



# BIOMASS

## AS A SOLID FUEL

### Introduction

#### What is biomass?

Biomass is the term used to describe all the organic matter, produced by photosynthesis that exists on the earth's surface. The source of all energy in biomass is the sun, the biomass acting as a kind of energy store. To make use of biomass for our own energy needs we can simply burn it in an open fire to provide heat for cooking, warming water or warming the air in our home. More sophisticated technologies have been developed for extracting this energy and converting it into useful power and heat in more efficient and convenient ways.

Until relatively recently it was the only form of energy which was used by humans and is still the main source of energy for more than half the world's population for their domestic energy needs.

The extraction of energy from biomass is split into 3 distinct categories:

- **Solid biomass** - the use of trees, crop residues, animal and human waste (although not strictly a solid biomass source, it is often included in this category), household or industrial residues for direct combustion to provide heat. Often the solid biomass will undergo physical processing such as cutting, chipping, briquetting, etc. but retains its solid form.
- **Biogas** - biogas is obtained by anaerobically (in an air free environment) digesting organic material to produce a combustible gas known as methane. Animal waste and municipal waste are two common feedstocks for anaerobic digestion. See the [Biogas Technical Brief](#) for more details.
- **Liquid Biofuels** – these are obtained by subjecting organic materials to one of various chemical or physical processes to produce a usable, combustible, liquid fuel. Biofuels such as vegetable oils or ethanol are often processed from industrial or commercial residues such as bagasse (sugarcane residue remaining after the sugar is extracted) or from energy crops grown specifically for this purpose. Biofuels are often used in place of petroleum derived liquid fuels. See the [Liquid Biofuels and Sustainable Development Technical Brief](#).



Figure 1: Domestic biomass use in Sri Lanka. Photo: Jean Long / Practical Action.

This technical brief looks at the use of solid biomass fuels, and their associated technologies.

## Biomass use

Solid biomass is widely used in developing countries, mainly for cooking, heating water and domestic space heating. Biomass is available in varying quantities throughout the developing world - from densely forested areas in the temperate and tropical regions of the world, to sparsely vegetated arid regions where collecting wood fuel for household needs is a time consuming and arduous task.

In past decades the threat of global deforestation, provided a focus for the efficient use of biomass (as well as introducing alternative fuels) in areas where woodfuel was in particular shortage. Although domestic fuelwood users can suffer greatly from the effects of deforestation, it often arises because of land clearing for agricultural use or for commercial timber.

There have been many programmes aimed at developing and disseminating improved stove technologies to reduce the burden, primarily borne by women, of fuelwood collection as well as reducing health risks associated with smoke from burning fuelwood. Technologies have also been introduced to help with the processing of biomass to improve efficiency, allow for easy transportation or to make it more useable.

Crop and industrial biomass residues are now widely used in many countries to provide centralised, medium and large-scale production of process heat for electricity production or other commercial end uses. There are several examples in Indonesia of timber processing plants using wood waste-fired boilers to provide heat and electricity for their own needs, and occasionally for sale to other consumers. There are also small scale options to utilising crop residues.

## Combustion theory

For solid biomass to be converted into useful heat energy it has to undergo combustion. Although there are many different combustion technologies available, the principle of biomass combustion is essentially the same for each. There are three main stages to the combustion process:

**Drying** - all biomass contains moisture, and this moisture has to be driven off before combustion proper can take place. The heat for drying is supplied by radiation from flames and from the stored heat in the body of the stove or furnace.

**Pyrolysis** - the dry biomass is heated and when the temperature reaches between 200°C and 350°C the volatile gases are released. These gases mix with oxygen and burn producing a yellow flame. This process is self-sustaining as the heat from the burning gases is used to dry the fresh fuel and release further volatile gases. Oxygen has to be provided to sustain this part of the combustion process. When all the volatiles have been burnt off, charcoal remains.

**Oxidation** - at about 800°C the charcoal oxidises or burns. Again oxygen is required, both at the fire bed for the oxidation of the carbon and, secondly, above the fire bed where it mixes with carbon monoxide to form carbon dioxide which is given off to the atmosphere.

It is worth bearing in mind that all the above stages can occur within a fire at the same time, although at low temperatures the first stage only will be underway and later, when all the volatiles have been burned off and no fresh fuel added, only the final stage will be taking place.

Combustion efficiency varies depending on many factors; fuel, moisture content and calorific value of fuel, etc. The design of the stove or combustion system also affects overall thermal efficiency and table 1 below gives an indication of the efficiencies of some typical systems (including non-biomass systems for comparison).

Type of combustion technology	Percentage efficiency
Three-stone fire	10 - 15
Improved wood-burning stove	20 - 25
Charcoal stove with ceramic liner	30 - 35
Sophisticated charcoal-burning stove	up to 40
Kerosene pressure stove	53
LPG gas stove	57
Steam engine	10 - 20

Table 1: efficiencies of some biomass energy conversion systems  
 Source: Adapted from Kristoferson, 1991

**Improved stoves**

Much of the research and development work carried out on biomass technologies for rural areas of developing countries has been based on the improvement of traditional stoves. This was initially in response to the threat of deforestation but has also been focused on the needs of women to reduce fuel collection times and improve the kitchen environment by smoke removal. There have been many approaches to stove improvement, some carried out locally and others as part of a wider programmes run by international organisations. Figure 2 below shows a variety of successful improved stove types, some small, portable stoves and others designed for permanent fixture in a household.

Some of the features of these improved stoves include:

- a chimney to remove smoke from the kitchen
- an enclosed fire to retain the heat
- careful design of pot holder to maximise the heat transfer from fire to pot
- baffles to create turbulence and hence improve heat transfer
- dampers to control and optimise the air flow
- a ceramic insert to minimise the rate of heat loss
- a grate to allow for a variety of fuel to be used and ash to be removed
- metal casing to give strength and durability
- multi pot systems to maximise heat use and allow several pots to be heated simultaneously

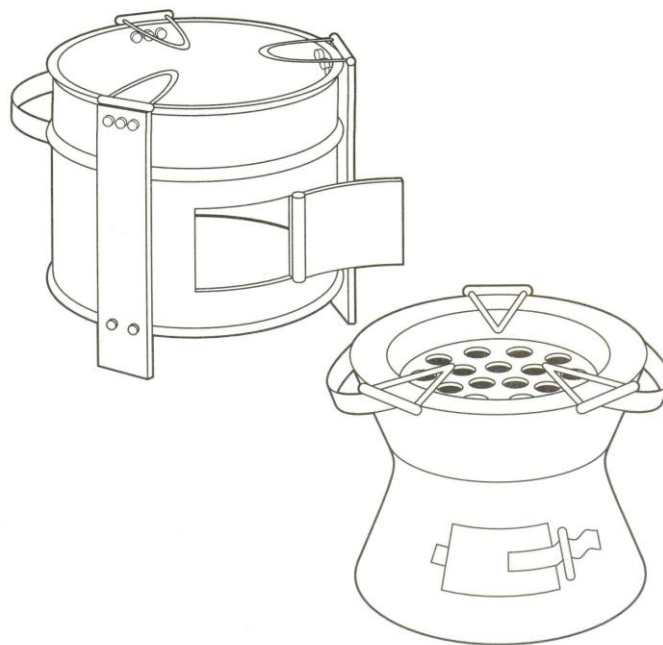


Figure 2: Examples of improved stoves.

Improving a stove design is a complex procedure which needs a broad understanding of many issues. Involvement of users in the design process is essential to gain a thorough understanding of the user’s needs and requirements for the stove. The stove is not merely an appliance for heating food (as it has become in Western society), but is often acts as a social focus, a means of lighting and space heating. Tar from the fire can help to protect a thatched roof, and the smoke can keep out insects and other pests. Cooking habits need to be considered, as well as the lifestyle of the users. Light charcoal stoves used for cooking meat and vegetables are of little use to people who have staple diets such as Ugali (Cornmeal commonly made from maize flour),

which require large pots and vigorous stirring. Fuel type can differ greatly; in some countries cow dung is used as a common fuel source, particularly where wood is scarce. Cost is also a major factor among low-income groups. Failing to identify these key socio-economic issues will ensure that a stove programme will fail. The function of an improved stove is not merely to save fuel.

### Local manufacture of stoves

Since 1982, the Kenya Ceramic Jiko (KCJ), an improved charcoal-burning stove aimed at the urban market has been developed and manufactured by large numbers of small producers. The KCJ has two main components; metal and fired clay. Both these parts are made by entrepreneurs; the metal part (cladding) being made by small-scale enterprises or individual artisans, while the clay part (liner) is manufactured by slightly larger and more organised enterprises or women's groups. The KCJ is sold by the artisans directly to their customers or through commercial outlets such as retail shops and supermarkets. The stove was initially promoted heavily to develop the market, by the NGO KENGO and by the Kenyan Ministry of Energy, through the mass media, market demonstrations and trade fairs.

As a result of this substantial promotion, there are now more than 200 artisans and micro-enterprises manufacturing some 13,600 improved stoves every month. To date, it is estimated that there are some 700,000 such stoves in use in Kenyan households. This represents a penetration of 16.8% of all households in Kenya, and 56% of all urban households in the country.

Source: Dominic Walubengo, Stove Images, 1995

### Charcoal production

Charcoal production is the most common methods for processing wood to make them cleaner and easier to use as well as easier to transport but charcoal does not increase the total energy content of the fuel - in fact the energy content is decreased. Charcoal is often produced in rural areas and transported for use in urban areas.

The process can be described by considering the combustion process discussed above. The wood is heated in the absence of sufficient oxygen which means that full combustion does not occur. This allows pyrolysis to take place, driving off the volatile gases and leaving charcoal (carbon). The removal of the moisture means that the charcoal has a much higher specific energy content than wood.



Figure 3: Charcoal Kilns, Malawi. Photo: Practical Action / Paul Harris.

Other biomass residues such as millet stems or corncobs can also be converted to charcoal.

Charcoal is produced in a kiln or pit. A typical traditional earth kiln will comprise of the fuel to be carbonised, which is stacked in a pile and covered with a layer of leaves and earth. Once the combustion process is underway the kiln is sealed, and then only once process is complete and cooling has taken place can the charcoal be removed.

A simple improvement to the traditional kiln is also shown in Figure 5. A chimney and air ducts have been introduced which allow for a sophisticated gas and heat circulation system and with very little capital investment a significant increase in yield is achieved.

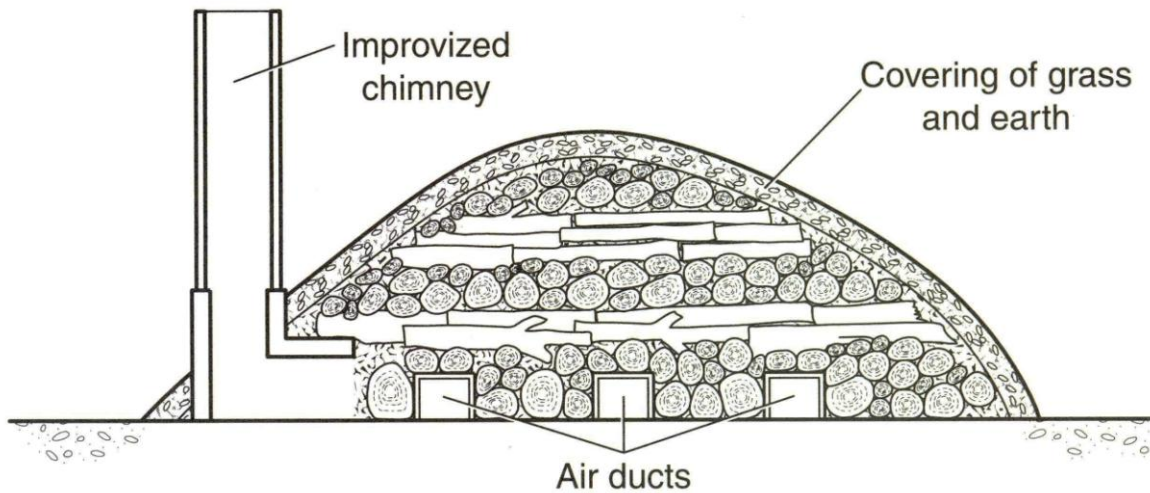


Figure 4: Improved Charcoal Kiln found in Brazil, Sudan and Malawi.

Pro-Natura has developed a process based on the continuous carbonisation of renewable biomass, savannah weeds, reeds, straw of wheat or rice, cotton and corn stems, rice or coffee husk and bamboo to produce green charcoal.

### Briquetting

Briquetting is carried out on many materials to make them more suitable to be used as an energy source. Nearly all biomass has the potential to be briquetted into a hard stable fuel that has a high energy density and provide more consistent combustion and improved storage and transportation.

The important factors in making briquette are the ash content or non combustible components and the moisture content. The raw materials that are commonly made into briquettes and pellets include:

- Wood & Sawdust
- Biomass waste such as rice husk, cotton stalks etc.
- Bagasse from sugar cane

Although briquetting is often a large scale commercial activity most waste biomass can be used as a fuel source either by directly briquetting or through the production of charcoal that is then briquetted on a small scale. Binders used for direct briquetting include starch paste, cellulose from woody material, cowdung and clay, which can be extruded or formed by hand into balls.

One example of briquetting sawdust with a binding agent in Malaysia first carbonised the sawdust then uses starch as a binder. The starch paste is made in a separate cooking tank.

Charcoal = 73%

Starch = 5%

Calcium carbonate = 2%

Water = 20%.

These charcoal briquettes can be made with a low-pressure mould.

Research by Chardust Ltd

Into making charcoal briquettes from various crop wastes including sisal waste. One report concluded that carbonising sisal was technically quite difficult in respect to regulating the temperature resulting in non-homogenous carbonisation but once the sisal waste had been carbonised it was relatively easy to produce briquettes. These were made by producing a paste of carbon dust and water which is then combined with 15% clay.

Briquettes made without a binder are partially carbonised or not carbonised at all. The drawback is that the pressure has to be increased and the equipment used is more complicated.

Most waste materials can be burnt directly without being briquetted beforehand. Sawdust stoves and rice husk stoves are relatively common; see the [Stoves for Rice Husk and Other Fine Residues technical brief](#).

### Dung collection

Many poor families in rural and urban areas use animal dung as a fuel source or collect dung as their source of income. There is a group of women in Bangladesh, who traditionally collect dung, make cakes and sell them to commercial markets. The traditional collectors of dung are teenage girls from poor families. They bring back dung to their homes and convert it into round cakes and cone-like sticks for drying in the open air.



Figure 5: A woman putting cow dung onto sticks prior to drying. These will be used as fuel, Bangladesh. Photo: Zul Mukhida / Practical Action.

Dung is considered to be one of the best fuels for the traditional mud stove for the following reasons

- it burns slowly
- cooks fast
- generates powerful heat compared to other sources of fuel found locally
- easy to store
- Less toxicity

Problems related to dung as a fuel are;

- there is a scarcity of dung
- cattle owners do not permit collection from their fields
- as dung is being dried there is a risk that it could be stolen
- It burns faster than wood when it is not properly compressed

Source: Mohammed Aslam, Practical Action Bangladesh

The alternative approach to using cow dung and other animal waste is the biogas digester which will produce gas that can be used for cooking and lighting or to generate electricity. It will cost more money to implement and maintain.

### Other issues

#### Commercial utilisation of biomass

Biomass can be used for a variety of commercial activities. There are several technologies which employ direct combustion of unprocessed or semi-processed biomass to produce process heat for a variety of end-uses. The most common is the simple furnace and boiler system which raises steam for such applications as electricity generation and beer brewing. Biomass is also used to provide direct heat for brick burning, for lime burning and cement kilns. The advantage of using biomass is that it can be locally sourced, thereby avoiding shortages associated with poor fuel supply networks and fluctuating costs. Rice husk has been used as a heating source for drying in Sri Lanka; see the [Anagi Tray Dryer technical brief](#).

### Biomass energy and the environment

Concern for the environment was one of the major inspirations for early research and development work on improved stoves. One of the greatest paradoxes of this work is that, the more that is learnt about people, fuel and cooking, the more it is realised how little was understood about the environment and the implications concerning domestic energy use.

Initially, one environmental concern dominated the improved stoves work - saving trees. Today, this issue is considerably downplayed as time has brought a clearer understanding of the true causes of deforestation. At the same time, other environmental issues have become dominant.

Climate change due to the emission of greenhouse gasses, especially carbon dioxide with relation to stoves and combustion of biomass is a complex issue. Wood is carbon natural over long time periods but not on smaller time scale. Therefore, fuel efficient stoves can reduce CO<sub>2</sub> emissions. Large-scale combustion of biomass is only environmentally feasible if carried out on a sustainable basis. For obvious reasons continual large-scale exploitation of biomass resources without care for its replacement and regeneration will cause environmental damage and also jeopardise the fuel source itself.

Household smoke and the related health issues are now being given greater consideration. These micro environmental needs are often as complex as the broader environmental concerns and this is reflected in the fact that no one improved stove design can meet the needs of a wide and diverse range of peoples.



Figure 6: Women design and manufacture improved cook stoves.  
Photo: Simon Ekless/Practical Action

### Women, woodfuel, work and welfare

For resource-poor women the working day stretched from dawn to long after dark. The pressures on women's time are heavy, cooking and fuel collection are among the most arduous of their tasks. The effects of inhaling biomass smoke during cooking are receiving attention from researchers; chronic bronchitis, heart disease, acute respiratory diseases and eye infections have been linked with smoky interiors, but the impacts of fuel shortage on cooking and nutrition are scarcely noticed.

As fuel shortages make extra demands on time and energy, women are driven to various coping strategies. More time spent collecting fuel can mean less time growing or preparing food so that quality and quantity of food diminish. Malnourished women become more vulnerable to smoke pollution which damage their lungs, eyes, children and unborn babies. But improved stoves can cook faster and burn fuel more efficiently, which lowers levels of exposure to biomass smoke and releases time for other activities. Adapting

kitchen design can also help remove smoke from the cooking area.

Greater technology choice can help to emancipate women from drudgery and give them more control over precious resources. In some places cooking is a particularly time-consuming task, so an improved stove which cooks faster may be a source of delight. Elsewhere, fuel management strategies by women save more fuel than carefully planned stove programmes. Stove technologists can offer choices, but decisions about household energy technologies should be left in the hands of women, the real experts on cooking.

## Resources and further reading

- [Anagi Tray Dryer](#) Technical Brief Practical Action South Asia,
- [Biogas](#) Technical Brief Dr. Liz Bates for Practical Action
- [Using a Biogas Digester](#) Technical Brief Sanjeevani Munasinghe, translated by Kanchana Wijesuriya for Practical Action
- [Liquid Biofuels and Sustainable Development](#) Technical Brief Liz Bates for Practical Action
- [Stoves for Rice Husk and Other Fine Residues](#) Technical Brief Dr. Liz Bates for Practical Action
- [Producer Gas for Power Generation](#) Technical Brief Andy Russell for Practical Action,
- [Appropriate Mud Stoves in East Africa](#) Steven Gitonga, Practical Action Kenya, 1997
- [How to Make an Upesi Stove: Guidelines for Small Business](#), Vivienne Abbott, Clare Heyting and Rose Akinyi, Practical Action Kenya, 1995
- [Appropriate Household Energy Technology Development](#), Lydia Muchiri and May Sengendo, Practical Action Kenya, 1999 Lydia Muchiri & May Sengendo, 43 pages
- [Stoves for Sale: Practical Hints for Commercial Dissemination of improved stoves](#), Caroline Ashley and Peter Young, IT, FAO, IDEA, GTZ, FWD, 1994
- [Improved Wood, Waste and Charcoal Burning Stoves](#). Stewart, B et al, Practical Action Publishing, 1987.
- [Smoke Health and Household Energy Volume 1: Participatory Methods for Design, Installation, Monitoring and Assessment of Smoke Alleviation Technologies](#), Daniel Theuri et al, Practical Action 2005
- [Smoke Health and Household Energy Volume 2: Researching Pathways to Scaling Up Sustainable and Effective Kitchen Smoke Alleviation](#) Daniel Theuri et al, Practical Action, 2006
- [Kenyan Biomass Waste Conversion Potential](#) Hedon
- [The Briquetting of Agricultural Waste for Fuel](#) FAO Environmental and Energy Paper 11, FAO/ SIDA. 1990
- [Smoke - the Killer in the Kitchen](#) Warwick H & Doig A Practical Action Publishing 2003

### **HEDON** <http://www.hedon.info/>

The HEDON Household Energy Network is an informal forum dedicated to improving social, economic, and environmental conditions in the South, through the promotion of local, national, regional and international initiatives in the household energy sector.

Boiling Point <http://www.hedon.info/BoilingPoint>

A practitioner's journal for those working with household energy and stoves.



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low-cost charcoal briquettes

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Pro-Natura International was started in Brazil  
in 1985 and by 1992 had become one of the  
first 'Southern' NGOs to be internationalised  
following the Rio Conference.

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# technical brief