) Poor for rocket version (expensive)
8	Safety-1 (stability, burns)	-Very good for fixed versions -Average for charcoal and rocket versions
9	Safety-2 (emissions)	-Poor for charcoal -Average for fuelwood -Good (rocket version)
10	Weight and space	-Very good for charcoal version (same size as tradition but a bit heavy) -Good for rocket version (slightly heavy)
11	Looks and cultural aspects	Good

6.5 Characteristics of All-metal Stoves

In Tanzania, tradition all-metal charcoal stoves are fabricated by small informal artisans who also fabricate a variety of other metal products such as fryers, pans, scoops, etc. Normally small scale artisans use scrap metals which are easily found in towns and cities from scrap-metal dealers. In most set-ups the artisans sell their products in bulk to retailers who have shops and market stands.

Apart from imported ICS, there are no all-metal domestic fuelwood stoves which have been locally developed. Due to the complexity, accuracy and tight tolerances of dimensions required for gasifier stoves to work properly, nearly all gasification stoves which have been developed in many countries in the World have been made of metal. In Tanzania, *Jiko Bomba* and *Jiko Safi* are also all-metal stoves. Figure 6.5 show tradition charcoal stove retailer and imported ICS stoves.

Charcoal Stove Retailer

Envirofit Stove

Figure 6.5 All-metal Stoves

Table 6.4 summarizes the characteristics of all-metal stoves on the important criteria for the assessment of ICS for commercialization in the country. The remarks indicated in each criterion compares all-metal stoves to other stoves made from ceramic, metal-clad, and all-metal stoves.

Table 6.4 Characteristics of all-metal stoves

	Criterion	General Characteristics
1	Manufacturability and scalability	Generally very good for big scale and poor for small scale -Metal expensive and not readily available in rural -Require metal skills
2	Fuel saving	-poor – average (charcoal stoves) -Very good for gasification stoves
3	Usability	-Good for charcoal -Average for gasification stove (require training and more instruction to operate a gasifier stove)
4	Durability	-Poor -Good (if appropriate materials are used in hot areas)
5	Maintainability	Poor (require skill and equipment) Good (if parts are made to be replaced, eg. grate)
6	Portability	Very good (light weight and strong)
7	Cost/affordability	Poor (expensive)
8	Safety-1 (stability, burns)	-Average –Good on stability -poor (hot surfaces)
9	Safety-2 (emissions)	-Poor (fuelwood and charcoal stoves) -Good (gasification stoves)
10	Weight and space	Very good
11	Looks and cultural aspects	Average - good

6.6 Evaluation of Existing ICS Technologies

6.6.1 Evaluation Method

A Multiple Criteria Decision Analysis (MCDA) approach is used to evaluate the ICS options which have been disseminated and are currently available in the country. The criteria selected for evaluation of ICS models are:

- **Manufacturability and scalability**: Ability to be build with local materials and skills and ease of mass production to reach commercial scale
- **Fuel saving:** Efficiency and percentage saving compared to tradition stoves
- **Usability:** Ease of use of stove (easy to regulate fire, fast cooking, fuel flexibility, ability to cook staple meals effectively)
- **Durability:** The ability of the stove to withstand use over time without damage or altering performance
- **Maintainability**: Ease to clean, repair, or replace damaged parts
- **Portability:** Ability of stove to be moved around
- **Cost/affordability:** Cost of stove and fuels it uses relative to tradition means
- **Safety-1:** Stability of stove or/and pot during cooking staple meals, and presence of external hot surfaces
- **Safety-2:** Smoke, and specifically carbon dioxide (CO) and particulate emissions

- **Weight and space:** Size of stove and the space it occupies in the kitchen, also considerations on transportation (mass production)
- **Looks and cultural aspects:** Stove appearance and how it fits in the tradition kitchen

The criteria selected above are general in such a way that they apply for and ICS irrespective of location in the country. Criteria which are important in only part of the country such as "space heating ability" have not been included.

Each criterion above is assigned a weight which reflects its importance or priority on mass-scale production (or commercialization), acceptance by users, and meeting the ICS usual expectations, i.e., fuel saving, emission reduction, etc. In this assignment the weights for the criteria ranges between 0 – 5, zero (0) for "not important" and 5 for "very important" criterion based on the objectives of assessment.

The overall importance of each criterion is then expressed as the fraction (in percentage) of its weight to the sum of the weights of all criteria. Table 6.5 shows the proposed weights and *criterion importance* of each criterion for evaluation of fuelwood and charcoal stoves. Higher ratings have been assigned to the criteria which are important in acceptance (market) and ease in quality low-cost mass production.

Table 6.5 Weight rating and importance of criterion for evaluation of fuelwood and charcoal ICS

	Criterion	***Fuelwood Stoves***		***Charcoal Stoves***	
		weight or rating (0-5)	*Criterion importance (%)*	*weight or rating (0-5)*	*Criterion importance (%)*
1	*Manufacturability and scalability*	*5*	*12%*	*5*	*12%*
2	*Fuel saving*	*4*	*10%*	*5*	*12%*
3	*Usability*	*5*	*12%*	*3*	*7%*
4	*Durability*	*4*	*10%*	*5*	*12%*
5	*Maintainability*	*3*	*7%*	*2*	*5%*
6	*Portability*	*3*	*7%*	*5*	*12%*
7	*Cost/affordability*	*5*	*12%*	*4*	*10%*
8	*Safety-1 (stability,burns)*	*4*	*10%*	*3*	*7%*
9	*Safety-2 (emissions)*	*3*	*7%*	*3*	*7%*
10	*Weight and space*	*4*	*10%*	*5*	*12%*
11	*Looks and cultural aspects*	*2*	*5%*	*1*	*2%*
	OVERALL SCORE	*42*	*100%*	*41*	*100%*

Scores

Each ICS model will be given a score between 0 – 10. Zero (0), for poor, and ten (10) for excellent, in the criterion. The criterion score will be multiplied by respective *criterion importance (%)* to get *Total Score* in each criterion. The *Overall Score* for each ICS model will be the sum of the Total scores of all criteria. The summary of the results of the scores of ICS models are presented below.

6.6.2 Summary of Evaluation

The objectives and goals for the evaluation of technologies is to identify technologies which will demand less effort to commercialize and still meet the requirements for ICS, mainly saving fuel, reducing emission, and the stove be accepted. The assessment method detailed above was used to evaluate the existing ICS technologies in Tanzania. The evaluations on the important characteristics of ICS are pivoted on material of construction of ICS, a feature which is closely related to standardized fabrication processes and commercial manufacturing.

Tables 6.6 and 6.7 shows the summary of evaluation results of common fuelwood and non-fuelwood ICS technologies, respectively. The evaluation of gasification stove is included in Table 6.7 for non-fuelwood stoves. From the obtained results the three top-ranked fuelwood stoves are ***Fixed ceramic (1st),*** ***Portable Ceramic (2nd),*** and ***Metal-clad Rocket (3rd)***, whereas for non-fuelwood stoves ***Metal-clad charcoal (1st)*** and ***gasification stove (2nd)*** have emerged above metal and clay charcoal stoves.

Table 6.6 Evaluation results for fuelwood stoves

Criterion	**Weight or rating (0-5)**	**Criterion importance (%)**	**Mud -Normal**		**Mud-rocket**		**Clay-fixed**		**Clay-portable**		**metal-clad rocket**	
			Point score	Total score	Point score	Total score	Point score	Total score	Point score	Total score	Point score	Total score
Manufacturability and scalability	5	12%	5	0.60	4	0.48	7	0.83	8	0.95	6	0.71
Fuel saving	5	12%	4	0.38	6	0.57	6	0.57	6	0.57	9	0.86
Usability	3	7%	6	0.71	4	0.48	8	0.95	7	0.83	4	0.48
Durability	5	12%	2	0.19	2	0.19	6	0.57	4	0.38	8	0.76
Maintainability	2	5%	8	0.57	8	0.57	8	0.57	4	0.29	5	0.36
Portability	5	12%	0	0.00	0	0.00	0	0.00	10	0.71	6	0.43
Cost/affordability	4	10%	9	1.07	8	0.95	8	0.95	8	0.95	4	0.48
Safety-1 (stability, burns)	3	7%	8	0.76	8	0.76	8	0.76	4	0.38	7	0.67
Safety-2 (emissions)	3	7%	4	0.29	8	0.57	6	0.43	6	0.43	9	0.64
Weight and space	5	12%	5	0.48	5	0.48	7	0.67	8	0.76	7	0.67
Looks and cultural aspects	1	2%	8	0.38	8	0.38	9	0.43	9	0.43	7	0.33
OVERALL SCORE	**41**	**100%**		**5.43**		**5.43**		**6.74**		**6.69**		**6.38**
		RANKING	**4**		**4**		**1**		**2**		**3**	

Table 6.7 Evaluation results for charcoal and gasification stoves

Criterion	**Weight or rating (0-5)**	**Criterion importance (%)**	**Clay Charcoal**		**metal clad-charcoal**		**All metal-charcoal**		**Gasifier stove**	
			Point score	Total score	Point score	Total score	Point score	Total score	Point score	Total score
Manufacturability and scalability	5	12%	8	0.95	9	1.07	9	1.07	7	0.83
Fuel saving	5	12%	9	1.07	9	1.07	4	0.48	10	1.19
Usability	3	7%	6	0.43	9	0.64	9	0.64	4	0.29
Durability	5	12%	2	0.24	8	0.95	5	0.60	6	0.71
Maintainability	2	5%	4	0.19	4	0.19	6	0.29	4	0.19
Portability	5	12%	10	1.19	10	1.19	10	1.19	10	1.19
Cost/affordability	4	10%	9	0.86	9	0.86	10	0.95	5	0.48
Safety-1 (stability, burns)	3	7%	7	0.50	8	0.57	5	0.36	8	0.57
Safety-2 (emissions)	3	7%	5	0.36	5	0.36	5	0.36	9	0.64
Weight and space	5	12%	8	0.95	9	1.07	9	1.07	9	1.07
Looks and cultural aspects	1	2%	9	0.21	8	0.19	6	0.14	4	0.10
OVERALL SCORE	**41**	**100%**		**6.95**		**8.17**		**7.14**		**7.26**
		RANKING	**4**		**1**		**3**		**2**	

6.7 Concluding Remarks and Recommendations

Since the introduction of ICS technologies in Tanzania in the 1980s, ICS models have been disseminated in many varieties with different materials of construction, designs, production methods, sizes, uses, and the form of biomass fuels used. Most of ICS models are fabricated by local artisans in the informal sector using locally materials and scrap metals obtained from nearby towns and cities. However, some ICS models use materials or components such as refractory bricks, grates, stove liners, etc, which are produced elsewhere and purchased by artisans.

It is generally accepted that there is a low level of acceptance of ICS in the country, even with subsidies, because of various reasons which most of them are known. There is also strong evidence that acceptance of a stove is highly area specific and governed by social, cultural and economic circumstances. A stove design that succeeded in one area can be unpopular in another area even if the fuel saving from the stove is excellent. Hence, a variety of ICS technologies need to be promoted in order to accommodate the different socio-cultural and economic diversity of biomass stove users.

Figure 6.6 shows the cook needing help to cook *ugali* using an ICS*.* In normal circumstances and without a helping hand the cook will prefer a three-stone fire to cook *Ugali* and other foods which require heavy stirring. This ICS will be very unlikely to succeed in areas where *ugali* is a staple food. The same ICS may be successful in other areas where staple foods don't require constant heavy stirring such as banana and rice.

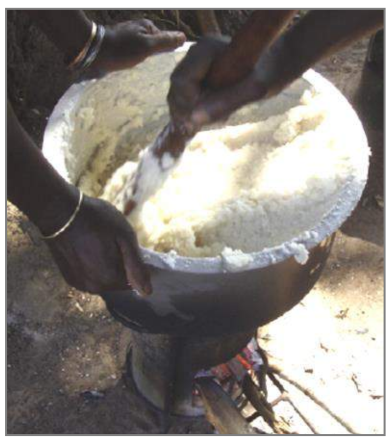


Figure 6.6 Helping hand is needed to cook ugali in some ICS

An area which is generally overlooked by stove developers is that a stove is just a part of the cooking system, which, depending on the type of food cooked or cooking times of the day or seasons of the year, etc, the cooks (which are mostly women) have their "preferences" during preparation and cooking processes. The preferences differ with the type of food processed and also between cultures. Other factors in the cooking system include the type of pot used and how well the pots fit the stove, whether pot lids are used, cultural values and management of the kitchen and fuel preparation in general (sizing, drying, fire starters, etc).

Most often preparations of meals intermingle with other household chores such that if a new stove is introduced its performance and characteristics have to very closely fit with the preferences of the cooks. The preferences are mostly similar in a certain culture or area, but often differ with other locations.

As an example, during the field tests (Controlled Cooking Test –CCT) conducted in Mwanza as first part of this task, the most experienced cook and whose kitchen was used for CCT produced test results with highest standard deviation compared to the other cooks. This was because the tests were conducted at her house and she was not just concentrating with the cooking, but was constantly moving in and out of the kitchen to attend other household chores. The experienced cook and host was noted to not tend the fire, turning food, and adding water to the food timely and consistently compared to the guest cooks.

One of the main technical recommendations from the SNV/Round Table Africa Desk Study[21] is to standardize few selected models and promote their large-scale production, or simply commercialisation. Among other factors, standardization of the models and up-scaling of production and creation of chain actors also contributed significantly to the successes of KCJ, Jiko Bora, and Anagi stove. Hence, the focus of the assessment was to evaluate the existing technologies and recommend ICS technologies that are *easier to standardize and easier to reach scale production.*

Results from the evaluation of ICS technologies which have been disseminated in the country in the past years revealed the following fuelwood stoves to be appropriate for promotion to commercial scale production:

- ***Fixed ceramic stove (1st)***
- ***Portable Ceramic stove (2nd)***
- ***Metal-clad Rocket (3rd)***

For the case of non-fuelwood stoves ***metal-clad charcoal (1st)*** and ***gasification stove (2nd)*** have emerged above metal and clay charcoal stoves for promotion to commercial scale. It has to be cautioned that ***there will never be a clear winner*** in a Multi Criteria Decision Analysis where the criteria are rated at different weights and the scores in some criteria are only subjective.

There will never be an ICS model which will fit the preferences of all users. This is due to the difference in cultures, staple foods and preferences. Hence it is important to first ***identify groupings of users with similar cooking preferences, etc.,*** which is very likely to coincide with the geographic areas. The appropriate ICS can then be identified and ***modified if needed by participatory approach involving women in the areas to set several specifications and versions of the stove such as: two or more sizes of the stove; multiport; portable and fixed versions; etc.***

Most households especially in urban and suburban areas have two or more stoves which use different types of fuels to enhance energy security and cooking preferences with different foods, time of the day, season of the year, etc. A survey of Envirofit stove users in suburban villages of Arusha revealed that households have an average of three types of stoves, apart from the Envirofit stove. In most multi-stove and multi-fuel households, a stove which is preferred for cooking staple foods is normally the *main stove* and is used more frequent than the other stoves. ***An ICS is more likely to have an impact (fuelwood saving, etc), if it is preferred for cooking staple foods, i.e., replacing the tradition main stove. Hence, the operability of the ICS has to be an improvement of the tradition stoves on aspects which are liked by the cooks in order to be preferred for cooking staple foods.***

It is further recommended that new cooking technologies such as gasification stoves which are becoming popular in other parts of the world be promoted in areas with acute scarcity of fuelwood. Pilot trials in parts of Arusha, Singida and Shinyanga regions where agricultural residues such as crop stalks and maize cobs

[21] Household Improved Cook Stove Sector in Tanzania. Desk Study. Joint SNV and Round Table Africa. Feb. 2000

are the main fuel source have showed positive results on acceptability of the *Jiko Bomba* gasifier stove. In general, advantages of a gasifier stove over conventional ICS include:

- Very clean burning hence can be used indoors
- Use a wider variety of biomass fuels (husks, shells, grass,)
- Higher efficiency
- Makes charcoal during the process

7. ALTERNATIVE FUEL FEEDSTOCKS FOR ICS

7.1 Introduction

Alternative solid fuels which have potential to be used in tradition stoves and ICS which use charcoal and fuelwood are:

- biomass briquette (uncarbonized)
- charcoal briquettes
- biomass pellets
- coal
- coal dust briquettes
- composite of coal dust and biomass briquettes

With exception to coal which can appear in different particle sizes, the most practical alternative fuels for domestic use are *reconstituted fuels* made by *densifying* or *agglomerating* small-particle biomass or coal materials using mechanical presses called briquetting and pelleting machines. The feedstock to make briquettes and pellets fuels normally appears in the form of waste from other activities. Big-particle biomass wastes and coal have no problems to be used directly for fuel in conventional appliances using fuelwood and charcoal. Table 7.1 summarizes options for production of reconstituted fuels.

Table 7.1 Densification technologies for reconstituted fuels

Reconstituted fuels	Densification Technologies	Common Feedstock	Appropriate Household Stove
Biomass briquettes	-High pressure briquetting -Low pressure densification with binder	Forest and agricultural waste	-Any fuelwood stoves
Charcoal briquettes	Low pressure briquetting with binder	Carbonized biomass waste	-Any charcoal stoves
Biomass Pellets	Pelleting (with binder)	Forest and agricultural waste	-Gasification stoves
Coal dust briquettes	Low pressure briquetting with binder	Coal waste (dust) from mines	-Ceramic lined charcoal stoves
Coal dust-biomass composite briquettes	Low pressure briquetting with binder	Coal dust and biomass waste	-Any charcoal stoves

7.2 Densification Technologies

7.2.1 Introduction

Densification of biomass wastes is a well-known technology and has been widely used in developed and developing countries, although for different applications. In developed countries, densified biomass fuels (briquettes and pellets) are mainly used for industrial energy applications and space heating, whereas in developing countries the main market is for household fuel.

Densification of biomass wastes typically entails an extrusion process which requires high pressures and sometimes temperatures to bond small particles into briquettes. In some small scale technologies casting of biomass waste with a binder produce briquettes. In high pressure cases, binding agents are not required.

Densified fuels can also be carbonized into charcoal after extrusion, or alternatively the small-particle waste can be carbonized into char and then mixed with a binder and extruded. Charcoal briquettes have huge market in urban areas but have a disadvantage of consuming a large amount of the heat energy in the carbonization process.

Medium and large-scale biomass densification projects are mostly of commercial scale. The dominating technologies in these scales can be classified into two categories:

- hot and high-pressure densification, and
- cold and low-pressure densification.

Hot and high pressure densification can be applied successfully for a wide range of materials where the cohesion of the particles is normally achieved by self bonding, or without addition of external binder. The type of equipment used in the two categories includes piston press, screw press, roll press and pelletizing machines. Piston, screw, and roll presses produce large products and are normally called briquettes. Pelletizing machines produce smaller products are normally referred as pellets. Pellets or briquettes of rectangular or square cross-section are sometimes referred as *cubes*. The main difference of briquettes and pellets is in their size as shown in Figure 7.1. Pellets diameter ranges between about 6-12 mm, while briquettes have diameter from 25 mm up to 70 mm.

Figure 7.1 Biomass briquettes and pellets

7.2.2 Medium and Large Scale Briquetting Technologies

Piston, screw, and roll presses are technologies used for medium and large scale briquetting production. The piston press consists of a reciprocating piston that forces the feed material in a discontinuous mode into a slightly tapered die. The piston pushes the material against the die wall friction, and compression forces is created as the material is forced through the tapering die. The die can be heated to increase the cohesion quality of the briquettes. Briquettes from piston press are usually cylindrical with diameter of up to 100 mm. Commercial briquetting machines have been reported to have capacities of up to 1000 kg/hr[22]. Figure .7.2 illustrates schematic arrangement of piston and screw presses.

Unlike piston presses, the pressure in a screw press builds up smoothly along the screw. In heated die versions temperatures up to 300^{o} C can be maintained which sometimes caused the extruded briquettes to be partially pyrolyzed at the surface, which was further reported to improve the shelf life of briquettes. Screw presses are usually sized in the range 75-250 kg/hr, though larger machines have been reported. Experience has shown that maintenance costs for screw press are considerably higher than other type of

[22] Erickson, S and Prior, M. The Briquetting of Agricultural Waste for Fuel. FAO. 1990.

presses because of the wear of the screw which has to be rebuilt rather frequently[23]. Briquettes from a screw press also needs more energy to form, though the quality of briquettes and the shelf life is better than briquettes from piston press[24].

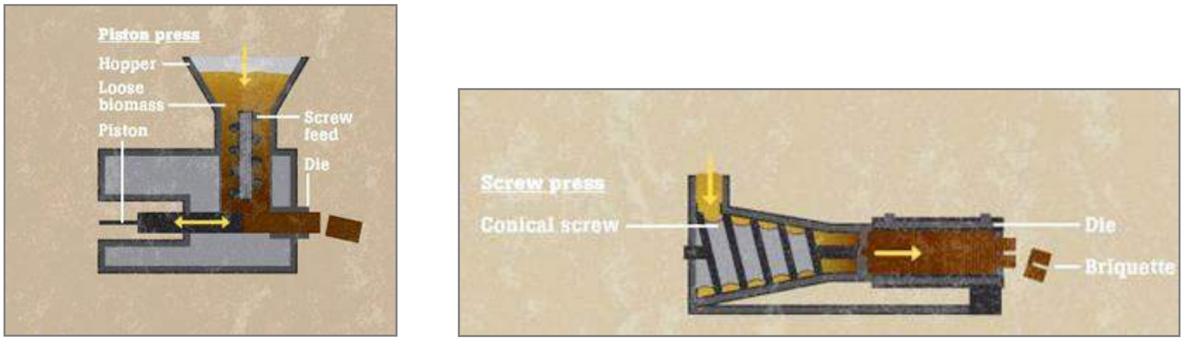


Figure 7.2 Schematics of piston (L) and screw (R) briquetting machines

In a roll press pre-compressed feed material is fed between two synchronized rollers with cavities on their peripheries rotating in opposite direction where trapped feed material is compacted into pillow-shaped briquettes. Roll presses require relatively smaller particle sizes of the feed material than other press types. The briquettes from the roll press are less durable than the extruded because of the shorter residence time during compression. Hence, the inability of the material to fully plasticize the lignin. Roller presses are successful when a binder is used and are often used to carbonized materials with binder to form charcoal briquettes. Figure 7.3 illustrates a roll press, and Figure 7.4 show biomass briquettes from piston, screw, and roll presses.

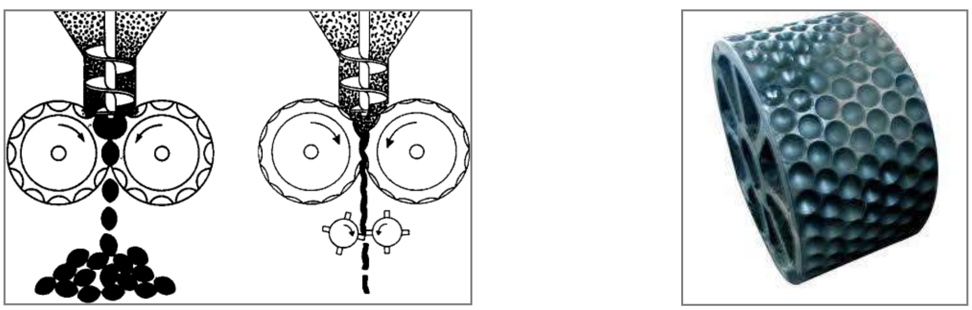


Figure 7.3 Roll press principle (L) and cavities in the rollers (R)

Figure 7.4 Briquettes from piston press (L), screw press (C), and roll press (R)

[23] Bhattacharya, S.C and Shrethra. Biocoal Technology and Economics. ISBN 974-8201-441. 1990.

[24] Carre, et. al. Critical Analysis of Dry Process Improvement of Ligneous Materials for Energy Producing Purposes. Centre de Recherche Agronomique. 1991.

7.2.3 Small-scale Briquetting Technologies

Small-scale biomass densification technologies are mostly for briquetting (not pelleting). Most of the small-scale briquetting technologies are labour intensive and are hand-operated or use simple machinery. The simple densification machines cannot achieve the high pressure required for self bonding of biomass particles and hence most small-scale technologies require the use of binders to form stable briquettes. Addition of binder increases the moisture content of feed materials which will require the briquettes to be dried for few days before packing and transporting to the users. Figure 7.5 show examples of simple briquetting technologies.

Hand-operated briquetting machine used by Mkombozi Women Group (Lushoto)

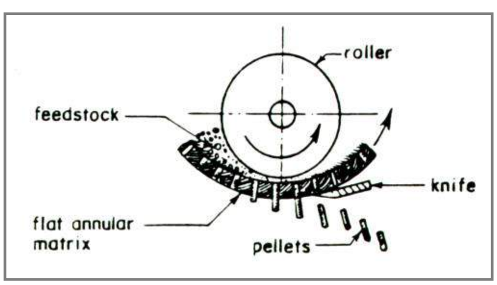
Briquettes (Mkombozi Women Group, Lushoto)

Making of charcoal briquettes at Nishati Poa (Arusha)

Figure 7.5 Small-scale briquetting technologies

7.2.4 Pelleting Technologies

A pelletizing press consists of a roller and a circular or flat plate matrix with perforations as illustrated in Figure 7.6. Most pelleting processes require a binder which is mixed to the feed material and extruded through the die holes of the circular plate or flat plate by rollers. Pellet technologies were originally developed for the production of animal feedstock and mineral-ore pellets. Pellet presses have output range from 0.5 to 20 tonnes per hour range.



Principle of pelleting

Circular die

Flat die

Figure 7.6 Pellet machine components

7.3 Status of Biomass Densification in Tanzania

In recent years there has been an increase of local companies that are involved in making briquettes. A list of companies which are involved with briquetting projects is shown in Table 7.2. The majority of briquetting projects in the country are small-scale. Two medium–scale plants are Kilimanjaro Industrial Development Trust (KIDT) located in Moshi, Kilimanjaro and MENA Briquetting Plant in Iringa use sawdust as feedstock to produced uncarbonized briquettes. KIDT has been producing briquettes for the past 25 years and the fuel briquettes are popularly used by institutions such as hospitals and schools in Kilimanjaro region and food vendors in Moshi town. Figure 7.7 shows KIDT briquettes factory and briquettes from MENA briquetting plant at Mafinga.

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Figure 7.7 KIDT briquettes factory (L) and briquettes from MENA briquetting plant (R)

Users of KIDT briquettes prefers them for various reasons, including consistency of quality and no cheating during purchasing (unlike bulk buying of fuelwood where sellers can cheat through tricky stacking/loading of fuelwood in the truck and inconsistent fuelwood moisture). During the survey it was further observed that for briquettes to be easily accepted, they have to be compatible to existing stoves as users prefer the versatility of switching between briquettes and fuelwood (depending on their cost and availability), than to have a different stove for each fuel

Table 7.2 Densification technologies for reconstituted fuels

	Company name/NGO	Feedstock	Technology	Scale
1	KIDT (Kilimanjaro)	Sawdust	Screw Press (briquettes)	Medium
2	MENA Briquetting Plant (Mafinga, Iringa)	Sawdust	Screw press (briquettes)	Medium
3	BEDOKO Traders (Dar)	Charcoal dust, etc	Piston and screw press (Briquettes)	Medium (?)
4	ARTI (Dar)	Carbonized rice husk and other biomass	Screw press (briquettes)	Small scale
5	TATEDO (Shinyanga)	Carbonized rice husk	Roll press (briquettes)	Small scale
6	African Women in Mining Network	Coal dust, sawdust, rice husk	Casting?	Small scale?
7	Kiwia and Laustsen (Arusha)	Rice husk, maize cobs, jatropha cake	Pelleting machine	Small - medium
8	Nishati Poa (Arusha)	Charcoal dust	Screw press	Small
9	Renewable energy	Carbonized forest	?	Small

	Awareness Promotion (Dar)	waste		
10	Mkombozi Women Group (Lushoto, Tanga)	Municipal waste, sawdust	Manual Piston press/casting	small
11	East African Briquetting (Tanga)	Carbonized biomass (all kind)	?	small
12	TREE (Arusha)	Rice husk, maize cobs, jatropha cake	Pelleting machine	Small -medium

7.4 Biomass Waste Generation in Tanzania

7.4.1 Introduction

In Tanzania and many other developing countries wood fuels (charcoal and fuelwood) dominate domestic energy supply, especially in rural villages. At the same time, huge amounts of non-wood biomass in the form of agricultural waste, forest residues, municipal and industrial wastes are generated each day. The energy potential of agricultural residues in Tanzania has so far not been evaluated and quantified accurately and the scientific basis for estimations of the sustainable potential of wastes and residues is still very limited. However, in 1990 the estimated amounts of agricultural and forest residues were about 15, and 1.1 million tonnes per year, respectively[25]. There has been no update for these figures for the past 20 years.

Forest residues comprise mostly of logging and timber processing residues, whereas agricultural residues can be divided into two categories as follows:

- *Field or farm residues* - these are crop residues that are left in the farm after harvesting. Examples are stalks and straws
- *Agro*-processing residues - these are generated when crops are processed in the mills such as rice and coffee husk, and nut shells.

Forest waste and farm residues are sometimes classified as *primary waste* because they are generated at the source of parent biomass. Biomass waste which are generated away from the source such as in crop processing mills and timber processing, are classified as *secondary waste*. Figure 7.8 shows categorization of biomass waste by source.

[25] Tanzania Energy Policy, (2005)

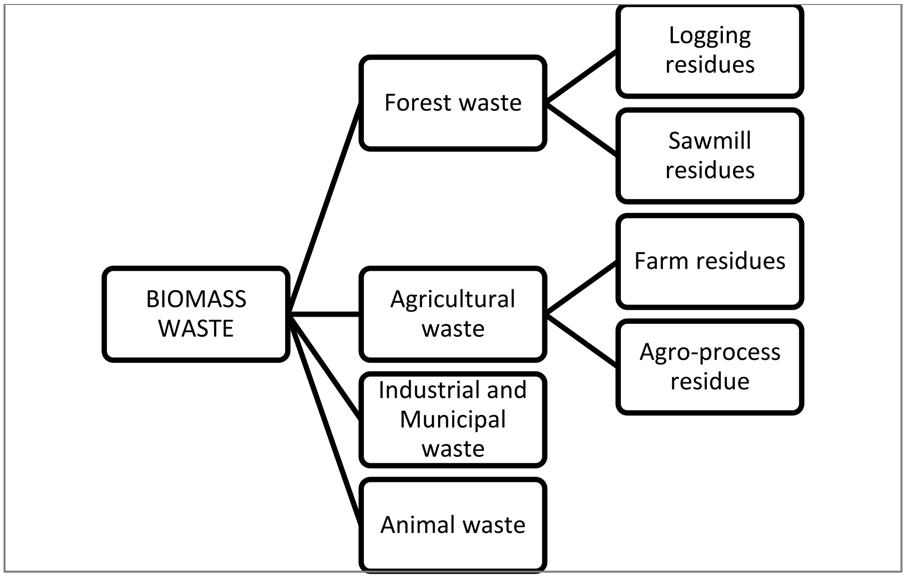


Figure 7.8 Categories of biomass waste by source

7.4.2 Forest Residues

Tanzania has a large land area (94.5 million hectares), with a tropical climate and 10 ecological zones with different physiographic zones and complex topography. About 38 percent of Tanzania's total land area is covered by forests and woodlands that provide for wildlife habitat, unique natural ecosystems and biological diversity, and water catchments. These forests are, however, faced with deforestation at a rate of between 130,000 and 500,000 hectares per year, which results from heavy pressure from agricultural expansion, livestock grazing, wild fires, production of charcoal, and unsustainable utilization of wood for construction activities, mainly in the general lands. Woodlands consist of just more than 96 percent of Tanzania's total forests. The majority of these woodlands are categorized as *Miombo*.

Forests in Tanzania can be divided into two broad categories: reserved forests and unreserved forests. About 37 percent (12.5 million hectares) and 57 percent (19 million hectares) of forests are reserved and unreserved, respectively. Reserved forests include central and local government forest reserves, government-owned industrial plantations, and village land forest reserves at the community level that have been gazetted by the central government. Unreserved forests are on "general" or "village" lands where forests and woodlands are not formally classified as reserves. Survey of the literature and websites of government institutions (Ministry, TAFORI, NBS) revealed no concrete data in relation to the exact amount of forests and woodlands in Tanzania. However, data collected by Kilahama[26] from various sources suggest woodlands and forest cover in Tanzania ranges between 33.5 – 38.5 millio ha.

The major source of forest residues is from wood harvesting and processing industries. For a typical commercially harvested tree for timber processing[27] the biomass distribution by mass is as shown in Table 7.3. Apart from the trunk which is the product, the other four components are left in the forest as waste. More waste is generated in the processing of the trunk at the sawmills. In general, the main source of forest residues is from wood industry activities, and the main components are:

[26] Kilahama, F. Impact of Increased Charcoal Consumption to Forests and Woodlands in Tanzania. 2005. http://www.coastalforests.tfcg.org/pubs/Charcoal&Forests.pdf

[27] L.P. White and L.G. Plaskett. Biomass as Fuel. Academic Press. 1981

- ***Forest harvest waste:*** This can present up to 40% of the total above-ground biomass of a clear felled forest. In addition to this are the roots which are normally not exploited.
- ***Process mill waste:*** This is composed of sawdust, bark and trimmings from sawmills, pulp plants and treated logs factories and can present up to 30% of the trunk delivered to the plant.

Table 7.3 Distribution by mass of a typical tree for timber

Tree part	Percentage (%)
Trunk	60 - 65
Top	5
Leaves and branches	10 – 15
Stump	5 - 10
Roots	10

Big-particle wastes either from forest harvesting or saw mills are normally collected by fuelwood scavengers and used for fuel. However, sawdust which is produced in large quantities in areas with many sawmills such as Iringa, Tanga and Kilimanjaro is normally not utilized with exception of small percentage of food vendors which use saw-dust semi-gasifier stoves. To a large extent the disposal of sawdust generated is a problem faced by sawmill owners. Figure 7.9 show a pile of sawdust at a sawmill in Mafinga, Iringa region.

Figure 7.9 A pile of sawdust surrounding a sawmill at Mafinga

7.4.3 Agricultural residues

Besides the intended crop products, large quantities of residues are generated in parallel with crop products every year. Rice, wheat, sugar cane, maize (corn), and groundnuts are just a few examples of crops that generate considerable amounts of residues. These residues constitute a major part of the total annual production of biomass residues can form an important source of feedstock for biomass fuels both for domestic as well as industrial purposes.

Agricultural residues can be categorized as *agro-processing (or crop-processing)* residues and *field* residues. Field residues are crop remainders that are left in the field after harvesting. They are mainly stover-type or straw-type materials. Depending on their heat value, bulk density, and distance from the village to the farms, they are not very attractive for fuel application due to economic (handling and transportation costs) and technical reasons (efficiency and emissions). Furthermore, they are thinly scattered and spread over a large area, which makes their collection laborious. These types of residues are normally left in the field, used as animal fodder, or collected and burned at the fields to control pests and diseases, among other reasons.

Agro-processing residues are crop wastes from crop processing industries mills (wastes include rice husk, coffee husk, groundnuts and cashewnut shells, and corn cobs). The main advantages of agro-processing residues is on their uniform physical-chemical properties (particle size, calorific value, moisture and ash contents), and are found in huge piles around the processing facilities within villages, small towns and cities. In most cases, the owners of the mills have to incur extra cost to dispose them according to village or city council disposal regulations.

From the above mentioned advantages, crop-processing residues have better prospects as alternative feedstock for small, medium and probably large scale densification projects to produce briquettes and pellets which will be used in tradition stoves and in ICS. This is because the collection and transport costs are much lower than those of field residues which are scattered in small farms. Furthermore, most crop-processing residues have lower moisture content compared to the field residues which will require further drying before processing for densification. The following sections highlight the crops residues which have good potential for densification projects in Tanzania.

Overview of Tanzania Agriculture Sector

Tanzania's economy depends heavily on agriculture which accounts for 45% of national GDP and provides livelihoods for 82 percent of the population. The sale of agricultural products has been the main source of cash income for 62 percent of Tanzanian households, and agriculture provides approximately 50 percent of total household income. Despite the importance of agriculture, particularly in rural areas, some 40 percent of rural household income is derived from sources outside farming activities.

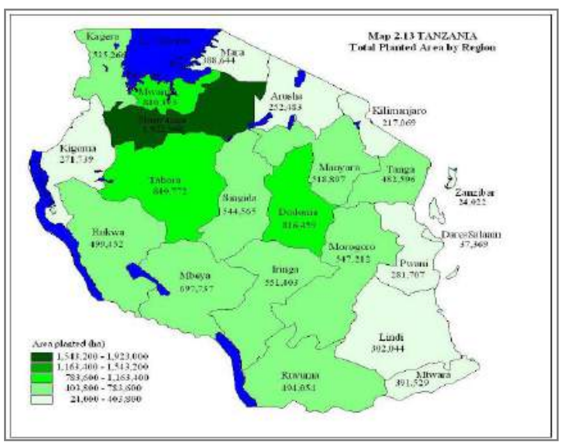


Figure 7.10 Total planted area by region (Source: National Sample Census of Agriculture. Small Holder Agriculture. Vol II. 2012)

Crops production in Tanzania is practiced either in one or two seasons per year, depending on the rainfall pattern. Areas with a unimodal rain pattern receive only the main rainy season (*Masika*) while areas with a bimodal rain pattern receive rains in two seasons, one being the short rainy season (*Vuli*) and the other being the long rain season-Masika. Masika rains occur throughout the country during which the bulk (80%) of annual crop production is obtained[28].

The total annual planted area reported in the 2007/08 Agriculture Census was 8,808,771 hectares. Regions with higher areas of cultivation are Shinyanga, Mwanza, Tabora, and Dodoma as shown in Figure.7.10. Among the annual crops, maize is the priority crop for the majority of farmers across the rainy seasons,

[28] National Sample Census of Agriculture. Small Holder Agriculture. Vol II. 2012

followed by beans, paddy, groundnuts, sorghum and sweet potatoes. Other crops which are showing apparent increasing popularity are sunflower cowpeas and sim sim.

According to the Agriculture Census (2007/08), permanent crop production is dominated by smallholders who cultivated 96 percent of the total area while only 4% of the area was planted by large scale farmers. By comparison, census data showed that most of the cultivated land in Tanzania (79% of total planted area) was planted with annual crops and the remaining 20% is permanent crops. This is indicative of the dependency of most farmers on annual and horticultural crops for household food requirements and income generation. At national level, crop production was the dominant agricultural activity which engaged 3,508,581 households (60.1%), followed by 2,268,255 (38.8%) households engaged in mixed crop and livestock, 57,770 (1%) households engaged in livestock only and only 3,917(0.1%) households are pastoralists[29]. Table 7.4 and Table 7.5 show quantities of permanent crops and major food crops produced in Tanzania for selected years.

Table 7.4 Quantities of permanent crops produced during 2007/08 season (Source: National Sample Census of Agriculture. Small Holder Agriculture. Vol II. 2012)

Table 2.8 Area Planted, Quantity Harvested and Yield by Type of Permanent Crop

Crop	Total Area Planted (ha)	Area harvested (ha)	Quantity harvested (tons)	Yield (tons/Ha)
Cashew nut	531,526	199,579	134,998	0.68
Banana	289,496	201,357	1,889,570	6.60
Coffee	197,050	132,942	186,250	1.40
Coconut	119,899	62,248	120,619	1.94
Pigeon pea	112,362	78,228	44,942	.57
Orange	67,950	42,335	197,522	4.67
Mango	64,332	24,832	190,402	7.67
Sugar cane	25,436	21,921	190,147	8.67
Cloves	15,425	4,248	8,654	2.04
Palm oil	15,411	11,830	12,217	1.03
Tea	6,796	6,388	43,588	6.82
Sisal	35	35	31	.88
Other	768,082	606,991		
Total	**2,213,801**	**1,392,935**	**3,018,940**	

[29] National Sample Census of Agriculture. Small Holder Agriculture. Vol II. 2012

Table 7.5 Quantities of major food crops' produced in 2002/03 and 2007/08 (Source: National Sample Census of Agriculture. Small Holder Agriculture. Vol II. 2012)

Production of Major Food Crops by Region in 2002/03 and 2007/08 Agricultural Years, Tanzania

Region	2002/03		2007/08	
	Maize	Paddy	Maize	Paddy
	Quantity Harvested (tons/ha)	Quantity Harvested (tons/ha)	Quantity Harvested (tons/ha)	Quantity Harvested (tons/ha)
Dodoma	149,492	2,587	350,979	1,983
Arusha	92,118	3,809	209,678	2,271
Kilimanjaro	105,222	10,724	150,138	8,831
Tanga	173,602	6,960	434,747	13,322
Morogoro	115,570	113,003	238,435	294,715
Pwani	22,991	7,062	70,265	33,207
Dar es Salaam	959	1,900	4,051	3,328
Lindi	24,854	5,180	62,571	16,814
Mtwara	29,807	4,932	63,470	22,420
Ruvuma	179,312	39,514	236,602	55,675
Iringa	265,951	8,099	384,273	17,711
Mbeya	286,213	62,780	494,810	164,065
Singida	54,396	1,973	190,491	15,051
Tabora	143,122	58,661	376,341	131,507
Rukwa	163,432	49,520	351,013	127,244
Kigoma	106,175	7,860	113,051	6,370
Shinyanga	191,402	104,847	678,746	257,944
Kagera	100,313	10,459	121,148	30,805
Mwanza	150,804	81,805	250,027	178,442
Mara	110,662	6,271	256,552	9,618
Manyara	147,773	6,674	401,389	8,360
Tanzania Mainland	**2,613,970**	**594,619**	**5,438,776**	**1,399,681**
North Unguja	1,027	2,300	2,163	5,799
South Unguja	1,432	596	1,154	2,700
Urban West	405	605	926	2,725
North Pemba	127	3,070	805	9,972
South Pemba	154	596	355	11,069
Tanzania Zanzibar	**3,145**	**7,167**	**5,402**	**32,265**
Tanzania	**2,617,115**	**601,786**	**5,444,178**	**1,431,946**

Source: Agriculture Sample Census, 2007/08

Crop-to-Residue Ratio (CRR) or Product-to-Residue Ratio (PRR)

The yield of the crop (product) has a definite relationship with the residues it creates during harvesting and processing. The crop-to-residue ratio (CRR) or product to residue ratio (PRR) is defined as the gravimetric ratio of the actual produce of the crop to the total residues generated during harvesting and processing. The accuracy of the PRR value for crops facilitates data for rough estimate of the total residues generated from the crops. A survey of literature revealed variations of the RPR values reported for different crops. It has also been acknowledged that the PRR value for a particular crop depends closely on cultivation, harvesting, and technology used to processes the final product.

Although the numbers may look very attractive for some crops, a distinction has to be made between residues generated in the field and those generated during processing. The reason for this is that it may be assumed that in the latter case residues probably will be found concentrated which will make its use, for instance as a source of energy, or disposal, more easy. In the former case (field) they may be found spread over large areas and may remain in the farms. Depending on the harvesting method used, examples of residues that often remain in the field are straw, stalks, stovers, tops and leaves.

7.4.4 Potential Residues for Fuel in Tanzania

Due to the domination of subsistence farming and small-scale rain-fed crop production in Tanzania, involvement of machinery which would assist in generation of uniform and quality crop residues in the farms is scarce. Depending on the region, a significant number of households are also engaged in livestock keeping which makes the farm residues, especially stover type, to be used for fodder and animal bedding.

The most potential crop residues in Tanzania are agro-processing residues which are generated at the processing mills. The main advantages of agro-processing residues is on their uniform physical-chemical properties (particle size, calorific value, moisture and ash contents), and are found in huge piles around the processing facilities and are easily accessible near villages, small towns and cities. In most cases, these residues have to be disposed by burning or dumping elsewhere.

Paddy Waste

Rice is one of the major staple foods in Tanzania. Although rice is grown in almost every region in Tanzania, the major paddy growing regions are Shinyanga, Mwanza, Morogoro, Mbeya, Kilimanjaro, Rukwa and Tabora, and are mainly produced by small-scale farmers. There are a few large-scale paddy farms, which used to be owned by the National Agriculture and Food Corporation (NAFCO), but have now been taken over by private farmers.

Large-scale paddy farming is generally irrigated using modern irrigation facilities while small-scale paddy farming is entirely dependent on rainfall. Small-scale paddy farming in lowlands normally uses traditional irrigation facilities. Tanzania has a big potential for the expansion of paddy farming. Paddy yield in the country has increased dramatically in recent years. Data from 2002/03 and 2007/08 seasons indicate doubling of paddy farming activities as displayed in the Table 7.5.

Paddy has two main wastes; rice straw which is left in the field after harvesting, and rice husk which are generated at rice de-hulling mills. Rice husks accumulation at the mills is a common sight when travelling in rice-growing regions as shown in Figure 7.11. Lack of significant usage of rice husks in some areas has lead to a potential disposal problem, with the main disposal means being burning. The burning of a pile of rice husk or any other smaller-particle biomass is not spontaneous due to air restriction to burn layers of husk underneath the surface for fast disposal. This result into slow smouldering of the pile, and depending on the size of the pile, the smouldering can last for weeks or even months creating poor air quality in the neighbourhood and the consequent respiratory infections.

The product-to residues ratio (PRR) of rice husk and rice straw cited in various references ranges between 0.2 to 0.33 and 0.416 to 3.96, respectively. The value for rice straw varies considerably (0.416 to 3.96) and the variation is attributed to the practice of harvesting rice in different parts of the world where the cited studies have referred. In some countries the practice is to cut the rice as low near the ground as possible, whereas in other countries only the top portion of the stem is cut leaving the remainder of the rice plant in the field.

The PRR value for rice straw in Tanzania should depend on the harvesting practices. Most paddy farmers in the country burn straws in the field with the ash used as organic fertiliser. Relatively small quantities are used as animal fodder and animal bedding. In other countries like Bangladesh, China, Vietnam and possibly India and Nepal straw is also widely used as a domestic fuel[30].

Figure 7.11 A pile of rice husks in Kyela, Mbeya region

Coffee Waste

Coffee is mainly produced in 12 out of 21 regions of the country. Based on percent area planted the leading regions are Mbeya, Kagera, Kilimanjaro and Ruvuma. Coffee is also grown by a substantial number of households in Ruvuma, Arusha as well as Kigoma. According to Tanzania Coffee Board the estimate for coffee production is 51,777 tonnes during the period 2004 -2009[31] The three main Arabica growing regions are Arusha, Kilimanjaro, Mbeya and Songea. Other Arabica areas include the Usambara Mountains, Iringa, Morogoro, Kigoma and Ngara. Robusta coffee is grown mainly in the Kagera region. More than 90% of Tanzania's coffee is produced by 400,000 smallholder farmers. Larger estates are found in Arusha, Kilimanjaro and Mbeya regions.

Coffee waste include significant amount of waste water whose treatment and disposal is an important environmental consideration for coffee processing as it is a form of industrial water pollution. The conversion of the cherry to green bean (the dried coffee bean which is ready to be exported) can be achieved through

[30] Visvanathan, C and Chiemchaisri, C. Management of Agricultural Wastes and Residues in Thailand: Wastes to Energy Approach. 1997.

[31] http://coffeeboard.or.tz

three different processing techniques: dry, semi-washed, and fully washed. In most areas of Tanzania the fully-washed process is mostly used. In this process washing of the coffee is done by the farmers through individual or cooperative washing stations.

At the washing station the outer pulp/husk is removed through a wet process. Coffee waste at the washing station is referred to coffee or cherry pulp. What is left is a coffee bean that still remains in the protective parchment casing. After drying, farmers take the coffee bean to the central processing stations where the parchment is removed and the resulting green coffee is sorted, checked for quality, and bagged for export. Coffee bean parchment (or simply referred as coffee husk) is the final waste product which accumulates and cause disposal problems in all coffee curing mills in the country as shown in Figure 7.12 taken outside the Kanyove Coffee Cooperative mill (Kigoma). The PRR values for cherry pulp and coffee husk have been reported by Julia[32] to be 1.4 and 0.25, respectively.

Figure 7.12 Pile of coffee husk at Kanyove Coffee Cooperative mill

Cashew Nut Waste

Cashews are an important export for Tanzania and an important source of income for small farmers in the coastal regions. Cashewnut is produced mainly in 6 out of the 21 regions which include Mtwara, Lindi, Coast, Tanga, Dar es Salaam and Ruvuma. Production data from the 2007/08 Agriculture Census reveals that Mtwara was the leading cashew producer followed by Lindi, Coast, and Ruvuma regions during the census period.

The main wastes from cashew are the cashew fruit (or cashew apple or false fruit) and the nut shells. In Tanzania the cashew fruits are eaten fresh as well as used to make local alcoholic drink. Attached with the fruit is the cashew kernel or the seed which has cashewnut surrounded by a tough shell, cashewnut shell, which are generated at the processing facilities to manually separate the nuts from the shells. In Tanzania more than 80% of cashewnut shells are exported with the cashew kernels hence reduce their availability as energy source[33].

Cashew nut waste (shell) accounts for about 30-50% of the cashew nut by weight. The amount of cashew nuts harvested annually is about 135,000 metric tonnes nationwide. The production of cashewnut in the

[32] Julia, C.T. Linking Energy- and Land-Use Systems: Energy Potentials and Environmental Risks of Using Agricultural Residues in Tanzania. Sustainability 2012, 4, 278-293
[33] Julia, C.T. Linking Energy- and Land-Use Systems: Energy Potentials and Environmental Risks of Using Agricultural Residues in Tanzania. Sustainability 2012, 4, 278-293

country is dominated by small-scale farmers, who produced 99.5% of the harvest in 2003[34]. According to Julia the RPR value for cashewnut shell is 2.1.

In Tanzania there are 4 large-scale and 10 medium-scale cashewnut processing facilities. The shells are abundantly available at the processing factories, such as BUCO Investment Ltd in Lindi. According to the operators of the factory, the shells produce irritant fumes when burned and hence not preferred for cooking by locals. Utilization of the shells for any other application would have positive effects to the environment, because the shells contain a poisonous liquid, cashew nut shell liquid (CNSL) which can cause serious irritations if it comes in contact with the skin. Also the leaking out of CNSL from piles of shells pollutes the soil and nearby water bodies. Currently the shells are burned to be disposed or sometimes spread on roads to fill potholes. Figure 7.13 shows a pile of cashew nut shells at BUCO factory in Lindi.

Figure 7.13 A pile of cashew nut shells at BUCO LTD Factory in Lindi

Coconut Waste

Coconut production is mainly in the coastal regions with Coast region having the largest area and highest proportion of the area planted with coconuts, followed closely by Tanga, and Lindi regions. After harvesting the coconuts are de-hulled on site leaving behind large amounts of waste, whereas the coconuts (with the shells) are transported to the markets. Both coconut wastes (coir and coconut shell) are normally used as fuel in tradition stoves. However this is only a small portion of the waste; the rest is destroyed by burning. Figures.7.14 show piles of coconuts in Lindi waiting to be de-hulled. It is important to note that large amount of the coconuts are not processed centrally but are processed and consumed by the household which have coconut trees or sold. A handbook on coconuts (PCA, 1979)[35] indicates that coconuts (on a wet basis) consist of husks (33-35%), shell (12-15%), copra (28-30%) and water (22-25%).

[34] Tanzania Agricultural Sample Census. National Sample Census of Agriculture. 2002/2003

[35] Technical data handbook on the coconut, its products and by-products, Philippine Coconut Authority, Casein City, Philippines, 1979.

Figure 7.14 Piles of coconuts before de-hulling in Lindi (L), and coconut shells after product harvest (R)

Maize Waste

Maize is the most widely planted cereal and it occupied 70% of all cereals planted in the country with Shinyanga recording the highest percentage of land under maize cultivation followed by Dodoma, Tanga, Tabora, Mbeya, Mwanza, Manyara, Iringa, Morogoro and Rukwa, in that order[36]. Countrywide, the production of maize has increased dramatically from 2.6 million tonnes in 2002/03 to 5.4 million tonnes in 2007/08 season. The main wastes from maize are stovers and cobs. Depending on the harvesting method stovers can be left in the farm or taken for the case where the whole plant is harvested. Cobs are normally available at maize de-hulling (or shelling) mills.

In many cases maize stovers are left in the field or used for fodder, while cobs become readily available at the de-hulling sites. Many small-scale farmers de-hulls maize at their homes using manual techniques as shown in Figure 7.15. The maize cobs obtained are mainly used for cooking.

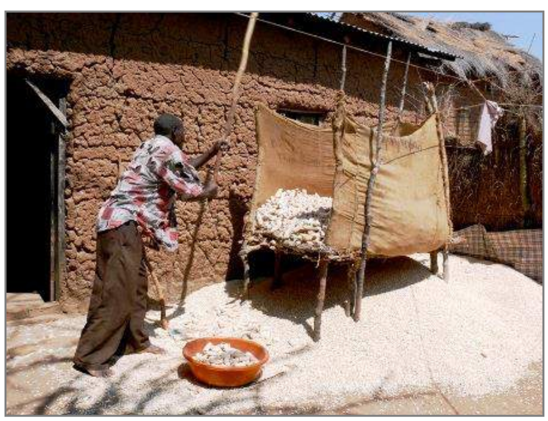


Figure 7.15 Tradition method of de-hulling maize

[36] National Sample Census of Agriculture. Small Holder Agriculture. Vol II. 2012

Other Agricultural Waste

Shinyanga, Tabora, and Dodoma, are the major ***groundnut*** production regions as recorded by the 2007/08 agriculture census and the production of groundnuts from the three regions accounted for 61.3% of the total production in the country. The main wastes from groundnuts are the plant tops (haulms) and groundnut shells. Depending on the harvesting methods, haulms can be left in the field or taken with the groundnuts for further processing. Groundnut shells are generated during the de-shelling processing at the mills. Shells from the groundnut are used as fire starters and fuel for domestic purposes. Some groundnuts are also sold to consumers with shells which make them no longer available as fuel.

In the case of ***cassava***, stalks and tops are sometimes left in the field but more often used as fuel, in particular the stem part. Cassava stalks can be used directly and the same is valid for millet stalks and pigeon pea (arhar) stalks. Using these residues as fuel is easy, as their size is quite small, they are easy to transport and they burn like fuelwood but their low density makes them burn faster than woody fuels.

Bagasse, sugar cane tops and ***leaves*** are the main residues from sugar cane. Huge amounts of sugar canes are generated in sugar plantations and industries in the country. All sugar industries in the country use bagasse in their boilers for steam generation (co-generation).

Cotton is planted in both Short and Long rain seasons, hence cotton waste are available for longer period of the year. Shinyanga region was the most important region for cotton production followed by Mwanza, Tabora, Mara, and Kagera. Cotton in Tanzania is mainly a smallholder's crop and farmers use Cotton stalks as household fuel, while cotton seed husks from the ginneries are often disposed by burning, however, a ginnery in Mwanza is using “gin trash” as fuel supplement in the boiler. Cotton cake produced after pressing the seeds for oil is mostly consumed by animal feed production sector.

7.4.5 Quantities of Agricultural Residues in Tanzania

In 1990 and 2005, the Ministry of Agriculture and Livestock estimated amounts of residues generated from major crops in Tanzania as shown in Table 7.6. Since that time no other estimates have been published. The basis for the quantities reported by the Ministry is not known, but if crop-residue ratios were used it should be cautioned that the amounts obtained only shows the theoretical amounts of residues which are generated. In practice fewer amounts should be expected due to a variety of reasons including alternative use of residues for non-energy applications.

Table 7.6 Quantities of residues estimated from major crops by the Ministry of Agriculture in 1990 and in 2005 .

Crop	Residue type	Quantity in tons (Year 1990)	Quantity in tons (Year 2002)
Maize	Stalks Cobs	4,483,623 700,569	6,116,250 954,135
Millet	Straw	577,993	361,375
Oil seeds	Shells	216,124	-
Rice	Straw Husks	917,526 140,118	1,851,878 281,418
Wheat	Straw Chaff	198,265 12,202	119,000 -
Cotton	Stalks Seed gin husks	605,776 142,552	667,500 -
Coconut	Husks Shells	462,140 136,480	321,373 92,040
Coffee	Husks	55,803	714
Sugar	Molasses Bagasse	76,000 776,000	441,670 -
Sisal	Sisal waste	900,000	
Sorghum	Straw	-	864,625

7.5 Status of Biomass Waste Utilization in Tanzania

As fuelwood scarcity increase due to population growth, increasing farmlands, and human settlements, rural villagers are beginning to rely more heavily on agricultural residues for fuel. At present, big-particle biomass residues are commonly used in tradition stoves, ICS, and SME kilns and furnaces. On the other hand, only small quantities of small-particle biomass residues (such as rice husk, coffee husk, and sawdust) are used as a supplement fuel in SMEs and industrial furnaces such as in brick kilns, and co-fired in boilers to raise steam for process heat and power generation.

In general, small-particle residues are not used in tradition stoves, conventional ICS and SME kilns and furnaces which require air to pass underneath the fuel to sustain combustion because the smaller biomass particles do not allow enough air to pass through due to small porosity they create. Small-particle residues also pose extensive pollution when used for fuel such that in places where these residues are disposed by burning, they create more air pollution, and where they are disposed by being dumped around processing mills they cause contamination to the soil and water downstream rivers and streams.

7.5.1 Biomass Waste use in Large and Medium-scale Industries

Some medium and large industries such as tea drying, sugar mills and timber processing, also completely, or to a large extent, use solid bioenergy either for direct heat generation or for co-generation of electricity and heat. Table 7.7 shows data of existing biomass waste fuelled power plants in Tanzania.

Table 7.7 Existing Biomass Fuelled Power Plants in Tanzania.

Table 7.8 Existing Biomass Fuelled Power Plants in Tanzania

Name of plant	Region	Power	Biowaste
Kilombero Sugar Company -K1	Morogoro	2MW steam turbine	Bagasse
Kilombero Sugar Company -K2	Morogoro	2.5MW steam turbine	Bagasse
Mtibwa Sugar Estate	Morogoro	3MW steam turbine	Bagasse
Tanganyika Planting Company	Kilimanjaro	2.5MW steam turbine	Bagasse
Kagera Sugar Company	Kagera	2.5MW steam turbine	Bagasse
Sao Hill Saw Mill	Iringa	1.025MW steam turbine	Sawmill Waste
Tanganyika Wattle Company	Iringa	2.5MW steam turbine	Wood waste

7.5.2 Heat Application in Small-scale Industries

Small and medium enterprises (SME) activities which require process heat are often heat intensive and use fuelwood or charcoal in large quantities making access to fuelwood within the areas difficult with the consequence of increasing fuel-fetching labour to women and degrading the local environment. SMEs utilizing biomass fuels for process heat vary in size and technology (processing temperature and heat transmission mechanisms). The fuel requirements vary widely because of differences in the firing temperature, the thermal efficiency of the conversion unit, the physical characteristics of the raw materials and the mode of operation (whether batch or continuous operation).

Rural SMEs which require heat energy include brick making, fish smoking, pottery, tobacco curing, lime making, salt drying, blacksmith, beer brewing. Despite the fact that wood fuels are the major source of heat energy in SMEs mentioned above, big-particle agricultural residues such as maize cobs and coconut shells are used when available in huge quantities. Small-particle residues and especially rice husk are also used in specially made kilns for brick making in many areas with good clay and availability of rice husk.

Most of the brick burning activities are informal, with the exception of a few formal medium-scale factories using fuelwood located in urban areas of Morogoro, Mbeya and Dodoma (Zuzu). The Kilimanjaro (KIDT) brick factory use sawdust briquettes which are made in the same factory. For smaller scale brick makers, the activity of brick making is seasonal and it takes place during the dry season. The technology of curing bricks using rice husks is likely to have first started in Mwanza Region.

In 1990, A Mwanza based NGO and 2006 Ashden Award for Sustainable Development winner, Mwanza Rural Housing Programme (MRHP)[37], developed a kiln for making burnt bricks made from local clay which uses rice husk and cotton waste instead of fuelwood to fire bricks. To date, many other regions which have access to rice husk have adopted this technology. Figure 7.16 illustrate the brick making kiln using rice husk fuel.

[37] MRHP. Laying the Foundations for Sustainable Rural Development. 2007. Tanzania

Brick Kiln using Rice Husk ***Arrangement of Bricks in Kiln using Rice Husk***

Figure 7.16 Brick burning using rice husk

Brick makers at Msamvu (Morogoro) reported that the overall quality of bricks from rice husk fuelled kilns is not as good as from fuelwood kilns[38]. According to the brick maker, they purchase both fuelwood and rice husk to fire the bricks, but rice husk is cheaper per brick compared to fuelwood. Rice husk kilns are only used if they receive a small order of bricks because of the arrangement of bricks in the husk kiln which make it to be unstable. Despite inefficient operation and lower quality of bricks compared to fuelwood kilns, rice husk has saved huge amounts of fuelwood in many areas with brick burning activities.

All coffee husk generated in coffee mills located in Arusha and Kilimanjaro regions are currently purchased by Kilimanjaro sugar factory (TPC) to fire their boiler after mixing with baggasse. Coffee husk from other mills in Mbeya (Mbozi Coffee Mill), Songea (Mbinga Coffee Mill), and Kigoma (Kanyove Coffee Cooperative) are currently not used. In these mills, piles of coffee husk create a disposal problem and they are dumped around the mills.

In the rural villages pottery making is a specialized activity for certain households and is carried out mainly by women on a part time basis during dry seasons. The process uses fuelwood or crop wastes in very inefficient methods. Normally pottery products are piled and fuel is fired directly on top. Big-particle biomass waste such as maize cobs are normally used when available as shown in Figure 7.17.

Maize cobs ***Curing of clay stoves using maize cobs at Mafinga (Iringa region)***

Figure 7.17 Maize cobs after de-hulling at a household (L), curing pottery items with maize cobs (R)

[38] Bioenergy Technology Baseline Survey. PISCES-UDSM. 2011.

7.5.3 Domestic Cooking with Biomass Waste

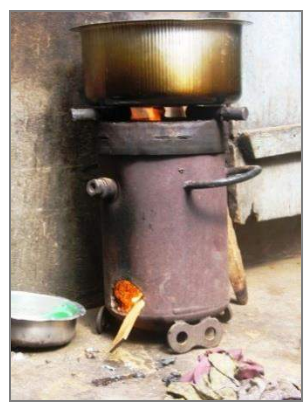
Big-particle agricultural waste such as maize cobs, coconut shells, cotton and cereal stalks, etc are commonly used in domestic stoves in areas with fuelwood scarcity such as Singida and Shinyanga regions. Apart from sawdust which is mostly used by food vendors in semi-gasifier stoves, the majority of small-particle biomass wastes which are generated from processing mills are not used in tradition stoves or conventional ICS.

A simple sawdust semi-gasifier stove which is made from circular metal enclosure with open top and a hole at the bottom side. Sawdust is compacted around cylindrical rods which are inserted into the bottom hole and at the axis of the stove. When the rods are removed, the sawdust stay agglomerated and creates a cylindrical space for airflow. The cost of sawdust stove is around the same with those of tradition metal charcoal stoves.

Though easy to make and cheap, the sawdust stove has not been very successful as a domestic stove, first due to the fragility of the compacted sawdust which may easily crumble and extinguish the stove during cooking, and secondly its batch mode of operation which does not enable the cook to add fuel (sawdust) when the fuel is finishing before the food is cooked.

Other types of small-particle residues such as rice and coffee husk cannot be simply substituted in the sawdust semi-gasifier stove because of their inability to be compacted and agglomerate around the pipes which create through holes for the fuel to burn. The ability for the biomass particles to agglomerate depends on the particle shape, texture, its flow characteristics, and moisture content. Users of the sawdust semi-gasifier stoves knows very well that when sawdust is too dry it does not compact and stay agglomerated when the pipes are removed, and they also knows that when sawdust is too wet it will not burn well. Figure 7.18 show a sawdust semi-gasifier stove which is common in most urban and suburban areas of Tanzania.

Compaction of sawdust before igniting the semi-gasifier stove



Cooking with semi-gasifier stove

Figure 7.18 Sawdust semi-gasifier stove

7.5.4 Other Uses of Biomass Waste

Crop residues have numerous competing uses such as animal feed, fodder, fuel, roof thatching, mushroom cultivation, packaging and composting. Cereal farm residues are mainly used as animal feed, hence in many areas households which have livestock use residues from their farms as fodder. Uses of residues are different in different areas. Residues which cannot be used as fodder or if the area has no livestock are left unused or burned in the field.

7.6 Environment Effects of Disposal and Excessive use of Biomass Waste

Due to biodegradable nature, several biomass wastes can be disposed off safely in small quantities in the open environment. However, accumulations of vast quantities in areas which they are generated either seasonal or continuously as in wood saw mills create air, soil and water pollution within the locality, and downstream rivers and streams. Furthermore, the practice of burning field residues in the farms after harvesting also affects global environment and reduce recycling of organic nutrients to the soil.

7.6.1 Inappropriate Disposal of Residues near Human Settlements

The major residues which are generated near human settlements in Tanzania are sawdust and crop-processing residues such as rice husk, coffee husk, cashewnut waste, and groundnut shells. A small percentage of these residues are normally used in some applications and for fuel in domestic stoves (big-particle waste) and in special stoves, furnaces and kilns. The vast majority of residues have no economic value and they occupy space surrounding the mills.

Appropriate disposal of these residues involve transporting to dumping sites located far from human settlements, which adds to the cost of the intended product. Due to lack of regulations or enforcement where they exist, operators of these mills normally burn the wastes near the mills or dump them on roads and nearby rivers and streams in order to maximize on profits. The disposal of biomass waste by dumping on nearby rivers and streams affects downstream natural habitats. To reduce the disposal problem, Mbozi Coffee Mill has constructed an air conveying system which uses blower and piping system to a specially made kiln to dispose the husk by burning. Figure 7.19 show coffee husk disposal kiln at Mbozi Coffee Mill.

Uncontrolled burning of residues produce acrid ground-level smoke and a significant amount green house gases (GHGs) such as CO_2, CO, CH_4, and N_2O, and emits large amount of particulates that are composed of wide variety of organic and inorganic species. Besides other light hydrocarbons, volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), sulphur oxides (SOx), and nitrogen oxides (NOx) are also emitted. These gases are important for their global impact and may lead to a regional increase in the levels of aerosols, acid deposition, increase in tropospheric ozone and depletion of the stratospheric ozone layer. Many of the pollutants found in large quantities in biomass smoke are known or suspected carcinogens and could be a major cause of health concerns.

Figure 7.19 Disposal system for coffee husk at Mbozi coffee mill (L) and rice husks open burning behind the mill in rural Morogoro (R)

7.6.2 Excessive Use and Burning of Farm Residues

Despite many advantages of recycling field residues to the soil, intentional burning of field residues is widely practiced in Tanzania. Reasons cited for burning field residues include:

- fast method of clearing farms to facilitate further land preparation for planting
- pests and diseases management
- burning is also perceived to boost soil fertility, although burning actually has a differential impact on soil fertility. It increases the short-term availability of some nutrients (e.g. Potasium) and reduces soil acidity, but leads to a loss of other nutrients (e.g. Nitrogen and Sulphur) and organic matter[39].

Impact on Soil Properties

Incorporation of field crop residues in soil or retention on surface has several positive influences on physical, chemical and biological properties of soil. It increases hydraulic conductivity and reduce bulk density of soil by modifying soil structure and aggregate stability. Mulching with plant residues stabilizes the soil temperature, and retention of field residues on soil surface slows rain water runoff, reduces surface crust formation, and enhances infiltration. The channels (macropores) created by earthworms and old plant roots, when left intact with no-till, improve infiltration to help reduce or eliminate runoff. Combined with reduced water evaporation from the top few inches of soil and with improved soil characteristics, higher level of soil moisture can contribute to higher crop yield in many cropping and climatic situations[40].

Loss of Nutrients

Farm (field) residues act as reservoir for plant nutrients, prevent leaching of nutrients, increase cation exchange capacity, provide congenial environment for biological nitrogen fixation, increase microbial biomass and enhance activities of enzymes such as dehydrogenase and alkaline phosphatase. Increased microbial biomass can enhance nutrients availability in soil as well as act as sink and source of plant nutrients. Leaving substantial amounts of field crop residues evenly distributed over the soil surface reduces

[39] Derpsch R and Friedrich T (2010) Global overview of conservation agriculture adoption. In Conservation Agriculture: Innovations for Improving Efficiency, Equity and Environment, (PK Joshi et al. eds), National Academy of Agricultural Sciences, New Delhi India, p 727-744

[40] Derpsch R and Friedrich T (2010) Global overview of conservation agriculture adoption. In Conservation Agriculture: Innovations for Improving Efficiency, Equity and Environment, (PK Joshi et al. eds), National Academy of Agricultural Sciences, New Delhi India, p 727-744

wind and water erosion, increases water infiltration and moisture retention, and reduces surface sediment and water runoff.

The field residues also play an important role in amelioration of soil acidity through the release of hydroxyls especially during the decomposition of residues with Carbon to Nitrogen ratio (C:N), and soil alkalinity through application of residues from lower C:N ratio crops. Yield response with residue management varies with soil characteristics, climate, cropping patterns, and level of management skills. Greater yields with residue application results from increased infiltration and improved soil properties, increased soil organic matter and earthworm activity and improved soil structure in 4-7 years from when the system is established[41].

Emission of Greenhouse Gases (GHGs) and Other Gases

The effects of emissions from uncontrolled burning of field crop residues are the same as those discussed above under crop-processing residues.

7.7 Concluding Remarks and Recommendations

The current situation on fuelwood scarcity in some areas of the country calls for immediate interventions on alternatives for fuelwood and charcoal to alleviate the problem. Briquettes are attractive alternatives because they can be used in the same stoves (tradition and ICS) which have been developed for fuelwood and charcoal. ***A quick assessment of biomass waste resource revealed good potential of utilizing the wastes for briquetting projects, however, area-specific and residues-specific information need to be gathered on the use and their availability for making fuel briquettes.*** Due to the scatter nature of most residues in the farms and small scale nature of many processing mills, promotion of briquetting projects should be of small- and medium-scale.

Apart from briquettes which can be used in tradition stoves and conventional ICS, it is recommended to promote cooking technologies such as the semi-gasifier sawdust stove which can utilize small-particle biomass waste. The full gasifier stove needs fuel particles of a certain size range to work properly by natural draft. Smaller particles like rice and coffee husk requires a fan which will need electricity source to drive the small fan. Hence, ***pelletization of smaller particle to appropriate size for natural draft gasifier stove will make the gasifier stove to have an impact in fuel scarcity areas.*** Pilot trials of *Jiko Bomba* gasifier stove with rice husk pellets in the villages in Singida, Arusha, and Shinyanga regions has recorded good acceptance of the stove.

The seasonal availability of residues and the form which they appear (foreign matter, wetness, size, etc) are important in examining the feasibility of briquetting projects. Some residues such as sawdust and rice husk are available almost throughout the year. Other residues are available during post-harvest period which could complicate the feasibility of using such residues for fuel. In areas with paddy farming and brick making activities, rice husk residues are completely unavailable for free, and it will be difficult for briquetting project to compete for rice husk.

[41] Derpsch R and Friedrich T (2010) Global overview of conservation agriculture adoption. In Conservation Agriculture: Innovations for Improving Efficiency, Equity and Environment, (PK Joshi et al. eds), National Academy of Agricultural Sciences, New Delhi India, p 727-744

Other important issues for assessing biomass waste for fuel include the following:

- Studies should be carried out to determine the possible effects of an increased use of field (farm) residues on soil conservation and degradation
- Promotion of the use of residues for a new application such as briquetting will not only put a value on the residues but may also deprive a part of the population (often the poorest) which use residues for fuel.
- There are large regional variations for particular residues according to farming and crop production patterns in the country. Hence development of a tool for assessing agricultural residues generation and inventory of amount of residues generated in different crops in different parts of the country.
- Identifying the major uses of crop residues and comparative assessment of their competing uses.
- Assessing and characterizing the quality of crop residues and their suitability for fuel application.

Appendix I: Policy Categories

A) Economic Sector Policies

- The Energy Policy of Tanzania
- National Telecommunication Policy
- Agriculture and livestock policy, 1997
- The Mineral Policy of Tanzania
- National Beekeeping Policy
- National Forest Policy
- National Tourism Policy
- The Wildlife Policy of Tanzania
- The national investment promotion policy
- Sustainable Industrial Development Policy SIDP (1996-2020)
- National Micro-Finance Policy
- Natural Forestry Policy for Zanzibar
- National Transport Policy
- National Water Policy

B) Key Development Policies/Strategies

- National Strategy for Growth and Reduction of Poverty (NSGRP)
- Tanzania Assistance Strategy (TAS)
- Poverty Reduction Strategy paper (PRSP)
- The Tanzania Development Vision 2025
- The National Poverty Eradication Strategy

C) Cross-cutting Sector Policies

- The National Science and Technology Policy for Tanzania
- The National Employment Policy
- National Environmental Policy
- National environmental policy for Zanzibar
- Cultural Policy
- National Policy on HIV/AIDS
- Cooperative development policy, 1997
- National Trade Policy
- National Livestock policy 2006
- Agricultural sector development Strategy
- Water Sector development Strategy (Draft)
- National ICT Policy
- Land Policy
- Rural Development Strategy

- National Biotechnology Policy

D) Sector Policies

- The food and nutrition policy for Tanzania
- Child Development Policy
- Community Development Policy
- National Higher Education Policy
- Education and Training Policy
- National Health Policy
- National Human Settlements Development Policy
- National youth development policy
- Sera ya Maendeleo ya Michezo
- The National Research and Development Policy
- Zanzibar Education Policy
- National Population Policy 2006
- Policy on women and gender development in Tanzania

Appendix II: Status of Various ICS Models

S/N	Developer	Stove Type	Fuel type	Stove Description	Benefits and/or Advantages	Challenges and/or Disadvantages	Development Status
1	CARE International[42], CREA Tanzania Ltd, World Vision since 1990s	Mud Stoves	Firewood	***Construction* materials: E**arthen mixture (sand, clay, cow dung, sawdust). Mostly constructed without chimneys. **Efficiency:** Can save firewood up to average of 20% compared to three stone stoves **Testing protocols:** Public demonstrations; WBT in Uganda **Cost:** Self help; in-kind, low cost **Market penetration:** Low	• Easy to construct and use • Cheap • Use local materials • Saves fuelwood • Reduces emissions • No special tools required	• Low durability • Monitoring quality of stoves is difficult • Not easy to standardize • Cracks • Frequency repairing	*Promotion stage*
2	ProBEC[43] under GTZ (now GIZ) and MEM 2005 - 2010	Lorena Rocket mud stove	Firewood	**Construction materials:** Clay soil, mud, sometimes mixed with anthill soil, straw or grass, ash, the base is constructed using bricks; normally constructed with chimneys made of mud. **Efficiency:** Can save firewood up to average of 30% - 60% compared to three stone stoves **Testing protocols:** Public demonstrations **Cost:** TZS 10,000 – 30,000	• Easy to construct and use • Use low cost local materials • Saves fuelwood • Reduces emissions • No special tools required • Durable	• Massive • Occupies large space • Frequency of attendance to the stove • Not easy to standardize • Cracks • Frequency repair (re-smearing)	*Did not go beyond field testing due to very low acceptability by the user in the selected testing area (Marangu District). Trained artisans continue to construct them at low scale*

[42] Firewood saving stoves; A review of stove models compiled by Susanna Makela; Liana 2008: wwww.liana-ry.org
[43] Draft Country Experience Report, Tanzania Programme for Basic Energy and Conservation - 2010

S/N	Developer	Stove Type	Fuel type	Stove Description	Benefits and/or Advantages	Challenges and/or Disadvantages	Development Status
				Market Penetration: very low acceptability			
3	CAMARTEC, ProBEC, Morogoro Fuelwood Stove Project (MFSP)	Clay stoves: • Upesi stove • Maendeleo stove • Morogoro stove	Firewood, Charcoal	**Construction materials:** Clay soil, sand, water, ashes. **Efficiency:** Can save firewood up to 60%[44] compared to three stone stoves **Testing protocols:** Public demonstrations, WBT, KPT **Cost:** TZS 10,000 – 30,000 **Market penetration:** Low.	• Use low cost local materials • Saves fuelwood • Reduces emissions	• Requires pottery and ceramic skills • Requires additional space for drying, a kiln and firewood for firing the stoves • Long distances between houses in rural areas • Delicate (requires careful handling) • Little motivation to buy a stove	*Promotion stage*
4	TaTEDO	Okoa Brick Stoves	Firewood	**Construction materials: Basic stove without a barrel:** Fired bricks or stones. The stoves are fixed with chimneys. They can be constructed for cooking and heating; cooking, heating and boiling water or multipurpose (cooking, heating, boiling water and baking). **Barrel:** Attached to the stove for storing warm water. The barrel is made of cement mortar and	• Saves fuelwood[45] • Reduced IAP • Cash saving on fuel expenditure • Income generated from surplus firewood • Fast cooking compared to three stone	• Occupy space • Use of not well dried firewood • Stack cleaning of chimney • Skills	*Promotion stage*

[44] Burning woodstoves www.keneweb woodstoves

[45] Verification of efficient stove project in Kilimanjaro, Tanzania by Oscar Kibazohi, April 2010

S/N	Developer	Stove Type	Fuel type	Stove Description	Benefits and/or Advantages	Challenges and/or Disadvantages	Development Status
				metallic pipe. **Efficiency:** Average of 60% – 70% **Testing protocols:** WBT, field evaluation **Cost:** TZS 70,000 - 200,000 **Market penetration:** Low.			
5	ProBEC	Fixed Rocket Brick stoves	Firewood	**Construction materials:** Burnt bricks, insulative bricks, sand, cement, lime, wire mesh, hard paper for insertion of air risers without chimney. **Efficiency:** Average fuel savings of between 50% – 60% compared to three stone stoves **Testing protocols:** Field demonstrations **Cost:** TZS 25,000 - 40,000 **Market penetration:** Low	• Saves fuelwood • Reduces emissions	• Availability of cement and wire mesh in rural areas • Requires skills	*Field testing and promotion stages*
6	ProBEC	Portable rocket stoves (claded stoves)	Firewood, charcoal	**Construction materials:** Insulative bricks, mild steel sheets, Galvanized mild steel sheets, Cement, Hydrated Lime, round bar, flat bar. **Efficiency:** Average fuel savings of between 50% – 60% compared to three stone stoves **Testing protocols:** Field demonstrations, WBT **Cost:** TZS 25,000 - 40,000	• Saves fuelwood • Reduces emissions • Income generation	• Heavy • Availability of insulative bricks • Require skills • Expensive for households	*Promotion stage*

S/N	Developer	Stove Type	Fuel type	Stove Description	Benefits and/or Advantages	Challenges and/or Disadvantages	Development Status
				depending on the stove size and cost of materials **Market penetration:** Low			
7	GTZ (now GIZ), MEM (under Special Energy Programme), UTAFITI (now COSTECH), CAMARTEC	Dodoma stove (All Metal stove)[46]	Charcoal	**Construction materials:** Scrap metals; wrap up metals, oil drums. The stove has an insulation gap between double walls **Efficiency:** Average of 36% **Testing protocols:** WBT **Cost:** TZS 10,000 – 20,000 **Market penetration:** Registered significant sales in Dodoma, Arusha, Tanga, and Dar es Salaam. General penetration is low	• Saves fuel • Reduces emissions, • Income generation, • Reduces expenditure on fuel	• Uses a lot of scrap metal compared to all metal stove • Requires skills • Availability of quality scrap metals	*Promotion stage*
8	MEM, TaTEDO	Jikobora (claded stove)	Charcoal	**Construction materials:** clay, rice husk ashes, vermiculite, sand, metal, cement **Efficiency:** Average of 29 -35% **Testing protocols:** WBT, KPT, Evaporation Test **Cost:** TZS 10,000 – 20,000 **Market penetration:** very high	• Materials locally available • Easy to produce • Saves fuel • Reduces emissions • Income generation • Employment opportunities	• Require pottery skills • Availability of metal and vermiculite	*Promotion stage*
9	COSTECH, ProBEC	KUUTE stove (Claded)	Charcoal	**Construction materials:** clay, rice husk ashes, vermiculite, sand, metal, cement	• Materials locally available • Easy to	• Require pottery skills • Availability of metal and vermiculite	*Promotion stage*

[46] Draft country study research report by N.C. X. Mwihava; H.A. Mbise; L. Mzava; and G. Kibakaya

S/N	Developer	Stove Type	Fuel type	Stove Description	Benefits and/or Advantages	Challenges and/or Disadvantages	Development Status
				Efficiency: Average of 29 -30% **Testing protocols:** WBT, KPT, Evaporation Test **Cost:** TZS 10,000 – 20,000 **Market penetration:** very high	produce • Saves fuel • Reduces emissions • Income generation • Employment opportunities		
10	Kiwia and Lausten Ltd	Jiko Bomba	Pellets	**Testing protocols:** WBT, KPT, CCT Cost: TZS 40,000 **Market penetration:** low	• Alternative to fuelwood • Reduces emissions • Uses locally available materials	• Require reliable supply of pellets • Require training to use stove	*Field testing and Promotion stages*
11	L'S Solutions, ProBEC	Imported stoves: - envirofit stove - StoveTech	Charcoal, Firewood	**Construction materials:** Imported stove manufactured in industries using high technology **Efficiency:** Average of 30% **Testing protocols:** Tested where manufactured and by Approvevo institute of the USA **Cost:** TZS average of 30,000 **Market penetration:** Low.	• Saves fuel • Reduces emissions • Income generation • Employment opportunities	• Imported • Costly for rural population • Difficult to repair	*Promotion stages*

Appendix III: CCT Data

COOK 1: MWAJUMA

STOVE TYPE	MWAJUMA - CCT RESULTS					
3-STONE		**Test 1**	**Test 2**	**Test 3**	**Mean**	**St Dev**
	Total weight of food cooked (g)	2245	2242	2396	**2294**	88
	Equivalent dry wood consumed (g)	620	541	475	**545**	72
	Specific fuel consumption (g/kg)	276	241	198	**239**	39
	Total cooking time (min)	28	24	24	**25**	2
MATAWI-I		**Test 1**	**Test 2**	**Test 3**	**Mean**	**St Dev**
	Total weight of food cooked (g)	2335	2405	2283	2341	61
	Equivalent dry wood consumed (g)	322	363	374	353	28
	Specific fuel consumption (g/kg)	138	151	164	151	13
	Total cooking time (min)	**29**	**28**	**30**	**29**	**1**
<u>Comparison</u> 3-STONE vs MATAWI-I		**% difference**		**T-test**	**Sig @ 95% ?**	
	Specific fuel consumption (g/kg)	**37%**		**3.7**	**YES**	
	Total cooking time (min)	**-14%**		**-2.4**	**NO**	
MATAWI-Y		**Test 1**	**Test 2**	**Test 3**	**Mean**	**St Dev**
	Total weight of food cooked (g)	2461	2424	2505	**2463**	41
	Equivalent dry wood consumed (g)	338	224	284	**282**	57
	Specific fuel consumption (g/kg)	137	92	113	**114**	22
	Total cooking time (min)	33	26	26	**28**	4
<u>Comparison</u> 3-STONE vs MATAWI-Y		**% difference**		**T-test**	**Sig @ 95% ?**	
	Specific fuel consumption (g/kg)	52%		4.8	**YES**	
	Total cooking time (min)	-11%		-1.0	**NO**	
PORTABLE		**Test 1**	**Test 2**	**Test 3**	**Mean**	**St Dev**
	Total weight of food cooked (g)	2461	2406	2508	**2458**	51
	Equivalent dry wood consumed (g)	236	296	234	**255**	35
	Specific fuel consumption (g/kg)	96	123	93	**104**	17
	Total cooking time (min)	24	21	24	**23**	2
<u>Comparison</u> 3-STONE vs PORTABLE	**Comparison of 3-stone and Portable**	**% difference**		**T-test**	**Sig @ 95% ?**	
	Specific fuel consumption (g/kg)	56%		5.5	**YES**	
	Total cooking time (min)	10%		1.5	**NO**	

COOK 2: ANASTERIA

STOVE TYPE	ANASTERIA – CCT RESULTS					
3-STONE		**Test 1**	**Test 2**	**Test 3**	**Mean**	**St Dev**
	Total weight of food cooked (g)	2348	2275	2201	**2274**	74
	Equivalent dry wood consumed (g)	438	453	425	**439**	14
	Specific fuel consumption (g/kg)	187	199	193	**193**	6
	Total cooking time (min)	30	26	24	**27**	3
MATAWI-Y	**2. CCT results: Matawi-I Stove**	**Test 1**	**Test 2**	**Test 3**	**Mean**	**St Dev**
	Total weight of food cooked (g)	2591	2396	2483	2490	98
	Equivalent dry wood consumed (g)	322	269	329	306	33
	Specific fuel consumption (g/kg)	124	112	132	123	10
	Total cooking time (min)	30	26	25	27	3
<u>Comparison</u>		% difference		T-test	Sig @ 95% ?	
3-STONE	Specific fuel consumption (g/kg)	36%		10.2	YES	
vs	Total cooking time (min)	**-1%**		**-0.1**	**NO**	
MATAWI-I						
MATAWI-Y		**Test 1**	**Test 2**	**Test 3**	**Mean**	**St Dev**
	Total weight of food cooked (g)	2380	2392	2377	**2383**	8
	Equivalent dry wood consumed (g)	247	245	236	**243**	6
	Specific fuel consumption (g/kg)	104	102	99	**102**	2
	Total cooking time (min)	18	20	20	**19**	1
<u>Comparison</u>		**% difference**		**T-test**	**Sig @ 95% ?**	
3-STONE	Specific fuel consumption (g/kg)	47%		24.3	**YES**	
vs	Total cooking time (min)	27%		3.9	**YES**	
MATAWI-Y						
PORTABLE		**Test 1**	**Test 2**	**Test 3**	**Mean**	**St Dev**
	Total weight of food cooked (g)	2385	2381	2341	**2369**	24
	Equivalent dry wood consumed (g)	285	251	247	**261**	21
	Specific fuel consumption (g/kg)	120	106	106	**110**	8
	Total cooking time (min)	25	29	25	**26**	2
<u>Comparison</u>		**% difference**		**T-test**	**Sig @ 95% ?**	
3-STONE	Specific fuel consumption (g/kg)	43%		14.1	**YES**	
vs	Total cooking time (min)	2%		0.2	**NO**	
PORTABLE						

COOK 3: SHIGELA

STOVE TYPE	SHIGELA – CCT RESULTS

3-STONE		**Test 1**	**Test 2**	**Test 3**	**Mean**	**St Dev**
	Total weight of food cooked (g)	**2563**	**2423**	**2285**	**2423**	**139**
	Equivalent dry wood consumed (g)	**415**	**412**	**369**	**399**	**26**
	Specific fuel consumption (g/kg)	**162**	**170**	**162**	**165**	**5**
	Total cooking time (min)	25	19	23	**22**	3
MATAWI-I		**Test 1**	**Test 2**	**Test 3**	**Mean**	**St Dev**
	Total weight of food cooked (g)	2268	2241	2404	**2304**	87
	Equivalent dry wood consumed (g)	388	406	289	**361**	63
	Specific fuel consumption (g/kg)	171	181	120	**157**	33
	Total cooking time (min)	24	23	25	**24**	1
<u>Comparison</u> 3-STONE vs MATAWI-I	**Comparison of 3-stone and Matawi-I**	**% difference**		**T-test**	**Sig @ 95% ?**	
	Specific fuel consumption (g/kg)	4%		0.37	NO	
	Total cooking time (min)	-7%		-0.90	NO	
MATAWI-Y		**Test 1**	**Test 2**	**Test 3**	**Mean**	**St Dev**
	Total weight of food cooked (g)	2499	2434	2423	**2452**	41
	Equivalent dry wood consumed (g)	240	265	240	**248**	15
	Specific fuel consumption (g/kg)	96	109	99	**101**	7
	Total cooking time (min)	21	25	25	**24**	2
<u>Comparison</u> 3-STONE vs MATAWI-I			**% difference**		**T-test**	**Sig @ 95% ?**
	Specific fuel consumption (g/kg)		**38%**		**13.3**	**YES**
	Total cooking time (min)		-4%		-0.4	NO
PORTABLE		**Test 1**	**Test 2**	**Test 3**	**Mean**	**St Dev**
	Total weight of food cooked (g)	2487	2568	2406	**2487**	81
	Equivalent dry wood consumed (g)	271	244	287	**267**	22
	Specific fuel consumption (g/kg)	109	95	119	**108**	12
	Total cooking time (min)	23	32	29	**28**	5
<u>Comparison</u> 3-STONE vs PORTABLE		**% difference**			**T-test**	**Sig @ 95% ?**
	Specific fuel consumption (g/kg)		35%		7.5	**YES**
	Total cooking time (min)		-25%		-1.8	**NO**

Appendix IV: Questionnaire for Envirofit Stove Users

A: HOUSEHOLD INFORMATION	
1. Date	
2. Name of Interviewer	
3. Village/street	
4. Arusha	

B: INFORMATION ON ICS		
5. What other stoves are present in the kitchen/household?		
6. Does the ICS (Envirofit) stove appear as if it has been used recently? Yes ....No................		
7. Does it appear as if other stove(s) are also being used? Yes /No What stove(s)?........................, ..., ...		
8. What is the condition of the ICS stove? Are there other noticeable damages? Yes / No Which parts?............................		
9. How long has the family been using the ICS stove (months or years)?		
10. Is it easier or more difficult to cook with the new ICS stove? Describe why.	Easier...... Harder........	Why?
11. What does the cook like most about the ICS stove?		
12. Is there anything that the cook would change about the new stove? Or recommendations for improvement of the improved stove?		
13. What problems does the cook have with the improved stove? Indicate Yes or No as appropriate.		

Issue	Problem exists (Yes/No)	Better/worse than old stove:
a. The ICS stove is hot to the touch and causes burns		
b. The pots are not stable		
c. Fire turns pots black		
d. ICS Stove makes a lot of smoke		
e. ICS Stove is hard to start		
f. It is difficult to cook certain foods (list locally appropriate foods below)		
g. Stove is too small for the size of pots I use		
h. Other problems (list) • • •		
i. Does it save fuelwood. Estimate of the cook in % on saving fuelwood compared to the old stove		