



EIE-06-256 REEPRO



# **Promotion of the Efficient Use of Renewable Energies in Developing Countries**

## **Rocket stove development**

### **Report**

#### **Author**

Dr. Khamphone NANTHAVONG, Faculty of Engineering (NUOL)  
Sivay CHANTHAVONG, 5th student, Mechanical Department (ME/FE/NUOL)  
Xayalak, 5th student, ME/FE/NUOL

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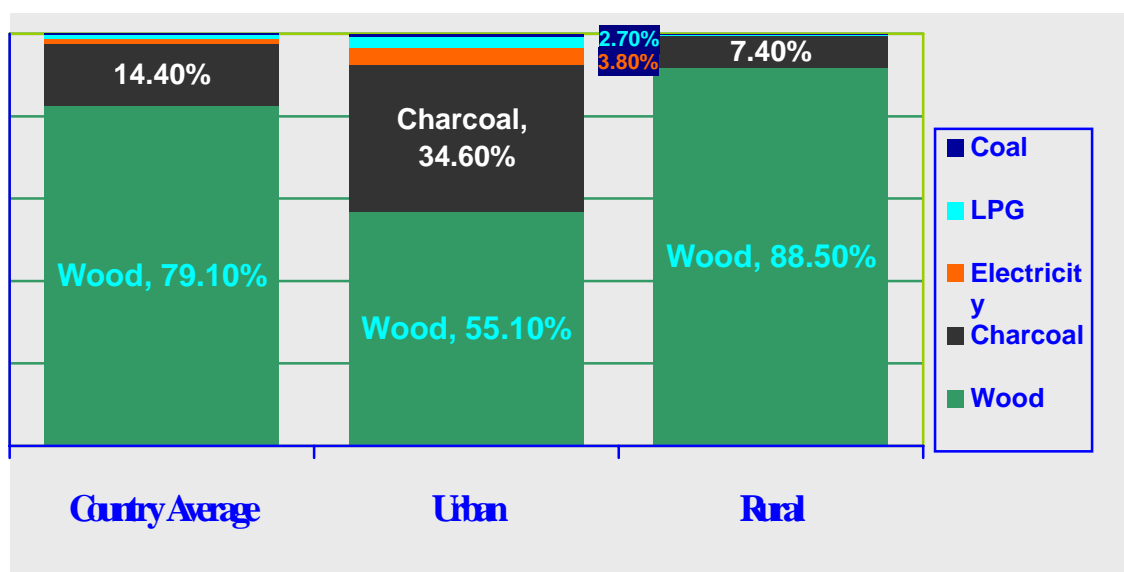
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## List of Acronyms

IBCS                      Improved Bucket Cook Stove

## 1 Background

Lao household energy consumption pattern is characterized by dominant share of biomass, particularly wood fuel. According to report of Population and household census 2005, about 94% of Lao households still rely on biomass (mostly fuel wood and charcoal) as energy source for cooking, while 90% and 96% are for urban and rural areas, respectively (CENSUS 2005, [1], see figure 1 ). From the different sources, average wood energy consumption in Lao PDR is estimated around 0.7 m<sup>3</sup>/person/year, or approximately 4,200,000 m<sup>3</sup>/year for all country.



**Figure 1: Household Energy use for cooking pattern (National census 2005)**

The reasons of such high share of wood energy in household energy source for cooking maybe many, but use of inefficient cook stove is probably the most important factor.

It is known that open fire cook stoves, such as three stone, are still widely used in Lao households, especially in rural areas (figure 2). The Heat utilization efficiency of such stove is around 11% only.



**Figure 2: Open fire cooking practice in Lao household**

Recently, several modifications of improved cook stoves have been introduced and widely available in Lao market, among those Improved Bucket Cook Stove (IBCS, see figure 3) with efficiency as high as 39%.



**Figure 3: Improved Bucket Cook Stove**

High efficiency of such kind of stoves will be achieved only if all design and production requirements are fully followed. Furthermore, there requires rather highly skilled crafters to make proper IBCS. Otherwise, faking stoves may result poor quality and low efficiency.

REEPRO project has promoted Rocket stoves to its project communities.

Although rocket stoves have slightly lower efficiency (around 30-36%) comparing to IBCS, but easy construction and relatively inexpensive may be the big advantages for its promotion in developing countries.

## **2 Objectives**

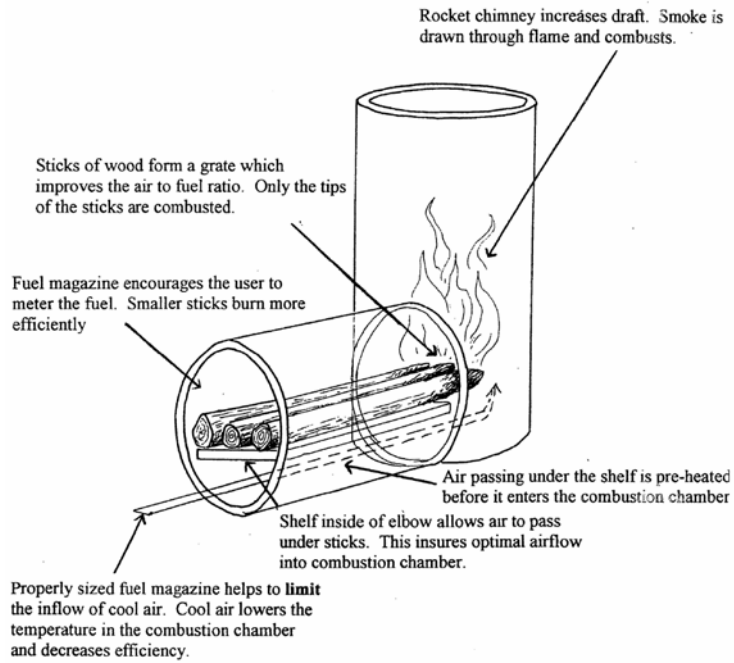
This adaptive research is to develop rocket stove for meeting availability of construction material and real stove use in Lao PDR.

## **3 Problems statement and solution**

### **3.1 Original (APROVECHO) rocket stove**

Rocket stoves are simple cooking stoves that can be assembled from a few basic components. Considered to be efficient, the rocket stove derives its name from the appearance of the piping that extends horizontally from the main portion of the unit (fig. 4-5 ).

Rocket stoves were firstly introduced by APROVECHO research Centre (Oregon, USA) since 1976.



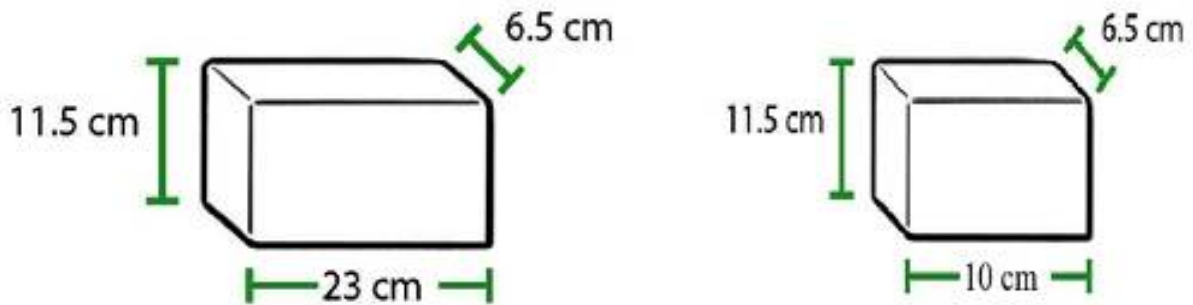
**Figure 4: Design principle of APPROVECHO Rocket stove**

Original APROVECHO rocket stove prototype was used for our study and development (fig. 5)



**Figure 5: APROVECHO rocket stove**

APROVECHO rocket stove is made off bricks of two sizes (figure 6): long (11.5x23x6.5, in cm) and short (11.5x10x6.5)



**Figure 6 Two sizes of bricks for APROVECHO rocket stove construction**

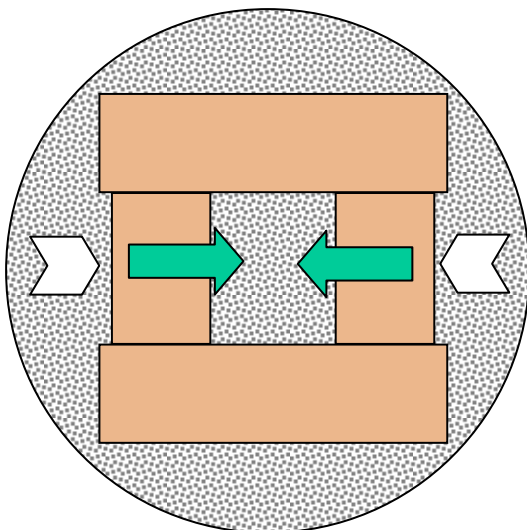
Used construction materials comprise followed components:

- (1) 900 g of moist clay;
- (2) 500 g of dry sawdust;
- (3) 1.2 L water (proportion for one brick)

The materials are mixed and then filled into mold. Appropriate density of burned brick must around 0.6 g/cc

There are found some problems or obstacles in production of APROVECHO rocket stove in Lao PDR:

- **Raw materials availability:** there is not always and anywhere available or sufficient sawdust in remote rural area of Lao PDR.
- **Construction problems:** there is possibility that the short bricks will move into fire hole of the stove (see fig. 7) due to the pressure from the insulation materials side. The shape and size of fire hole maybe changed when stove is in use for a while.



**Figure 7: Weak points**

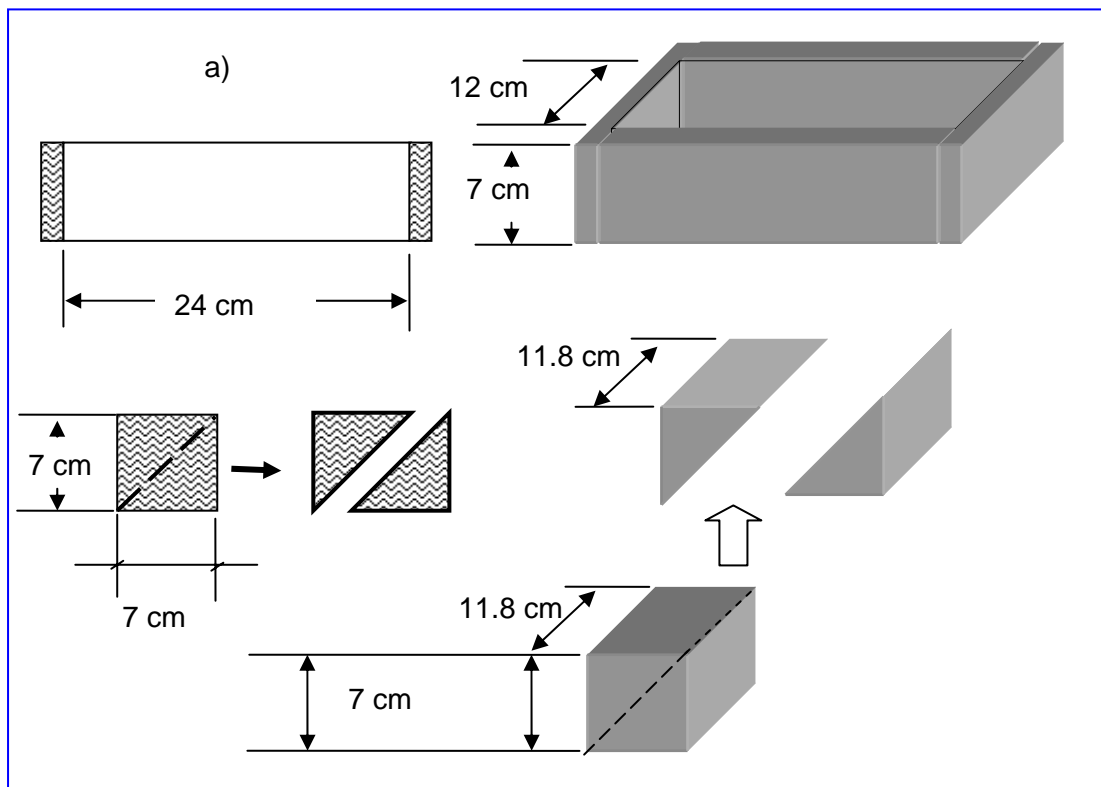
- There requires two of moulds for preparing two sizes of bricks.
- Stove body is made of mild steel sheet, which is expensive, not always available or affordable for rural people;

### 3.2 Rocket stove modification and development

Based on above mentioned considerations, we have made the following modifications.

#### 3.2.1 Modified brick mould

In figure 8 shown new design of brick mold. The mold was designed for producing multi-shape bricks. The modifications do consider all main technical requirements of APROVECHO rocket prototype, such as fire hole cross section size (10x10 cm) and height (33-35 cm); fuel feeder size (10x11.5 cm).



**Figure 8: Multi-purpose brick mold**

The mold is comprised of:

- Wooden or metallic rectangular mold (a) with internal size of 7x12x24 (in cm) so that produced brick size would be around 6.5x11.5x23 (cm);
- two triangular-shaped pieces (wooden ladders or metallic) of size 7x7x11.8 (cm)

This mold can produce several brick modifications, including APROVECHO's bricks.

### 3.2.1.1 Rectangular APROVECHO bricks

As described above, APROVECHO's rocket stove is constructed of 6 long and 5 short bricks. These bricks can be made by using our multipurpose mold (see figure 9)

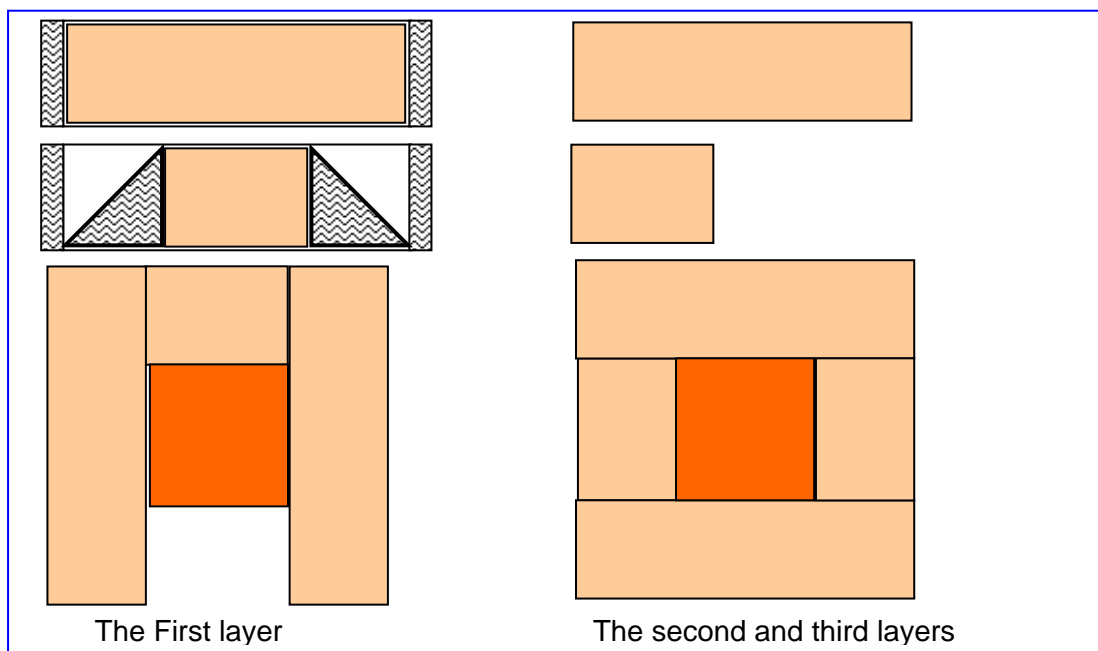


Figure 9: Production of APROVECHO's bricks

### 3.2.1.2 One-size's rectangular bricks

The rocket stove can be constructed by 11 one-sized bricks of 6.5x11.5x16.5 cm (fig. 12). In one hand, use of shorter bricks means saved raw materials and smaller stove body size, hence less metal sheet used. On the other hand, stronger structure would be achieved.

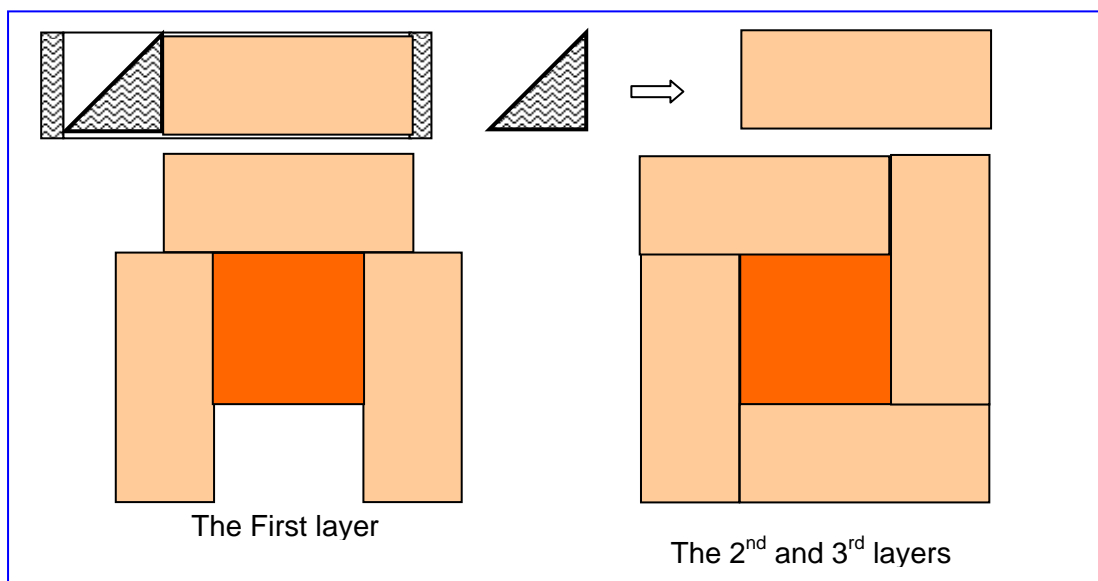
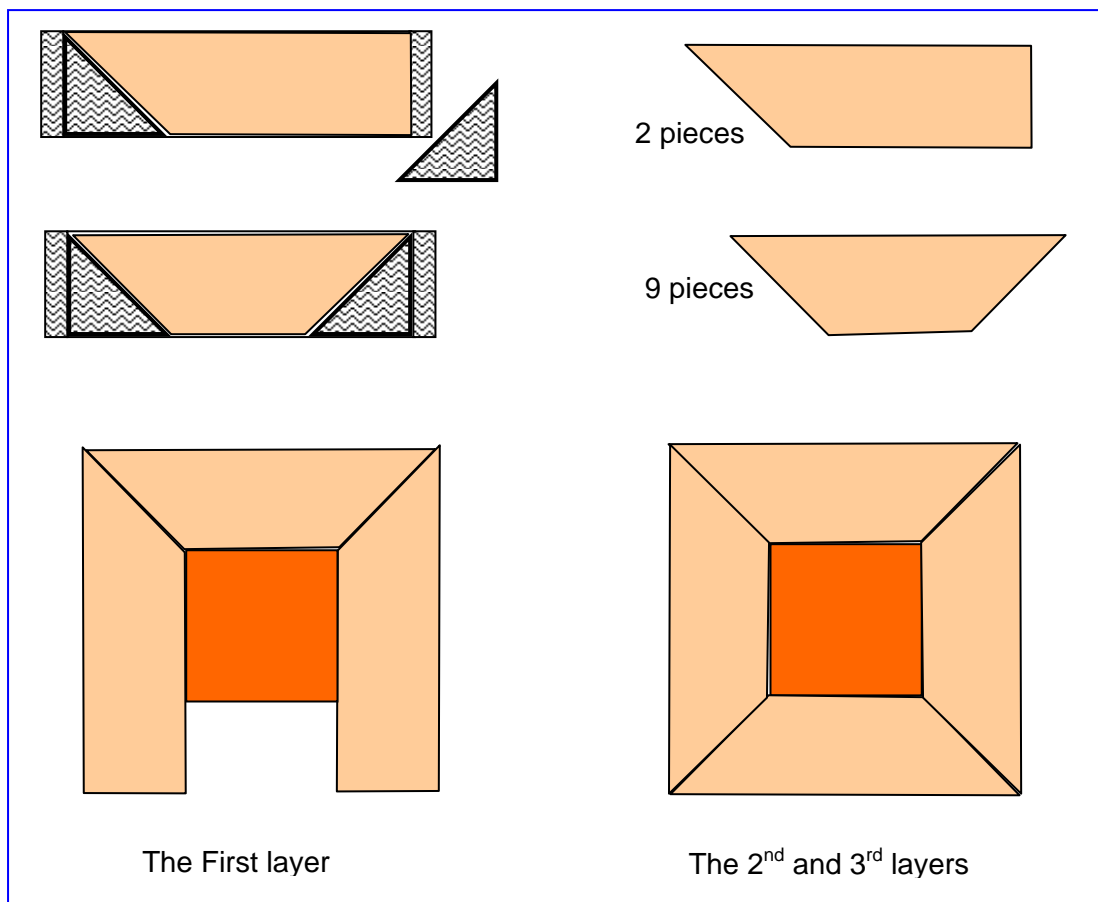


Figure 10: Rocket stove with long bricks

### 3.2.1.3 Trapezium bricks

Other our modification is using 11 trapezium bricks (see fig. 11).

Use of these trapezium shaped bricks allow achieving easy stove assembling, strong and compacter structure, saving construction materials.



**Figure 11: Rocket stove with long bricks**

### 3.2.2 Alternative Raw Materials

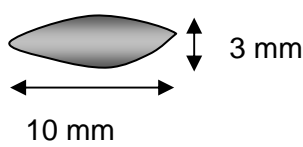
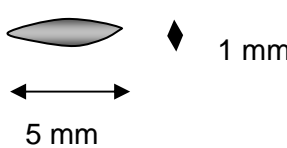
Rice husk use as organic material in brick's mixture because rice husk is usually everywhere available, even in remote rural areas.

Usually rice husk can be divided into three sizes, depending on rice variety and huller machine type:

- Largest size (7-12 mm) is as long as whole rice paddy (average length ~ 10 mm)
- Medium size (3-7 mm) (average ~ 5 mm)
- Small size (<3 mm), is counted as rice bran, which are rich of several useful nutritive components, and used as human food additive and animal fodder. Due to that fact, this type of rice husk was not considered as raw materials for rocket stove production.

In table 1 are shown characterized dimensions of rice husk type. The first two sizes are rarely used. At some where, people throw these rice husks to the paddy field, with or without burning, as organic fertilizer for soil improvement. The rice husk can also be used for cooking, for burning construction bricks or agriculture products drying.

**Table 1: Rice husks classification**

Rice type	Average dimension	Density, kg/m <sup>3</sup>
Large size		129
Medium size		194
Small size	< 1 mm	389
Rice ash (charcoal)		324

In our study several proportions of rice husk-clay-water mixture were tested to find out the best option, in one hand, for matching APROVECHO requirement (brick density ~ 0.6 g /cc), and in other hand to achieve certain thermo-mechanical characteristics (e.g., strength, insulation properties, ...)

While testing the mixture of rice husk + clay + water, the amount of clay was kept constant and equaled APROVECHO proportion. Proportions of rice husk (RH) were changed accordingly for large and medium size RH. Water proportion was also varied. In table 2 listed the bricks, mostly having closed to APROVECHO brick's density (~0.6 g/cc).

Some testing remarks:

- Large RH gave better matching brick density, but structure was too soft and weak, not suitable for stove making.
- Although medium size rice husks give slightly higher density, however, stronger structure stronger structure and density, and usually are by-products of small capacity rice hullers, which are more common in country sides.
- Therefore, medium size of rice husk was chosen as organic component of brick's mixture, with the proportion **clay + rice husk + water = 900 + 200 + 700** (in grams per one brick)

**Table 2: Brick samples' Test results**

Tested sample	Clay , g	Rice husk , g	Water, g	Density, g/cc	Properties
---------------	----------	---------------	----------	---------------	------------

Large RH	900	100	600	0.581	Soft-weak structure
Midium	900	200	700	0.714	Stronger structure, compared to rice husk of larger size

### 3.2.3 Stove body modification

#### 3.2.3.1 Metallic stove body

Stove body of original APPROVECHO rocket stove was made of mild steel sheet, which usually more expensive, not always affordable and available for rural people.

Galvanized steel is less expensive (~50% price of mild steel sheet of the same size), easily available and therefore, can be the option for rocket stove body. Other advantage is no painting needed. The weak point is probably shorter lifetime.

It was found that many types of used cans available in Lao market, two of which can be used for making stove body, as followed:

- used steel paint can: round cross section: dimension height x diameter = 38 x . The good point is matching with APPROVECHO stove body size, but steel can often rarely used.
- used vegetable oil can: rectangular cross section, with dimension height x cross section = 33 x 23x23 (cm). The cross section is smaller than APPROVECHO stove and height of fire hole nearly the same (33 ~ cm). Used vegetable oil can of this size can be easier found in, but due to the differences in cross-section size and height, there needs to change the bricks sizes and to modify pot holder (fig 13-13 ).

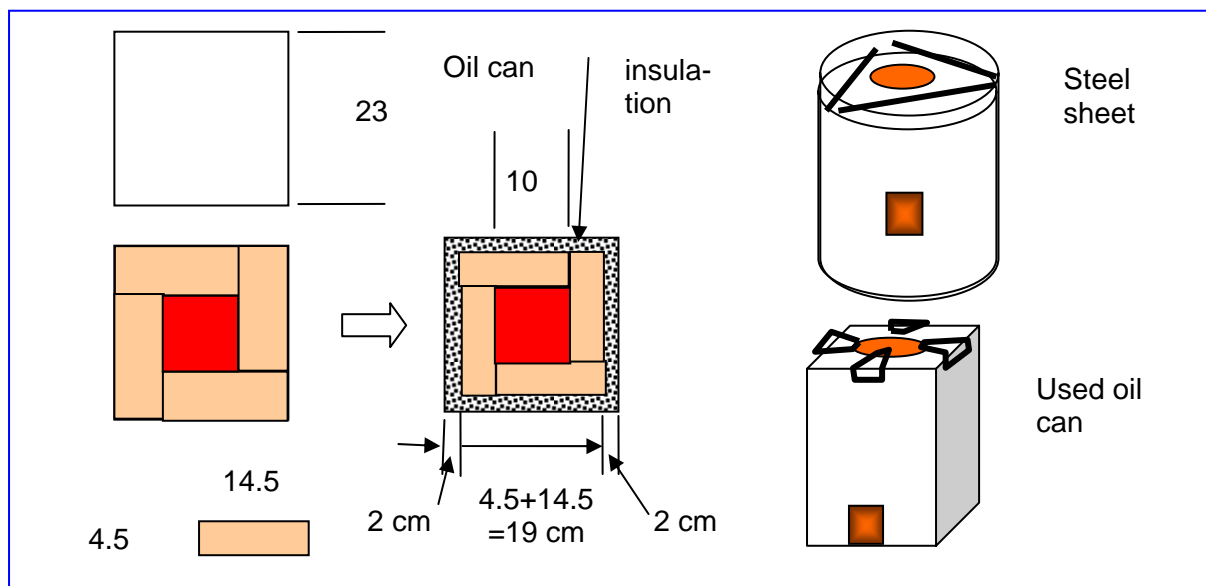
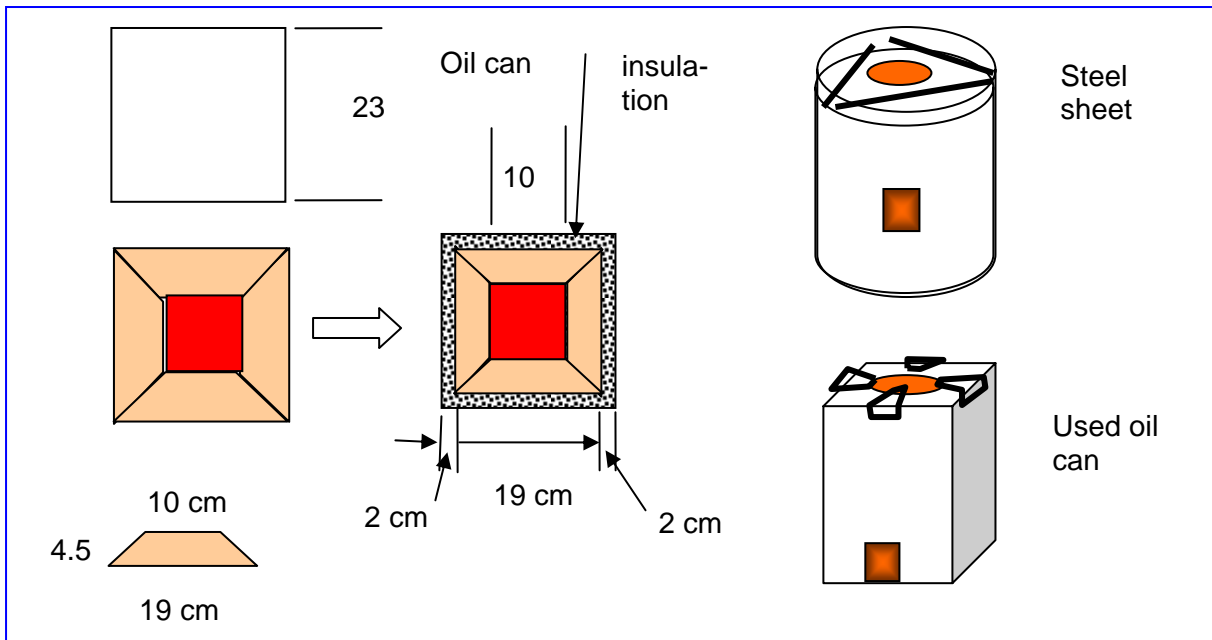


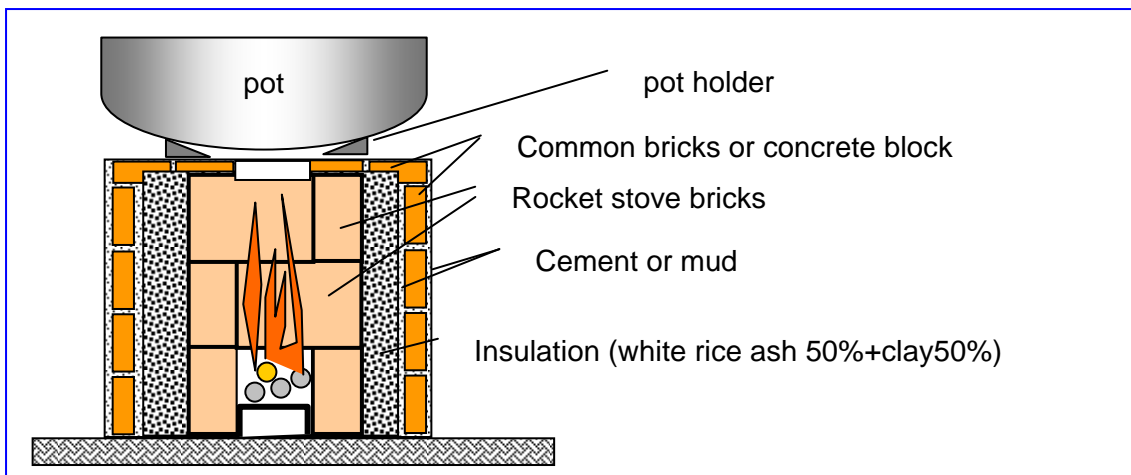
Figure 12: Used oil can as stove body and thinned rectangular bricks



**Figure 13: Used oil can and thinned trapezium bricks**

### 3.2.3.2 Other possible option for stove body

The Rocket stove can be assembled by using common bricks /cement blocks /mud blocks (see figure 14). The stove can be permanently installed in the kitchen.



**Figure 14: Rocket stove with non-metallic body**

### 3.2.4 Stove testing results

The produced stoves were tested on Heat Utilization Efficiency (HUE)

$$HUE = \frac{m_w C_{PW} (T_B - T_i) + m_{ev} \lambda_w}{m_F (\text{LHV})_F}$$

where

$m_w$  - total water mass, kg

$C_{pw}$  – specific heat capacity of water, kJ/(kg.°C); (4186 kJ/(kg.°C))

$T_B; T_i$  – Boiling and initial water temperatures, °C

$m_{ev} = m_B - m_{rem}$  - evaporate water (kg)

$m_{rem}$  – remained in the pot water (kg)

$\lambda_w$  – heat of water evaporation, kJ/kg (2257 kJ/kg)

$m_F$  - mass of fuel used, kg

(LHV)<sub>F</sub> – Latent Heat Value of fuel, kJ/kg. For wood (LHV)<sub>F</sub> ~ 15000 kJ/kg

The rocket stoves shown in figures **12-13** were tested for HUE.

Average test result of HUE is around **32-34%**.

In table 3 is shown estimation of production costs depending on stove body materials used.

**Table 3: Estimates of Production costs, depending on stove body materials**

Stove body materials	Mind steel	Thin Galvanized steel	Used cans
Production Costs	30,000 LAK	22,000 LAK	12,000 LAK

### 3.3 Conclusion

- Multipurpose mold is more flexible in stove making
- Rice husk is a good organic material for rocket stoves production
- Any suitable metallic containers can be used as for stove body
- Heat Utilization Efficiency is slightly lower than APROVECHO, but possibility to use old oil cans and hence make stoves inexpensive would be the advantage for its promotion in developing country.
- Fixed rocket stove with non-metallic body would be appropriate for remote rural areas

### 3.4 Photos

