Firewood-saving stoves

A review of stove models
based on the documentation on the Internet

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1. Justification of the review and some useful further introductory reading

Over the past few decades innumerable organisations and projects have developed models of firewood-saving stoves. It can be a daunting task for a person unfamiliar with the field to try to make some sense of what is available and what is already known about these stoves. Organisations and projects often concentrate solely on their own stove model comparing it with the traditional three-stone fireplace rather than with other existing firewood-saving stoves. As Liana needed information on stoves for a new project, we looked for a comparative review, but could not find one. This report was compiled to serve Liana's operations in East Africa by providing an introductory information package of the main categories and models of firewood-saving stoves documented on the Internet. The report is by no means a comprehensive study of all firewood-saving stoves, not even of all the ones found on the Internet. The report looks at small-size stoves that use firewood and which have been used in several projects so that there is enough information to describe the stove adequately. The stoves described here have been at least tested in Africa, however the original stove model might have been produced and used also somewhere else. The aim of this report is to guide the selection of stove models for further testing with the end users in order to narrow down the number of potentially useful models for our project areas.

Useful general information on energy-saving stoves, see for example:

- Cooking Options in Refugee Situations. A Handbook of Experiences in Energy Conservation and Alternative Fuels. Report of UNCHR.[1]
- http://en.wikipedia.org/wiki/Biomass_Cook_Stoves
- www.aprovecho.com
- http://bioenergylists.org/
- www.repp.org
- www.hedon.info//Category:ImprovedStoves
- www.hedon.info/goto.php/BoilingPoint
- www.practicalaction.org

2. Earlier studies and tools for comparing stove performance

Much useful material on how to compare stove performance is available. Some examples of tools and methods for comparative studies include:

- Controlled cooking test by Aprovecho[2]
- Benefit Matrix for improved stove dissemination projects[3]
- What makes people cook with improved biomass stoves. A Comparative International Review of Stove Programs[4]
- Biomass stoves: Engineering design, development and dissemination by Samuel Baldwin[5]

According to Ashok Gadgil and Susan Amrose who made a research of energy-saving stoves in a refugee camp in Darfur, Sudan, there are five factors in determining fuel efficiency[6]:

1. Skill / training of the cook tending the stove
2. Fuel (diameter, moisture content, density, wood species, etc.)
3. Stove design
4. Fit of the pot to the stove
5. Type of food and type of cooking performed

References to results of comparative tests found on the Internet are given in the next section.

3. Information for initial comparisons of different types of firewood-saving stoves

Well-documented, small stoves using primarily firewood, and potentially suitable for further testing in Liana's project areas in the drylands of East Africa were picked for a closer look. These are grouped under the main categories of mud-stoves, metal stoves and fired clay stoves.

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[1] www.unhcr.org/protect/PROTECTION/406c368f2.pdf
[2] www.aprovecho.org/web-content/publications/assets/CCT_simple.pdf
[3] www.un.org/esa/sustdev/csd/csd15/lc/gtz_tool.pdf
[4] http://go.worldbank.org/ZOBLWLDE30
[5] http://sleekfreak.ath.cx:81/3wdev/VITAHTML/SUBLEV/EN1/BIOSTOV.HTM
[6] www.bioenergylists.org/stovesdoc/LBNL/Darfur_FES.pdf

3.1 Mud-stoves

Mud-stove is used here to describe any improved form of stove compared to traditional "three-stone-fireplace". Mud stoves are usually easy to build with simple training, and material is available locally. The most basic improvement to the open fire involves filling in two sides with a mud or clay wall to prevent through-draughts (see 3.1.1), but stoves built of mud can also use so called rocket technique (fuel is fed to the combustion chamber through L-shape fuel magazine) and be suitable for 2 or 3 pots (see 3.1.2).

Mud-stoves are designed primarily for firewood, but can be adapted also for charcoal.

According to UNCHR report it is a mistake to try to standardise mud-stove designs. Innovation should be encouraged to make the stove comfortable and familiar for the user, which will ensure more extensive use of the stove. Still there are some basic principles to follow such as distance from ground to the base of a cooking pot. Basic principles and other very good information can be found from Appropriate mud stoves in East Africa by Stephen Gitonga.[7]

3.1.1 Traditional 1-pot mud stove

Description

a. *Who/which organisation invented/introduced and when, to be used where?*
1-pot mud stoves have been used in Africa for decades. It has very basic improvements compared to traditional three-stone fireplace – it has a mud surround to reduce heat loss and protect fire from wind.

b. Examples of organisations which have promoted the stove (links also contain more detailed information of construction and/or test results of a particular model)

- Action Aid has promoted mud stoves in Somalia in 1980's.[8]
- Aprovecho[9]
- Gaia Movement[10]

c. *What is it like and how does it work?*
The traditional mud stove is made by using earthen mixture of sand and clay. Some fixed models also use bricks to form the base of the stove, but for example Aprovecho has developed a portable model using only sand, clay and sawdust. It weighs approximately 6 kg.[11] It uses wood as fuel but can be adapted to charcoal. Most of the traditional models do not have chimneys. Mud stoves can be built in big sizes, however compared to fired clay stoves they are not very durable and they suit best for indoors, where they are not affected by rain.[12]

d. How is it made?
Materials: Earthen mixture (for example sand, clay, cow dung), possibly also bricks (for the base), sawdust (improving insulation and make it more lightweight), newspaper or cardboard for making the gap between the stove and the pot.

- *Skills and tools:* easy to make locally
- *Instructions:* see for example Appropriate mud stoves in East Africa by Stephen Gitonga.[13]

e. What's so special about this model?
Traditional mud stove is easy to make with practically no cost. Still compared to three-stone fireplace it saves fuel and can even slightly decrease harmful emissions.[14] Also compared to three-stone fireplace it provides stability to the pot and increases safety of a covered fire.[15] However, as the fire is covered it lacks

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[7] http://practicalaction.org/practicalanswers/product_info.php?products_id=319&osCsid=7cu2kv9ecg2fhqqpu0tresrrq2&osCsid=7cu2kv9ecg2fhqqpu0tresrrq2

[8] http://www.hedon.info/BP8:MudStovesInSomalia

[9] http://www.repp.org/discussiongroups/resources/stoves/apro/mudstove.html

[10] http://www.gaia-movement.org/files/stove%20manual%20TWP%20Gwembe.pdf

[11] http://www.repp.org/discussiongroups/resources/stoves/apro/mudstove.html

[12] http://www.hedon.info/ImprovedCookstovesInMalawi

[13] http://practicalaction.org/practicalanswers/product_info.php?products_id=319&osCsid=7cu2kv9ecg2fhqqpu0tresrrq2&osCsid=7cu2kv9ecg2fhqqpu0tresrrq2

[14] http://www.repp.org/discussiongroups/resources/stoves/apro/mudstove.html

[15] http://www.hedon.info/BoilingPoint4

the warmth and light provided by three-stone fireplace. Another problem is that 1-pot mud stove is designed for specific pot size. If the household is using many pots in different sizes, many stoves or a 2-pot model is needed.

f. *What has been learned about its performance and how does it compare with others similar?*
Energy savings of about 20% over three-stone fireplaces are achievable with basic mud-stoves[16].

A common problem with mud stoves is that a lot of energy is wasted in heavy stove mass. Sand and clay cannot work as insulation as such.[17] In Aprovecho's model sawdust is used to lighten the wall and to create better insulation. The narrow channel on the sides of the pot increases the amount of heat that gets into the pot and leaves larger air space between the pot and the wall, which helps to insulate the fire and reduces heat lost into the earthen wall.

Surrounding the fire with earthen walls protects the fire from the wind, which helps saving fuel. If the air space between the pot and the walls is missing, too much heat will be lost into the wall. Like the three-stone fireplace it is difficult to keep the fire lit in this stove. However, adding a grate that lifts the wood up above the ground would help a small fire to keep burning. According to tests traditional mud stove boiled 1 litre of water in 3 min 24 sec. It used 81.1 g of fuel.[18]

According to a study performed in Darfur refugee camps, one-pot mud stoves can have several problems in design and dissemination. Common design flaws were that stove did not provide primary air supply, monitoring the fire was difficult and building of one stove took one man-day. In dissemination good quality was difficult if not impossible to maintain resulting to poor performing stoves.[19]

g. *How much does it cost?*
Cost for making the stove is normally free or a least very low.

Images of the stove

Picture 1. 1-pot mud stove promoted by ITDG[20]

More pictures, see: http://www.repp.org/discussiongroups/resources/stoves/apro/mudstove.html

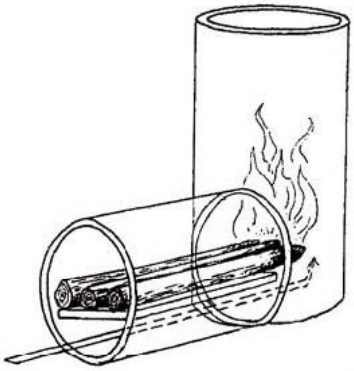
[16] http://www.unhcr.org/protect/PROTECTION/406c368f2.pdf
[17] http://www.hedon.info/EfficiencyOfHeavyMudStoves
[18] http://www.repp.org/discussiongroups/resources/stoves/apro/mudstove.html
[19] www.bioenergylists.org/stovesdoc/LBNL/Darfur_FES.pdf
[20] www.bioenergylists.org/stovesdoc/LBNL/Darfur_FES.pdf

3.1.2 Rocket mud stoves

Description

a. *Who/which organisation invented/introduced and when, to be used where?*
The rocket stove principles were developed about 10 years ago by Dr. Larry Winiarski at the Aprovecho Research Center in Oregon.[21]

The idea of a rocket stove is that it has "an elbow". Fuel is fed to the combustion chamber through vertical J-shaped elbow or horizontal L-shaped fuel magazine. Fuel magazine is small for two reasons: it encourages the user to feed wood in bit by bit and also it stops too much cool air to enter combustion chamber.[22] The fuel magazine often has a (metal) shelf for fuel to allow air to flow underneath. Insulated combustion chamber is in the bottom of a small internal chimney. Very often rocket mud stoves also have external chimneys to remove smoke from the kitchen.



Picture 2: Idea of the rocket stove [23]

Lorena stove is one of the most commonly named rocket mud stoves on the Internet. In 1976 consultants from the Aprovecho Research Center helped to design the Lorena stove in Guatemala.[24] Since then it has been used in several projects all over the world and there is also several different designs from the original Lorena (see for example http://www.cooking-energy.org/stove-fact-sheets/New/DRaft_Rocket_Lorena_Uganda_Stove_fact_sheet-lf-ed.pdf)

b. Some examples of projects where rocket mud stoves have been promoted successfully:
- USAID field research in IDP camps in Northern Uganda 2005 (Lorena)[25]
- Chimp-n-Sea project in Kibale, Uganda 2006 – 2008 [26]

c. *What is it like and how does it work?*
The rocket mud stove is a wood-burning stove, which is available as a mobile unit or can be fixed in the kitchen by a trained stove installer. The stove is designed for household use and is suitable for both large and small families.[27]

Lorena stove is quite massive, fixed stove. It has a chimney to remove smoke from the kitchen and it comes in 2-pot or 3-pot versions.[28] It uses a single combustion chamber and can heat several pots simultaneously as the hot gasses pass through internal heat distribution tunnels. The original Lorena was designed for mountainous areas where in addition of cooking at the daytime it can use stored heat for heating at night time.[29]

The stove model used in Kibale was a fixed model, using the same rocket principle.

[21] www.boingboing.net/2008/06/26/rocket-stoves-use-tw.html
[22] http://www.paceproject.net/UserFiles/File/Energy/improved%20stoves.pdf
[23] http://www.paceproject.net/UserFiles/File/Energy/improved%20stoves.pdf
[24] http://www.hedon.info/IncreasingFuelEfficiencyAndReducingHarmfulEmissionsInTraditionalCookingStove
[25] www.usaid.gov/our_work/economic_growth_and_trade/energy/publications/EGAT0020.PDF
[26] http://www.chimp-n-sea.org/projects/kibale-community-fuel-wood-project/plan/family-stoves/
[27] http://www.hedon.info/RocketMudStovesInKenya
[28] http://www.hedon.info/IncreasingFuelEfficiencyAndReducingHarmfulEmissionsInTraditionalCookingStove
[29] www.usaid.gov/our_work/economic_growth_and_trade/energy/publications/EGAT0020.PDF

d. *How is it made?*
   - *Materials:* The Lorena stove is made from mud (clay), sometimes mixed with straw or anthill soil (for better efficiency). Stove model used in Kibale needs brick, mud, ash and metal.
   - *Skills and tools*: stoves can be produced by local artisans and no special tools are needed
   - *Instructions to build Lorena stove*: http://www.appropedia.org/Rocket_Lorena_Stove

e. *What's so special about this model?*
In general rocket stove is easy construct, and it uses low-cost materials. Because of the design it burns efficiently and produces less smoke.

Lorena stove is generally not very widely promoted in Africa, but it has been taken widely (by NGO's) to Uganda where it is the dominant firewood-saving stove. The word "lorena" is now often used in Uganda as a generic term to describe a fuel-saving stove, irrespective of the design. [30] Because of the external chimney, it removes smoke from the kitchen. It is very durable, once built it is estimated to last even for 10 years.[31] However, the problem is that building Lorena is time-consuming and it occupies a large space from the kitchen.

Rocket principle can also be used in metal stoves, but mud is often more cost effective and an easy way of building stoves. As all rocket models, fuel should be in small pieces, i.e. also twigs can be used. Compared to traditional three-stone fireplace, they also reduce risk of burning, as the fire is not open.

f. *What has been learned about its performance and how does it compare with others similar?*
As with many other stove models, rocket mud stove has very different study results for its abilities to save firewood. In general, the rocket mud stoves can save up to 50 – 70 % firewood compared to traditional three-stone fireplace.[32]

Lorena stove was studied with water boiling test and controlled cooking tests in USAID's study in Ugandan IDP camps. Lorena was compared against traditional mud stoves, 6-brick stove and 1-pot moulded stove. Out of these Lorena got the worst results and in water boiling test it was more inefficient than open fire. Also in controlled cooking test it ended up using 14 % more firewood than open fire. According to the study, reasons for this are for example combustion chamber which is not insulated, design that allows pot surfaces be largely exposed to air, not stove's body. Lorena stove was also found difficult because of its big size.[33]

However there are also studies which have shown that Lorena Stove has been able to save up to 60 % compared to traditional three-stone fireplace, provided that it's installed and used correctly.[34] Much of the efficiency seems to depend on the density of the materials.[35]

In Kibale project, the stove used on average 37 % less firewood compared to cooking with three-stone fireplace.[36]

g. *How much does it cost?*
Cost of a Rocket Lorena Stove has been estimated to 4 EUR (life span 4 years) in Uganda in 2005 [37]
Deviation of the price seems to be quite high varying between 1-20 USD[38]
In Kibale, the cost has been USD 2, which is mainly the cost of the metal sheet. [39]

[30] www.usaid.gov/our_work/economic_growth_and_trade/energy/publications/EGAT0020.PDF
[31] http://www.appropedia.org/Rocket_Lorena_Stove
[32] http://www.hedon.info/RocketMudStovesInKenya
[33] www.usaid.gov/our_work/economic_growth_and_trade/energy/publications/EGAT0020.PDF
[34] www.gtz.de/de/dokumente/en-cost-benefit-analysis-uganda-2007.pdf
[35] http://www.appropedia.org/Rocket_Lorena_Stove
[36] http://www.chimp-n-sea.org/projects/kibale-community-fuel-wood-project/plan/family-stoves/
[37] www.gtz.de/de/dokumente/en-cost-benefit-analysis-uganda-2007.pdf
[38] www.cooking-energy.org/stove-fact-sheets/New/DRaft_Rocket_Lorena_Uganda_Stove_fact_sheet-lf-ed.pdf
[39] http://www.chimp-n-sea.org/projects/kibale-community-fuel-wood-project/plan/family-stoves/

Images of the stove

Picture 3: Lorena 2-pot stove[40]

Picture 4: Lorena 1-pot stove[41]

[40] www.cooking-energy.org/stove-fact-sheets/New/DRaft_Rocket_Lorena_Uganda_Stove_fact_sheet-lf-ed.pdf
[41] http://www.cooking-energy.org/stove-fact-sheets/New/Draft_Shielded_Fire_Stove_fact_sheet.pdf

3.2 Metal-stoves

Metal stoves can be built simply by using scrap metal, however building requires semi-skilled artisans. Simple models use firewood, but metal stoves can also be adapted to use charcoal. Even if the production costs are fairly low, the metal body radiates heat so the energy savings are relatively low (25 % at most). Also the metal stoves usually do not last very long.[42]

3.2.1 The metal rocket stove

Description

a. *Who/which organisation invented/introduced and when, to be used where?*
General description of rocket stove principles, please see 4.2 (Mud rocket stoves).

b. Some examples of projects where rocket mud stoves has been promoted successfully:

- Project in Uganda to build portable, commercially viable household rocket stoves [43]
- Winiarski rocket stove has been successfully built in 20 countries in the last 13 years.
- VITA stove, which was designed by Sam Baldwin in the early 1980's. [44]
- Probec-GTZ project in Malawi [45]
- SunSmiles project in Mauritania in 2005[46]

c. *What is it like and how does it work?*
Compared to rocket mud stoves (see 4.2), metal rocket stoves are usually 1-pot solutions, lightweight and thus portable. Like the rocket mud stove it also uses small pieces of wood, branches and twigs. Most common models do not have external chimneys.

d. How is it made?

- *Materials:* Scrap metal (such as tin cans). Insulation material (for combustion chamber) should be as light as possible and full of air pockets, such as ashes, pumice rock or perlite. However, if these are not available, sand and clay can be used, but it reduces the efficiency and makes the stove heavier.
- *Skills and tools:* A tool to cut thin metal sheet. Building of a metal rocket stove is estimated to take one day.
- *Instructions how to build a metal rocket stove:*
  www.repp.org/discussiongroups/resources/stoves/Scott/ugandarocket/Uganda_Household_Rocket.pdf
  http://www.howtopedia.org/en/How_to_Build_a_Winiarski_Rocket_Stove
  www.bioenergylists.org/stovesdoc/Still/AprovechoPlans/Rocket%20Stove%20Design%20Guide.pdf

e. What's so special about this model?
Compared to rocket mud stoves metal ones are smaller, more lightweight and portable. They are still effective, because of insulated combustion chamber. Pot size can be made adjustable.

f. What has been learned about its performance and how does it compare with others similar?
SunSmiles tested several stove types in Mauritania and they found that rocket stoves consumed less firewood compared to traditional three-stone fireplace. Their rocket stoves worked better than for example VITA stoves, because rocket stoves were able to use different pot sizes. The metal elbow is estimated to last from 6 to 12 months and in a metal rocket it is easy to replace, compared to rocket stove made of insulated bricks. However the metal stove is more expensive than stove built of bricks.[47]

g. How much does it cost?
Aprovecho has evaluated the price varying between 100 – 200 Rand depending on which material is used.[48] In a stove project in Uganda, the retail price of the metal stove was estimated to USD 16.[49] In a project in Malawi cost for the more modest model has been estimated to approximately 15 USD in 2006.[50]

[42] http://www.unhcr.org/protect/PROTECTION/406c368f2.pdf
[43] http://www.repp.org/discussiongroups/resources/stoves/Scott/ugandarocket/Uganda_Household_Rocket.pdf
[44] http://www.howtopedia.org/en/How_to_Build_a_Winiarski_Rocket_Stove
[45] http://www.cooking-energy.org/stove-fact-sheets/Malawi%20-%20Stove%20Fact%20Sheet_Rocket%20household%20Portable.pdf
[46] http://www.sunsmiles.org/slide_show/MauriPhotoWeb/index.html
[47] http://www.sunsmiles.org/slide_show/MauriPhotoWeb/index.html
[48] http://www.bioenergylists.org/stovesdoc/Still/AprovechoPlans/Rocket%20Stove%20Design%20Guide.pdf
[49] http://www.repp.org/discussiongroups/resources/stoves/Scott/ugandarocket/Uganda_Household_Rocket.pdf

h. Where is it made and/or sold at the moment?
These stoves are mainly made by local craftsmen.

Images of the stove

Picture 5: A metal rocket stove[51]

Picture 6: A metal rocket stove[52]

3.2.2 The Tara

Description

a. *Who/which organisation invented/introduced and when, to be used where?*
The Tara is a cylindrical, metal stove developed for low-income peasants in India by Development Alternatives (www.devalt.org) in 1980's. [53]

b. Some examples of projects where the Tara has been promoted successfully:
- Study of fuel-efficient stoves in Darfur by Lawrence Berkeley National Laboratory and University of California, Berkeley [54]

c. *What is it like and how does it work?*
The Tara is a portable design which can be hand-built or mass produced. It is multi-fuel stove, which can use firewood, charcoal etc. It can be adjusted for several pot sizes. It has openings on both sides for air and fuel and the cooking pot rests on brackets just beneath the top rim of the stove. Tara does not have a chimney.

d. How is it made?
- *Materials:* sheet metal
- *Skills and tools*: can be produced in local workshops

e. What's so special about this model?
The Tara seems to be an efficient metal stove. One of the strengths is that it can be adjusted for several pot sizes. It is relatively easy to produce with quite low cost. It also has low smoke emissions.

f. *What has been learned about its performance and how does it compare with others similar?*
The Tara is tested to have very low smoke emissions and high efficiency under field conditions in India.[55]

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[50] http://www.cooking-energy.org/stove-fact-sheets/Malawi%20-%20Stove%20Fact%20Sheet_Rocket%20household%20Portable.pdf
[51] www.bioenergylists.org/stovesdoc/LBNL/Darfur_FES.pdf
[52] http://www.repp.org/discussiongroups/resources/stoves/Scott/ugandarocket/Uganda_Household_Rocket.pdf
[53] www.bioenergylists.org/stovesdoc/LBNL/Darfur_FES.pdf
[54] www.bioenergylists.org/stovesdoc/LBNL/Darfur_FES.pdf
[55] www.bioenergylists.org/stovesdoc/LBNL/Darfur_FES.pdf

In side-by-side tests in Darfur refugee camps the Tara was tested as best out of four different stove models (other ones were the ITDG, the Priyagni and the Rocket Stove). It was demonstrated to save 50 % of fuel as compared to traditional three-stone fireplace. However it had a few design flaws such as stove tended to tip when food was stirred hard and performance degraded under windy conditions.[56]

g. How much does it cost?
Cost in Sudan in year 2005 has been estimated to USD 10.[57]

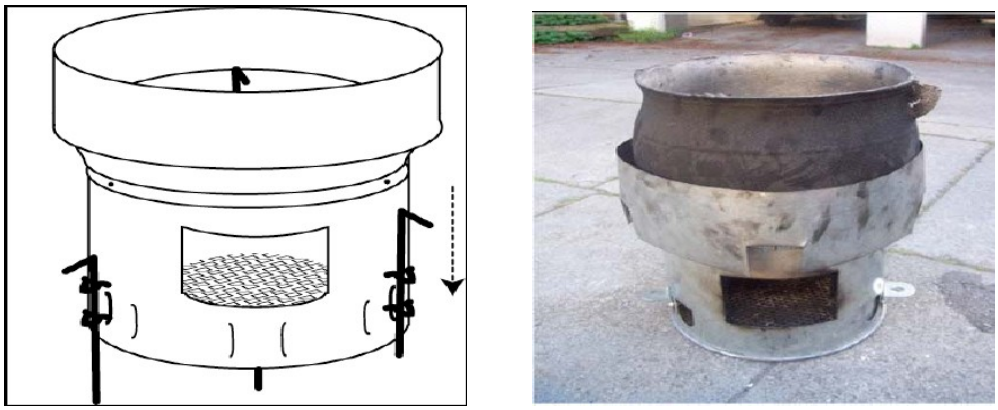
h. Where is it made and/or sold at the moment?
No information of retailers available. However, see Berkeley Tara for instructions for building more efficient version of the Tara.

Images of the stove

Picture 7: The Tara[58]

Berkeley Tara

Berkeley Tara is a more developed version of the Tara as a result of study performed in Darfur refugee camp. The new Berkeley Tara stove was developed by scientists at the University of California's Lawrence Berkeley National Laboratory (LBNL). Compared to the original Tara it has wind shields to maintain the stove performance under windy conditions and also pegs to improve stability. [59]



Picture 8: Modified version of Tara and Berkeley Tara prototype [60]

[56] www.bioenergylists.org/stovesdoc/LBNL/Darfur_FES.pdf
[57] www.bioenergylists.org/stovesdoc/LBNL/Darfur_FES.pdf
[58] www.bioenergylists.org/stovesdoc/LBNL/Darfur_FES.pdf
[59] www.bioenergylists.org/stovesdoc/LBNL/Darfur_FES.pdf
[60] www.bioenergylists.org/stovesdoc/LBNL/Darfur_FES.pdf

When Berkeley Tara was compared with original Tara, it had relative fuel savings from 8 % up to 75 % depending on food prepared and wind (see more details in www.bioenergylists.org/stovesdoc/LBNL/Darfur_FES.pdf, pp. 26 – 28). Compared to traditional three-stone stove savings were estimated to 70 – 75 %. [61] See more information of developing and testing Berkeley Tara: http://eetd.lbl.gov/staff/gadgil/docs/2006/darfurcookstove_final.ppt

Building instructions and more information of Berkeley-Tara: www.darfurstoves.org/darfur-stove.

Estimated making price of Berkeley Tara in Sudan in 2006 was USD 15. [62]

3.2.3 VITA Stove

Description

a. *Who/which organisation invented/introduced and when, to be used where?*
VITA stove was designed by Sam Baldwin in the early 1980's. [63]

b. Some examples of projects where the VITA has been promoted successfully:
VITA stove seems to be quite well known and widely used stove, however no links to single projects using VITA was found.

c. *What is it like and how does it work?*
The VITA stove is a single pot stove that can be constructed easily from sheet metal. It is inexpensive to build and is suitable for cooking outdoors and in refugee situations.

The VITA stove is a simple metal cylinder that surrounds a dedicated pot. The cylinder is slightly larger than the pot, creating a small channel (6mm to 14mm depending on pot size) all around the pot. Hot flue gases are forced to scrape against the sides of the pot after touching the bottom. The increased heat transfer efficiency improves fuel used, time to boil, etc. compared to the three stone fireplace.[64] The air inlets and size of the opening into the fire are scientifically designed. The VITA stove demonstrates how a narrow channel works, forcing more of the heat into the sides of the pot. The grate in the VITA stove allows air to pass up through the burning wood, which helps to maintain the fire.[65]

d. How is it made?
- *Materials:* sheet metal
- *Skills and tools:* hammer and chisel, but also special tools such as a press for forming the pot support can be used to reduce time. Can be produced by unskilled workers, with supervision and a few days of training.[66]
- *Instructional video:* Building a VITA stove: http://www.aprovecho.org/web-content/media/vita/vita.html (link also contains a pdf document for building the stove)

e. *What's so special about this model?*
The main arguments for using the VITA stove are that it is relatively low cost stove which is easy to build. It also cooks rapidly, and as with all metal stoves, fire is contained, which reduces risk of burns.

f. *What has been learned about its performance and how does it compare with others similar?*
One problem with VITA stove is that it can only fit one size pot. For this reason it was discarded in SunSmiles project in Mauritania. However, it was the cheapest stove tested, had good handles and cooked rapidly.[67]

In water boiling tests done at Aprovecho, the three stone fire used 1118g of kiln dried Douglas fir to boil and simmer (for 45 minutes) 5 litres of water. The VITA stove used 689g. The three stone fireplace boiled the 5 litres in 26.7 minutes. The VITA stove boiled the water in 14.0 minutes. However, it did produce

[61] www.bioenergylists.org/stovesdoc/LBNL/Darfur_FES.pdf
[62] www.bioenergylists.org/stovesdoc/LBNL/Darfur_FES.pdf
[63] http://listserv.repp.org/pipermail/stoves_listserv.repp.org/2007-July/006902.html
[64] http://listserv.repp.org/pipermail/stoves_listserv.repp.org/2007-July/006902.html
[65] http://www.reap-canada.com/online_library/IntDev/id_mts/MTS%20Performance%20Report%20by%20Aprovecho.pdf
[66] http://www.cd3wd.com/cd3wd_40/vita/stovport/EN/STOVPORT.HTM
[67] http://www.sunsmiles.org/slide_show/MauriPhotoWeb/index.html

high amount of CO.[68] See more detailed information in studies for improving VITA: http://listserv.repp.org/pipermail/stoves_listserv.repp.org/2007-July/006902.html

g. How much does it cost
No information found.

Images of the stove

Picture 9: Vita stove [69]

3.2.4 KSG Metal Stove

Description

a. *Who/which organisation invented/introduced and when, to be used where?*
This stove was introduced by Kisangani Smith Group in Tanzania in 2005.[70]

b. Some examples of projects where the KSG stove has been promoted successfully:
No other examples were found, but the stove project (and design) got Ashden Awards in 2008 especially for their sawdust burning stove.[71] However this report concentrates on the KSG stove that uses firewood.

c. *What is it like and how does it work?*
The stove is designed to burn wood more efficiently and has a sheet metal exterior, lined with clay and bricks to form the combustion chamber. The stove burns firewood and is portable.

The stove is lit by inserting burning wood in the inlet port and setting light to it. Once the fire is established, a cooking pot is put in place. Due to the high thermal mass, this stove takes some time to heat up but once the bricks and clay are hot, they retain their heat well. Pieces of wood are continually inserted to keep the fire burning. The expected life of these stoves is three to five years.[72]

d. How is it made?
- *Materials*: sheet metal, clay and bricks
- *Skills and tools*: needs trained blacksmiths
- *How to construct a KSG stove:*
  The wood stove has a cylindrical body about 400 mm tall and 400 mm in diameter, with feet to raise it off the ground. At one side an entry port at the base serves as the air inlet. The lid has a pot stand, and a heat spreader. Stove parts are cut from sheet metal according to eight templates and then fastened by folding and riveting. Once the metal body and entry port have been made, the floor of the stove is covered with clay. Insulating bricks are fitted around the sides and held in with clay, making sure that the air inlet is kept free. The bricks help to form an internal chimney and direct the combustion gases towards the hole in the centre of the lid. A steel tube is used to pack the clay and smooth the top

[68] http://listserv.repp.org/pipermail/stoves_listserv.repp.org/2007-July/006902.html
[69] http://www.bioenergylists.org/en/taxonomy/term/220
[70] http://www.ashdenawards.org/files/reports/ksg_case_study_2008_0.pdf
[71] http://www.ashdenawards.org/files/reports/ksg_case_study_2008_0.pdf
[72] http://www.ashdenawards.org/files/reports/ksg_case_study_2008_0.pdf

surface. The stove lid normally remains in place once it has been attached, but it can be removed for maintenance.[73]

e. *What's so special about this model?*
The wood stove is similar to other designs, but still has potential for replication given its simplicity of manufacture.

f. What has been learned about its performance and how does it compare with others similar?
Preliminary measurements suggest that this stove uses 75% less wood than an open fire, and opinions of users confirm this. For users, the main advantage of the stove is saving the time and drudgery of collecting wood, but they also find it allows quicker and cleaner cooking.

KSG demonstrated the sawdust and wood stoves to Government officials in 2005, and measured how much wood the two stoves and an open fire used to complete the same cooking task. Based on these approximate measurements, KSG estimates fuelwood use of about 24 m3/year for an open fire, compared with 6 m3/year for the wood stove and 2 m3/year for the sawdust stove.[74]

g. How much does it cost?
The cost of the stove is around 30.000 TSh (in 2005, about USD 27).[75] Stoves are sold mainly through retailers, who place bulk orders with KSG at trade fairs and are given a small discount on the price. Purchasers pay for their stoves in full in cash: no credit system is offered by KSG.[76]

h. *Where is it made and/or sold at the moment?*
Contact Kisangani Smith group: +255 754 458 126 or kisagroups@yahoo.com

Images of the stove
No images available, but a short video clip can be found from Ashden Awards:
http://www.ashdenawards.org/winners/ksg08

3.2.5 The Vesto

Description

a. *Who/which organisation invented/introduced and when, to be used where?*
The stove was developed by New Dawn Engineering (Crispin Pemberton-Pigott) in Swaziland.[77] It has been designed for mass production, and the prices are set so that it would be in the reach of low income households.

The Vesto has been given the Chairman's Special Award for design by the Design Institute of South Africa (DISA) in 2004. The stove was also a winner in the Houseware category of the annual event held by the South African Bureau of Standards to promote design excellence.[78]

b. Some examples of projects where the Vesto stove has been promoted successfully:
- New Dawn Engineering in Swaziland[79]
- Blue Ventures Carbon Offset - Energy Efficient Stoves Programme in Madagascar and South Africa [80]

c. *What is it like and how does it work?*
The Vesto is a one-pot stove based on a modified 25 litre paint can. It consists of five main components:
1) the main stove body with a wire handle
2) the fire grate with holes punched through it, including a replaceable insert at the bottom
3) the folded stainless steel strip to support the pots
4) the secondary air controller
5) the primary air controller.

[73] http://www.ashdenawards.org/files/reports/ksg_case_study_2008_0.pdf
[74] http://www.ashdenawards.org/files/reports/ksg_case_study_2008_0.pdf
[75] http://www.ashdenawards.org/files/reports/ksg_case_study_2008_0.pdf
[76] http://www.appropedia.org/Sawdust_stove
[77] http://www.vesto.co.za
[78] http://www.vesto.co.za
[79] http://www.newdawnengineering.com/website/trader/
[80] http://www.bvco.org.uk/documents/BVCO_Newsletter_3.pdf

The steel sheet cylinder is 45 cm in height and has a diameter of approximately 35 cm.[81] Air and therefore also the fire is controlled by separate levers. Air also insulates the firebox and the recycled heat is transferred to the fire.[82]

In addition of firewood, the Vesto can use a variety of biomass. It weighs about 5 kg and is portable. That way it can be lit outside and then carried inside for cooking. This in itself reduces harmful smoke emissions. The Vesto can be used both for cooking and heating the kitchen.[83]

d. How is it made?

- *Materials*: metal
- *Skills and tools*: for industrial mass production only

e. *What's so special about this model?*
The Vesto' efficiency is based on preheating of the primary and secondary air. Thus it uses only one third of fuel used normally for cooking. Still it is a low cost stove but it has been designed rather for mass production than local handmade production.

f. What has been learned about its performance and how does it compare with others similar?
Probec tested the efficiency of the Vesto and found out that 70 – 75 % savings of combustion material compared to three-stone fireplace could be achieved. When refilling firewood to Vesto, the pot has to be lifted, which increases risk of burns. Life expectancy of the Vesto has not been established, but it is made in thin sheet metal and is thus prone to corrosion in wet regions. [84]

Aprovecho tested several stove types in Lesotho. The Vesto was not adopted by the households, but the reason remained unclear. It was suspected that the Vesto did not work well together with the iron pot used in the area. [85]

g. How much does it cost?
The cost of Vesto has been tried to keep the same as large size pot, in the region of USD 20 – 30 [86]

h. *Where is it made and/or sold at the moment*
See www.vesto.co.za

Images of the stove

Picture 10: The Vesto[87]

[81] http://www.probec.org/docs/LaboratorytestVestostove.pdf
[82] http://www.hedon.info/NewDawnEnergySystemsSouthAfrica
[83] http://www.hedon.info/NewDawnEnergySystemsSouthAfrica
[84] http://www.probec.org/docs/LaboratorytestVestostove.pdf
[85] http://www.repp.org/discussiongroups/resources/stoves/Scott/lesotho/Part%201Lesotho%20report2004.pdf
[86] http://www.vesto.co.za/vesto/vesto1.htm
[87] http://www.vesto.co.za/vesto/vesto1.htm

3.3 Fired Clay Stoves

Producing fired clay stoves requires quite high expertise and they need very high quality ingredients (clay) compared to traditional method of making clay pots. However, if made properly, they can be more effective than metal stoves (up to 40 % compared to the traditional three-stone stove, depending on the source).

To make fired clay stoves requires a firing kiln. For building instructions, see:
http://www.hedon.info/KilnConstruction

3.3.1 The Upesi/ The Maendeleo

Description

a. Who/which organisation invented/introduced and when, to be used where?
The Upesi Stove was developed in the mid-1980s by the Kenyan Ministry of Energy, the German government agency GTZ and the Kenyan national women's organisation Maendeleo ya Wanawake, and has been growing in popularity ever since.[88] The stove is also known as Maendeleo.

b. Some examples of projects where the Upesi has been promoted successfully:
- The Sustainable Technology Education Project in Kenya[89]
- Upesi Project by ITDG initiated in 1995 in Kenya[90]

c. What is it like and how does it work?
The Upesi is a one-pot stove with no chimney. It is made of a pottery cylinder (known as the stove liner), built into a mud surround in the kitchen. It can be used to burn wood or farm waste such as maize stalks and animal dung. Upesi means 'fast' in Swahili, because the stove not only cuts fuel use, it also cooks food faster.[91] It has low cost and it can be built locally.[92] It can use firewood, animal dung, maize husks or cane stalks. It appears to have a life span of 4 years.[93] Upesi as such is not portable, but portable versions have also been introduced (see for example Practical Action's guide How to make an Upesi[94]).

Main disadvantages with Upesi are that it produces less light and less heat than three-stone fireplace. However, the clay stores a lot of heat so it can be used for heating also. The Upesi needs pottery skills and equipment to make the stove liner. It needs maintenance (mud smearing) in every 1- 2 months.[95]

d. How is it made?
- *Materials:* clay, sand, water, stove liner (for installing mud, ashes and stones)
- *Skills and tools:* pottery skills
- *Instructions:*
  * Practical Action: How to Make an Upesi Stove
  http://practicalaction.org/practicalanswers/product_info.php?products_id=304
  * Boiling Point no 28 (1992)
  http://nzdl.sadl.uleth.ca/cgi-bin/library?e=d-00000-00---off-0envl--00-0--0-10-0---0---0prompt-10---4-------0-1l--11-en-50---20-about---00-0-1-00-0-0-11-1-0utfZz-8-00&a=d&c=envl&cl=CL3.17&d=HASH016f1ae266f1bb906e829b4e.17
  * Instructions for installing the Upesi
  http://www.zhn.cz/literatura/uzitecne_manualy/cd3wd/pottery/A%20Guide%20to%20Make%20your%20Own%20Maendeleo%20One-pot.pdf

e. What's so special about this model?
In ITDG's project in Kenya it was found that the stove model not only saved firewood and reduced smoke, it also created a source of income to women, who were making the stoves.[96]

[88] http://www.paceproject.net/UserFiles/File/Energy/improved%20stoves.pdf
[89] http://www.stepin.org/casestudy.php?id=upesistove&page=1
[90] http://www.hedon.info/TheUpesiRuralStovesProject
[91] http://www.paceproject.net/UserFiles/File/Energy/improved%20stoves.pdf
[92] www.bioenergylists.org/stovesdoc/LBNL/Darfur_FES.pdf
[93] http://www.hedon.info/TheUpesiRuralStovesProject
[94] http://practicalaction.org/practicalanswers/product_info.php?products_id=304
[95] www.probec.org/fileuploads/fl11122007190326_stovewshop03matrix.xls
[96] http://www.hedon.info/TheUpesiRuralStovesProject

In most cases the stove liner is produced commercially and the installation (mud surround) is then built locally from local ingredients.

As Upesi is quite heavily insulated, it stores heat compared to some metal stoves and thus suits best for foods that need to be cooked for a long time. Also the pot rests have been designed so that they are suitable for foods that need heavy stirring such as ugali.

f. *What has been learned about its performance and how does it compare with others similar?* Practical Action claims 50 – 60 % reduction in wood use and a large reduction in harmful smoke exposure. However according to study performed in Darfur refugee camp neither claim is supported by data. [97]

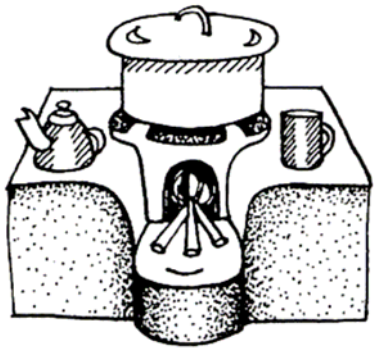
ITDG's Upesi project in Western Kenya says the Upesi can save up to 43 % compared to three-stone fireplace. Users have been able to save in health costs (as the amount of smoke has been reduced) as well as in firewood costs. [98] However, the price of the stove has been a problem, as in rural areas firewood is free and thus poor families have not been willing to pay the price of the stove.[99]

The Upesi is relatively easy to build if pottery skills are available. It needs to be mass produced. It has been estimated that the mould equipment costs at least £100 and in addition space to store drying liners and a place to work is needed. Therefore it is not viable to make less than 100 stoves per month.[100]

g. *How much does it cost?*
According to Probec the stove price is 2 - 3 USD for the liner and total installation price is 5 USD.[101]

h. *Where is it made and/or sold at the moment?*
No information found

Images of the stove



Picture 11: Upesi stove[102] [103]

[97] www.bioenergylists.org/stovesdoc/LBNL/Darfur_FES.pdf
[98] http://www.hedon.info/TheUpesiRuralStovesProject
[99] http://www.hedon.info/RocketMudStovesInKenya
[100] http://practicalaction.org/practicalanswers/product_info.php?products_id=304
[101] www.probec.org/fileuploads/fl11122007190326_stovewshop03matrix.xls
[102] http://www.paceproject.net/UserFiles/File/Energy/improved%20stoves.pdf
[103] http://www.repp.org/discussiongroups/resources/stoves/Ezzati/Home%20Page%20of%20Majid%20Ezzati_files/Lira-Upesi.jpg

3.3.2 *Mulanje (fired portable clay stove)*

Description

a. *Who/which organisation invented/introduced and when, to be used where?*
Integrated Food Security Programme in Mulanje, Malawi. Stove is also known as Chitetezo Mbaula.

b. *Some examples of projects where the Mulanje has been promoted successfully:*
- Integrated Food Security Programme in Mulanje, Malawi. For project evaluation made in 2004, see: www.gtz.de/en/dokumente/en-mw-impact-assessment-2005l.pdf

c. *What is it like and how does it work?*
Mulanje is a one pot portable stove. It can burn firewood, maize husks, pigeon pea stalks etc. and also use small pieces of wood, such as branches and twigs. It is relatively easy to produce locally with local materials, but it needs pottery clay and firing kiln.

Average life span if the stove is 1 – 3 years.[104]

d. *How is it made?*
- *Materials:* (pottery) clay
- *Skills and tools:* some pottery skills, firing kiln – though stove can also be used without firing
- *Instructions:* http://www.hedon.info/goto.php/view/404/forum.htm

e. *What's so special about this model?*
Mulanje is a portable stove model, which can also be used without firing the clay – however firing prolongs its life span.

f. *What has been learned about its performance and how does it compare with others similar?*
IFSP's programme tested the stove and according to them it can save up to 60% compared to three-stone fireplace. Some users have even reported savings as high as 80% because Mulanje can burn also maize husks and pigeon pea stalks (which are not easy to use in three-stone fireplace).[105]

Mulanje tends to break especially above the fire grate and if left in rain. Cracking can be reduced by adding more sand to the clay mixture, and broken stove can be reused as a liner for fixed mud stove.

g. *How much does it cost?*
1- 2 USD in 2006[106]

h. *Where is it made and/or sold at the moment?*
Produced locally

Images of the stove

Picture 12. The Mulanje[107]

[104] http://www.cooking-energy.org/stove-fact-sheets/Stove%20Fact%20Sheet_Portable%20Clay.pdf

[105] http://www.probec.org/fileuploads/fl120336415824046800HEDON_How-To_Guides_Different_types_of_energy_saving_stoves_in_Southern_Malawi.pdf

[106] http://www.cooking-energy.org/stove-fact-sheets/Stove%20Fact%20Sheet_Portable%20Clay.pdf

3.3.3 The Six Bricks Rocket Stove

Description

a. Who/which organisation invented/introduced and when, to be used where?
The six brick stove was developed with the technical input from Aprovecho.[108]

b. Some examples of projects where the Six Brick Stove has been promoted successfully:
- Aid Uganda 2004[109]

c. What is it like and how does it work?
As the name says, the six brick stove is built with six bricks, which are formed so that the stove uses a rocket principle. There might also be two more bricks that are used at the stove entrance or as an elbow.[110] The bricks which form the combustion chamber are very lightweight, made of perlite and clay (also other materials can be used, see reference).[111]

The bricks stand on one end in a circle and are tied together with a wire. The front of a stove has a hole, where the fuel is passed. To make the stove more stable and safe it can be surrounded by mud or metal.

d. How is it made?
- *Materials:* perlite, clay, possibly mud and metal
- *Skills and tools:* pottery skills, kiln
- *Instructions:* Making an insulated metal stove: http://www.repp.org/discussiongroups/resources/stoves/Still/VC%20Stove/vcstove.html

e. What's so special about this model?
The six brick stove has very good insulation and is therefore able to burn in very hot temperatures. Brick can be installed in mud or metal stoves, or even used without any surroundings.

f. What has been learned about its performance and how does it compare with others similar?
Compared to stoves made with mud or metal, but without the insulative bricks, the six brick stove seems to be more efficient. It lasts longer in very hot temperatures and is so also able to burn more efficiently and it also produces less smoke.[112] However, making of the bricks need pottery skills and a kiln, so they are at their best in mass production.

USAID tested the six brick stove and compared to the three-stone fireplace, the stove was at least slightly better in both controlled cooking test and water boiling test.[113] Some references say that the six brick stove uses half or less fuel compared to open fire.[114]

g. How much does it cost?
Making of the six bricks is around 2-3 USD.[115]

h. Where is it made and/or sold at the moment?
No information available.

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[107] http://www.hedon.info/goto.php/view/404/forum.htm
[108] www.usaid.gov/our_work/economic_growth_and_trade/energy/publications/EGAT0020.PDF
[109] http://aiduganda.home.comcast.net/~aiduganda/
[110] http://www.bioenergylists.org/en/darfursixbricks
[111] http://www.repp.org/discussiongroups/resources/stoves/Ogle/Clay/MAKING%20LIGHT%20WEIGHT%20REFRACTORY%20CERAMIC.pdf
[112] http://www.repp.org/discussiongroups/resources/stoves/Still/VC%20Stove/vcstove.html
[113] www.usaid.gov/our_work/economic_growth_and_trade/energy/publications/EGAT0020.PDF
[114] http://www.bioenergylists.org/en/darfursixbricks
[115] http://aiduganda.home.comcast.net/~aiduganda/

Images of the stove

Picture 13: The Six Brick Stove

3.4 Comparative matrix of the main categories of firewood-saving stoves

Advantages and disadvantages of most common types of firewood-saving stoves:[116]

	Advantages	Disadvantages
Mud stoves	Easy to build Require only locally available materials Costs nothing or very low Can be sized to fit the family's own pots Can be maintained by the owner Can promote self-led innovation and home improvement Up to 25% fuel efficient	Low durability Requires regular repair (re-smearing)
Metal stoves	Portable Suitable for charcoal or firewood Production provides source of income for artisans	Often of low durability due to use of flimsy cooking oil tins Hot exterior can be dangerous Maximum 20-25% efficient
Fired clay stoves	Durable Fuel-efficient (up to 30%) May be portable, depending on style Potential for producers to generate income from sale	High degree of ceramics expertise required Need high quality clay, moulds and access to kiln Firing requires firewood Refugees may not buy stoves, prompting need for subsidy
Combination clay/metal stoves	Durable Prestigious Portable Most fuel efficient (30%+) Safe Can be made to burn either firewood or charcoal Potential for producers to generate income from sale	High degree of expertise needed in ceramics and metalwork Raw materials needed, some of which may be hard to source (e.g. vermiculite for attaching liner to cladding) Refugees may not buy stoves, prompting need for subsidy

Other further reading:
Selected examples of household stoves in developing countries:
http://www2.gtz.de/hep/english/e09b.htm
Comparison between various cooking stoves for households by Probec:
www.probec.org/fileuploads/fl11122007190326_stovewshop03matrix.xls
Comparisons of stove types used in Darfur:
http://www.darfurstoves.org/darfur-stove/chartOfStoves.pdf

[116] www.unhcr.org/protect/PROTECTION/406c368f2.pdf