

Cooking options for rural areas

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Introduction

It is estimated that around 3 billion people worldwide rely on wood, stubble, dung and leaves for cooking fuel. Burning biomass fuels on open fires and in inefficient stoves, releases many harmful pollutants. These pollutants results in excess respiratory illnesses and death in women and children. Known as a "silent killer", over 1.6 million children die annually throughout the developing world from the consequences of exposure to biomass fuel smoke (Edelstein et al. 2008). Some governments subsidise kerosene and propane. This is not a renewable solution and large volumes of kerosene and propane are diverted to other uses.

There are a number of options to reduce the amount of smoke inhaled by the cooks and their children. They have different costs, some of them are not sustainable and most of them do not recycle plant nutrients.

Sustainable agriculture requires that all plant nutrients contained in the crop, animal and human faeces and agricultural residues are recycled to the fields.



**Smoky kitchen with traditional
cookstoves in Saidpur**
Photo credit: Winrock International

Biobrandstof



Energy requirements

Ravindranath et al. (1997) studied a number of fuel/stove combinations as they are used in Indian villages.

Devices tested

1. Three-stone fires continue to be used by the very poor in both rural and urban areas. This versatile stove accommodates all shapes of vessels and a variety of fuels (tree and crop biomass as well as dung cakes).
2. The three-pan traditional wood stove is made of mud. A large variety of fuels (including dung cakes) and vessels can be used in this stove. It is usually built by the user and is unvented.
3. The single pan Swosthee improved firewood stove is a 4 kW portable tin stove. Since the fuel box is not big, firewood must be cut into small pieces.
4. The Astra stove is an improved vented three-pan stove. It can achieve improved efficiency.
5. The single-pan portable tin charcoal stove is marketed commercially in most towns in India.
6. The single-pan Swostheed sawdust stove has a 2 kg fuel capacity. Once the stove is lighted, the fuel cannot be recharged. One charge or load is sufficient to operate the stove for two hours.
7. The biogas burner of the Khadi and Village Industries Commission was used in these tests.
8. The Nutan kerosene stove was developed and is disseminated by Indian Oil.
9. The Perfect kerosene stove.
10. The Superflame double burner LPG stove.

Table I energy use for cooking

Fuel	Energy content MJ/kg;MJ/m³; MJ/kWh	Device	Efficiency	Daily use kg/d;m³/d;kWh/d Family of six; three meals a day
Dung cakes	14.5	Traditional three pan	11%	7.2
Fire wood	16.5	Three stone fire	16%	3.8
Fire wood	16.5	Traditional three pan	14%	4.7
Fire wood	16.5	Swosthee	33%	3.2
Fire wood	16.5	ASTRA three pan	34%	2.6
Charcoal	28.5	Traditional three pan	23%	1.4
Sawdust	16.5	Swosthee	30%	5.9
Biogas	22.2	KVIC burner	45%	1.3
Kerosene	44.5	Nutan	60%	0.6
Kerosene	44.5	Perfect	40%	0.7
LPG	44.9	Superflame	60%	0.5
Electricity	3.6	Hotplate	71%	4.3

Data for the Swosthee stove with sawdust are not consistent.

Solid fuels

Stoves with chimneys

These stoves are cheap and use waste materials (stubble, dung and leaves) as fuel. They produce nearly the same amount of smoke as the stoves without chimney and depending on the weather conditions whole villages may be blanketed in smoke.

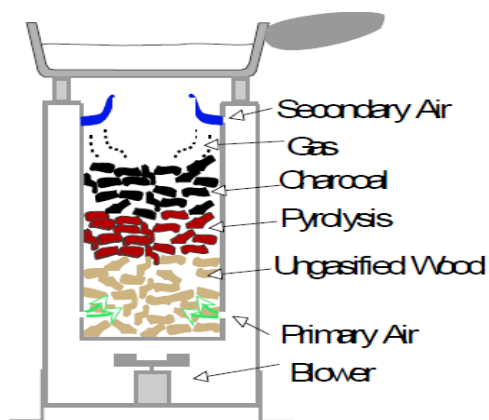


**BCSIR 2 pot fixed cookstove
with chimney**

Photo credit: Winrock International

Gasifying stoves

These stoves produce only smoke when they are lit and extinguished. They are relatively expensive (made of steel) and require an electricity supply. The electricity can come from solar powered batteries or a battery exchange system. Gasifying stoves of rice husks use a waste material. They are not cheap. These stoves are produced in the Philippines and Indonesia.



Example with FA:

FA = Forced Air or Fan Assisted

Briquettes

Saw dust and rice husks can be made into briquettes or pelletized and these briquettes and pellets can be used in advanced stoves. Other materials need to be dried and reduced in size using a hammer mill before they can be made into briquettes. This milling is energy intensive and expensive as the materials are springy and resist size reduction.

Rice husk have about 20% ash which wears the equipment out. In Northern Bangladesh this is locally made and welders are available to refurbish the equipment on a daily basis.



Charcoal stoves

In most countries the bush is no more due to the production of charcoal. This is also true of Western Europe. In some countries there are systems to make char from agricultural residues (cotton stalks, sugar cane leaves). Briquettes are formed from this material using a suitable binder.

The US NGO Envirofit has developed charcoal stoves with 43 % efficiency using charcoal. Stoves burning charcoal fines need to be fan assisted as the hydraulic resistance of the fines bed is too high. Ceramic inserts need to be developed with extra fine holes so that fines will not fall through. Envirofit got in 2013 the economist annual successful innovation price. (Economist 2013)



Charcoal production

Charcoal is a better fuel than wood as it has a higher energy density (28 MJ/kg; wood 16 MJ/kg) is nearly smoke free and burns at a higher temperature than wood. In the charring process about 70 % of the original mass of the wood is lost as water vapour, a tarry pyrolysis oil (when condensed) and a flammable gas. The pyrolysis oil and the flammable gas contain half of the energy from the wood. Heating up the wood and vaporising the water that is released in the charring process requires about 10% of the energy from the wood. There are also heat losses from the reactor vessels (kilns).

In the oldest system of carbonisation a limited amount of air is admitted in the kiln during the heat up phase of the process. More energy efficient kilns separate the heating from the material to be charred using metal tins or retorts. The most efficient kilns use a twin retort system where the pyrolysis gases from one retort are used to heat up the other and vice versa.

A number of kiln designs for village use are given by Kalenda et al. (no date).



Mekko Kiln and the Designer Mr Mutua



Charcoal from agricultural residues

Agricultural residues have a low packing density (30 kg/m³ for sugarcane leaves) and the carbonisation product consists mostly of fines. These fines have to be agglomerated into briquettes before they can be used as cooking fuel.

Siemons (1993) developed a carbonization and agglomeration system for sugar cane bagasse in Sudan. He first compacted the bagasse with a baler that is too large for use at the village level. The bales have the advantage that the bagasse can sundry from 50 % humidity to 15 % humidity.

Arti (Karve, 2001) sells a carbonisation and agglomeration system where the kilns can be transported to the fields. The kilns consist of an open cylinder that can be rolled to its destination. The top is a dome with an attached chimney that has to be carried. The kiln is packed with thin walled stainless steel tins, that can be closed with a lid leaving only a small gap so that the carbonisation gases can escape and contribute to the fire underneath the tins. They use several sets of tins so that the tins after processing can cool and the kiln can be used in the mean time.

A female cooperative near Bamako (Mali) carbonises cotton stalks in the field with kilns similar to that of Arti. They have to wait until the kilns have cooled down before they can fill them with a new batch. They pack the carbonised stalks in sacs and sell the charcoal to a company that uses the system of Siemons (1993) for agglomeration. Haraguchi (no date) has developed a kiln based on locally made ceramic vessels used for carrying water. These vessels have a capacity of 10 l and produce 0.1 kg charcoal per charge. Larger vessels, if locally made, are more appropriate. A family requires 1.4 kg charcoal per day. That means 14 charges per day, of two hours per charge.

There are videos on internet that depict the Arti system for carbonisation and agglomeration in India and the system used in Mali.

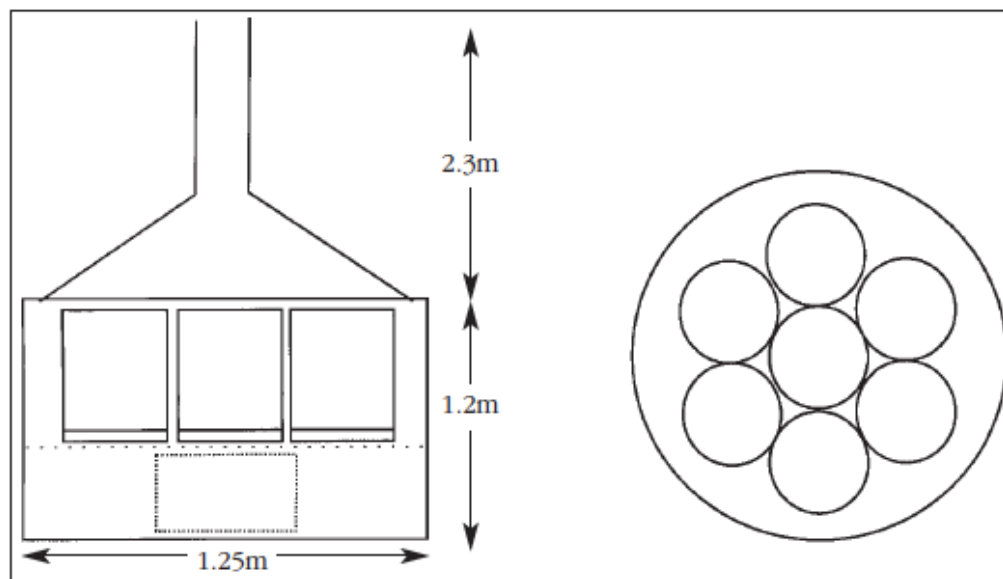


Figure 1: The charring kiln – heights are approximate (vertical and horizontal cross sections)

Liquid fuels

LPG (propane)

LPG is a clean burning fuel and the preferred fuel for the upper and middle classes. It has a high energy density and can be easily transported. It is not a sustainable fuel.

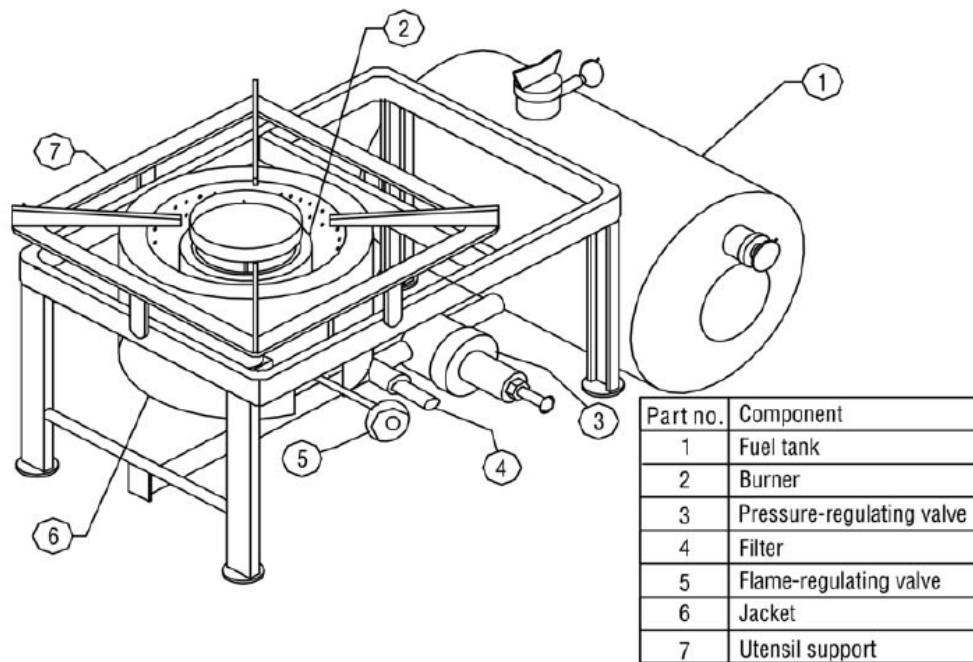
Kerosene

Kerosene (paraffin) has the same advantage as LPG. It requires no investment in transport cylinders. It produces soot and carbon monoxide when used as a fuel and it stinks. It is not a renewable fuel.

Alcohol

A mixture of 50 % alcohol and water can be used in modified kerosene stoves and produced locally from sugar cane or cassava. The mixture should be made unfit for human consumption (Rajvanshi et al. 2007). It can be made from fermented sugar cane juice and one stage batch distillation. The energy density is only one quarter of that of kerosene.

Nineteen three percent alcohol is commercially available. It should be more expensive as more energy is required in the distillation. It is highly flammable.



Gaseous fuels

Piped natural gas is an excellent cooking fuel. The costs for the infra structure are high and it is not suited for rural areas. It is non renewable.

Biogas consists of methane and carbon dioxide as a product of the transformation of biomass through the action of microbes. There remains a waste slurry that has all the nitrogen, phosphate and potassium from the incoming biomass and can be used as fertiliser. The carbon in the slurry will improve soil fertility.

Biogas can be used and is renewable. It is possible to make village size distribution networks, but it is not clear which business model should be used to allocate the costs.

Low pressure transport is being developed by the university of Hohenheim (Puetz 2011). Two rucksacks (30 € each) with a capacity of around 1 m³ are required. One at the stove and one at the biogas plant.

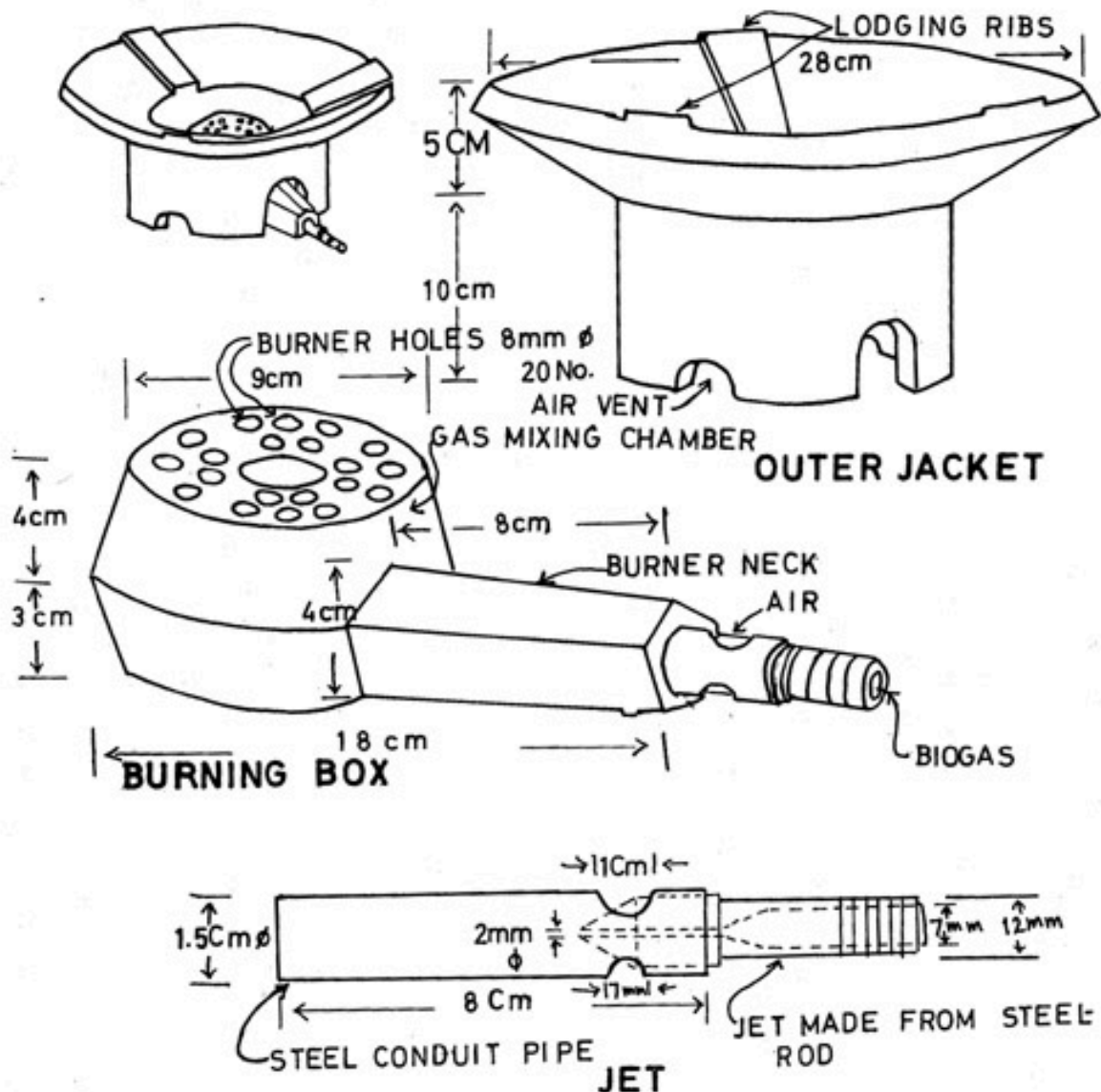
Steel LPG tanks are widely distributed, but are not suitable for medium pressure transport of biogas. Steel suffers from stress corrosion due to a combination of humidity and H₂S. Thirty five litres aluminium or plastic LPG vessels are expensive (150 €); equivalent to 0.8 m³ of biogas.

High pressure biogas compressors (200 bar) are expensive. Biogas compressed to high pressure is normally cleaned from CO₂, which involves complex systems.



Biogas burners

Most biogas burners are adapted from LPG stoves. The Indian organisation Envis made a design available of a clay biogas burner that can be made by local potters incorporating a pre fabricated gas jet. These are significantly cheaper than LPG stoves. A few have been fabricated and tested by the author in Bangladesh.



Biogas from food stocks

Karve (1995) has developed a compact biogas system based on food stocks (sugar, starch and fat). The stocks are converted into biogas that can be used instead of LPG. There is an ethical question if food stocks may be used as fuel. Karve wants to use only waste stocks. The argument can be made, that hunger in the world is caused by draughts, war and underemployment. Where sugarcane, cassava and jatropha can be grown locally, a case can be made for the use of food stocks as input for biogas installations. Sugar cane juice (12 % sugar) can be easily produced from sugar cane by pressing and is easily transported over small distances. It can be supplemented by kitchen waste.



Biogas from animal excrements

Biogas on the basis of animal manure is promoted in India, China and south-east Asia. There is however not enough manure for all the cooking needs.

Biogas from human excrements

Human excrements are rich in nitrogen and phosphate, but have little carbon. Agricultural residues have little nitrogen and phosphate. The combination is an excellent stock for the production of biogas. Human excrements should be kept in quarantine for hundred days in order that pathogens and in particular worm eggs are destroyed. This requires some smart solution like having two sets of toilets or the Ecosan toilets (Terefe 1999) where only the urine is recycled. In China it is common to combine human excrements with animal excrements and straw.

Biogas from agricultural residues

Agricultural residues are available in most rural areas. Many of them are burned in the fields as they are not compact enough to be used as a fuel. Examples are maize stalks and cobs, straw from rice, wheat, cotton, peanuts; husks from rice and peanuts; bagasse from sugar production; weeds, jatropha husks and press cake. These materials can be converted into biogas provided extra fertilizer is used so that the microbes that convert the material into biogas can multiply. Tests in the US showed that 25 % of the energy content of maize stalks could be converted into biogas, with swine manure as a source of nitrogen and phosphate (Wu et al.2010). A yield of 50 % in three months seems possible.

Aquatic weeds

Sewage from most urban areas in tropical countries is discharged untreated in rivers and lakes. This leads to eutrofication. Fast growing aquatic weeds use the nutrients and form thick mats hindering fishing and navigation. Lake Victoria is a prime example. Biological control of the waterweeds is seen as one method to reduce the problems, but does not address the root cause of eutrofication. There are a number of instances where aquatic weeds are used as an

organic fertiliser, but this practice is not wide spread. The weeds can be digested in biogas plants and the remaining slurry used as fertiliser.

Data on biogas production of chopped water hyacinth suggest that around 4 m³ methane per m³ digester volume and batch can be obtained. (Vaidyanathan 1985).

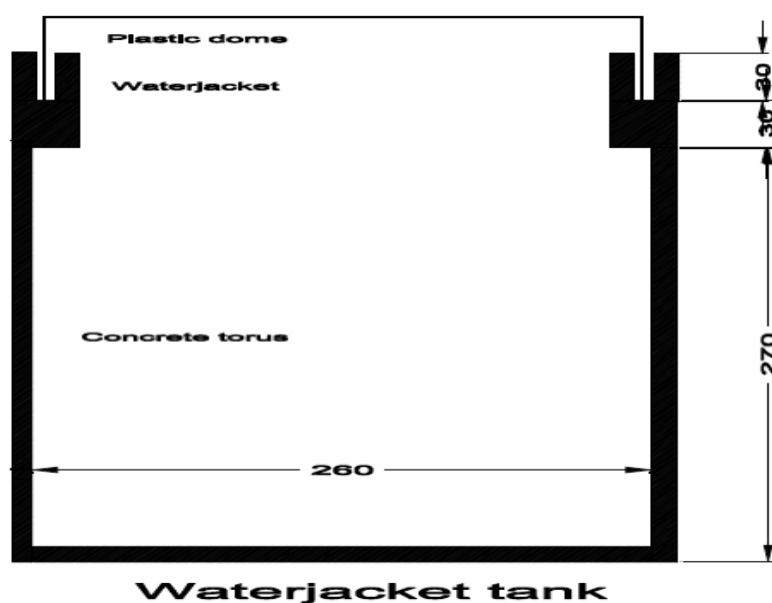
Batch digester

Agricultural residues and aquatic weeds have the tendency to float. They are also bulky. Tests (Chanakya et al. 2004) have shown that these types of materials will generate biogas when they have been in contact with digester fluid for at least three days. This is difficult to achieve in a continuous flow digester. Therefore batch digestion is proposed.

Water jacket tanks have a dome that can be removed. The tank can then be filled with residues and weeds. On top wet compost is added. This will keep the bulk of the material submerged. Then slurry from an existing manure biogas plant is added. The slurry is enriched with fertilizer, so that the carbon to nitrogen and carbon to phosphate ratios are 20 and 200 respectively. The dome is closed and water is filled into the jacket. Once per month the plant is opened and residues or weeds plus compost are added. Once per year the tank is cleaned using a hand operated grab crane. The resulting material is composted. Part of it is used in loading the tank. Most of it is used as fertiliser.

A design has been made of a tank with a concrete torus, water jacket and a plastic removable dome. The investment is estimated at 1500 €. Depreciation (5%) and financing (5 %) will cost 150 €/a. The equivalent amount of kerosene is (at 0.60 €/l) 150 €/a. The operational costs should be compensated by the fertiliser value of the digested slurry.

There are designs of the digester tank that are cheaper. This requires further research. Enzymes from fungi in the compost (Horsch 2011) or the use of micronutrients (Oosterkamp, 2013) will make it possible to reduce the size of the tank and lower the investment costs.





Electric stove in Bangladesh

Electricity

Electricity may be considered, where there is a grid, for cooking foods that needs to simmer for long periods (rice, pulses and maize). The author has observed electric rice cookers in a Bangladeshi village. Ravindranath (1997) tested a 1.5 kW stove.

Discussion

The different options are given in Table I

Table II Cost, sustainability and recycling of plant nutrients of different fuels

system	Cost €	renewable	Recycling of plant nutrients
Solid fuel			
Chimney	5	yes	P and K
Gasifying	50	yes	P, K and C
Charcoal	50	yes when made from agricultural residues	P and K
Liquid fuel			
LPG	80	no	no
Kerosene	40	no	no
Alcohol	50	yes	Possible
Gaseous fuel			
Natural gas	50	no	no
Biogas from food stocks	150	yes	P, K and C
Biogas from animal excrements	350	yes	N,P,K, and C
Biogas from agricultural residues	1500	yes	N,P, K and C
Electricity			
From biogas	??	yes	N,P, K and C

The costs given are approximate. The use of chimneys is the cheapest, but no real solution to the smoke problem. The gasifying stove can be used with rice husks, but requires wood when those are not available. Charcoal stoves, with charcoal from agricultural residues, are a good option. The char needs to be briquetted for use in those stoves. Some research should be done into the suitability of stoves with charcoal fines.

Charring of agricultural residues gives a volume reduction and increases the energy density making transport easier. The extent of this volume reduction is not clear. In some countries (e.g. Kenya) it is prohibited by law to transport charcoal, most likely also charcoal from agricultural residues.

Biogas from food stocks depend s on local conditions. In an introductory phase they could be operated by combining kitchen waste of various households. In some countries (e.g. Mozambique) it is forbidden to use food as fuel.

Biogas from animal excrements is promoted by various governments and a number of NGO's.

Biogas from agricultural residue gives the opportunity to recycle a large fraction of the plant nutrients removed from the fields. The investment costs of plants using this material must be reduced. Research in that direction should be stimulated.

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