1 A Short Account on Agricultural Natural Resources

Introduction

Natural resources can broadly be divided into Renewable and Non-renewable. Whereas the non-renewables include such resources as minerals, which cannot replenish themselves once used, the renewables include plants, animals, soil, water and the atmosphere, which do replenish themselves.

In addition to its economical significance, forest-a renewable resource plays a key role for ecological balance and environmental sustainability in general. Thus, the misuse of the resource has not only its economical implication but also influences the environmental security surrounding humanity. The destruction of forests negatively affects soil erosion, climate change (local and global), agricultural productivity as well as poverty and the environment in general.

Ethiopia's Forest Resource Situation

It is believed that more than 60% of the country's soil used to be covered with High Forest, Savannah Woodland and Bushland forests before the last couples of centuries. However, due to the unwise utilization and destruction sustained for the last several decades, the coverage declined to 40% in the turn of the 19th century. It further declined to 16% in the beginning of the 1960's. Due to the increased economical, social and political activities following the change of government in 1974, the situation worsened and in the late 70's the resource was found further dwindled to 3.5%. Currently, the coverage is estimated at a mere 2.7% since the destruction is ever worsening. It is therefore evident that less emphasis is given to the protection and development of the resource in the country. For the majority of the society, the importance of the resource in respect of the aforementioned benefits has yet to come into the picture. Still, we are in a situation where almost everybody has free access to the resource as a means of income. It is therefore implied that the general awareness by the society towards forest and its importance is minimal.

The causes of the destruction of forests in Ethiopia are several and complex: the increase for the need of arable and grazing land, expansion of towns and new settlements, and the increase in the firewood demand as well as materials for construction are some of the main. These, mixed with the ever increase in the population, exacerbate the situation further and especially the resulting soil erosion forced smallholding farming households move to areas already affected by soil erosion.

Except some sporadic endeavors, however, extensive and prudent measures towards solving the problem are yet to be taken. On the contrary, the practice today is that more forested areas are being cleared in search of new cultivable lands to compensate for the decline in agricultural productivity.

The majority of the population uses firewood as a source of household fuel. Moreover, raw materials for such applications as building construction, household furniture manufacturing, animal feedstock, etc all come directly or indirectly from the forest. These practices of utilization, in unsustainable manner, have obviously accelerated the deforestation rate resulting in the environmental degradation, climate change, and decline in the soil fertility and agricultural productivity, which led ultimately to desertification, the impact of which have been eventually affecting the livelihood of the people.

The following are among the basic factors inherent to the problems surrounding the forest resource of the country:

- Lack of policy addressing forest and land use issues
- Increase in the population of both inhabitants as well as animals
- Lack of awareness of the public for the protection and development of forest
- Lack of strong institutional framework vested with the responsibility of developing and administrating the forest resources of the nation

In sum, we are in a situation locked with several problems surrounding our forest resource base.

The two universal solutions for alleviating the problems, agreed up on by many scholars and professionals in the field, are:

1. Utilization of the existing resource in a sustainable way and
2. Afforestation measures to increase the level of the resource base

On the other hand, it has already been mentioned that the majority of the population is utilizing firewood and agricultural remains as their main sources of fuel.

Since the last couples of decades, the government of Ethiopia has implemented successful measures for the dissemination of improved stoves in a bid to promote the efficient utilization of fuel. With the same cause, the MoARD/GTZ-Sustainable Utilization of the Natural Resources for Improved Food Security-Energy (GTZ-SUN: Energy) project is currently implemented by the Federal Ministry of Agriculture and Rural Development and the German Technical Cooperation (GTZ).

The GTZ-SUN: Energy project

The project's general goal is to contribute to the sustainable development and utilization of the natural resources of the country. With these goals, the project intervenes to meeting the following main objectives:

- Catalyze the developments of the energy resources, especially Renewable Energy (RE) resources and technologies, to promote rational use of natural resources, poverty reduction and food security
- Enhance the capacity of the different partner government agencies and other stakeholders to integrate and execute energy development measures into their development programs
- Promote energy efficiency at all levels (especially the efficient use of

biomass resources at the households)

The project embarks on the following strategies towards hitting its goal and meeting its objectives:

- Undertake capacity building measures for the different stakeholders in developing strategies for, and implementation of energy development measures
- Promote strong participation of the private sector in the development and provision of energy services
- Promote the awareness about, and the adoption of different environment friendly energy technologies and measures
- Actively promote the awareness of decision makers and the general public on environment and energy issues

The project's strategy regarding the promotion of Mirt improved Injera baking stove include:

- Focus on the commercial dissemination of the stove
- Involving the private sector, through the formation of small holding stove production and sales enterprises, for the commercial dissemination of the stove
- Promote and support the decentralized production and dissemination of the stove
- Close cooperation with government and non-government agencies

The project has commenced its activities in 1998 and has since established more than 350 private stove production facilities in more than 200 towns in Amhara, Tigray, Oromia and Southern Nations Nationalities and Peoples' regions.

Moreover, the project has been closely cooperating with different agencies, institutions and organizations to promote and disseminate the stove all over the nation.

2 Fuel Saving Stoves

Introduction

Energy from fire has long been used in activities such as cooking, which require energy. In addition, especially in the ancient civilizations, fire served as a typical means of protection against predator animals. Then, the sources of energy serving the purpose were mainly from plants that are known, by their collective name, as Biomass Fuels.

Energy is an indispensable part of every civilization. However, according to the level of civilization, different sources of energy are utilized. Mineral fuels such as gasoline and gasoil have been used to run locomotives and different machinery whereas to produce electricity, hydropower, solar energy, wind and coal have been used.

Food, being a necessity for life, has to be cooked before serving. For this purpose, different forms of energy such as electricity, gasoline, natural gas and coal, as well as biomass are being used. From all these, the share of biomass energy, worldwide, is significant and about 80% of the planet's population depend on this resource for their daily livelihood. The picture is never different in our country where about 95% of the energy demand is satisfied by the utilization of these sources.

The direct burning of biomass fuels in the traditional way emits partially burnt gases, which are harmful to human respiratory and visual systems. This is not only dangerous to women and the accompanying children usually exposed to these gases but is also wastage in terms of fuel utilization as the energy that could otherwise be obtained from burning them, is lost. Moreover, fire hazard associated with the three-stone open fire is among the common household problem especially in the rural Ethiopia.

Currently, in some areas of Ethiopia, households are forced to expend 30 to 40% of their income on cooking fuels. In the areas where fuel is acquired through free collection from the jungles, women and children responsible for the duty have to travel 5 to 6 hours in search of fuel.

As pointed out earlier, the causes of the problem are the clearing of forests in search of cultivable land, excessive use of the forest resource for construction and fuel purposes, etc. These led to firewood shortage and people have to travel farther away from their residences to collect fuel.

In addition, the country has long been suffering from recurrent droughts and erratic rainfall. Since the agricultural remains and animal dropping outs are used as fuel, the soil fertility is declining very fast. The loss of soil fertility is not, however, remedied by chemical fertilizers and consequently the agricultural productivity is very much low.

In an effort to alleviate the problem, though only partially, fuel use efficiency at household level is one of several measures that need to be taken. It is well known that the three-stone open fire, which is common all over the nation, is a very inefficient way of cooking, from energy utilization point of view. Only 8-10% of the heat goes to cooking the food where as more than 90% of the heat is simply wasted.

In this article, a brief account on fuel characteristics with due emphasis on firewood, the combustion phenomenon and process, heat transfer mechanisms, heat dissipation mechanisms from stoves and the methods to minimize it are presented. Finally, it is discussed about mirt stove, all its features, how it is produced, in more detail.

2.1 How Do Fuels Burn?

For it is the most relevant fuel in this context, let's take the case of firewood to investigate the combustion phenomenon.

Typically, wood consists of cellulose, lignin-a compound of carbon and hydrogen, resin and water together with gum bases. To fire wood, oxygen is needed in addition to the minimum amount of heat energy to start the combustion process. When burning wood, the source of oxygen is atmospheric air. Atmospheric air is 79% nitrogen gas and almost 21% oxygen. In any combustion process, the amount of oxygen being supplied plays a crucial role. Whenever there is enough oxygen, the wood burns well, with less smoke.

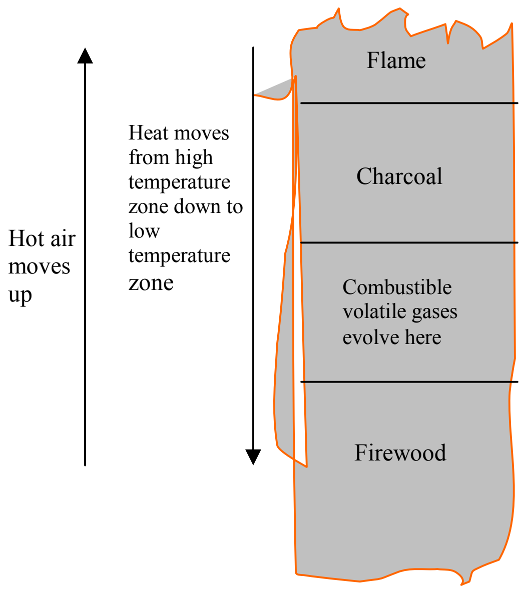
In the early stage of the combustion of wood, water and carbon dioxide come out of the wood and begin to cover its exterior. This shielding prevents the contact of the wood from oxygen and consequently smoke is emitted.

However when the combustion progresses, the amount of the heat of combustion increases resulting in the evaporation of the water and in the evolving of combustible gases and liquid tar like compound from the interior of the wood. More gases come out when the liquid tar is heated with the already carbonized wood. Finally, the chemical reaction of the emitted gases with oxygen produces chemical compounds that we see as flame.

For combustion, every combustible gas requires its own minimum amount of temperature and oxygen. In closed stoves if more than required amount of oxygen enters the stove, the extra amount of air robs some of the heat of combustion on its way leaving the system. Also, if the speed of incoming air is more than necessary, then it will be difficult to attain enough temperature in the stove that would otherwise progress the combustion. Nor is it possible to have a good combustion in the stove if the amount of incoming air is less than the required.

Once the situation of good combustion is attained in the system, all the combustible gases will come out of the wood and burn further developing the process. Eventually, carbon monoxide and nitrogen begin to burn and the carbonized wood gives off heat burning as charcoal.

When the combustion occurs very fast, the production of liquid tar and combustible gases will be very fast which produces more heat in a relatively short period. Here the produced charcoal is relatively smaller. On the contrary, when the air supply is small the combustion occurs slowly and results in the production of more charcoal.



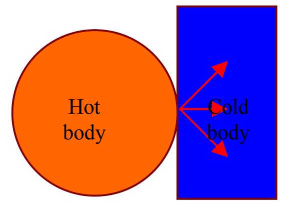
2.2 Heat Transfer

The three modes of heat transfer that occur in nature are:

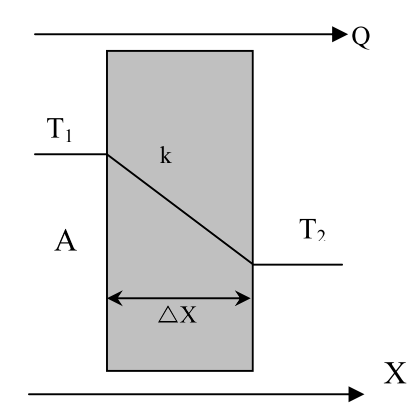
a. Conduction
b. Convection and
c. Radiation

1. Conduction

Heat transfer, by conduction, occurs by virtue of temperature difference in the direction from the body of higher temperature to that of lower temperature. This transfer will continue until a state, called thermal equilibrium, is reached at which the two bodies are at the same temperature.



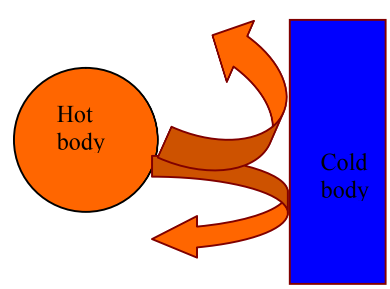
The amount and the rate of the transferred heat depend on the heat conduction characteristics, expressed as the thermal conductivity, of the two bodies. Some materials are good conductors of heat but others are not. Materials such as steel and basalt are good conductors of heat. Materials such as clay, sand, earth (soil) as well as wood and sponge, are poor conductors or good insulators of heat.



$$Q = \frac{k \triangle T\, A}{\triangle X}$$

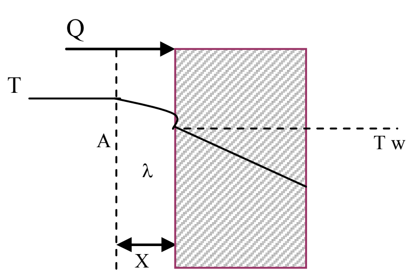
Q = Heat conducted
k= thermal conductivity
△T= Temperature difference
△X= Distance of heat conduction
A= Surface area of heat conduction

2. Convection



To understand the transfer of heat by convection, let's consider a certain liquid in a metal container whose bottom is exposed to a source of heat.

Under a state of high temperature, molecules of gases and liquids (collectively known as fluids) rise against the pull of gravity. This movement induces the movement of colder molecules in the downward direction. This continuous motion will keep on so long as the heat is being supplied and every molecule of the fluid is at the same temperature. The resulting motion is circulation in which hotter molecules move upwards and colder molecules move downwards. This dynamics of material transport effects the distribution (i.e. the transfer) of heat, which we call convection, in the fluids.



$Q = hA\Delta T$
h = convective heat transfer coefficient
A = heat transfer area
ΔT = Temperature difference

Another instance of convective heat transfer is when a fluid is forced to flow over a hot/or cold solid surface. According to whether the fluid is hotter or colder than the solid, heat is transferred from the fluid or to the solid, respectively, by convection. Such kind of convection is called forced/or active convection. Examples of active convection include, cooling of water in automotive radiator and the cooling of hot pot by the surrounding air.

3. Radiation

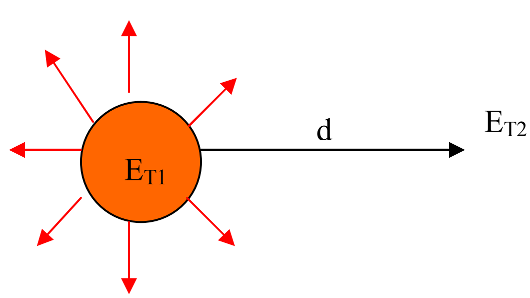
A good example of such energy transfer is the sun's radiation coming to our planet.

No matter small it may be, every material radiates heat energy as long as its temperature is above -273.15 °C. Materials that intercept the radiation reflect part of the energy while they absorb some of it. Some of the energy could also be transferred to other bodies, by either one or the combination of the other modes of heat transfer.

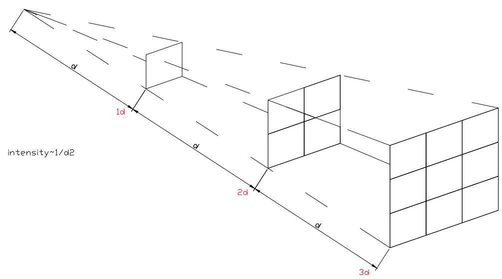
Radiation cannot be recognized with naked eye when emitted and transferred at lower temperatures. But, it becomes more visible when the temperature increases. When burning, wood gives off a flame radiating a lot of energy.

$$Q = \sigma F_e F_A (T_1^4 - T_2^4)$$

σ= Stefan Boltzmann's constant ($5.7x10^{-8}$)
F_e= Emissivity coefficent
F_A= View factor
T_1=Temperature of body 1
T_2= Temperature of body 2



Radiative heat transfer



$$E_{T2} = \frac{E_{T2}}{d^2}$$

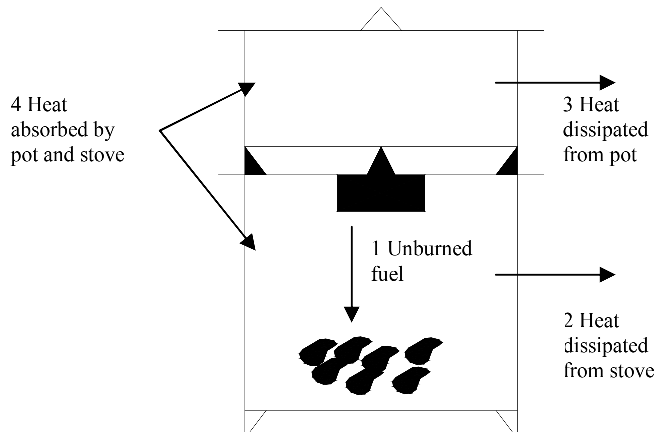
E_{T1} = source radiation intensity
E_{T2} = radiation intensity at distance d
d= distance from the radiation source

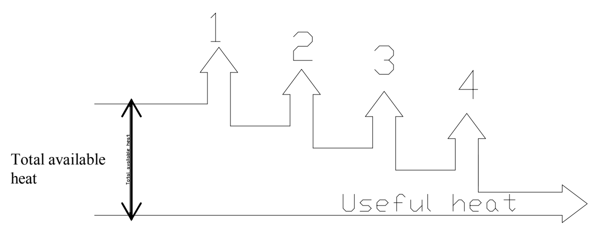
2.3 Heat Leakage from Stoves

As already pointed out, the heat leakage from three-stone open fire is unmatched. Heat is lost through convection and radiation from the three stones, since their temperature is very high. Since the 'stove' is not closed, the hot gases burn and simply leave the system without heating the cooking pot (or *mitad* (plate) in the case of baking). The combustible gases may even leave the stove without burning, making the fuel wastage even worse. This phenomenon is observed as dark smoke coming out of the stove.

The common clay stoves in use also have problems. Their clay walls are thin and heat can be lost easily through that. Since the size of the stoves itself is not properly designed, the amount of air flowing and fuel put into them is not proportional. This makes the combustible gases escape the stove without burning and hence the heat that could otherwise be obtained is lost.

In general, the following are the main mechanisms of heat loss from stoves:





Mechanisms of Heat Dissipation from Stoves

1. ***Incomplete combustion***

Some of the emitted gases from the fuel leave the system without burning. The remaining fuel left unburned as charcoal, is considered also waste.

2. ***Heat loss due to loss of hot flue gases from stove***

The inert parts in the incoming air such as nitrogen rob some of the heat generated in the stove on their way leaving the stove. The nitrogen containing air comes into the stove with a lower temperature, say 23 ^{o}C. But, when leaving the stove its temperature could go as high as 400 to 500^{o}C but never less than 250^{o}C. This means some of the heat is lost together with the smoke. In addition to this, the moisture of the firewood is given off from the stove in the form of vapor, which cannot be realized without stealing some of the heat of combustion.

3. Heat loss due to absorption by the stove and cooking utensil

During operation, before heating/cooking the food, the cooking utensils have themselves to be heated. Also the stove itself takes some of the heat of combustion. Since it is only then some of the heat transfers to the food, the remaining heat contained in the utensils and the stoves, is considered wasted.

Heat absorbed by stoves and cooking utensils

Q= mC△T

C = Specific heat capacity

m = Mass

△**T**= Temperature difference

(Specific heat capacity (kJ/kg.K)

- Air	0.1
- Concrete	1.0
- Water	4.189
- Full wood	1.8
- Clay	0.92-1.0 (depending on its moisture content)
- Iron	0.45-0.5
- Aluminum	0.9
- Copper	0.39
- Vermiculite	0.84-1.08 (Total condition)

4. Heat loss from the stove parts to the surrounding environment

During operation, since the stove is at higher temperature than the surrounding environment, it is obvious that heat transfers by the three modes of heat transfer, from the stove to the surrounding environment.

5. Heat loss from the cooking utensil to the surrounding environment

By similar argument as in the case of the stove, heat transfers from the cooking utensils to the surrounding. In addition to that, heat of evaporation is one way of heat loss in *injera* baking, *wot* (sauce) cooking and water boiling, especially when there are not lids to cover the utensils*.

2.3 How can we minimize heat loss?

The strategies for minimizing heat loss from stoves are born from the causes of the problems of heat losses themselves. They are summarized as follows:

1. Shielding the fire against ambient

It has been already said that three-stone open fire is exposed from all its sides to the surrounding environment. This makes it easy to give off the heat of combustion especially by convection and radiation. Therefore, the obvious remedy is to shield the fire against the ambient. This not only decreases the heat loss by the aforementioned mechanisms but also minimizes the creation of smoke, as the peripheries of the flame will not be exposed to the lower surrounding temperatures that otherwise would cool the flame and inhibit the burning of the combustible gases evolving from the firewood.

* The amount of heat energy needed to raise the temperature of 1 liter water from 20°C to 100°C is about 335kJ, whereas 2260kJ (more than 6 folds) of heat is required to evaporate the same amount of water at the same temperature of 100°C.

The selection of the proper material for the shielding plays significant role, as well. The common stoves with metal walls loose heat to the surrounding easily. However, such materials as earth, clay, concrete, cast iron are good insulators as they heat up slowly and do not give off heat fast either, thus can be considered as good candidates for shielding material.

2. Regulating the incoming air streaming into the stove

In biomass stoves, the place where the wood burns is called firebox. For we have to obtain a good combustion, we have to make sure that just enough air is reaching to the firebox. One strategy to do that is to design the stove air inlet so that it allows just enough amount of air into the stove.

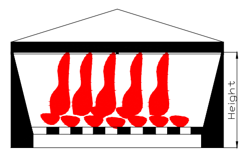
Another important part of the stove in relation to this issue is the flue gas (smoke) exit. Stoves 'breath' (i.e. suck in fresh air and give out exhaust gases) on their own thanks to the pressure difference between their two extremes (i.e. air inlets and exhaust gas outlets). When the pressure difference is beyond the requirement, more air comes in disrupting the proper combustion that would otherwise occur, just as mentioned earlier. The over-pressure situation may occur when, for example, the fuel outlet chimney is higher (in height) or wider (in area) than necessary.

3. Sizing the fire box

We have also to determine the proper distance between the fire bed and the cooking utensil to ensure maximum amount of heat being transferred to the utensil. To do this, we have to make sure that the utensil's part exposed to the flame is not very far from the heat source, i.e. from the burning fuel. This is so because the most relevant heat transfer mechanism is either conduction (through physical contact) or radiation or both, which both need close distance.

On the other hand, the combustible gases need space and time to heat up and eventually burn. This calls for the distance to be not very close.

Heat transfer in stoves



When the height is increased beyond the design value

Conduction: (from flame to the baking pan) decreases

Convention: (from hot gases in the stove to the baking pan) decreases

Radiation: (from the red-hot charcoal to the baking pan) decreases

When the stove wall is thin or made of conductive material

Conduction: (from flame and red-hot charcoal to the stove wall and to parts of the stove in contact with the wall) increases

Convention: (from hot gases in the stove to the stove wall and then to the ambient air) increases

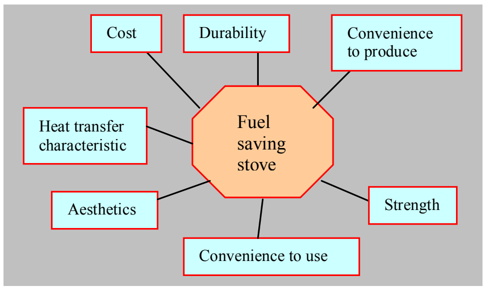
Radiation: (from the red-hot charcoal to the stove wall and then to the ambient air) increases

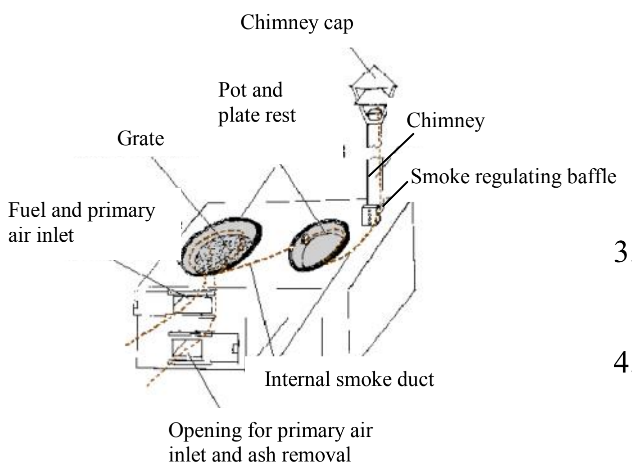
General Characteristics of Improved Stoves

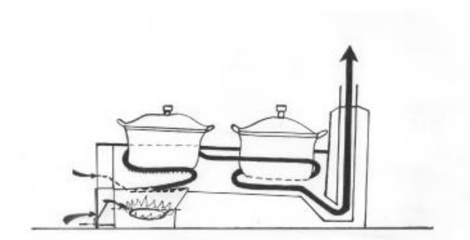
The general criteria an improved stove has to fulfill are fuel saving, one that prevents the user from heat and fire hazards, one that is acceptable and affordable by the users. It has also to work on the fuel, which the users can normally afford.

Improved Stove

Like any other product, one has to consider many other elements, beyond heat characteristics, when designing an improved stove. The following pictorial representation illustrates the problem one has to solve to provide an improved stove.





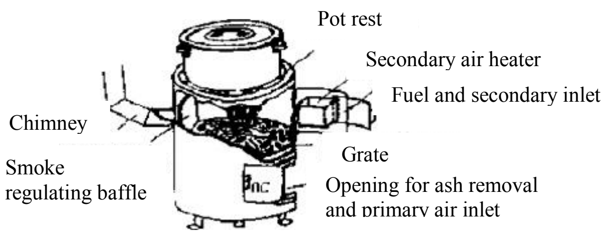


Characteristics of the stove

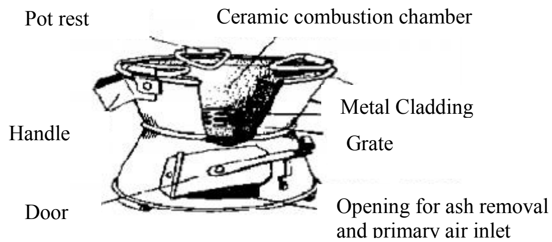
The stove depicted in the above figure can handle two pots at a time. In addition to the parts to serve the aforementioned purposes common to all improved stoves, it features some other units making the stove even better:

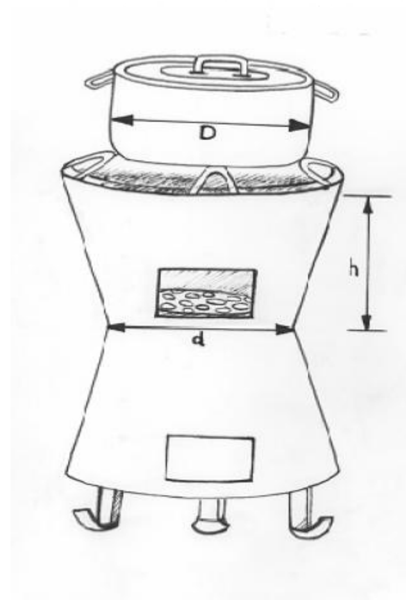
1. The combustible gases coming out of the burning wood make the flame while the solid part burns forming charcoal. Thus, the primary air, which burns the solid part (i.e. charcoal), comes into the stove from beneath and the secondary air, which burns the gases, comes into the stove from above the fuel. These are made possible through the two different doors; one is at the bottom and the other is at the top. Note that the top door also serves to put in fuel. We also see that there are control baffles used to regulate the incoming air flow.
2. The stove also features internal conduits usually made out of concrete or clay. Their purpose is to transport the exhaust gases while transferring their heat to the cooking pots on their way out. This effect is enhanced by making the conduits spiral around the pots, which creates more contact-area and -time between the conduits and the pots.
3. There are exhaust regulators around the exit of the stove just as there are on the inlet.
4. The caps fitted to the chimney can also be multiple. This is to alter the height of the chimney, in effect, to regulate the pressure difference between the inlet and the exit of the stove thereby regulating the incoming airflow according to the varying power needs.

Hypothetical improved firewood stove design



Improved Charcoal Stove



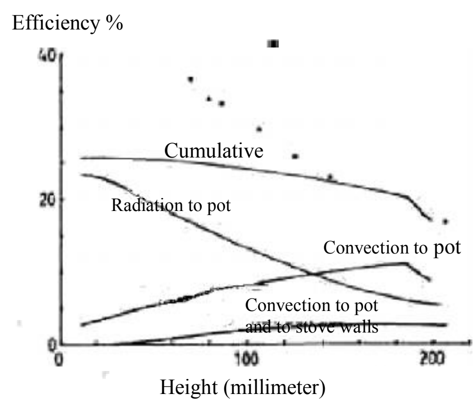


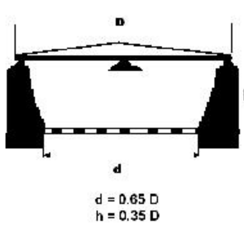
2.4 Stove sizing basics

The examples and descriptions so far illustrate the general characteristics that affect the fuel saving criterion of stoves and design considerations that should be kept in mind. Let's now see how we can determine the basic parts influencing the fuel saving characteristics of stoves.

The following dimensions have been obtained from literature. They have been determined through extensive research and trials and therefore they can be used, at least, as the starting point to design different fuel stoves.

Relationship between height and heat transfer rate in stoves





D= diameter of the pot (or any cooking utensil) on the stove

d= diameter of the fire bed

h= the height of the pot bottom from the fire bed

The fire bed /grate/ in different wood stoves can be provided with perforations, which are used to filter down ash from the burning wood and let in primary air to the firebox. As can be seen from the figures, the fact that the fire bed is smaller in diameter than around the top gives more room and more time for the combustible gases to heat up and combust before they leave the stove. Further, the fuel is made to keep its central position in the stove, which is needed for uniform heat distribution in the stove. Another advantage is the lower cost of production material because of smaller physical size of the grate.

Fuel and Air Inlet

It has already been mentioned that determining the proper size of the fuel and air inlet is an important part of the design of stoves.

Before going directly into it, however, we have to see some facts regarding the reacting substances-the fuel and the air:

- Typically, wood is composed of 50% carbon, 43% oxygen, 6% hydrogen and 1% ash. The fact that oxygen is available already in the wood in some amount makes the amount of external air needed small.
- To burn 1kg of firewood, the theoretical amount of air necessary is only 5m^3. However, since the theoretical conditions are not available in practice (such as the fuel is split into smaller pieces and virtually every atom of carbon and hydrogen is contacted by that of the oxygen) more air, up to 40% extra is needed; hence a total of 7m^3 is needed.
- The rate of airflow for a naturally aspirated stove (i.e. air flows into the stove without being blown) is about 1m/s.

Moreover, we have to know about the capacity of the stove we want to design:

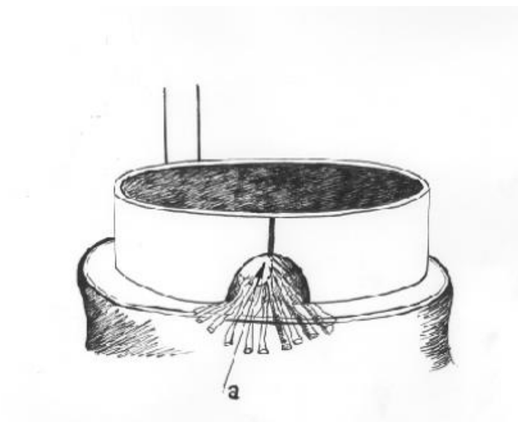
- A stove capable of burning 1kg of wood within an hour has about 5kW of power.

Knowing this we can determine the size of the air inlet, *a*, as:

$$a = \frac{amountofai\quad r}{speedofair\quad * timeneeded}$$

$$a = \frac{7m^3}{1m/s * 3600s} = 0.002m^2 = 20cm^2$$

The air inlet area for a 5kW power stove thus should not be too much different from 20cm^2.

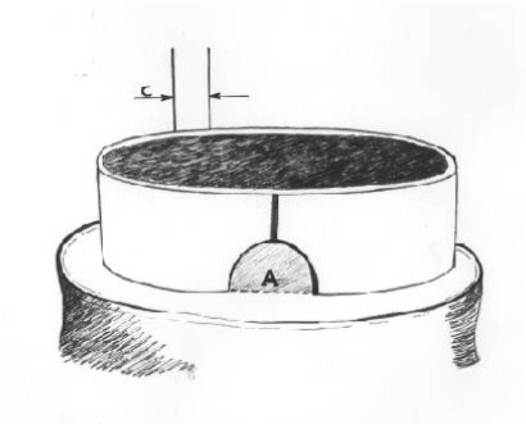


However, we have to determine the total size of air and fuel inlet, since both are usually put into the stove together. We have to employ a recommended ratio of fuel to air inlet areas to determine the area to be occupied by the fuel. Here we will assume that 70% of the total area will be occupied by fuel.

Thus, since we have already calculated the area of air inlet, to determine the total area of air and fuel inlet, *A*, we set, $a = 0.3 * A$ or

$$A = \frac{a}{0.3} = \frac{20cm^2}{0.3} = 67cm^2$$

This means that the area of the air and fuel inlet is about 8.5cm by 8.5cm.



It should be born in mind that the calculations presented are only to show the methods of determination of the different sizes of the stove and in real life, the values may differ significantly from one stove to another depending on the specific cooking needs and fuels to be used.

Exhaust outlet area

The following should be in mind to determine the exhaust area:

- The air entering the stove should exit the stove although changing its form (i.e. it leaves the stove as a different chemical compound)
- Additionally, there are combustible gases coming out of the firewood

These two facts call for the exhaust area to be greater than that of the air inlet. As recommended in literature we can make it 30% larger than the air inlet, in this case. Therefore, it becomes, *B*:

$$B = 1.3 * a = 1.3 * 20cm^2 = 26cm^2$$

Chimney

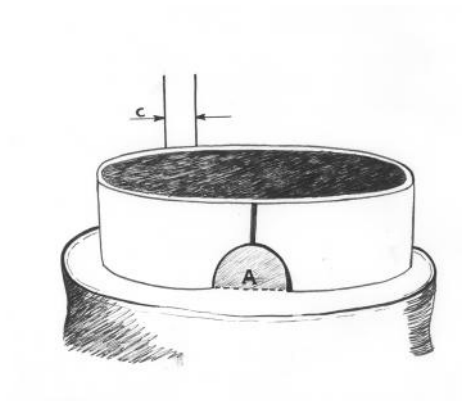
If chimney is required for the stove, then its area should obviously match that of the exhaust area. And since chimneys are usually cylindrical in shape, the diameter of their circular cross section can easily be calculated employing the formula of area of a circle. Thus, calling the diameter *C*, from

$$area = B = \frac{\pi C^2}{4},$$

$$C = 2\sqrt{\frac{B}{\pi}}, \quad \pi = 3.141$$

Doing the math gives,

C=5.75cm^2.

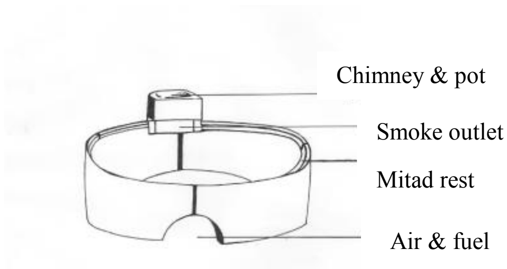


During operation, the chimney gets clogged with soot after some time and this would impede the exhaust flow. Therefore, the diameter can be increased up to 10 cm.

Regarding the height of the chimney, it should not be higher than half a meter especially for small kitchens. But, to eliminate smoke completely from the kitchen it can be made to rise up to another half a meter beyond the roofing of the kitchen. This means that the total length could go as high as 2 to 3 meters.
If chimney is not to be used, a pot should be rested on the pot rests provided on the exhaust outlet. This is to regulate the smoke as a baffle as well as to utilize the heat of the flue gases before they leave the stove.

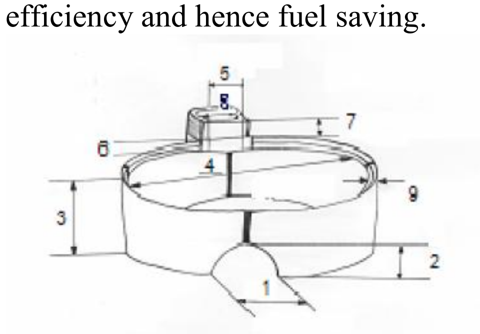
3 Mirt Stove

Mirt Injera baking stove was first developed by the Ethiopian Rural Energy Development and Promotion Centre in early 90's, when the stove was introduced for the first time to the Addis Ababa Market. Compared to the traditional open fire, the stove is proved to save fuel by 50%. All the fuels that we use on three-stone open fire (firewood, animal dung, branches, leaves, wood chip ...etc.) could also be used on mirt stove.



3.1 Main component parts of Mirt stove

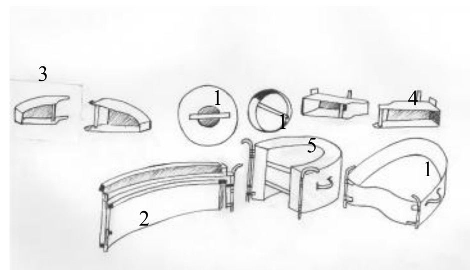
Mirt stove is made of 6 different parts. Like any other improved stoves, it is important to maintain the dimensions of the stove, in addition to maintaining the raw materials and production procedures, to obtain the expected efficiency and hence fuel saving.



1. Fuel inlet base width: 24 cm
2. Fuel inlet central height: 11 cm
3. Wall height (outer): 24cm
4. Wall diameter: 62 cm
5. Smoke outlet width: 19 cm
6. Smoke outlet height: 7cm
7. Pot rest height: 14cm
8. Pot rest hole diameter: 18cm
9. Wall thickness: 6 cm

3.2 Production mold

A set of mold consisting 8 different parts is used to produce mirt stove. The mold is to be manufactured from steel sheet metal of 1.5 mm thickness. Depending on its manufacturing quality and usage the mold can serve for not less than 3 years. Current market price of the mould is estimated ETB 600-900.

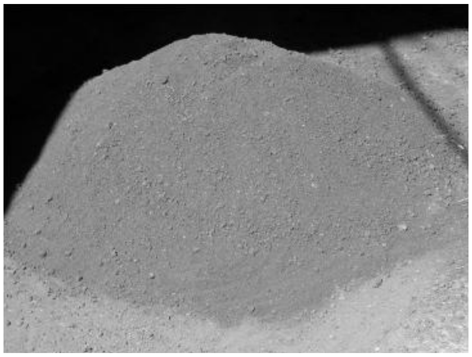


1. Mold for pot rest
2. Mold for wall
3. Mold for fuel inlet
4. Mold for smoke outlet
5. Mold for pot rest support structure

3.3 Raw materials for mirt stove production

Mirt is produced from cement and river sand. If red ash (scoria) is available, it is preferred to river sand. For best quality stove, the sand or the scoria should be free from dust or any other foreign material. Otherwise, we may risk the strength and the efficiency of the stove. The biggest particle size of either of the sand or the scoria should not be greater than 5mm.

Regarding river sand, it is seldom available free of dust. There could also be lustrous particulate materials called silica which affect the strength and heat transfer characteristics. Thus, material selection is an important element of production to guarantee a good quality stove.



To select a good quality river sand

1. Observe a sample. If there is too much silica in it then avoid it.
2. To see the proportion of dust in the sand, take a portion and put it in a transparent glass bottle. Pour some water and shake well to mix it uniformly and let it settle. After 5 to 10 minutes time, observe. If the amount of pure loam is not more than 2% then the material could be used with some washing. If not then avoid the sand.

To investigate the quality of scoria, the most important factor is the particle size of the material. Material consisting of particulate sizes either smaller than 3mm or bigger than 5mm should be avoided since both affect the physical strength and the heat characteristics of the stove.

Non-fresh cement or that which is exposed to air and/or moisture is a good recipe for a bad quality stove. Care has thus to be taken to avoid such material to produce the stove as it greatly affects the strength of the stove, especially at its higher operating temperatures.

3.4 Preparation of production place

a. Shade

Shade is needed as a workshop, to produce and store the stove. The size may depend on the production capacity needed but should not be less than $24m^2$ (6mX4m) in any case. For good ventilation, the minimum height should be 2.5m.

The floor should be made plane, whether made out of earth or concrete, to put fresh cast (which is wet and very fragile) without breakage or failure.

b. Space for screening sand

River sand is to be sieved with 3mm mesh-size sieve. Scoria shall be sifted first with 3mm mesh-size sieve and then the remaining, which is retained on the 3mm mesh-size sieve, shall be screened on 5mm mesh-size sieve.

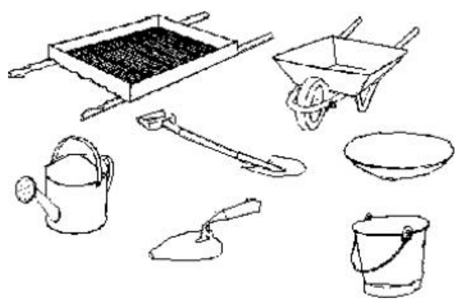
The sifted sand must be kept out of soil or any other dirt. For this purpose, a material, such as plastic canvas or any piece of cloth could be used. If not a special place should be prepared where the floor is lined with a thin layer of concrete. As much as possible similar care needs to be taken for the unsifted sand.

c. Storage

If accumulation of produce is deemed unavoidable, a special place should be prepared. Care has to be taken in order that the produces are not eroded by water especially during the rainy seasons.

3.5 Tools and raw materials for stove production

a. Tools



- Sieve for sand screening (3mm and 5mm mesh sizes)
- Jug for water
- Shovel (for cement/sand mixing)
- Mason's bucket (for sand and cement measurement)
- Mason's trowel
- Bowl (for river sand cleaning)
- Brush
- Stomping stick (wood or metal)
- Wooden board (or Chip wood board)
- Gloves
- Set of mold

b. Raw materials

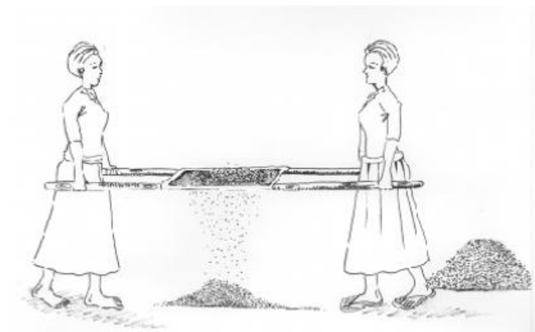
- cement (fresh)
- river sand or red ash(scoria)
- clean water (but not necessarily potable)
- used car engine oil (for lubrication of mold and for easy ejection of cast from mold)

3.6 Production

Raw material preparation

a. River sand

- Like already said, raw sand is first screened using 3mm mesh-size sieve



- The screened sand then shall be mixed dry with cement, with a sand to cement ratio of 3:1. The mixing is such that it should be homogenous.

- The homogenously mixed material is again mixed with water. Water is poured in to the mixture little by little and in steps while doing the mixing. It is difficult to measure the amount of needed water in advance but it can easily be known from the texture of the mix by looking at a handful of sample. In any case, the water should not be too much that the mix is very wet. This otherwise could lead to non-uniform cement distribution, more material consumption during production and heavy stove which all eventually lead to bad heat characteristics of the stove.

Another disadvantage of excess water is that it makes production difficult, especially to eject the cast from its mold.

b. Red ash (Scoria)

- Raw scoria is first to be screened with 3mm mesh-size sieve. The retained material on the sieve then is put on 5mm mesh-size sieve for another screening. Note the step that the screening should start from the smaller mesh-size sieve. Then a homogeneous mixture is to be formed, by mixing, from both particle sizes of material in 3mm to 5mm ratio of 3:1.
- The mixture is again mixed with cement in 4:1 ratio before it is mixed with water. The water is mixed just in a similar fashion as in the case of river sand; little by little while mixing and checking the amount.

Production

- The producer shall first check that he/she wears his/her gloves and that all the necessary tools for production are available nearby.
- It shall be made sure also that the mold is clean and free from any debris that hinder production and extraction of cast stove part. If possible, one can make use of used car engine oil before starting production by applying it in thin film on the interior of the mold. Be wary of the oil against contact with skin, however.
- Putting the mold on the appropriate wooden board, mixed material is then to be poured into the mold. While doing so it should not be forgotten to pound the material with a piece of blunt-ended wood or iron bar with a moderate force.
- It should not also to be forgotten that, when producing the wall part of the stove, the appropriate mold parts that create the openings for fuel inlet or smoke outlet are put.

- After filling the material into the mold, then the cast is ejected from the mold. Note that the cast should not be ejected before putting it on its place where it is to be dried. For easy ejection, hitting gently the sides of the mold with a piece of stick might help.
- The cast is then let to dry for about 24hrs before it is put off from the wooden board it has been standing on.
- After dismounting, the produce is then ready for watering. Once produced a stove part must be watered twice a day, at least for 7 days before putting it for sale or into service.
- After each day of production, cleaning the molds and all the working tools is imperative. Applying a thin film of engine oil, especially, to the interior of the mold helps protect it against damage by the cement.

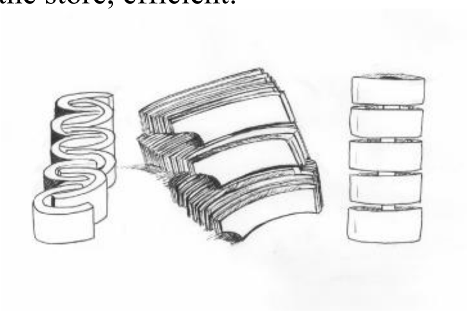
Notes:

The following pieces of advice are good for quality product, safety against personal injury and for prevention of damages to the working materials:

- Producers are advised always to lower bending their legs, rather than bending from their waste, to pick up or lower heavy things, such as stove parts.
- Tools, such as shovels and mason's trowel should be put in such a way that

they are not to recoil when for example accidentally stepped on them.

- Whenever watering the produces we should not do that while the produces are on the wooden boards in order to avoid damage to the boards.
- Produces of different days are advised to be sorted during watering and storing.
- Orderly storage of parts makes easy sorting and hence First-In-First-Out of them and makes the management of the store, efficient.



3.7 Transportation of mirt stove

a. Man power

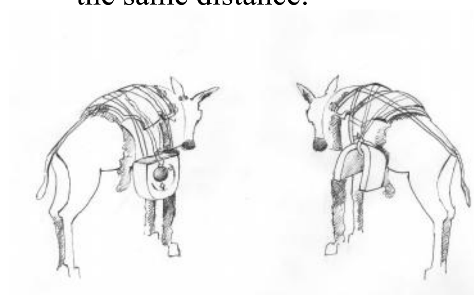
- 2-3 people can transport one full set of stove for 1.5 to 2kms.

b. Wheel barrows

- It is possible to transport one full set of stove for up to 6kms.

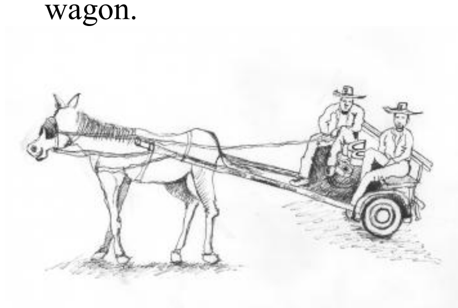
c. Pack animals

- A donkey, a mule or a horse can transport a stove for up to 10kms.
- It is possible to transport one more stove on a camel covering the same distance.



d. Animal powered wagons

- For up to 25kms it is possible to transport 2 to 5 full sets of stoves, according to the accommodation capacity of the wagon.



e. **Vehicles**

- On gravel roads, according to the specific situation of the roads, we can transport stoves for 50-100kms. The number of stoves being transported may vary according to the carrying capacity and space of the specific vehicle.
- However, for asphalted roads it is possible to transport more than 100kms of distance.
- If stoves are to be loaded on the roof-racks of vehicles, care must be taken to avoid damage by rubbing against each other. Thus, used carton paper, straw or any other thing serving the purpose, could be put between the parts and every thing must be tied tight with rope. It is also possible and helpful at the same time, to put light loads (e.g. sacks of grains, etc.) on top of the stove parts.

3.8 Installation of Mirt stove

It is recommended to install mirt, and any other stove for that matter, on an elevated platform. Therefore, preparation of such unit in the kitchen precedes the installation of the stove. The following are among the advantages of the platform:

- Tiredness and inconvenience during Injera baking are greatly minimized
- It is easy to control the fire in the stove
- It is possible to put around and to use required materials for the baking easily and conveniently
- Children and animals, which dwell usually in and around the kitchen, may be less risked of any fire danger
- Wetting from spill over of water and other liquids inside and around the stove is less likely to happen.

Different Types of Platforms

a. *Wett* (Solid) Platform

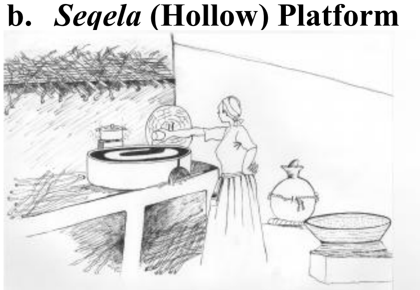
***Wett* Platfrom from Earth and Stone**

- Bigger stones are first put along the apparent rim of the platform.
- The interior then is filled with gravel and earth to the desired level.
- The top of the platform shall be compacted and (water) leveled well, wetting it with water. All the exposed faces could also be lined with mud to keep the aesthetics.

***Wett* Platform from Stone/Hollow Block/Brick**

- Like in the above case, the would-be rim of the platform is set first by putting either stones, or blocks or bricks, all around, to the desired level of the platform.
- Again, the interior is to be filled with gravel and earth.
- The top most part is then to be filled with a layer of concrete, by first putting small pieces of stones and gravel beneath. The concrete is to be made out of cement, sand and gravel, in the respective ratio of 1:2:3. The alternative to the concrete is brick or hollow block. Do not forget to water level them all, however.

b. *Seqela* (Hollow) Platform

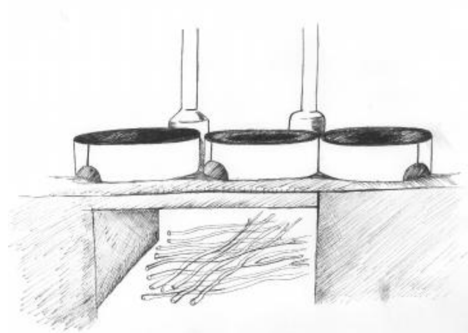


- This type of platform leaves a space underneath; the space can be used for storage.
- Firewood, for example, may be stored in the space. This is important as dry fuel itself saves fuel.

***Seqela* Platform Made from Earth and Stone**

- Wooden poles, preferably of branches of 'Y'-shape, are first erected in distances of 50 to 80 cm, depending on the desired area of the platform.
- A mesh made of wood is then constructed, put, and joined by any means, with the top of the erected wooden poles.
- A layer of gravel is applied on the mesh before applying a layer of soil finally and is finished.

***Seqela* Platform Made from Stone/Hollow Block or Bricks**



- The structure supporting the platform can be constructed from stone, or bricks without any reinforcement, but with reinforcement in the case of hollow blocks or concrete.
- The platform is usually made of concrete with steel or wooden reinforcement. The recommended reinforcing steel mesh size is 10 to $15cm^2$ using 10 to 12mm thick bars.
- Once made, the concrete has to be watered for 7 to 10 days.

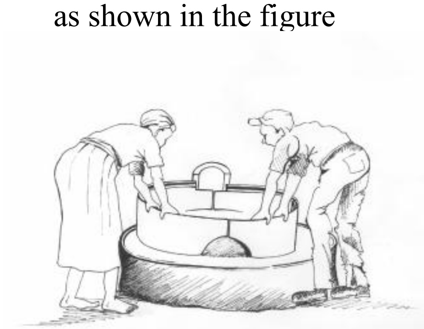
Note:
The fire bed in mirt stove is strongly advised to be made of clay material such as used/broken Injera baking pan, *Mitad*.

Installation of Mirt Stove

1. First mud mixed with straw is to be prepared as a bonding material for the parts

2. Start the installation from the back of the stove, i.e., from the 'U' and follow with the rear walls

3. Then assemble the rest of the walls as shown in the figure



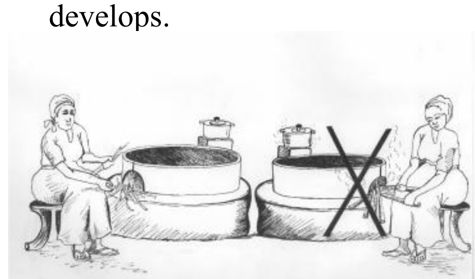
4. Continue with the baking pan, the *mitad*

5. Then the last part to assemble will be the pot rest. The opening that may be created between the pot rest and the *mitad* should be stuffed with mud together with small pieces of stone or broken pieces of clay material.

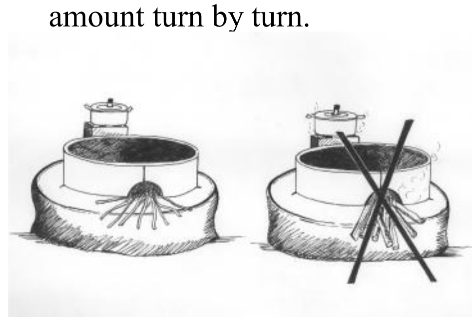
6. Finally all the joints shall be filled, lined and finished with mud.

3.9 How to Use Mirt Stove

- Start firing the wood just outside of the stove at its door in order to develop it and push in as the fire develops.

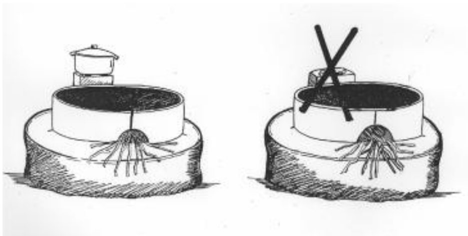


- Do not stuff too much fuel into the stove. It suffices to put just a little amount turn by turn.



- Use dry wood.
- Always put something on the pot rest, if not a pot of something to cook or

boil. This not only allows the efficient utilization of the fuel but also regulates the speed of the smoke exiting the stove thereby optimizing the heat distribution in the stove.



- It is advised not to puff into the stove to restart the fire. Use a flap like thing (e.g. a piece of hard paper) to blow in air. Otherwise, the flame may bounce back and harm the face.

- Water or any similar liquid is bad for the stove during or after operation. Contact against such things must therefore be avoided.
- After each session of operation, ash has to be removed from the stove. This is important for the proper combustion and hence fuel saving of the stove.
- It is desirable to repair the stove joints whenever necessary. The only openings on the stove should be the fuel/air inlet and the smoke outlet.
- It is possible and necessary to substitute any failed part of the stove.
- Whenever necessary the user may seek assistance from a stove producer or the concerned technical staff from the nearby energy or agriculture offices.