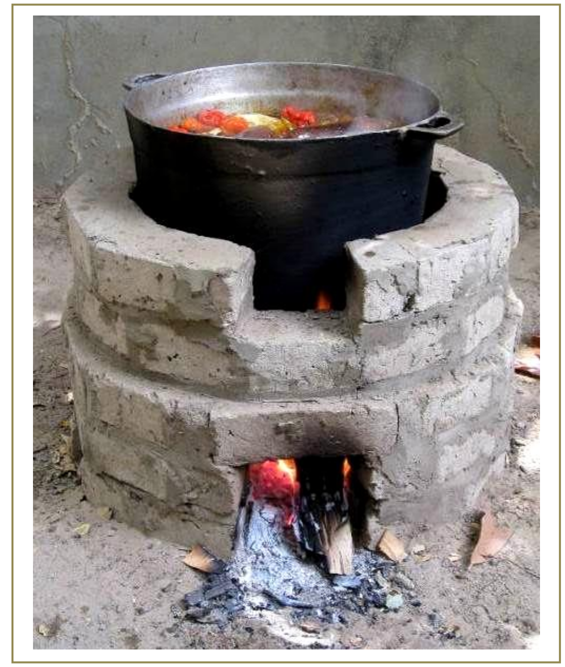
Photos by: Audrey Yank

The evolution of the NoFlay Design was made possible with funding from DFAIT – the Department of Foreign Affairs and International Trade – Canada.

NoFlay Improved Clay Brick Stove TRAINING MANUAL



Resource Efficient Agricultural Production - Canada

In Partnership With:

Njawara Agricultural Training Center (NATC)

Cadre Locale de Concertation des Organisation de Producteurs (CLCOP)

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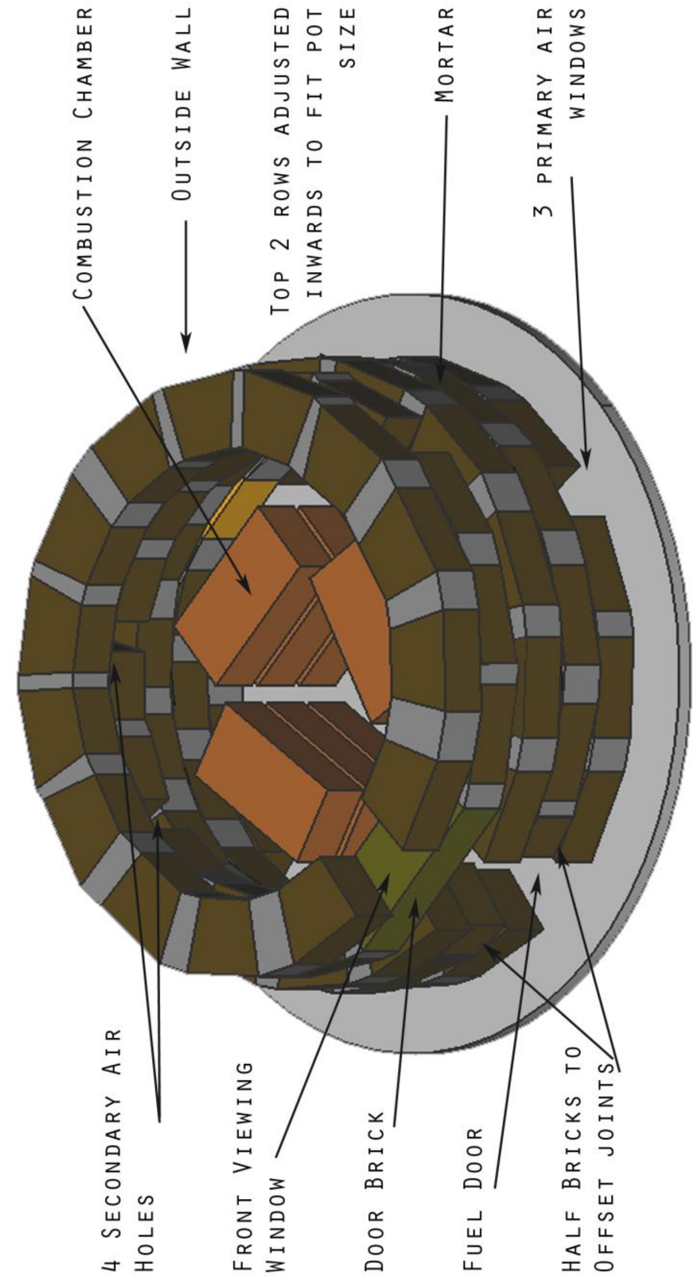


Noflay: Introduction

In rural West Africa, more than 90% of the energy requirements are currently met with wood which is commonly burned in three-stone open fires[1]. Nearly 3 billion people in the world use this cooking method every day, despite the low efficiency and the significant amount of smoke produced[2]. Furthermore, the dependence on fuel wood is exacerbating ecological decline in the form of deforestation and soil erosion.

The innovative Noflay clay brick stove addresses these issues. The name ‘Noflay’ is a West African expression understood across many local dialects as ‘convenience’, ‘easy’ or ‘no problem’ and insinuates that the users are enjoying themselves.

The overall objective behind the design of the Noflay stove was to create a culturally appropriate, low cost stove made from local materials that could reduce fuel wood consumption, indoor air pollution and improve cooking convenience and safety. The Noflay is built *in-situ* and can be easily built by community members.

The Noflay presents the following advantages:

- ✓ Reduces wood consumption
- ✓ Improves livelihoods and reduce costs associated to wood
- ✓ Reduces smoke and improve respiratory health
- ✓ Promotes local employment and skills in the communities
- ✓ Uses locally available material
- ✓ Reduces risks of kitchen fires and burns to children
- ✓ Contributes to kitchen cleanliness
- ✓ Is easily adopted (very similar to cooking with a 3-stone fire)
- ✓ Is cheaper and appears to have greater longevity than metal stoves

Conclusion

The Noflay clay brick stove has an innovative design, has great potential to increase livelihood, improves respiratory health and significantly reduces deforestation in West Africa. Developed with local communities and local partners, it was specifically designed to meet the need in rural West Africa for a lost cost stove which can be easily built.

The Noflay is meant to involve the local communities, including youth and women, at all levels of production, including supply of local raw material such as lime and clay. It has become a great livelihood opportunity for young West Africans in putting value into their local knowledge and providing them with new skills. Women were also actively involved in providing feedback and knowledge to make the Noflay as user friendly as possible to ensure the stove would be readily accepted. Women also play a key role in the marketing and dissemination of the Noflay stove.

With its participatory design, its use of inexpensive and locally available materials and its tremendous impact on improved livelihoods and environmental preservation, the Noflay is undoubtedly unique. It is a promising new alternative to help solve complex issues of introducing improved household cookstoves in developing countries.

For Information on Stove Design and Manufacture:

Resource Efficient Agricultural Production (REAP) - Canada
21 111 Lakeshore Road, CCB-13 Centennial Center
Ste. Anne de Bellevue, QC, Canada, H9X 3V9
Tel.: *(514) 398-7743*; ***Fax:*** *(514) 398-7972*
E-mail: info@reap-canada.com
Website : ***www.reap-canada.com***

Stove Use and Maintenance

The longevity of the stove depends not only on appropriate construction, but also on proper maintenance and adequate use.

The stove should be built inside the kitchen, but could be placed outside under a covered area to protect it during the rainy season. It is recommended to build the stove with the door of the stove facing away from the wind to prevent wind blowing into the combustion chamber. In the kitchen, the stove should also be located near a downwind window for the smoke to readily escape.

The stove user should:

- Let the stove dry for 3 days before cooking on it for the first time
- Gently place the pot on the stove to avoid impact and to reduce the risk of cracks
- Remove the pot by lifting the pot high enough not to knock any bricks with the pot.
- Use smaller wood branches and/or split larger pieces of wood. Avoid forcing wood through the door.
- Not pour any water or liquids on the hot stove. This will crack the bricks
- Empty the ash inside the stove after cooking
- Not use an oversized pot on the stove (the pot should rest on the center bricks and not on the wall bricks)
- Preferably cut the legs of the pot to about 1.5 cm to increase stability and proximity to the fire.
- Cover the stove in the rainy season (if built outside)

The Noflay Design Evolution

The Noflay builds upon previous field experience and research on improved steel and clay wood-burning stoves[3]. The stove is made out of fired and unfired clay bricks which are easy to transport to communities with no clay resources. The design integrates the principles of simplicity and low-cost and sought to include:

- ✓ Preheated combustion air
- ✓ Improved heat transfer to the pot
- ✓ Reduced excess air through the use of round walls
- ✓ Several entry points for primary and secondary air

The combustion chamber was designed as a pot support to allow for the pot to sit inside the shroud of the outer wall. This allowed for efficient heat transfer and eliminated an outward force on the outer wall and its eventual weakening which is a common problem with many clay stove designs[4]. Therefore, the two main elements of the stove design are:

1) An improved combustion chamber which also acts as a pot support.
2) A round shroud of bricks for the outside wall which reduces excess air[4 and] reduces heat loss and improves heat transfer and user safety from injury or accidental fire.

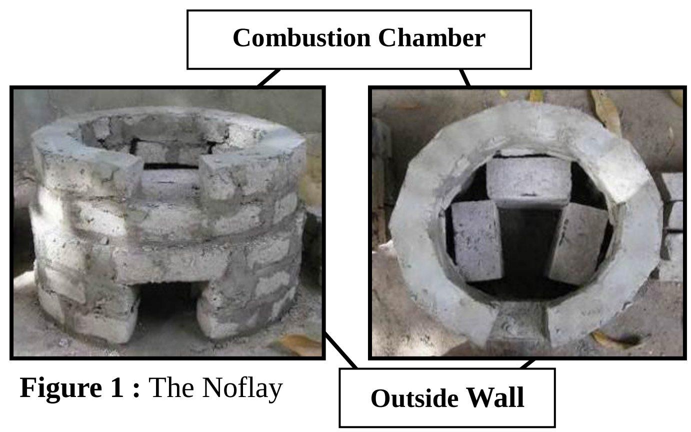


Figure 1 : The Noflay

Clay Brick Production

Different scenarios exist for the production of clay bricks. Depending on the social structure of the community, the production can involve youth, women's groups and/or contractors. Sustainable clay resources need to be identified near the production site.

Material required for brick production:

- Quality clay (below top soil)
- Sifted lime
- Metal molds made of high quality steel (ideally stainless)
- Shovels and Pick axes
- Trowels
- A smooth and even surface
- Water buckets
- Wheel barrow (or other container)
- Plastic tarp (or other mulching material)
- Rubber gloves
- Safety glasses
- Rubber boots

Figure 2: A clay resource collection site in The

Different types of minerals are present in clay deposits. Kaolinite and Montmorillonite are the most common type found in West African. Kaolinite clay is often used for pottery, and has a high permeability and clay content[5]. Montmorillonite has a lower clay content and a higher water absorption capacity[6]. Both are usually found near river banks.

Cost Estimate and Material List

Suggested Cost for the Noflay Stove Construction for a 30-34cm Cooking Pot in The Gambia and Senegal, May 2012
(1 USD = 30 Dalasi = 500 CFA)

Item	*Description of Item*	*Number of Stoves Produced per item*	*Cost (D) /Stove*
Brick Production			
Clay Transport	50D / cart (cart = 1.1m x 2m)	about 5 stoves / cart	10
Lime	110D / bag of 50kg + 10D transport	8kg / stove	20
Stove Construction			
Sub-Soil	-	~ 7L / stove (3 big tomato cans)	Free
Lime	110D / bag of 50kg + 10D transport/bag	~ 15 stoves / bag (3.5 kg - 1½ tomato can)	8
Cement	215D / bag of 50kg + 10D transport/bag	~ 15 stoves / bag (3.5 kg - 1½ tomato can)	15
Clay Brick	1D / window brick 1D / wall brick 1.5D / door brick	57 window bricks/stove 3 window bricks/stove 1 window brick/stove	57 3 1.5
Fired Brick	4D / fired bricks	9 center bricks / stove	36
Labour			
Brick Transport	~ 150 D / cart	~ 4 stoves / cart	38
Masonry	Labour for 1 mason	40D / stove	40
		Total Cost	**228 D**
		(Equivalent to about 7.60 USD)	

The total cost is based on the assumption that the cost of brick production is not covered by the brick making teams. The cost of brick transportation may also vary depending on the distance covered (ex: 100D for 2 km or less)

23) Add the 5th layer of bricks keeping the 1.5cm gap around the pot. This helps increase heat transfer to the pot without blocking air flow[9].

Figure 17: Window and Mortar on the 5th layer

24) If the pot has a smaller diameter, the 4th and 5th row will be smaller than the three bottom layers (minimal space required for the combustion chamber). If the pot has a larger diameter, all five layers will follow the pot's diameter (following the initial trace of the pot).

25) Leave a front viewing window (the size of one brick) at the front of the stove to allow the stove user to see the fire (Figure 18).

26) Mortar the top of the last row to increase stability (Figure 18), especially around the bricks of the front window.

27) Depending on the height of the pot, there may be 4, 5 or even 6 layers of bricks. Adjust accordingly.

28) Let the stove dry for 3 days before cooking on it for the first time.

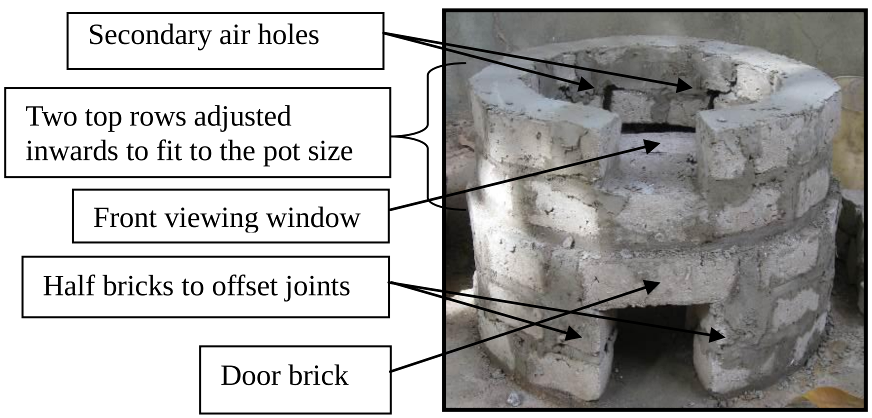


Figure 18: Stove features

Figure 3: Oysters and lime production site

A) Lime Production

Lime is a product derived from local oyster shells and often used in local paints. Locally, lime is sometimes mixed with clay to produce housing bricks. Lime can help create an improved construction material as it increases strength[7]. To produce lime, oysters are collected from the salty waters and boiled. The shells are separated from the oysters which are sold separately at the food market. The shells are burned subsequently and the lime consists of the remaining white powder (Figure 3).

The lime is sifted to remove the remaining shell particles that otherwise reduce the homogeneity of the bricks. It is important to obtain a homogeneous soil-lime mixture before making the bricks to avoid variations in strength due to non-uniform lime content[7]. In the case of brick production for the Noflay stove, lime is added to Montmorillonite clay which gains strength through lime addition. The lime can be bought from local producers. In the case of Kaolinite clay, no lime is generally required.

The lime and clay is mixed with water to allow for hydration to occur. To allow effective mixing and to protect the workers from the alkaline material, the mixing can be done wearing rubber boots. This will create strong bonds between the lime and clay particles[7]. The mixture should rest for 5 days before it is used to make bricks. Lime also reduces erosion of clay due to water[7, 13].

B) Metal Molds:

Metal molds are used to produce bricks (Figure 4a). Ideally, they are made of stainless steel to avoid rust. The molds are also welded on the outside to create smooth inside surfaces. A double mold can be made by welding two molds side by side to increase production rate (Figure 4b). The bricks are to be produced on a smooth and flat surface, ideally a concrete slab, to produce level bricks.

All clay bricks of the Noflay are 6 cm thick. Thicker bricks take longer to dry and fire in the kiln.

The mold needs to be soaked with water before being filled with clay to ease the brick removal.

In the case of Kaolinite, the inner surface of the mold should be covered with ash or lime before filling it with clay. Otherwise, the brick can barely be removed from the mold because of strong cohesion.

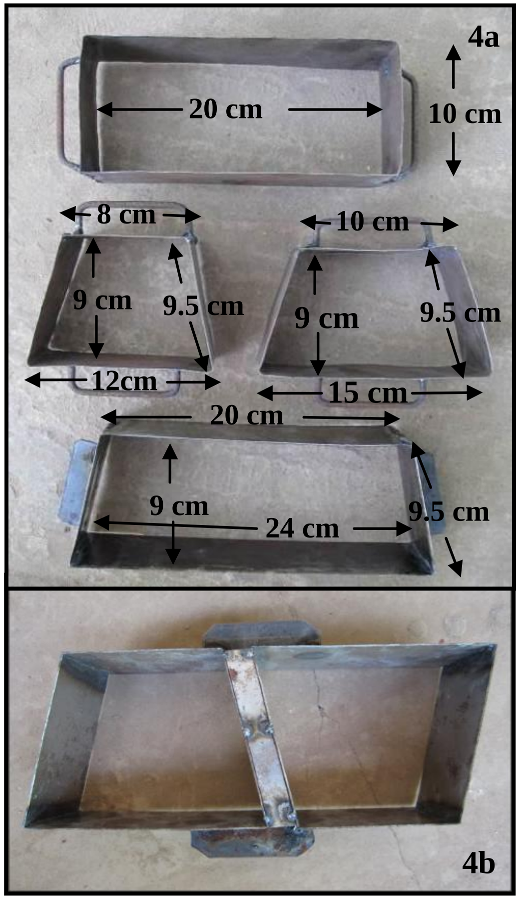


Figure 4: Mold dimensions (All have a thickness of 6 cm)

19) Build the 3^{rd} layer of bricks. Add the door brick over the door opening to make the door frame. Complete the 3^{rd} row with wall bricks (Figure 14).

20) Put the pot on the stove to build the 4^{th} layer. Adjust the bricks to the pot's diameter (Figure 15a). There should be a gap of about 1.5 cm (about a finger) between the pot and the bricks[9] (Figure 15b).

Figure 14: Completing the 3rd layer of bricks

Figure 15: Adjusting the 4^{th} layer to the pot

21) When mortaring the 4^{th} row, leave 4 joints evenly distributed with no mortar for secondary air entrance in to the stove (Figure 16). Secondary air provides oxygen to further combust gases exiting the combustion chamber[12].

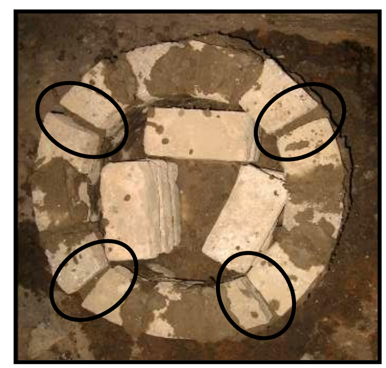


Figure 16: Secondary air holes in the 4^{th} brick layer

Figure 12 : Finishing the first layer

14) Apply mortar with the trowel between each brick (Figure 12b) and on top (about 1.5cm thick) of the brick layer. Leave the window openings without mortar.
15) Place 3 window bricks over the window gaps (Figure 12c).
16) Split one wall brick in half with the trowel and add each half (Figure 13a) on each side of the door (Figure 13b) to offset the brick joints of the rows below.
17) Add wall bricks to complete the 2^{nd} layer.
18) Depending on the pot's diameter, more wall bricks may need to be cut in half for subsequent layers to offset the joints below. Keep a 1.5cm gap between each brick for mortar (Figure 13c).

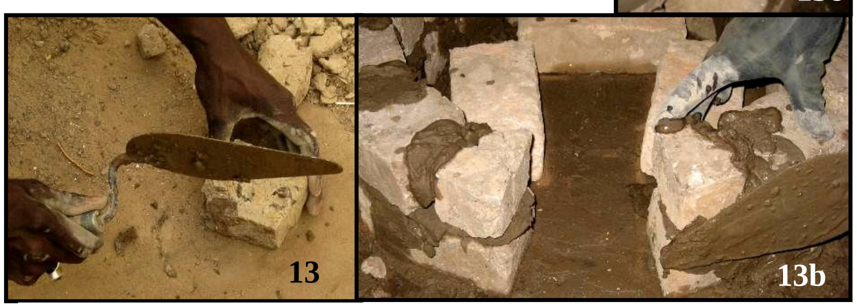


Figure 13: Cutting a brick in half to offset the joints

C) Step by Step Brick Production:

1) Collect the quality clay by removing the first topsoil layer.
2) Break the clay lumps into small pieces (Figure 5a).
3) Mix clay and lime with shovels in the following proportion:
5 parts clay for 1 part lime
4) Mix with a significant amount of water to create bonding between the clay and lime[7].
5) Cover with plastic tarp and **leave to rest for up to 5 days**.
6) After 3 to 5 days, mix well and apply enough water to obtain a homogeneous and smooth mixture (Figure 5b).
7) Soak a metal mold in water.
8) Fill up a metal mold with the clay mixture using a trowel. The mold can be filled properly by pushing down the clay mixture with the trowel (Figure 5c).
9) Wet the trowel and scrape the top of the mold to remove excess clay and to even the surface (Figure 5d).
10) Remove the mold by lifting up gently by holding the handles (Figure 5e).
11) Repeat steps 6 to 8 until more clay is required.
12) Leave the bricks to dry for at least 5 days before stacking.

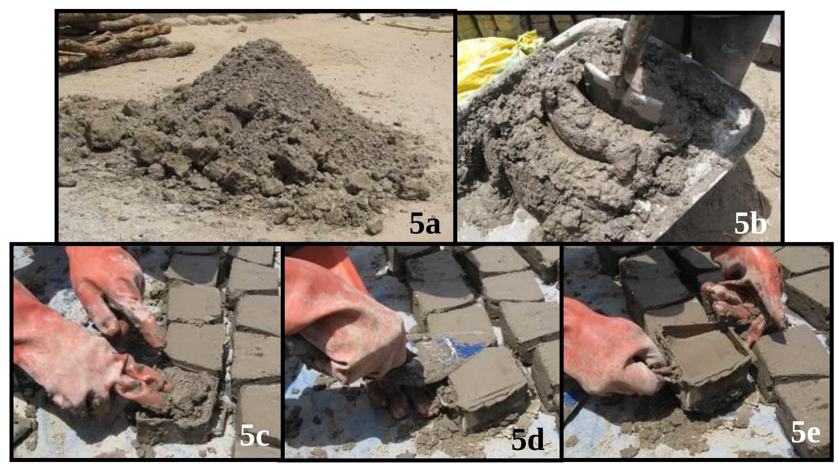


Figure 5 : Clay brick production

D) Production of Fired Clay Bricks:

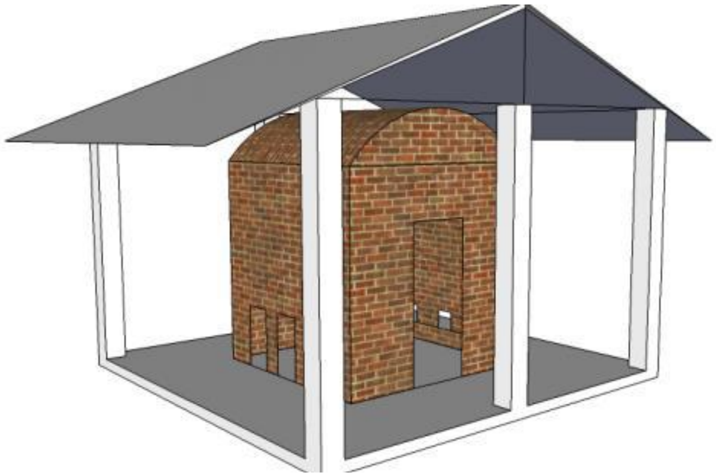


Figure 6: Kiln for the production of fired bricks

The Fired bricks are recognized to be stronger, more heat resistant and more water resistant than sun-dried clay bricks. Prior to firing, combustion chamber bricks are made using the same brick production method mentioned in the previous section except that no lime is required. Then, when the clay bricks are dried, they are heat treated to enhance their structural properties. No lime is added to the clay when the bricks are to be fired in a kiln for either type of clay.

Using a kiln will reduce the wood consumed in firing bricks as it conserves heat. The kiln design feature in Figure 6 is 2 x 2 x 2 m and is made to fire 1 000 bricks. The kiln should be built on a concrete slab, with a roof over the kiln, made from corrugated steel to protect it during the rainy season. The kiln is designed with 3 openings for wood insertion along the base, and 3 smaller holes on the opposing side for additional air input.

10) Tap each new brick with your fist or with the handle of the trowel to place the brick properly into the mortar (Figure 9e).

11) The combustion chamber will always remain the same size (Figure 10) even if the pot is slightly bigger.

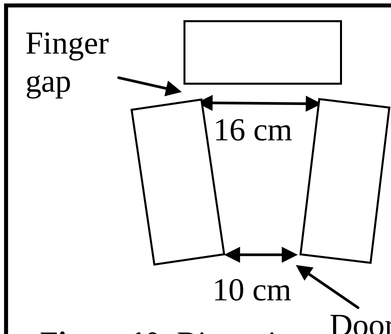


Figure 10: Dimension of the combustion chamber

12) Place 12 wall bricks, with the wider side outwards, around the combustion chamber following the trace of the pot perimeter. Leave 1 to 1.5cm gaps between each brick to apply mortar. A gap the size of a finger should remain between the wall bricks and the center bricks for air circulation (Figure 11).

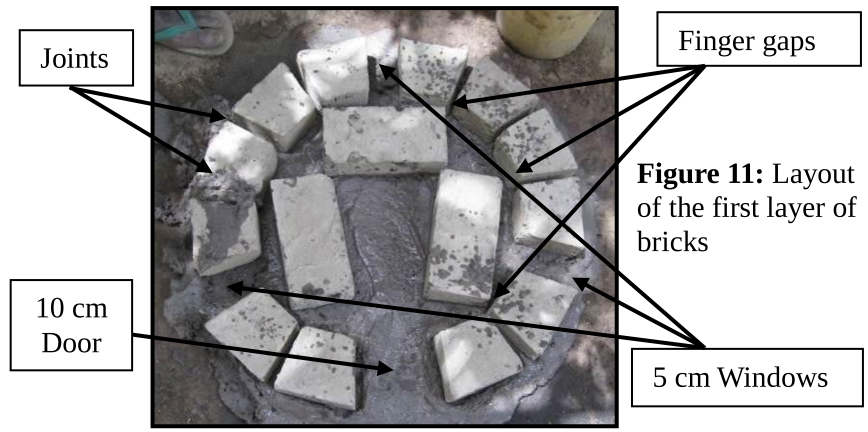
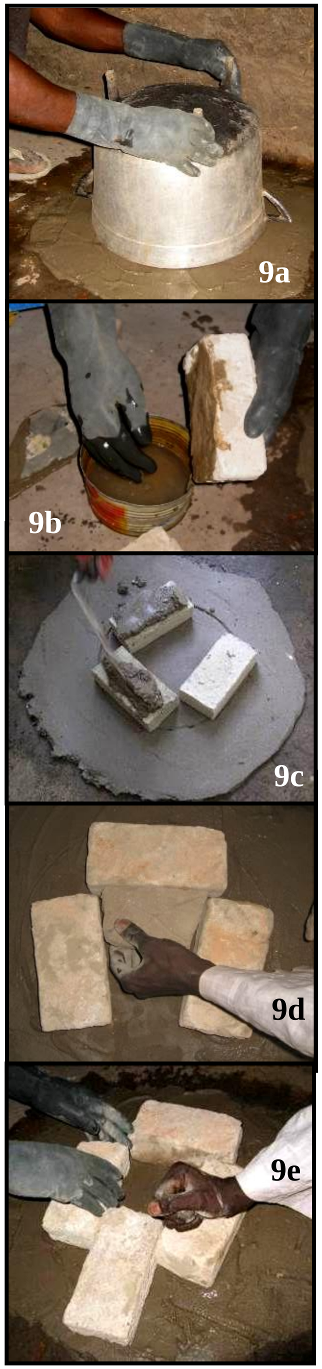


Figure 11: Layout of the first layer of bricks

13) Leave a window of about 5 cm wide behind each center bricks to restrict excess air to the fire[4] (Figure 11). Use a wall brick vertically as a jig to measure the window opening (Figure 12a).

C) ***Step-by-Step Construction***

1) Prepare the mortar to obtain a smooth thick paste (Figure 8b).
2) Level the ground where the stove is to be built inside the kitchen. Wet the floor to create greater adherence between the mortar and the ground.
3) Using mortar, create a level surface on which to build the stove.
4) Turn the cooking pot upside down on the surface and trace the perimeter (Figure 9a).
5) Wet the bottom surface of the bricks before placing them. This allows the brick to stick well to the mortar (Figure 9b).
6) Place the three first center bricks in an open triangular shape in the middle of the circle to form the first brick layer of the combustion chamber (Figure 9c).
7) Measure the top of the triangle using a window brick as a jig (Figure 9d). The distance should be 16 cm (Figure 10).
8) Leave a gap the size of a finger between each bricks at the two top corners of the triangle to allow air circulation (Figure 9e).
9) Measure the opening of the door (10 cm) at the bottom of the triangle with a center brick (Figure 9e).



The Noflay Stove Concept

The Noflay is made from 70 clay bricks (for a 30-34cm diameter pot) and has two main features: a central combustion chamber and a surrounding outside wall (Figure 4b). The stove has four different shapes of clay bricks required for its production (Figure 4a).

A) The Combustion Chamber

The combustion chamber is made of center bricks (Figure 7a) which are fired in a kiln. This heat treatment renders the bricks more resistant to the high temperatures in center combustion chamber. Firing also improves the strength of the bricks to better support the weight of the pot. The combustion chamber design encloses the fire[11], cuts excess air[4] and allows the fire to reach higher temperatures. The chamber is about 20cm to allow good flame formation and residence time to combust gases and reduce the smoke[8 10]. The chamber has an open triangular shape. Overall, there are 9 center bricks in the combustion chamber (3 sides of 3 bricks each). Also, the Noflay is readily acceptable since the combustion chamber reminds the user of a three-stone fire with its 3 points of contact with the pot.

Features of the combustion chamber are:

- <u>High temperature combustion</u>: the combustion chamber has preheated air and is defined with 20cm walls that confine the fire to improve heat transfer[11]
- <u>Improved heat transfer</u>: the central combustion chamber directs hot flames under the pot and allows them to pass through the narrow gap along the outside of the pot[9]
- <u>Turbulent flame formation:</u> the triangular shape creates air movement which benefits the fire in forming turbulent flames[10]
- <u>Reduced smoke:</u> gases are combusted in the combustion chamber[8, 10]

Figure 7: Stove Design

B) Outside Wall

The outside wall experiences lower fire temperatures than the central combustion chamber. The main material considerations in designing the outside wall are: to keep production costs low (fired bricks are at least twice the cost), to provide adequate strength to maintain wall integrity and to protect the bricks from water erosion from spillage from the pot. The most appropriate solution was to use unfired clay bricks (with lime in case of Montmorillonite clay). The outside wall is composed of three types of bricks (Figure 7a): 3 window bricks, 1 door brick and about 57 wall bricks (for a 32-34 diameter pot). The wall keeps the heat close to the pot and protects it from cooling winds. It is built at a distance of 1.5cm from the side of the pot[9]. The wall allows air entering the stove through the windows to be preheated before entering the combustion chamber.

Features of the outside wall are:

- <u>Reduced excess air:</u> with smaller entry points for primary air (3 windows in the bottom layer of bricks) and making a round shroud that is adjusted to fit to local pot size (the pot plugs the hole that creates excess drafts in most stoves)[4]
- <u>Primary air restricted & diversified:</u> 3 of the 4 entry points are nonaligned with the combustion chamber[4]
- <u>Preheated air:</u> cooler outside air is drawn in and along the narrow gap between the inner combustion chamber and outside walls where it preheats
- <u>Secondary air:</u> 4 small air entry points for secondary air in the 4th layer of bricks

The Noflay Stove Construction

The Noflay can be easily built by local masons. The stove construction is intended to honor local masonry knowledge and build upon their knowledge of brick applications. Other local community members, including youth and women, can also be easily trained to build the Noflay.

Material required to build the stove (for a 30-34cm diameter pot):

- Cement & Lime
- Water
- Sub-soil
- Measuring tape
- Wheel barrow (mixing container)
- Trowel
- 1 Door brick
- 3 Window bricks
- 57 Wall bricks
- 9 Center bricks

C) Mortar

Mortar (about 1.5 cm) is added between each brick to fix them together and increase the stove's stability. The mortar is made using the following proportions: **1 part cement for 1 part lime and 2 parts sub-soil**

The sub-soil can be collected by removing the top-soil and its debris and by digging into the ground (Figure 8a).

The mortar is prepared by mixing the lime and sub-soil in the right proportions with a bit of water and letting it rest for 5 days. Then, the cement is added with sufficient water to create a homogeneous mixture (Figure 8b). The stove is allowed to dry for 3 days before first cooking on it to ensure proper drying of the mortar.

Figure 8 : Mortar preparation