



A Dozen Innovative Renewable Energy Technologies



SGP The GEF
Small Grants
Programme



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Cover page

1. *Matribhumi* stove; 2. Rice husk stove; 3. Bio-briquette stove;
4. Puxin biogas plant; 5. Improved distillation unit; 6. Improved charcoal kiln; 7. Community biogas dome under construction.

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Disclaimer:

The opinions expressed herein are those of the writer and may not necessarily reflect the official view of the United Nations Development Programme in Nepal.



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Acknowledgements

This booklet introduces a dozen innovative renewable energy technologies, including a variety of improved cook stoves, bio-briquettes, biogas plants, improved kilns and distillation units. It also reflects the success of the Global Environment Facility (GEF) Small Grants Programme (SGP) of the United Nations Development Programme (UNDP) in promoting these technologies at the grassroots level.

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I hope that this booklet will help promote the dissemination and replication of locally acceptable innovative rural energy technologies among a wider group of users.

Gopal Raj Sherchan
National Coordinator

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Introduction

The Global Environment Facility Small Grants Programme of the United Nations Development Programme has supported a number of projects which have promoted innovative renewable energy technologies in Nepal. These include different prototypes of improved cook stoves, numerous biogas technologies, and bio-briquettes suitable for domestic purposes. Some of the biogas technologies are also suitable for institutional purposes. Improved kilns for cardamom drying and charcoal-making and energy-efficient improved distillation units are suitable for promoting enterprises.

Renewable energy technologies replace or reduce the use of conventional energy sources, which in Nepal, is mainly firewood. Of the dozen technologies described, the various models of biogas plants, improved kilns, improved cook stoves and the improved distillation unit reduce the consumption of firewood.

These dozen technologies are not just theoretically possible; on the contrary some have been successfully tested and used in other parts of the world. Why they are termed “innovative” is that they have been tested for the first time in Nepal and have been modified and remodified in order to suit local settings. “Innovative” also means adopting a new working approach in order to popularise an old technology as is true in the case of the community biogas plant and the group production of bio-briquettes. Another innovative aspect of these technologies is the use of notoriously invasive exotic species such as *Eupatorium* and water hyacinth as the raw material to produce energy.

Promoting Innovative Renewable Energy Technologies

Promoting different technologies provides users with choices. In rural lowland areas, rich and middle-class people

can afford to rear the cattle needed to be able to use biogas technology. But for the rural poor, rice husk stoves and improved cook stoves or bio-briquettes may be better options. In the hills and mountains, however, none of these technologies are appropriate. Highlanders will instead opt for cooking technologies such as metal stoves and stoves with smoke hoods which also keep their houses warm.

Aside from renewable energy technologies’ commercial benefits, these technologies improve human health, provide environmental services, and promote forest conservation. Their introduction also helps initiate gender-sensitive dialogue in local communities. Promoting renewable energy technologies is a win-win proposition for all stakeholders. It has opened a huge market niche for traders and producers and enabled them to make profits. For users, in contrast, adopting renewable energy technologies is a proven money-saving step.

Improving Health and Hygiene and Reducing Mortality

Presently, the major tasks of rural Nepali women are to collect firewood, cook, and care for their children and families. Because forest resources have been depleted, women spend several hours a day collecting firewood. Carrying heavy loads of wood exposes women to injury from falls, including fractures and miscarriages. The drudgery of everyday chores leaves them very little time for other income-generating activities. In addition, spending hours cooking in poorly ventilated kitchens increases the incidence of eye infections and other respiratory problems¹.

When biomass is burnt, it emits harmful chemicals such as particulates, carbon monoxide, formaldehyde, nitrogen dioxide, carbon dioxide and water vapour². Nepal’s

traditional technology—burning solid fuels in three-stone, open stoves or rudimentary stoves has poor combustion efficiency and produces high levels of indoor air pollution. A study conducted in 2001 by Nepal Health Research Council and others demonstrated that where biomass (wood) is burned, the concentration of PM10 (particulate matter less than 10 microns) in cooking areas is 8,207 $\mu\text{g}/\text{m}^3$, a figure which far exceeds the standards set by the U. S. Environment Protection Agency (50 $\mu\text{g}/\text{m}^3$)¹. The fine particles in such smoke can go deep into the lungs and, alone or in combination with other air pollutants, cause pre-existing lung diseases to worsen.

Rural Nepali children, who live in poorly ventilated conditions are up to four times more likely to suffer from acute respiratory infections (ARIs) than children who live in cleaner indoor environments. Likewise, women who cook using biomass fuel are nearly four times more likely to suffer from chronic bronchitis than women in developed nations². Although no up-to-date information on the total number of deaths resulting from indoor air pollution and ARIs in Nepal is available, ARIs are recognised as one of the major health problems in the country. It is estimated that between 6,000 and 8,000 Nepali die from tuberculosis every year. In the fiscal year 2001-02, the total reported deaths caused by ARIs was 184 and the reported incidence of ARI was 229 per 1000 children under five³. The total deaths among children under five years of age due to ARI accounted for over 30% of the total deaths in the fiscal year 1999-2000⁴.

Studies have shown that the use of improved cook stoves reduces human exposure to pollutants in the kitchen considerably. Concentrations of carbon monoxide decrease on average by 69%; total suspended particle concentrations by 53% and formaldehyde concentrations by 63%⁵.

Saving Forests

In Nepal, more than 75% of the demand for energy is met by firewood. In rural areas, where 84% of the population

live, 65% of the energy used is for cooking⁶ (WECS 1995 referred by Shrestha et al). Thus, a small shift from conventional cook stoves to more efficient cook stoves would save significant amounts of firewood, conserve forests and support carbon sequestration. Studies conducted in Nepal demonstrate that improved cook-stoves are 15-25% more efficient and use 30-35% less firewood than traditional stoves. Using improved cook stoves reduces pressure on forests⁷.

Providing Environmental Services

On the regional and global scales, the unsustainable use of biomass, especially firewood, has increased the concentration of greenhouse gases in the atmosphere significantly and thereby contributed to global warming, which itself has had several adverse effects, including increases in average temperatures and the increase of extreme weather conditions, and changes in patterns of rainfall and the distribution of wildlife. Because large populations in Asia and Sub-Saharan Africa rely on biomass fuels for cooking, large concentrations of greenhouse gases have been traced in these areas. Globally, wood used for heating also contributes to greenhouse gas emissions⁸. The burning of fossil fuels and the extensive use of biomass are the major sources of greenhouse gases emissions in Nepal. Increasing combustion efficiency or switching to cleaner energy sources are two possible ways to reduce such emissions⁸.

Promoting Gender-Sensitive Dialogue

Promoting improved cook stoves and biogas plants not only conserve the environment but also improve human health and ease the workload of women. Introducing such technologies is also an ideal means of promoting gender-sensitive dialogue. In a male-dominated society like Nepal, removing gender barriers is a very challenging task. Villagers become very suspicious when men from outside their community communicate with the women of their

community. Using improved cook stove or biogas as an entry point, however, development worker can go directly into the kitchen, remove communication barriers, and initiate gender sensitive dialogue.

Improved Cook Stove Technology

Over the last several decades, different prototypes of improved cook stoves have been developed in particular localities across the world and later modified and remodified to suit their rural settings. The Kenyan ceramic stove (*zico*) used in Kenya and neighbouring countries in East Africa, the earth stove (*sanjha chulha*) popular in India, the Lorena adobe stove seen in Central America, and the improved Lorena stove (*justa*) used in Honduras are just a few examples. In rural Nepal, various prototypes have been developed and are currently in use. These include the traditional domestic stove with a chimney, the improved domestic stove, the beehive briquette stove, the improved mud stove (both the one and two-pot-holes), the two-pot-hole improved stove with a raised second pot-hole, the three-pot-hole multi-function improved cook stove, the metal stove, the smokehood in highland areas, the rice husk stove, and the *bayupankhi* stove.

Cultural Considerations

Because food habits differ from culture to culture, preparing the varieties of cuisine consumed in different cultures requires different prototypes of stoves. In addition, family size, the purpose of cooking (whether it includes tasks like preparing alcohol or animal feed), and the frequency with which the extended family gathers to celebrate auspicious occasions also determine the type of cook stove people prefer. The lifespan of a cook stove also depends upon cultural practices. For example, to some ethnic communities in Nepal, who destroy the cook stoves used during death rituals, improved cook stoves might not

always be a culturally acceptable proposition. In some extreme cases, as is the case with nomadic Rautes, when a member of the group dies, not only are cook stoves destroyed, but the group moves to an entirely new location. Similarly, in Huay Hin Lad Nai, in Wiang Pa Pao District of Thailand, the Pgakeunyaw Karen used to move to a new house after completing death rituals. But nowadays, since building a new house is costly, the grieving family moves only its cook stove. In Nepal, as well, local people have adjusted their culture to avoid destroying a key asset: they use a separate cook stove outside the house which they can destroy after completing the required of death rituals.

The adage that old practices die hard is true for cooking. Women members in rural households are used to cooking food over a blazing fire that requires lots of firewood and, as a result, feel uncomfortable using improved cook stoves which produce virtually no flames.

Matribhumi Stoves

The efficiency of the *matribhumi* stove is as high as 29%, and it is strong. It includes an air supply disc and a small fan operated by a 12-volt battery.

The *matribhumi* stove is a modified improved cook stove made of mud which has two cooking holes, the second of which is slightly raised. It includes a round air supply disk and a small fan, the type used to cool the central processing unit of a computer, operated by a 12-volt battery. The air supply disk is made of kit and has numerous small holes. It was developed by Mr. Madhukar KC.

The air-supply disk is placed inside the firewood chamber to serve as the burner of the stove. The fan, which is placed laterally underneath the burner, provides a continuous supply of oxygen. The efficiency of the stove is enhanced due to the controlled supply of oxygen which the air supply disk provides (see Annex 1). The disc also controls the unwanted emission of ash into the kitchen.

According to an efficiency test conducted by National Academy of Science and Technology, the efficiency of the *matribhumi* stove is relatively high (24% - 29%) Firewood savings are nearly 60% and a single log can also be burned.

In order to improve the strength of the stove by ensuring that bricks were of uniform size, two different metal dyes were developed. The bigger dye is used to make the bricks needed for the main body of the stove, while the smaller one is used to make the bricks used to construct the chimney. The bricks used for the mouth of the stove are reinforced with iron bars so that they can withstand the weight of the pots placed on the stove. The bricks are glued together so that it is easy to align the baffle. Since only minimal amounts of binding clay are used to cement the bricks together, a *matribhumi* stove can be operated the day after it is made.

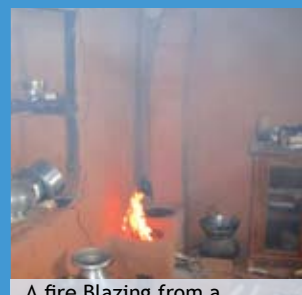
1



A *matribhumi* stove in Chaimale VDC



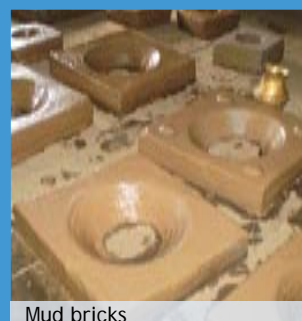
A *matribhumi* stove



A fire Blazing from a *matribhumi* stove



Metal dyes



Mud bricks



Accessories for a *matribhumi* stove

Advantages

- Fuel efficient, strong

Limitation

- Requires electricity

Tentative cost

- Rs. 1,000-1,500

Promoted by

- NEW Initiatives
- *Matribhumi* Stove

Rice Husk Stoves

The metal rice husk stove is ideal for lowland communities where rice husks are plentiful. It is easy to operate and economical.

The rice husk stove is a metal stove which uses rice husks as fuel. It is conical and supported on a tripod. It consists of an inner cone where the fire is ignited and an outer cone where rice husks are burnt. These two cones are separated by a heat shield and the lower parts of both are perforated with small holes. At the base of the inner core, there are two burners; these provide a steady supply of oxygen.

The rice husk stove works on the principle of the gasification of husks. The stove is fired from the top by inserting waste paper inside the combustion chamber (inner core). When the husks are heated, combustible gases are released from the perforations in the base of the core and flames rise.

The rice husk stove is promoted in the Terai, where rice husks are found in abundance. On average, a five-member family requires five kilogrammes of firewood a day to cook its meals. In a firewood-deficit area, that much firewood costs nearly Rs. 25. A rice husk stove, in contrast, burns only two kilogrammes of rice husks daily. Since rice husks can be purchased for Rs. 1 per kilogramme, the average household can save Rs. 8,395 per annum.

The first model of rice husk stove tested consisted of a main conical body supported on three legs, but many users complained that the heat caused the legs joints to separate. Since welding them back on is not feasible in most villages, a separate tripod was developed.

The stove is gaining popularity in rural Terai as it very easy to use and rural households can afford it. Metal Nepal in Bhairahawa produces 500 stoves per day and employs 60 employees in its manufacturing unit. The company has also engaged a Lucknow, India based metal workshop to produce 300 stoves per day. As of mid-2010, over 100,000 stoves had been sold.



Rice husk stove

Advantages

- Easy to use and very economical; burns rice husk (agricultural residue) as fuel

Limitations

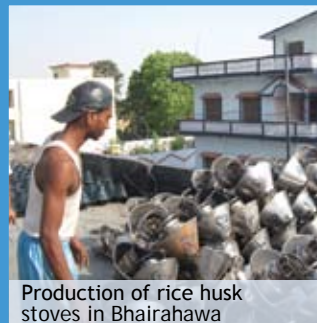
- Can only be used where rice husks are available and the services of a metal workshop are needed for repair and maintenance

Tentative cost

- Rs. 620-1,200

Promoted by

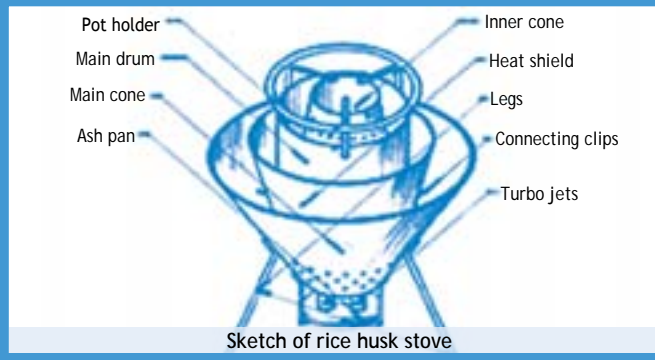
- Nature and Human Development Centre
- Metal Nepal



Production of rice husk stoves in Bhairahawa



Women cooking food over a rice husk stove in Bara



Sketch of rice husk stove

Smoke Hoods

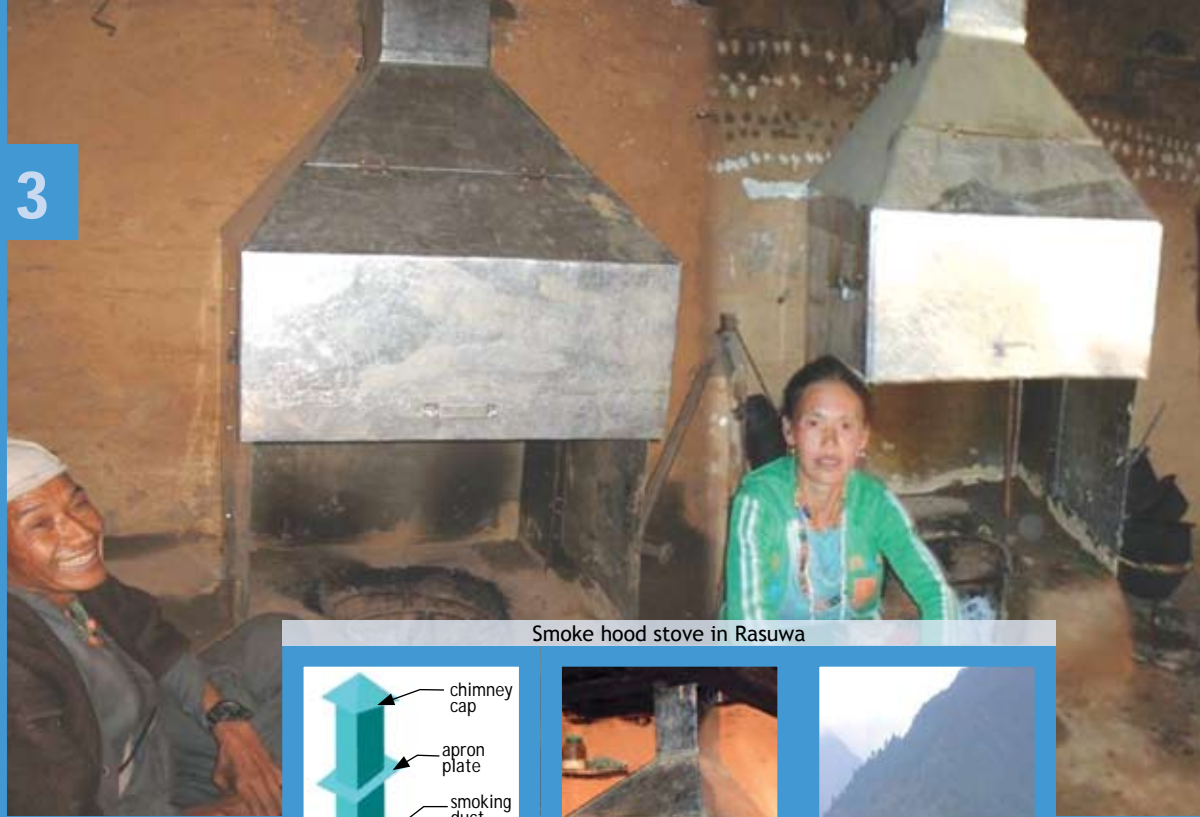
Installing smoke hoods, improving existing stoves and insulating kitchen walls are effective technology changes in a cool climates. Metal hoods promote room heating and save firewood.

A smoke hood, which is installed above an improved stove, is a suitable technology for the high hills or other places with a cool climate. So they can be used with a hood, traditional stoves are improved by building a protective base around the back and two sides of the tripod, leaving a wide area in the front exposed so that users can feed the stove with fuel and see the fire. A bar is set across the front of the stove to allow in sufficient air for effective combustion. Kitchen walls are also insulated with a mixture of locally available clay, straw and dung to reduce heat loss. If the height and cross-section area of the flue and the ratio between the area of the opening and the area of the flue are carefully calculated, a hood will draw up smoke well. (See Table 1).

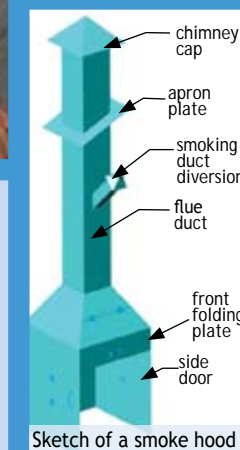
A survey carried out by Practical Action revealed that a smoke hood reduces firewood consumption by 32%. A smoke hood is made of 50 mm steel. It will last for nearly 12 years and is also suitable for making alcohol.

A project undertaken by Indoor Air Pollution Health Network in Rasuwa has mobilised existing saving and credit groups and local community female health volunteers to promote the smoke hood. The project also trained four local smoke hood experts and adopted innovative financial mechanism. The project provided groups with a Rs. 1,800 subsidy to start an income generation fund and additional Rs. 3,000 to start a revolving fund for each smoke hood they installed. On their part, each user had to deposit Rs. 1,000 for front running costs and Rs. 200 as a membership fee in the group. When over 20 households ask to install a smoke hood, smoke hood experts manufacture the smoke hood in bulk to reduce the per unit cost. The users pay Rs. 50 per month for five years. Under this system, the funds collected can be used to purchase new smoke hoods. The project in Rasuwa has installed 270 smoke hood stoves.

3



Smoke hood stove in Rasuwa



Sketch of a smoke hood



Chimney

Advantages

- Can be used with existing stoves and to make alcohol; reduces firewood usage; keeps rooms warm

Tentative cost

- Rs. 5,500

Promoted by

- Practical Action, Indoor Air Pollution Health Network

Table 1: Dimensions of two models of smoke hood

Parameter	Model A	Model B
Hood opening type	A single front opening	A single front opening
Dimensions (L x B x H)	37.79 x 25.20 x 36.61 in (96 x 64 x 93 cm)	29.92 x 29.92 x 39.37 in (76 x 76 x 100 cm)
Width of opening	37.79 in (96 cm)	29.92 in (76 cm)
Height of opening	22.83 in (58 cm)	24.01 in (61 cm)
Area of opening	863.04 sq in (5568 sq cm)	718.58 sq in (4,636 sq cm)
Side of (square) flue	11.02 in (28 cm)	11.02 in (28 cm)
Area of flue	121.52 sq in (784 sq cm)	121.52 sq in (784 sq cm)
Area of opening/ area of flue	7.10	5.91

Eupatorium (Banmara) Bio-Briquettes

The production of bio-briquettes is not a new technology in Nepal, but the use of banmara as a raw material and a group working approach have made bio-briquettes more popular than ever before.

The technology of making bio-briquettes is similar to that of making charcoal but does not rely on wood. Instead, woody biomass from herbs or shrubs is charred in a charring drum or pit and the resultant char is ground and mixed with clay and water in a specific ratio. The mixture is then compressed in a briquette mould with 16-20 holes and dried in the sun. The equipment used to produce bio-briquettes includes a briquette mold, a charring drum, a plain iron plate, a grinding machine or roller, and accessories, including an apron, gloves, a bucket, a hammer, a mask, and scales. Various prototypes of cook stoves for use with bio-briquette have also been promoted.

While making bio-briquettes itself is not new in Nepal, but this approach to it is. The first change is the use of an invasive exotic species, *Eupatorium adenophorum* or 'banmara' in Nepali, as the raw material. Around the world, countries spend an enormous amount of money to rid themselves of various invasive plant species; Australia, Brazil and India, for example, spend USD 6.8 billion, USD 6.7 billion and USD 25 billion respectively⁹. Using such a weed productively is indeed commendable.

The second approach deserving commendation is the division of labour during production, which is carried out by a group. First, the group collects and dries *Eupatorium*. Then, some members char the *Eupatorium* while others grind the char and produce the briquettes. Yet another sub-group is responsible for marketing.



Burning a bio-briquette in a briquette stove

Advantages

- Creates energy from waste.
- Improves forest health by removing *Eupatorium*
- Generates income through the sale of bio-briquettes
- Creates less indoor air pollution than firewood
- Makes it easier to clean pots
- Reduces the cost of clearing *banmara* from forests

Disadvantages

- It takes a long time to ignite bio-briquettes.
- A burning bio-briquette cannot be extinguished until it has burned completely.
- Gloves, aprons and face masks are required during the charring and moulding processes.



Biobriquettes made from *Eupatorium*



Eupatorium adenophorum

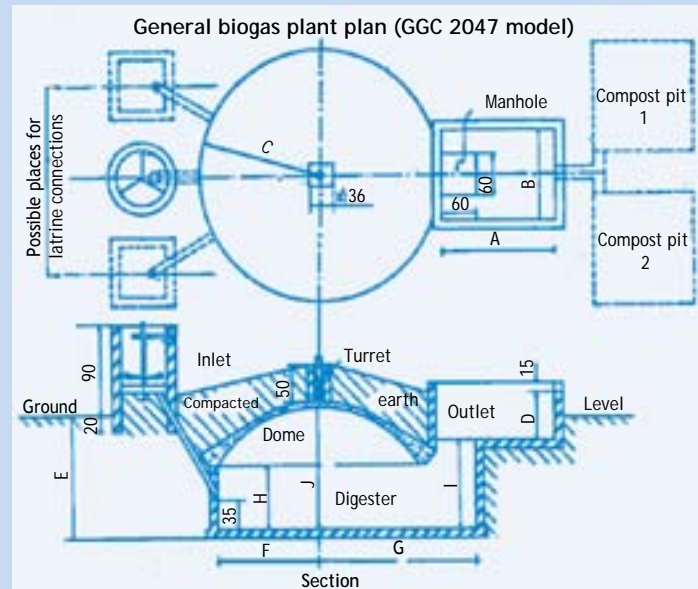
Bio-briquettes have a strong popular following in Nepal. They are used especially to grill foods and to warm newborns. They are also sought after in areas where community forest user groups have enforced strict controls on the cutting of firewood and as well as in areas where firewood is scarce.

Biogas Plants

Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. Biogas originates from biogenic material and is a type of biofuel. It is produced by the anaerobic digestion or fermentation of biodegradable materials such as biomass, manure, sewage, municipal waste, green waste, plant material and energy crops. It is composed of 50-70% methane, 30-40% carbon dioxide (Karki and Dixit 1984 referred from NBPG, 2007)¹⁰, and traces of other gases, and is about 20% lighter than air. It is an odourless gas that

burns with a clear blue flame similar to that of liquified petroleum gas.

Biogas technology is very popular in Nepal. As of December 2010, the Biogas Support Programme run by the Alternative Energy Promotion Centre had supported the construction of 225,356 biogas plants¹¹. The model used is a fixed dome model (see the diagram and table). It comes in a range of sizes—two, four, six and eight cubic meters— suitable for individual households. The biogas digester is constructed underground to maintain the temperature at the optimal level. The biogas plant is fed with cattle dung, water and human excreta.



Plant parts Capacity m ³	Measurements (cm)					
	4	6	8	10	15	20
A	140	150	170	180	248	264
B	120	120	130	125	125	176
C	135	151	170	183	205	233
D	50	60	65	68	84	86
E	154	155	172	168	180	203
F	102	122	135	154	175	199
G	185	208	221	240	261	288
H	86	92	105	94	115	115
I	112	116	127	124	132	137
J	151	160	175	171	193	203

Biogas from waste

Biogas is often released from landfill sites as wet organic waste decomposes under anaerobic conditions. The mechanical compression of the waste material deposited on it prevents oxygen from penetrating the depths and enables methane-producing anaerobic microbes to thrive. Methane gas builds up and is slowly released into the atmosphere. Landfill gas is hazardous for three key reasons. First, it becomes explosive when it escapes from the landfill and mixes with oxygen. The lower and upper explosive limits are 5% and 15% methane respectively. Second, methane is 21 times more potent as a greenhouse gas than carbon dioxide. For this reason, landfill gas which escapes into the atmosphere may have a significant impact on global warming. Third, the volatile organic compounds contained within landfill gas contribute to the formation of photochemical smog¹².

Waste-fed biogas plants are suitable for places like hotels, schools, army barracks and monasteries, where large

quantities of waste are generated. Urban residents who use liquefied petroleum gas may not wish to use biogas from waste. Before a potential user constructs a waste-fed biogas plants, she or he should be aware of the cost

of biogas construction, cooking time, the availability of space, the volume of waste and slurry generated, plant handling and slurry management. Table 2 compares liquefied petroleum gas and biogas from waste.

Table 2: Comparison of liquefied petroleum gas and waste-fed biogas

SN	Particular	Liquefied petroleum gas	Waste-fed biogas
1	Combustion material	Propane, butane or mixture of both with a calorific value of 46.1 MJ/Kg	50-70% methane with a calorific value of 20 MJ/Kg
2	Portability	Portable; it is filled in the cylinders	Not portable
3	Availability	Can be purchased in the market	Has to be generated
4	Handling and care	Regular cleaning of the stove and maintenance of regulator are required. Since liquefied petroleum gas is heavier than air, whenever there is a leak, the gas may accumulate in the base. In a poorly ventilated room this poses the risk of fire.	Care should be taken during the daily feeding of the biogas plant that as equal volume of dung and water should be fed. Sour waste such as lemon and tomato should not be added. Whenever a toilet is attached with the plant, no toilet cleaner, detergent or soap should be used.
5	Time to cook	Since the calorific value is high and the pressure can be increased or decreased, it takes less time to cook with liquid petroleum gas than with waste-fed biogas.	One cannot increase or decrease the pressure of biogas and due to its low calorific value, it takes longer to cook with waste-fed biogas than liquefied petroleum gas.
6	Slurry management	No need	Needed
7	Cost	Rs. 1,250 per cylinder at present market price	Although the initial investment is high, the cost can be recovered within 9-15 months.

Table 3: Raw material required to construct biogas plants of different sizes

Capacity (m ³)	Model	Daily optimum gas production (cft)	Dung input (kg/day)		Stone or brick (no.)	Sand (no. bags)	Gravel (no. bags)	Cement (no. bags)		Rods 8mm (kg)	Total labor (m-day)	Biogas from waste*	
			Terai	Hill				Terai	Hill			Land required (m ²)	Waste required (kg/day)
2	GGC	22	15	12	900	44	18	9	10	10	12		
4	GGC	42	30	24	1200	60	30	11	12	15	15		
6	GGC	65	45	36	1400	70	35	13	14	15	20		
8	GGC	75	60	48	1700	80	40	16	18	16	23		
10	Modified	105	75	60	2800	90	50	20	24	20	40	4x6	60-80
15	Modified	165	112	90	3500	120	60	30	35	30	60	4.5x7	90-110
20	Modified	225	150	120	5500	150	70	40	45	50	75	5.5x8.5	120-150
35	Modified	390	162	210	8000	300	100	80	90	80	100	7.5x12	210-250
50	Modified	525	375	300	11000	400	175	120	130	120	140	4.5x18	350-450

RGG Brochure

* Presented by Jeevan Shrestha

Community Biogas Plants

With a community biogas plant, even cattleless households can enjoy biogas.

The prerequisite of a biogas plant is a continuous supply of dung, so poor households which do not have any cattle cannot operate one of their own. They can, however, benefit from a community biogas plant, whose aim is to encourage cattle-less households to use biogas for household purposes. Depending upon the number of participating households, a biogas digester with a capacity between 20 and 50 cubic meters is constructed. The gas produced is distributed to all participating households, even those who have no cattle.

Three community biogas plants in Sarlahi District (in wards 1 and 2 of Bhaktipur VDC and ward 9 of Jabdi VDC) have been successfully constructed. In Jabdi, six households, two of which have no cattle, benefit from the community biogas plant. It is a GGC 2047 model with a fixed dome and a capacity of 35 cubic meters. It has six outlets instead of the single one found in an individual biogas plant.

The total cost of installing a community biogas plant with attached toilets ranges between Rs. 90,000 and Rs. 110,000 depending upon the number of toilets and the location of the houses to which the biogas is to be distributed.

Social preparation is necessary prior to construction in order to determine the size of the plant and to define the roles and responsibilities of each participating households. These duties include deciding who will collect the cow dung, who will feed the digester, and who will manage the slurry. The mechanism by which biogas is distributed also must be established.

5



Inlet, gas outlet and slurry outlet of a community biogas plant in Sarlahi



Community biogas dome under construction in Sarlahi



Cooking food using biogas in Sarlahi



Feeding a biogas plant

WEPCO's Metal Waste-Fed Biogas Plants

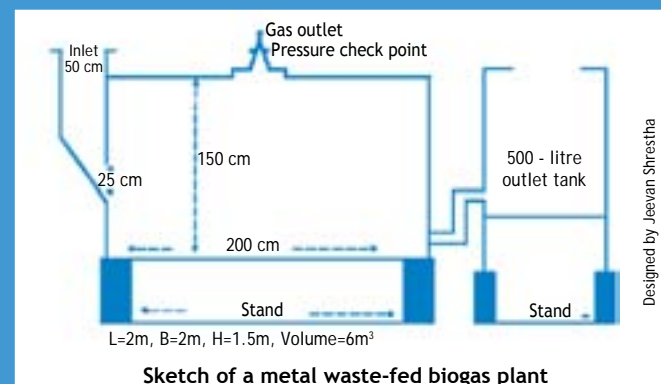
Nepal's first ever metal waste-fed biogas plant, an above-ground model, has served its dual purpose—study and demonstration.

The Women Environment Preservation Committee (WEPCO) collects six tonnes of waste per day. Two tonnes of organic waste are used to produce compost, whereas remaining organic waste are used to produce biogas. In order to demonstrate the production of biogas from waste, WEPCO built a six-cubic-meter metal biogas plant above the ground at the WEPCO premises. It took precautions to make sure the plant is airtight and heat-proof so that the methanogenic bacteria would get the anaerobic and warm conditions they need to thrive. Every day, 100 kilogrammes of waste is fed into the plant and every other day, 30 litres of slurry is removed. The biogas produced is used between 45 minutes to one hour twice a day to make tea and snacks. The plant was designed by Mr. Jeevan Shrestha.

As the biogas plant is above ground, the plant is very suitable for demonstration purposes. Every year, more than 5,000 visitors visit the WEPCO premises to observe the production of biogas from waste and other practices of solid waste management. However, because day and night temperatures vary so dramatically during Kathmandu's winters, the level of the biogas production is not satisfactory, even with the heat-shield.



The metal waste-fed biogas plant at the WEPCO premises



Sketch of a metal waste-fed biogas plant

Institutional Kitchen Waste-Fed Biogas Plants

The success of institutional kitchen waste-fed biogas plants proves that waste can also generate energy. This plant is suitable for urban areas.

Drawing upon lessons learned and expertise gained from constructing a metal waste-fed biogas, an institutional kitchen waste-fed biogas plant was designed for Budhanilkantha School. (See Annex 4.)

The nearly 1200 students at Bhudhanilkantha School generate 500 kilogrammes of waste in the cafeteria every day. In order to manage the waste and generate energy, the school constructed a 50-cubic-meter institutional biogas plant of the modified GCC 2047 model. After one year of operation, a leak appeared in the dome due to a construction fault and the plant ceased to function. However, with support from various donors, similar plants have been successfully constructed at other schools as well as at Maoist cantonment sites, at monasteries, and at vegetable markets

The cost of constructing a 50-cubic-meter biogas is around Rs 500,000 and the annual cost of feeding it and managing its slurry is around Rs. 60,000. The average plant produces nearly one cylinder of liquified petroleum gas daily. Given that a cylinder of liquified petroleum gas costs Rs. 1,250, the plant saves Rs. 465,250 per annum. Thus the initial investment in a biogas plant can be recovered within 14-15 months. In addition, nearly 350-450 kilogrammes of waste can be managed daily. If slurry is properly managed, it can be sold for a tidy sum.

Advantages

- Toilets can also be connected.
- Waste can be managed at the source.
- Slurry can be used as compost.

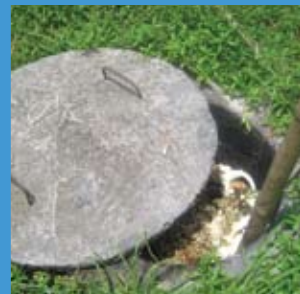
7



Cooking pulses in Shenchen Monastery using biogas



Digging earth for biogas dome



Feeding the plant through inlet



Underground biogas plant (inlet, gas outlet and slurry outlet)

Disadvantages

- Decomposable and non-decomposable waste need to be separated before waste is fed into the digester.
- No soap, detergent, toilet cleaner, or acidic food can be fed into the digester as these substances kill the methane-producing bacteria
- It may be difficult to manage the large volumes of slurry.
- Biogas burns with a steady pressure and, unlike liquefied petroleum gas, the pressure cannot be increased.

Risks

- If the biogas dome and the outlet fitting are not airtight, methane gas will leak and the efficiency of the system will decline.
- Landslide-prone and water-logged areas are not suitable for the construction of biogas plants.

Institutional Multipurpose Biogas Plants (Puxin Biogas Plants)

The advantage of the Puxin biogas plant over other waste-fed biogas plants is that it can be constructed in a small space.

The institutional multipurpose biogas plant, also known as the Puxin biogas plant, is a fixed-dome, hydraulic-pressure biogas plant. It has a concrete digester and a glass fiber-reinforced plastic gas holder. Its components include an inlet, a digester, a neck, a gas holder outlet and a gas outlet. Three such models, each 10 cubic meters in volume, have been constructed in Nepal, one each at Mirabel Hotel, the office of environment section of Lalitpur Sub-Municipality, Balkumari, and Namuna Machindra School. Initially 1400 kilogrammes of waste — 400 kilogrammes of garden waste, 500 kilogrammes of kitchen waste and 400 kilogrammes of cow dung were fed to the digester. Since then, the plant has been fed with three to ten kilogrammes of kitchen waste per day. It produces five hours of gas daily (the equivalent of 1.81 cylinders of liquid petroleum gas monthly) and is used to cook meals for the hotel staff. (See Annex 3)

A Puxin biogas plant is expensive as an iron cast has to be used to construct it. A 10-cubic-meter plant costs between Rs. 60,000 and Rs. 130,000, depending upon the location of the plant, the season and the market price of raw materials. If the demand for such plants in urban clusters increased, the cost per unit would decline considerably.

Risks

- There is a danger that methane gas will leak if the plant remains out of use for a long time.

Advantages

- Toilets can also be connected to it.
- Waste can be managed at the source.
- Since the slurry produced is in liquid form, it is easier to remove than the slurry from a dung-fed plant.
- A Puxin plant takes less space than a modified waste fed GGC 47 plant.
- It can be fed daily or at intervals.

Disadvantages

- No soap, detergents, toilet cleaner or acidic foods should be added to the digester as these ingredients kill the methane-producing bacteria.
- Unlike the liquefied petroleum gas, which has a lot of pressure and can be regulated, biogas has less pressure and cannot be adjusted.

Gas from a Puxin biogas plant



Bio-degradable waste



Gas holder



Preparing waste to fed to the Puxin biogas at Hotel Mirabel

Water Hyacinth-Fed Biogas Plants

If water hyacinth-fed biogas plants are promoted on a large scale, there would be no need to invest money in removing this invasive species from lakes and ponds. Instead it could be sold to produce energy.

A species native to tropical South America, the water hyacinth (*Eichornia crassipes*) is one of the most productive plants on Earth. It is also one of the world's most undesirable aquatic plants because it forms a dense interwoven mat and interferes with navigation, recreation, irrigation, power generation and slowly engulfs lakes and wetland ecosystems.

Every year, a lot of time and resources are spent removing water hyacinth from Fewa Lake in Pokhara. In 2010 alone, the Tourism Board of Pokhara spent Rs 200,000 on this expensive and time-consuming task¹³.

In February 2010, a four cubic meter toilet-attached biogas plant was installed at the premises of Mr. Chitra Bahadur KC, a resident near Rupa Lake, another water hyacinth-infested lake in Pokhara. Chopped-up stems and leaves of water hyacinth are fed to the digester. The plant now produces enough biogas to cook daily meals.

The plant is a modified GGC 2047 model with a water hyacinth storage tank and an attached toilet. Initially, two-and-a-half metric tonnes of fresh cow dung and water was fed to the digester. Once it began to produce methane, three to four kilogrammes of water hyacinth biomass and equal volume of water have been fed to the digester every day. The daily production of gas is between one and one-and-a-quarter cubic meters. The plant costs Rs. 47,000.

9



Water hyacinth in Rupa Lake



Mrs. KC cooking food using biogas produced by a water hyacinth fed plant



Water hyacinth storage tank



Toilet - attached water hyacinth-fed biogas plant

Kilns and Distillation Units

Large cardamom (*Amomum subulatum*), charcoal and essential oils are commodities of great economic significance in Nepal. Nepal is the second largest exporter of large cardamom after India and has a 25% share of the global cardamom market¹⁴. Its average annual production ranges from 6,200 to 6,800 metric tonnes. Almost all of what is produced is sold outside of country, with 90% of the harvest exported to India¹⁵.

The annual production of charcoal in Nepal is also high. According to the energy statistics database of United Nations Statistics Division, Nepal's per capita charcoal production was 2,580 tonnes per million people in 2005¹⁶. The Dalit caste of traditional blacksmiths are usually responsible for charcoal production. Since they produce charcoal in open pits, they are vulnerable to occupational health hazards and are often blamed for accidentally igniting forest fires.

Nepal also exports significant volumes of non-wood forest products and medicinal and aromatic plants. The volume

and value of trade of these products in the international and domestic market are very difficult to estimate due to the lack of data and to the unreliability of the limited data that is available. A report prepared by Asia Network for Sustainable Agriculture and Bio-resources estimated that each year Nepal sells medicinal plants and non wood forest products worth more than 18 million U.S. dollars. Since these products are exported in raw form, they are considered to be high-volume, low-value commodities. If however, the essential oils of medicinal and aromatic plants are extracted, then they become low-volume but high-value products. Essential oil extraction has only recently started in Nepal.

The production of large cardamom and charcoal and the extraction of essential oils are all energy-intensive practices. Improving these technologies can not only increase energy efficiency of production but also improve the quality of the products.

Improved Cardamom Dryers

The improved cardamom dryer produces cardamom of superior quality and is energy efficient and economical, too.

Cardamom should be dried or cured within a week of harvest; otherwise, it rots. The curing of cardamom is very energy intensive if it is practised in a traditional drier. In addition, cardamom dried in a traditional dryer is of inferior quality and has a smoky odour.

Improved driers help improve the quality and quantity of cardamom by preventing it from burning (see Annex 5). Because cardamom dried in improved dryers is of superior quality, the existing trading practice, the “*fawa system*”, in which the trader gets a discount of two-and-a-half kilogrammes for every 100 kilogrammes of dry cardamom he buys, has been abandoned and farmers get paid 5% more. In addition, firewood is saved and there is no loss in the form of burnt cardamom pods. Calculating all these changes in monetary terms, improved dryers enable farmers to earn Rs. 3,733 (USD 51) more for every 500 kilogrammes of fresh cardamom they harvest (see Table 4).

An improved cardamom dryer reduces the amount of firewood consumed in the drying process by 28%. For example, to dry 500 kilogrammes, the weight of typical batch, it requires just 1300 kilogrammes of wood, 500 kilogrammes less than a traditional dryer. An improved dryer may be used up to 15 times in one season, providing an annual savings of 7.5 metric tonnes of firewood.

The cost of establishing an improved cardamom dryer is Rs. 60,000 (USD 800). With the savings per drying at Rs. 3,733.50 (USD 51), the cost incurred can be recovered in a single season, or after using it just 16 times.

10



Drying cardamom in improved cardamom dryer



Improved cardamom dryer

Cardamom plant

Risk

- Since the dryer is used only during cardamom harvesting season, care should be taken to prevent the drum from rotting.

Table 4: Comparison of traditional and improved cardamom driers

Parameter	Traditional	Improved	Savings	Savings (Rs)	Remarks
Amount of fresh cardamom (kg)	500	500	-	-	
Amount of dried cardamom (g)	103	108	5	1000	Rs. 200 per kg
Recovery from <i>Fawa</i>	-	1	1	540	Rs. 200 per kg
Premium price per kg	-	5%	5%	1080	5% more for superior quality (Rs. 210 per kg)
Amount of firewood burned (kg)	1800	1300	500	1000	Rs. 2 per kg
Time to dry (hr)	35	26	9	112.5	Rs. 100 per 8 hr work day
Total savings (Rs)				3733.5	

Field study: ECDF 2007

Improved Charcoal Kilns

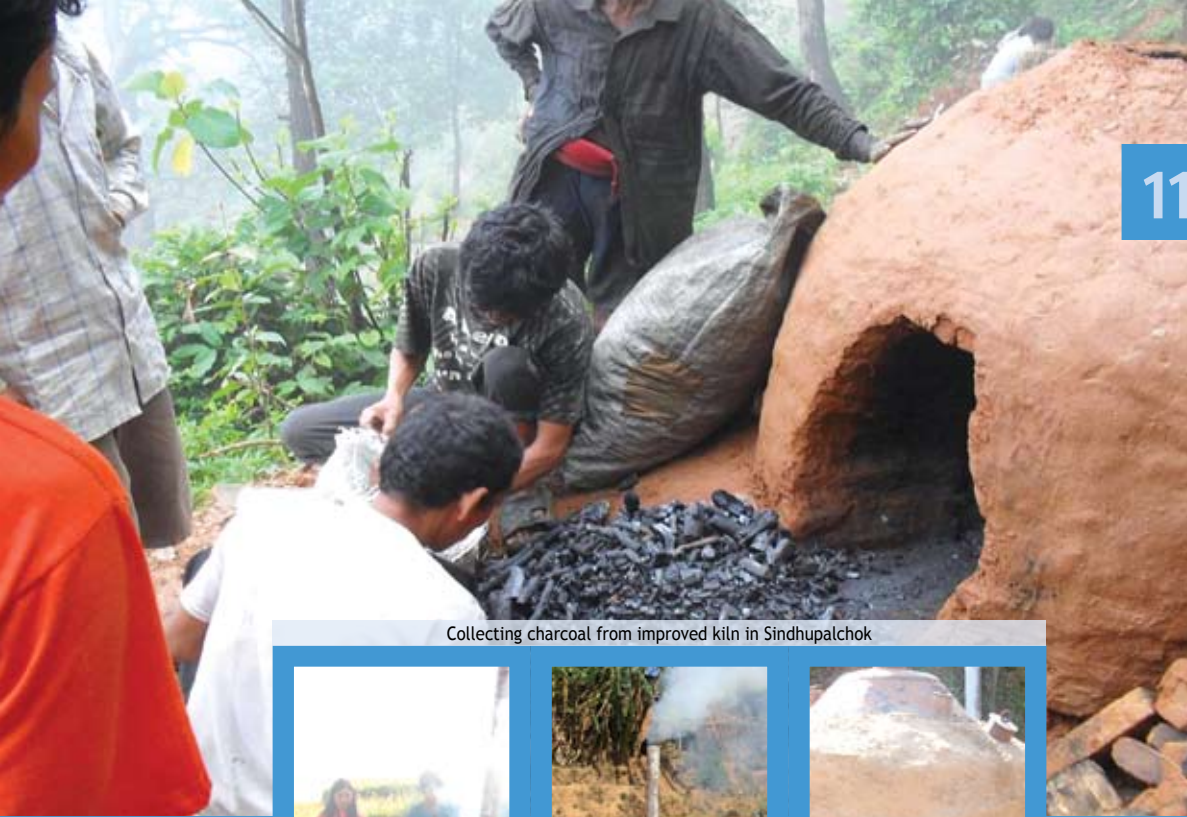
With improved charcoal kiln, the blacksmiths no longer have to worry about forest fires or poor health. In addition, the new kiln is more efficient than the traditional mode of charcoal production.

The traditional process of charcoal production involves burning sticks of wood in a mud pit. After the initial burning and when the charcoal has started to form, the fire is extinguished with mud and water. The charred wood is then cooled and the resultant product is charcoal. This practice is an inefficient one that requires a lot of firewood but produces little charcoal.

An improved charcoal kiln is easy to construct. A pit between eight to ten inch in depth and three feet in diameter is dug in the ground and covered with iron netting and ten iron rods. A four-inch-diameter hole (a) is made below the rods to allow for a supply of oxygen. Then a three-to-four-feet-high cylindrical mud-brick wall with a large opening (b) in one side is constructed around the pit. The resultant cylinder is covered with a metal dome having one four-inch-diameter smoke outlet (c) or chimney and three small outlets (d) each with a two-inch-diameter (See Annex 2). A kiln costs nearly Rs. 8,000. Credit for the design go to Mr. Chintamani Sharma.

To produce charcoal, sticks of wood are placed inside the fire chamber through the large opening (b), which, after wood is lit, is sealed with brick and mud. By opening or closing the small holes in the metal dome (c), the volume and rate of charcoal production can be increased or decreased. Generally, opening all three small holes in the dome yields more charcoal but increases production times. A four-foot-high kiln with a 30-inch-diameter can convert 200 kilogrammes of firewood into 50 kilogrammes of charcoal in 12 hours' time.

This kind of charcoal kiln has been tested in Kunchok, Sipapokhare and Bhotshipa VDCs of Sindhupalchok District. It has several advantages over traditional kilns (see Table 5).



Collecting charcoal from improved kiln in Sindhupalchok



Improved charcoal kiln

Table 5: Comparison of traditional and improved charcoal kilns

Particular	Traditional	Improved
Charcoal production from 100 kg of firewood	10 kg of charcoal	25 kg of charcoal
Fire hazard	Prone to accidental fire hazards as it is difficult to extinguish fire in an open pit	Fire hazard almost nil as fires can be extinguished easily without damaging the charcoal.
Health hazard	Smoke affects lungs, eyes, hand, clothes and hair	Very little smoke
Charcoal harvesting	Very difficult, and the charcoal may be washed away by rain	Very easy

Improved Distillation Units for the Extraction of Essential Oil

The essential oil produced by an improved stainless steel distillation unit is of export quality. It is easy to handle and energy efficient, too.

The improved distillation unit for the extraction of essential oil is made of stainless steel and has a distillation chamber, an attached boiler, a fire chamber and a lid with a chain pulley. The old model of distillation units is made of mild steel and does not have an attached boiler or a chain pulley in the lid. The advantages of the new unit over the old one are shown in Table 6.

The improved distillation unit requires that firewood be used only once in the process of extracting essential oil the first time. After that, the dried plant residue left after extracting the essential oil can be used as fuel to distil essential oils from the next batch. Dried plant material, which is generally considered to be waste, is used to heat the boiler. The steam produced from the boiler is passed into the distillation chamber and essential oil is produced through steam distillation. The old model, in contrast requires firewood for each batch of plant material that is distilled.

The improved distillation unit was first installed in Napke Yen Mara, a village on the way to the town of Dolakha, and has been replicated in eight other places.

12



Extracting essential oil in Dolakha



Stainless steel distillation unit

Table 6: Comparison of the old and the improved models of distillation units

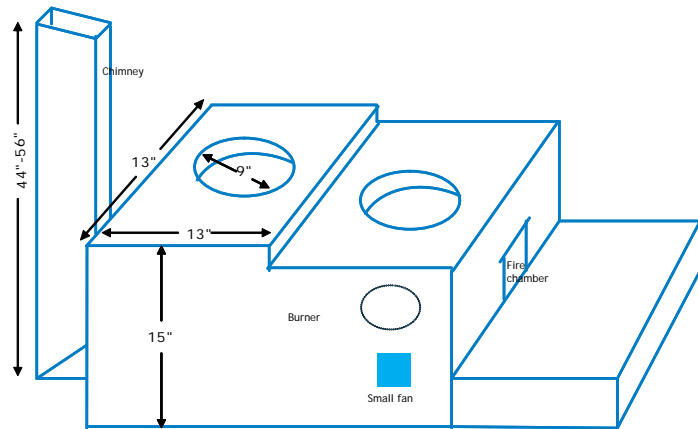
Particular	Old model (mild steel)	Improved model (stainless steel)
Capacity	300 kg of raw material	500 kg of raw material
Fuel wood requirement	150 kg	160 kg (dried raw material can also be used)
Yield	0.5% (1.5 kg)	0.7% (3.5 kg)
Time required	12 hrs.	11 hrs.
Quality of charcoal	Needs further treatment with oxalic acid; prone to corrosion	Pure
Other		Has a chain pulley in the lid and an attached boiler

References

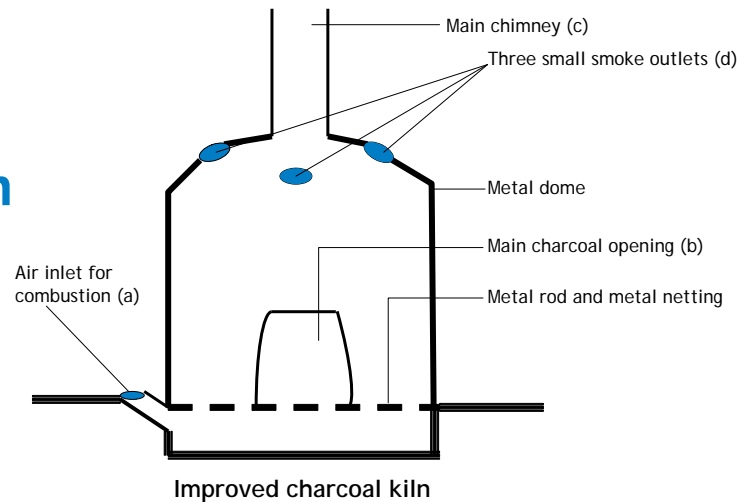
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Annex

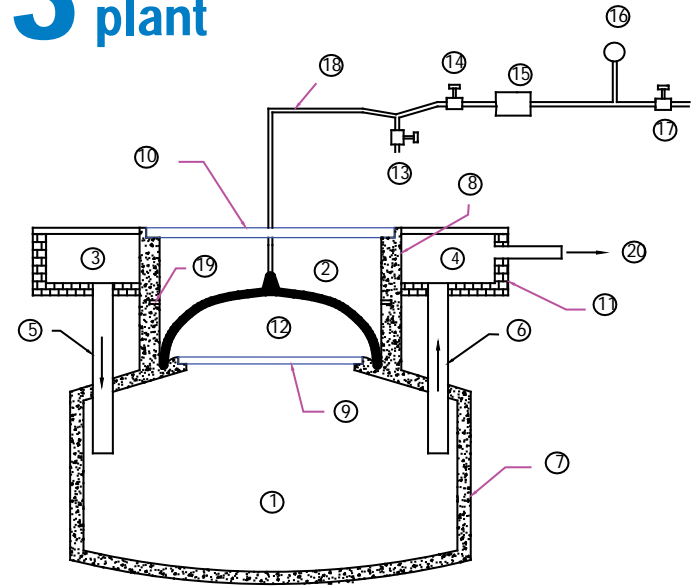
1 Matribhumi stove



2 Improved charcoal kiln



3 Puxin biogas plant



Part No.	Name	Material
1	Digester	
2	Neck	
3	Inlet	
4	Outlet	
5	Inlet pipe	HDPE pipe
6	Outlet pipe	HDPE pipe
7	Digester wall	PCC - 4 inch thick
8	Neck wall	PCC - 6 inch thick
9	Digester cover slab	RCC slab - 5 pieces, 4 inch thick
10	Neck cover slab	RCC slab - 4 pieces, 4 inch thick
12	Gas holder	Fiber reinforced plastic
13	Water trap	
14	Valve	
15	Desulfurizer	
16	Pressure gauge	
17	Valve	
18	Gas outlet pipe	Polymer pipe, dia.10 mm
19	Slot for clipping gas holder clamp, 3 numbers at 120 degrees apart	
20	Slurry outlet	

Different parts of IMBP

Institutional Multi-Purpose Biogas Plant

Drawing No. IMBP-2

For more information

- 1 The *matribhumi* stove
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SGP The GEF
Small Grants
Programme

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