

New Rocket Stove Designs for Central and Southern Africa



PETER SCOTT

JAYME VINEYARD

APROVECHO /GTZ

apropeter@hotmail.com



Our approach in Africa

- Principles, not one particular stove
 - Adapt to cooking culture – easier to change the stove than change the cook
 - Goal of zero training and zero maintenance
 - Affordable
 - durable
 - commercial viability
 - Target communities that use a mixture of charcoal and wood if possible
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Rocket Bread Oven



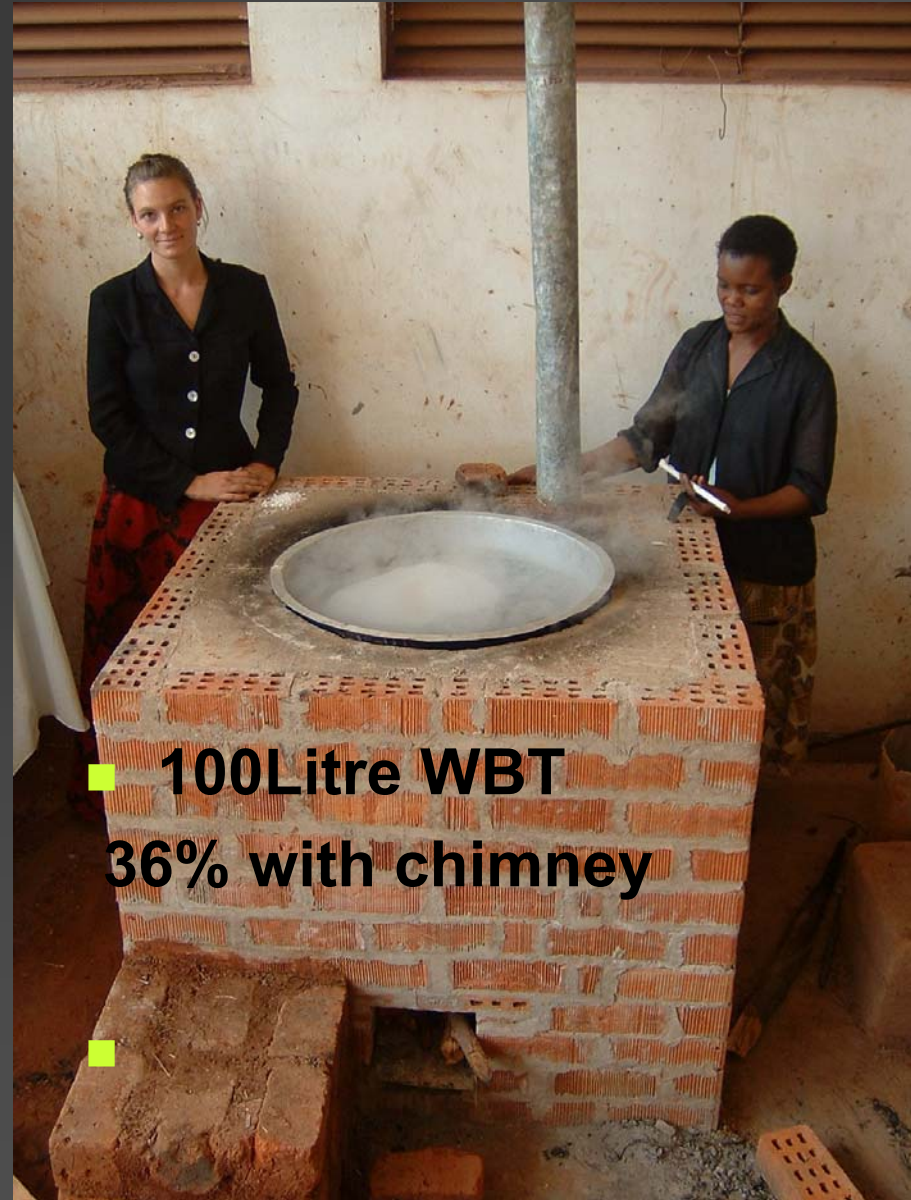
Existing Institutional stoves (Central Africa)

- Expensive (\$700-1000)
- High maintenance (chimney)



Rocket 100-300L (Uganda)

- 100Litre WBT
- PHU Efficiency
- 49% without chimney
- Boiled 75 Litres of water in 52 min (no lid) approx 6 kgs of wood



- **100Litre WBT**
- **36% with chimney**

Portable Rocket 100-300 L (Uganda)



- Existing Markets for institutional stove
- Material costs approx US\$100
- Pre-existing stoves already sell for approx US\$3-500

Improved Lorena (Uganda)



4 types of new Lorena stoves (pumice, sawdust, tile/wood ash, vermiculite)

Improved heat transfer

Rocket combustion elbow

Efficiencies: 26-32% for 2 pots

Household stoves (Uganda)



- Average 8 person Urban/periurban household spend US\$.50-1 for wood and US\$.50-2 for charcoal
- Stoves will retail for US\$10-20

Nkokonono Household (Lesotho)



- Multiple pot sizes 1-6
- Material costs about US\$10
- Retail US\$15-30

Institutional stoves for WFP (Lesotho)

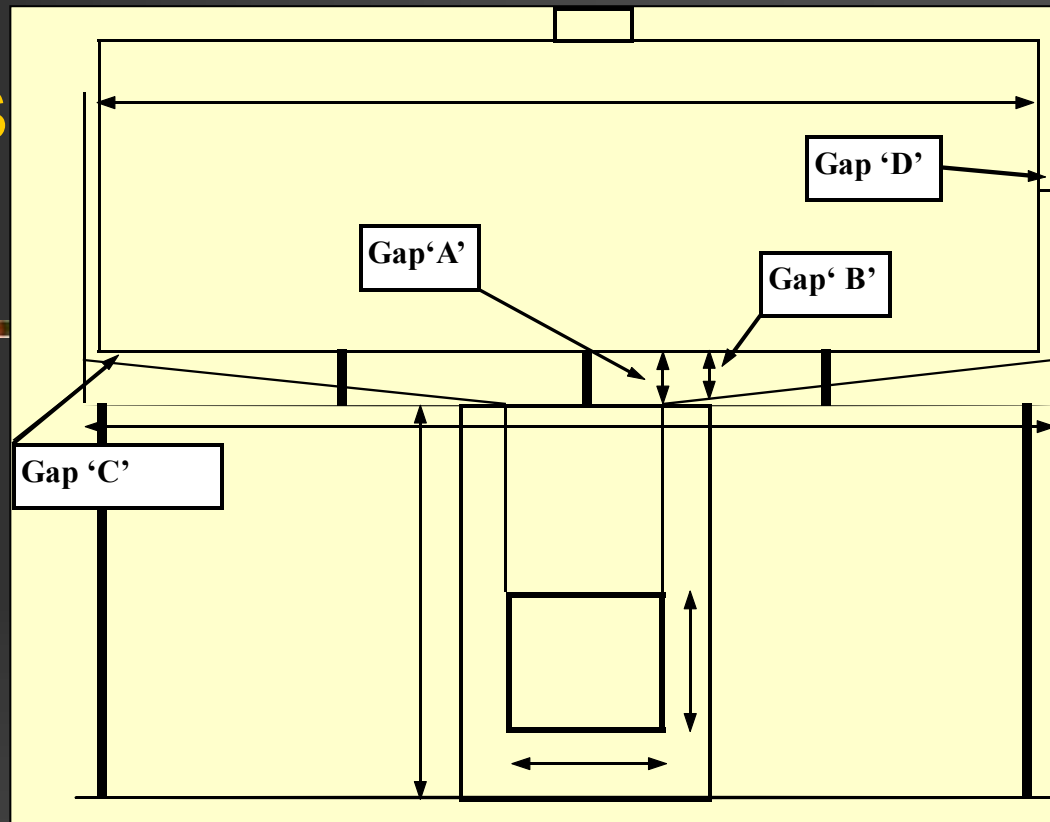
No Food Without Fuel Project



Nkokonono Poloko 20



Institutional stoves Fagao



To calculate gap^A (between the top of the combustion chamber and the pot)

$$\text{gap}^A = \frac{\text{Area of feed chamber}}{\text{Perimeter of feed chamber}}$$

To calculate gap^B (between the pot and the outer edge of the combustion chamber)

$$\text{gap}^B = \frac{\text{Area of feed chamber}}{\text{Perimeter of outer feed chamber} = [(D+10 \text{ cm}] * 3.14)}$$

To calculate gap^C (under the outer edge of the pot and the stove body)

$$\text{gap}^C = \frac{\text{Area of feed chamber}}{\text{Circumference}_{\text{Pot}}}$$

To calculate gap^D (between the sides of the pot and the stove body)

$$\text{gap}^D = \text{gap}^C * 0.75$$

Cement Vermiculite

bricks in Mozambique

■ Basic recipe

1 liter Vermiculite plus
170 g Cement mix dry
then add

290 g Water

Don't tamp , dry for 10
days



Sawdust/clay bricks in Mozambique



Stoves in Hillcrest South Africa





The Rocket Stove Principle

Maximizing combustion and heat
transfer efficiency

Aprovecho Research Center

- Appropriate technology based in
- Building
- We offer projects
- Interested designers to improve local designs

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Center

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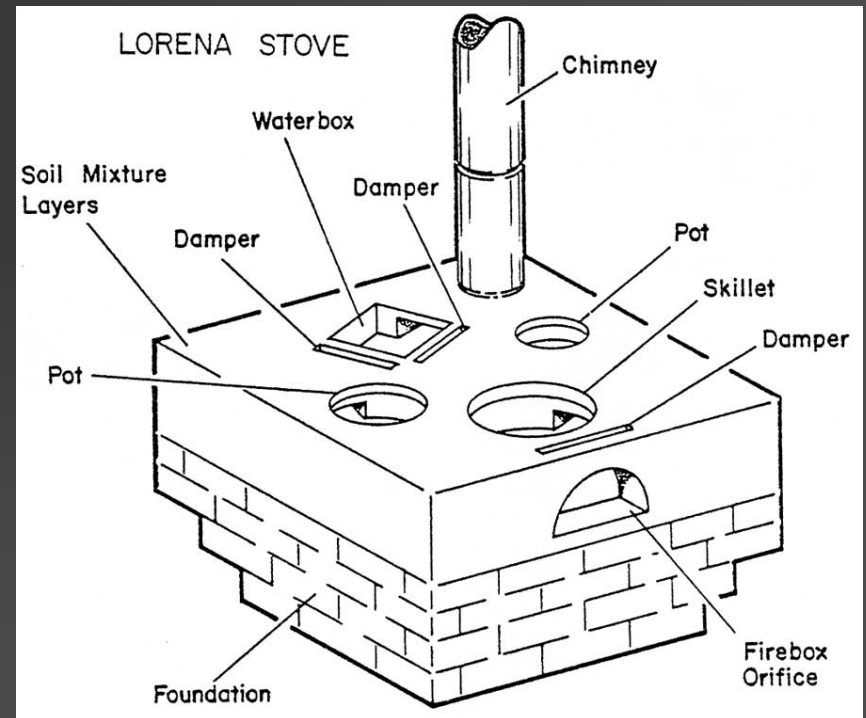
mer stove



The Lorena Stove

■ Benefits

- 50% wood savings
- Chimney
- Enclosed firebox
- Owner built
- BUT
- In certain cases used significantly more wood than a traditional 3 stone fires



Simplified stove theory

- Wood doesn't burn
 - Wood gets hot and releases volatile gases that then combust
 - For this to happen we need to have sufficient temperature
 - If wood is heated to 650 degrees Celsius (and sufficient oxygen is mixed with the volatile gases) the result is complete combustion. The products of clean combustion are CO₂, water vapour and heat.
 - A lot of heat, roughly speaking, dry wood has **half** the energy per kg as gasoline, if it is utilized
 - Smoke is wasted energy
-

What are limiting factors to high temperatures ?

Challenge # 1

- **Cool stove body**
- **Cool earth**
 - the body of the stove or of the earth **robs** heat from the fire
 - which lowers combustion temperatures... which decreases efficiency...and increases smoke

Solution?

- Insulate the stove with low mass, heat resistant materials in order to keep the fire as hot as possible
- Remember mass is the opposite of insulation
- Effective stove insulators are pumice , vermiculite, and wood ash
- Dense things such as earth,sand, cement, water and cast iron are poor insulators

Maximizing combustion efficiency

■ Challenge #2

- Cool wood
- which lowers combustion temperatures...which decreases efficiency...And increases smoke

■ Solution?

- Meter the fuel!
 - Use small sticks whenever possible
 - Maximize the surface area of the wood exposed to coals
 - Heat only the fuel that is burning
 - Burn the tips of sticks only as they enter the combustion chamber
-

Maximizing combustion efficiency

■ Challenge # 3

■ Cool air/ Too much air

- which lowers combustion temperatures... which decreases efficiency... And increases smoke

- Note: an open fire can draw 20 times more than is required for stoichiometric (chemically ideal) combustion

■ Solution ?

- Do not allow too much or too little air to enter the combustion chamber.
 - there should be the minimum excess of air supporting clean burning.
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Maximizing combustion efficiency

■ Challenge # 4

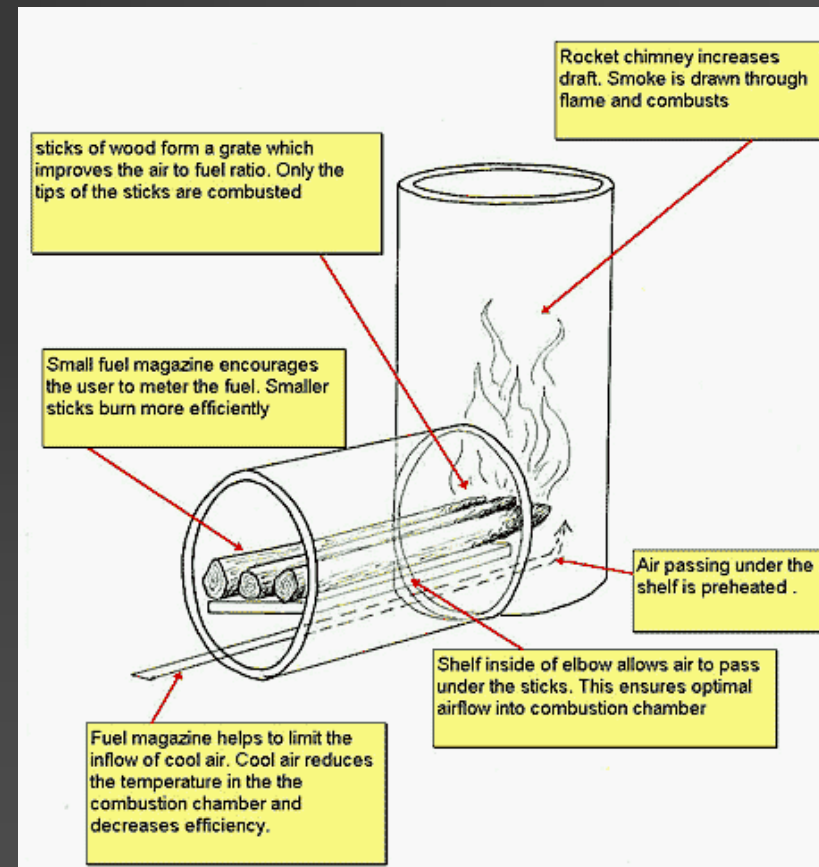
- Cool cooking pot
- The cooking pot is generally no more than a 100 –200 degrees Celsius
- Flames touching the pot?
- **Soot and smoke!**

⑩ Solution?

- ⑩ Elevate the pot above the height of the flames
- This creates an internal ‘chimney’ which increases draft
- And gives time for improved air/ fuel mixing

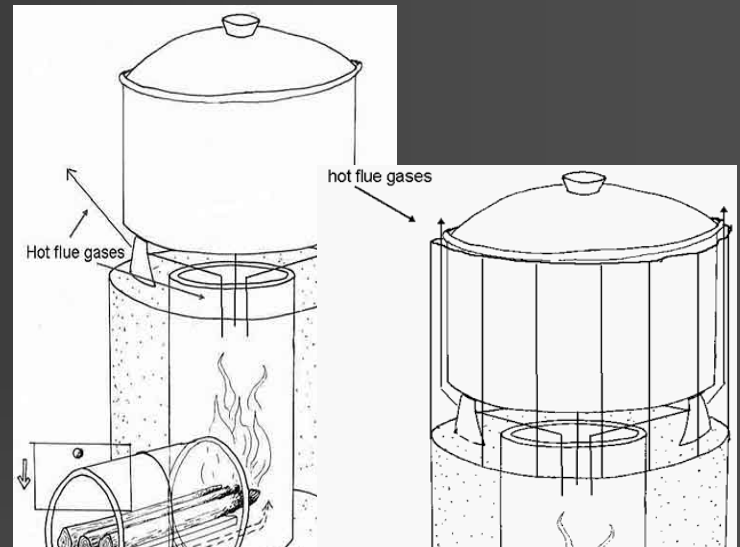
The Dr Winiarski Rocket Stove

- Insulated low mass combustion chamber
- Internal shelf allows sticks to form a grate. Stick/air/stick/air
- Small amount of high velocity air is drawn under the coals and the wood 'grate' which improves air to fuel mixture
- Stove power is controlled by regulating the fuel supply **not** the air intake
- Horizontal feed chamber is convenient
- Since its invention in 1984 over 15,000 rocket stoves have been built



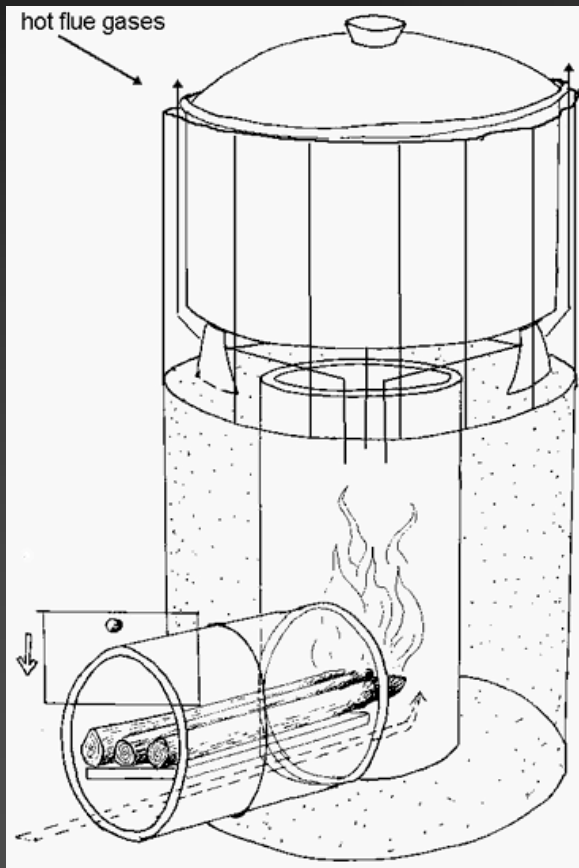
Optimising heat transfer

- Force hot flue gases around pot
- Maximize velocity of hot flue gases to disturb boundary layer
- Maximize Delta T



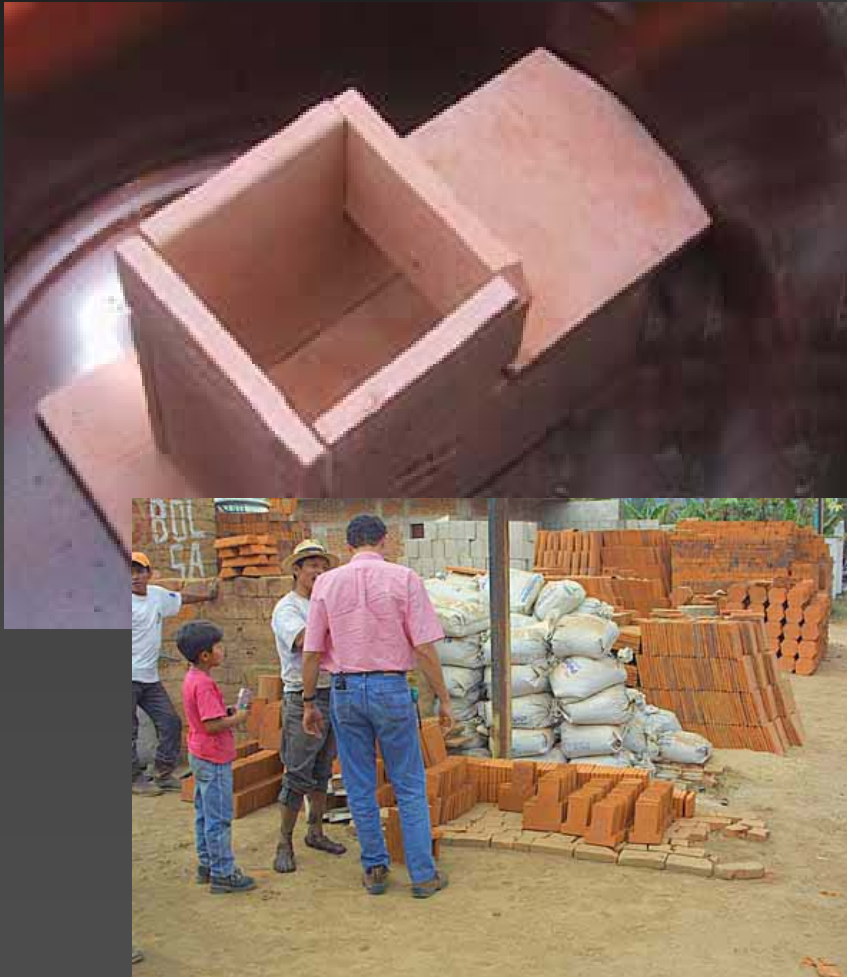
With a heat exchanger, overall efficiency can be improved by 50% or more

Rocket stove heat exchanger/skirt



- Minimize the gap between the skirt and the pot while maintaining the cross sectional area of the combustion chamber (for average size pots 1cm is good rule of thumb)
- Make it adjustable to accommodate different size pots
- Make it as tall as feasibly possible

Material options (clay tiles)



The Baldosa clay tile

Very durable: 4 years of success in Central America

Inexpensive: less than 1US\$ per combustion chamber

Not monolithic: individual parts 'float' so they can withstand greater thermal shock.

Low mass: needs insulation

Can be cut from pre-existing tiles or made from moulds

Material options VIC (vernacular Insulated Ceramic)

- The six brick stove
- Can be made from
 - Clay/pumice
 - Clay/pearlite or
 - Clay/vermiculite
- **OR** with a clay/cement and an organic material , such as fine sawdust or ground coffee husks
- These bricks can then be placed in a metal stove body **or** in a mud stove
- Very cheap/not monolithic



Material options (metal)



- Rocket Stoves can be made with steel drums, 3mm mild steel, stainless steel, 3CR12.
- Life expectancy 1- 4 years

Shown here is a Rwandan refugee camp stove made from used cans (used to deliver food supplies to the camp)

5,000 were made in 1994

Emission data

(UC Berkeley/Aprovecho emission test in Nicaragua 2000)

Table 4. Emission factors in grams per MJ delivered.

<i>Stove test</i>	<i>Thermal Efficiency</i>	<i>Emission Factors (g pollutant per MJ delivered, g/MJdel)</i>			
		<i>CO₂</i>	<i>CO</i>	<i>CH₄</i>	<i>TNMHC</i>
EcoStove #2	13.98 %	537	8.0	0.13	0.29
EcoStove #4	21.01%	352	2.9	0.026	0.091
Rocket #1	33.67 %	220	3.2	0.063	0.094
Rocket #2	28.89 %	263	5.7	0.037	0.097
Three-stone fire	10.29 %	589	18	1.0	0.88

Guatemalan single pot rocket

Materials

- pumice,
- baldosa tiles
- galvanized corrugated skirt
- 1/3 of a 200 litre drum
- **Cost** approx. 7US\$ for materials
- **Efficiency** 35%
- 80% Reduction in fuel consumption



Double Burner Rocket Stove (SA)

Materials

- Two thirds of metal drum
- 10 kg Vermiculite
- Mild steel elbow
- Can be adapted to hold size 1-8 cast iron pot
- Can bake w/25 litre drum
- **Material cost** :w/donated drum 95R
- **Efficiency**: 25% per elbow



Rocket stoves with chimneys

- Decrease the gap between the heat exchanger and stove body (compared to un-vented stove)
 - Force heat to rub against heat exchanger
 - Insulate all parts of the stove body
 - Keep exit temperatures low (around 180)
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- Remember that chimneys use heat to operate (steal approx 1/3 of heat from stove or room) clean burning stoves have less of a need for an external chimney
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Helps/Aprovecho Cement stove



Materials

Stove body made from 3 independent 2.5 cm thick cement walls (made w/ portable fibreglass moulds)

Baldosa combustion chamber

Removable rings

Reduces fuel consumption by 65%

1,000 made in last 2 years

Sunken pot Eco Stove (SA)



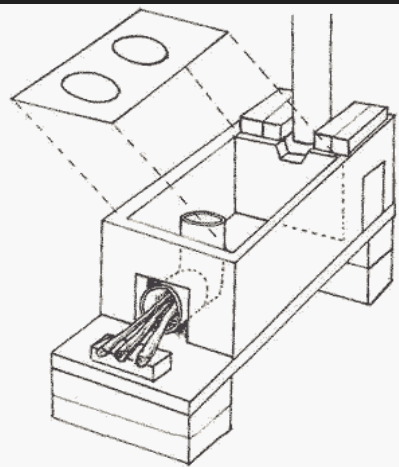
- 2 models: one for flat bottomed pots and one for round bottom. Both bake bread in about 25 min.
- Stove body: galvanized steel
- Combustion chamber: 3CR12
- Material cost 300R
- Efficiency (Stainless Steel version) 34%

Aprovecho/Prolena Ecostove



- Made with 2 piece refractory ceramic combustion chamber Insulated w/Pumice
- Bakes bread
- Ideal for flat bottomed pots (I.e Nicaragua or Zimbabwe)
- Efficiency 22%
- Wood savings 40-75% depending on usage
- Cost 65US\$

EcoStove/Estufa Justa



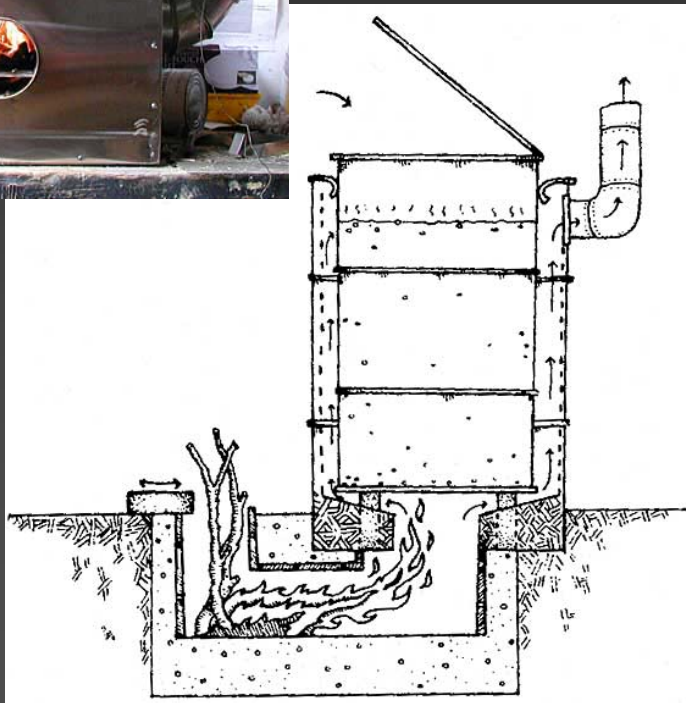
- Made with brick stove body and baldosa combustion chamber
- Over 3,000 made in Central America
- Cost** approx 45US\$
- Efficiency** 22% with three pots
- 3,000 made in the last 3 years

Wood fired cocoa dryer (Nica)



- In two tests of 125 pounds of apples and tomatoes, the dryer used one pound of wood to dry one pound of wet produce. The dryer uses about 10 pounds of wood per hour to keep at 130F a space 4' by 10' by 4' full of screens of sliced fruit, etc. Full of cacao is about 500 pounds.

Other Aprovecho Designs



- We also have designs for:
- 30-200 liter institutional stoves
- garbage incinerators
- community bread ovens
- Space and water heating stoves
- Chinese wok stoves

The ETHOS Network

Our university partners play a key role in stove development

- ISU focuses on virtual reality modelling
- CSU and NOAA perform emissions testing
- And University of Dayton performs material testing.
- UC Berkeley and NOAA provide emission testing

This research is then incorporated into stove designs that are disseminated by our NGO partners such as Helps Int'l , Trees Water and People, and Winrock Int'l

IOWA STATE UNIVERSITY



ETHOS Research

Students at University of Dayton Perform

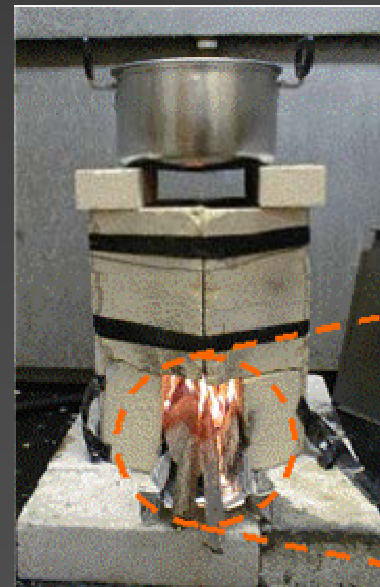
- compression,
 - thermal shock and
 - 3-point bending tests on on our 6 Brick VIC stove
- We invite you to join our network to make use of this amazing volunteer program



Hands-on Learning: Students making bricks



Stove bricks take a lot of abuse



Other useful contact sites

- <http://www.repp.org/discussiongroups/resources/stoves/Smith/Primer/Primer.html>
 - http://www.repp.org/discussiongroups/resources/stoves/#Dean_Still
 - [MAKING LIGHT WEIGHT REFRACTORY CERAMIC FROM PERLITE AND CLAY](#) Damon Ogle Jan 13, 2003
 - [Rocket Stoves - Controlling Draft](#), August 17, 2002
 - [Ceramic Stove Tests Aprovecho July 2002](#)
 - [Rocket Stove User Guide](#) (pdf 40 k)
 - [Rocket Stove Design Guide](#) (pdf 100kb)
 - <http://faculty.washington.edu/~yark/stoves.html>
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Way Forward

- Introduce the 6 Brick VIC Stove to Lesotho and Uganda.
 - Build a portable (metal clad) and a fixed mud version
 - Link with Shell Foundation/UC Berkeley testing protocol project
 - ?????? Pilot projects for commercializing the Rocket in Africa
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NCE
