Compact digester for producing biogas from food waste

Organisation	Award Category	Technology	Region	Year
Appropriate Rural Technology Institute (ARTI)	Food	Biogas	India	2006

Summary of the Award-winning work

The Appropriate Rural Technology Institute (ARTI) in Pune has developed a biogas plant which uses food waste rather than manure as feedstock and supplies biogas for cooking. The plant is sufficiently compact to be used by urban households, and over 700 are currently in use.

Ajit Gokhale with his biogas plant which he feeds with spoilt figs and food left over by the street dogs he rescues.

Pune is a relatively affluent city in south India, and many people use liquid petroleum gas (LPG) or kerosene for cooking. Waste food is often discarded at the side of the road, as in many cities, attracting stray dogs, flies and rats and creating a public health hazard. The ARTI compact biogas plant is made from two standard high-density polyethylene (HDPE) water tanks: the larger tank acts as the digester and the smaller one is inverted and placed into it to serve as a gas-holder. The plant safely digests kitchen waste, food waste or waste flour from mills, thus reducing the problem of waste disposal. A 1,000 litre plant produces sufficient biogas to at least halve the use of LPG or kerosene for cooking in a household, as well as a small amount of liquid effluent which can be used as fertiliser. ARTI has developed the technology, field tested it, and managed the supply of about 700 biogas plants in Maharashtra. Around 100 plants are now being installed every month.

The first-prize Ashden Award to ARTI recognises the enormous potential for using this compact biogas digester in towns and cities, both to supply cooking gas and to assist in the disposal of organic waste.

The organisation

ARTI is a charitable trust, founded in 1996 by a group of scientists, technologists and social workers. It currently employs ten staff and has 22 members. The biogas project, started in 2003, is one of over ten different projects run by ARTI. Many of its staff are involved in more than one project and so there is continuous cross-fertilisation of ideas.

ARTI won a First Prize Ashden Award in 2002 for using sugar cane waste to make char briquettes.

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Technology

Biogas systems take organic material (feedstock) into an air-tight tank, where bacteria break down the material and release biogas - mainly a mixture of methane with some carbon dioxide. The biogas can be burned as a fuel, for cooking or other purposes, and the solid residue can be used as organic compost.


Cooking with gas from an ARTI biogas plant is easy and convenient

Most biogas plants currently in operation in India and elsewhere are designed to use animal manure as their main feedstock, and are therefore used in rural areas. ARTI have developed a compact biogas plant which uses highly digestible organic materials available in urban areas, such as waste flour or kitchen waste as feedstock. The plant can be made in a small size and still produces enough gas for a family, because its feedstock has a much higher energy density than manure, and the digestion takes place more quickly (typically only one to two days, compared with 30 to 40 days for a manure-based plant); so a much smaller quantity of decomposing material needs to be held in the plant.

The compact plants are made from cut-down HDPE water tanks, which are adapted using a heat gun and standard HDPE piping. The standard plant uses two tanks, with volumes typically of 0.75 m^3 and 1 m^3. The smaller tank is the gas holder. It is inverted and attached to the larger one which holds the mixture of decomposing feedstock and water (slurry). An inlet is provided for adding feedstock, and an overflow for removing the digested residue. Because the feedstock is almost completely digested, the effluent contains a much smaller amount of solid matter than the residue from a manure-based plant, and ARTI recommends that the liquid is mixed with the feedstock and recycled into the plant. A pipe takes the biogas to the kitchen, where it is used with a biogas stove. Such stoves are widely available in India, which has a long tradition of using manure-based biogas plants. The gas holder gradually rises as gas is produced, and sinks down again as the gas is used for cooking. Weights can be placed on the top of the gas holder to increase the gas pressure.

ARTI has found that the gas produced in these plants has a higher methane concentration than is found using manure based plants, and therefore has a higher energy content. Experiments suggest that the reason for the high methane concentration is that the carbon dioxide dissolves in the very liquid slurry. The methane concentration is further increased when weights are used on the gas holder, because more carbon dioxide dissolves under the increased pressure.

The plant is provided as a kit that takes only two to three hours to install. It needs a space about 2 m square and 2.5 m high, although adaptations can be made if it is placed under a roof. The plant is filled with a starter mix: either cattle dung mixed with water and waste flour, or effluent from an existing biogas plant mixed with flour. The feeding of the plant is built up over a few weeks until it provides a steady supply of gas, typically 250 g of gas per day from 1 kg (dry matter) of feed. The feed can be waste flour, vegetable residues, waste food, fruit peelings and over-ripe or rotten fruit. Feedstock with large lumps (more than 20 mm) can be broken up with a food blender. Hand- and pedal-powered food blenders are being developed for when electricity is not available. Oil cake, left over from oil-pressing, is another useful feedstock. Non-edible oils (such as jatropha, castor and linseed) are being promoted in India for making biodiesel, and oil-cake that cannot be fed to animals is likely to become more abundant.

A biogas plant can become acidic and fail if it is over-fed, and this is a particular problem with a plant using highly digestible organic materials. If this happens, ARTI has found that the plant can be recovered by ceasing feeding, partially flushing out the contents with fresh water, and then building up the feed rate again slowly. This problem was more common with the early smaller systems (0.5 or 0.75 m^3) than with the later, larger systems.

How users pay

At the time of writing (July 2006) 85 Rupees (Rs) = UK£1 = US$1.8

All plants are paid for in full by the owner when they are constructed. If the plant is installed by ARTI, the user purchases the plastic tanks and the relevant hardware. An ARTI technician assembles and commissions the system and the total cost to the owner is about Rs 6,500 (about £76) for a 1 m^3 system, plus Rs 500 (£6) for a biogas stove. ARTI is not allowed to make a profit and so the cost of installation is lower than with private entrepreneurs, who build plants for Rs 10,000 (about £120). This includes the cost of fabrication, transport to site and installation. There are no subsidies or loan facilities. The project does not have a micro-credit facility but a supplier may accept payment by instalments.

Training, support and quality control

ARTI develops sustainable technologies and trains people to use them. Knowledge is transferred either through local entrepreneurs or through representatives of other NGOs who are trained by ARTI at their centres. About 30 people have so far been trained and ten are actually functioning as entrepreneurs. ARTI employs five people who focus on improving the biogas technology, and training entrepreneurs to install biogas plants. They also install biogas plants in places where no-one has yet been trained in this role.

'Feedstock' - spoilt fruit and leftover food - for an ARTI biogas plant

ARTI's technicians each have their own biogas plant at home, and some are testing out new configurations, identifying and solving problems. Two test sites are also used to verify further improvements, such as the design of gas burners. Alternative designs, based around a fixed dome, are also being tested.

Benefits and replicability

The immediate benefit from owning a compact biogas system is the saving of the cost of kerosene or LPG for cooking. The up-front cost of a biogas system (Rs 6,000 for a 1 m^3 system plus stove) is higher than for LPG, since an LPG bottle plus a two burner stove costs only Rs 5,000 (£60). However the running cost for biogas is only about Rs 2 per day if waste flour is purchased as feedstock, and can be zero if the plant uses only food waste. This is much cheaper than LPG which costs about Rs 15 per day, even with the current subsidy of 50%. Biogas can easily halve the amount of LPG used by a family. Some families who use a pressure cooker for cooking and collect food waste from their neighbours have replaced all their LPG use.

The replacement of fossil fuels reduces the emission of greenhouse gases. ARTI estimates that, for a typical urban household, biogas saves 100 kg of LPG or 250 litres of kerosene per year, which is equivalent to 300 to 600 kg CO_2 per year. A rural family could save about three tonnes of wood per year, which would generate about five tonnes of CO_2 if burnt.

Indoor air pollution is reduced by cooking with biogas as opposed to wood or kerosene. This is better for the health of those in the kitchen (who are mainly women). Further reductions in pollution and energy use arise from not having to transport LPG cylinders to be re-filled. The small amount of liquid residue produced by the biogas plant makes a good fertiliser.

In villages, food waste was traditionally fed to livestock or left by the side of the road for animals to devour. People in the city continue to do this, but there are fewer animals to consume it. The result is that smelly, rotting food attracts flies and rats. Some authorities collect food waste and dispose of it in landfill. The municipal authority in Pune has decided it can no longer do so because of lack of space, and local officials are therefore strongly encouraging the use of biogas plants to dispose of food waste. Local council offices have set up demonstration plants, which use local food waste and provide gas for making tea for local officials and their visitors.

Between 2003, when the project started, and May 2006, 600 biogas plants had been installed. At least 100 more plants were installed outside the project area (the project is operative only in Maharashtra), and several independent producers have copied the design for themselves. These existing plants are a useful advertisement

RTI, India. View project details here.

Ajit Gokhale with his biogas plant which he feeds with spoilt figs and food left over by the street dogs he rescues.

Cooking with gas from an ARTI biogas plant is easy and convenient.

An ARTI technician tests out a new biogas plant design in his own home.

'Feedstock' - spoilt fruit and leftover food - for an ARTI biogas plant.

ARTI Biogas Plant: A compact digester for producing biogas from food waste

ARTI has developed a compact biogas plant which uses waste food rather than dung/manure as feedstock, to supply biogas for cooking. The plant is sufficiently compact to be used by urban households, and about 2000 are currently in use – both in urban and rural households in Maharashtra. A few have been installed in other parts of India and even elsewhere in the world. The design and development of this simple, yet powerful technology for the people, has won ARTI the Ashden Award for Sustainable Energy 2006 in the Food Security category. This makes ARTI the only organization in the world to win the prestigious Ashden Award twice. ARTI won its first Ashden Award in 2002 for its chain of technologies for converting agricultural waste into charcoal, and using this as a clean domestic fuel. The impending scarcity of petroleum threatens the world’s fuel supply. Mankind can face this threat successfully with the help of biogenous methane, but the world is yet to take full advantage of this technology, because its practitioners have so far ignore the basic tenet of science – viz. output of work is dependant on the energy available for doing that work. This fact is seen in the current practice of using low calorie inputs like cattle dung, distillery effluent, municipal solid waste or sewerage, in biogas plants, which makes methane generation highly inefficient. To rectify this skewed approach, in around 2003, Dr. Anand Karve (President of ARTI) developed a compact biogas system that uses starchy or sugary feedstock (waste grain flour, spoilt grain, overripe or misshapen fruit, nonedible seeds, fruits and rhizomes, green leaves, kitchen watse, leftover food, etc). Just 2 kg of such feedstock produces about 500 g of methane, and the reaction is completed with 24 hours. The conventional biogas systems, using cattle dung, sewerage, etc. use about 40 kg feedstock to produce the same quantity of methane, and require about 40 days to complete the reaction. Thus, from the point of view of conversion of feedstock into methane, the system developed by Dr. Anand Karve is 20 times as efficient as the conventional system, and from the point of view of reaction time, it is 40 times as efficient. Thus, overall, the new system is 800 times as efficient as the conventional biogas system. To know how this technology works, click here.

Benefits

Comparison with conventional Biogas plants

Establishing a new trend: Biogas in cities

Purchasing your own compact biogas system: Cost & Payment

What the numbers say

BenefitsMost biogas plants which are currently in operation in India and elsewhere are designed for animal manure as their main feedstock, and are therefore used in rural areas. Whereas in cities, a majority of the people use LPG or kerosene for cooking. The immediate benefit from owning a compact biogas system is the savings in cost as compared to the use of kerosene or LPG for cooking. The up-front cost of a biogas system is higher than for LPG, since an LPG bottle plus a two burner stove costs only Rs 5,000 (spprox. USD 100) whereas the compact biogas plan plus a biogas stove costs about Rs.10000 (approx. USD 200). However, the operational cost for biogas is only about Rs 2 per day if waste flour is used as feedstock, and can be zero if the plant uses only food wastes. This is much cheaper than LPG, which costs about Rs 30 per day, even with the current subsidy of 50%. Biogas can easily replace 50% of the LPG used by a family. Some families who use a pressure cooker for cooking and collect food waste from their neighbours have replaced all their LPG use.Methane burns with a blue flame, without producing any smoke or soot. It is therefore an environmentally friendly cooking system. Thus, introduction of the new efficient, compact biogas system would not only help urban households in utilizing their domestic wet waste, but also help prevent millions of premature deaths of women and children in rural households due to indoor air pollution caused by smoke and soot from burning fuelwood in traditional chulhas. This markedly impacts the health of the people in the kitchen (mainly women) positively. Further reductions in pollution and energy use arise from not having to transport LPG cylinders to be re-filled. The small amount of solid residue produced by the biogas plant makes a good fertiliser.On a global scale, it is well known that the replacement of fossil fuels reduces the emission of greenhouse gases. ARTI estimate that for a typical urban household, biogas saves 100 kg of LPG or 250 litres of kerosene per year, which is equivalent to 300 to 600 kg CO2 per year. A rural family could save about 3 tonnes of wood per year, which would generate about 5 tonnes CO2 if burnt.

Comparison with conventional Biogas plants Biogas systems are those that take organic material (feedstock) into an air-tight tank, where bacteria break down the material and release biogas – a mixture of mainly methane with some carbon dioxide. The biogas can be burned as a fuel, for cooking or other purposes, and the solid residue can be used as organic compost. The current practice of using low calorie inputs like cattle dung, distillery effluent, municipal solid waste, or sewerage, makes methane generation in conventional biogas plants highly inefficient. Through this compact system, it has been demonstrated that by using feedstock having high calorific and nutritive value to microbes, the efficiency of

methane generation can be increased by several orders of magnitude. Operating the system on this simple tenet also brings in many more advantages over the conventional systems: As a result of the higher efficiency, the size and cost of the new system are also lower. While the conventional biogas system occupies about 4 cubic meters of space, the compact biogas system is about as large as a domestic refrigerator. It is an extremely user friendly system, because it requires daily only a couple of kg feedstock, and the disposal of daily just 5 litres of effluent slurry.

Conventional Biogas Systems

ARTI Biogas system

Amount of required feedstock

40 kg + 40 lit water

1-1.5 kg + 15 lit water

Nature of required feedstock

Dung

Any starchy material

Amount and Nature of slurry to be disposed of

80 lit, sludge

15 lit, watery

Reaction Time for full utilization of feedstock

40 days

48-72 hours

Standard size for household

4000 lit

1000-1500 lit

Capital Investment per unit including stove

Rs 20,000

Rs 10,000

Running Expenses per meal

Rs 25

0 to Rs 5 Establishing a new trend: Biogas in cities
In cities, waste food is often discarded and its rising heap attracts flies and rodents, thus creating a public health hazard. The compact biogas plant technology developed by ARTI readily accepts highly digestible organic materials such kitchen waste as feedstock and can easily blend into the urban lifestyle. A single plant produces sufficient biogas to at least halve the use of LPG or kerosene for cooking in a household, as well as a small amount of solid residue which can be used as fertiliser. ARTI’s compact biogas plant could be replicated anywhere where there is the space for the plant, and the temperature is sufficiently high.This technology offers a solution not just for domestic waste disposal, but also for collective disposal of community waste. In villages, food waste was traditionally fed to animals or left by the side of the road for animals to devour. People continue to do this in cities but there are fewer animals to consume it. The result is that smelly, rotting food attracts flies and rats. Some authorities collect food waste and dispose of it in landfill. Here again, available land space presents its own constraints. For example: the authority in Pune has decided it can no

longer dispose city waste in a landfill because of lack of space, and local officials are therefore strongly encouraging the use of biogas plants to dispose of food waste. Local council offices have set up demonstration plants, which use local food wastes and provide gas for making tea for local officials and their visitors.

Communities in city residential and commercial set-ups can avail this technology to convert starchy waste into clean useful energy.
Purchasing your own compact biogas system: Cost & Payment Samuchit Enviro-Tech (SET) Pvt. Ltd., a company set up by members of ARTI, is in charge of commercialising the ARTI compact biogas system. ARTI’s trained technicians install the biogas plants using locally available plastic tanks (commonly used for water storage) and a plumbing kit supplied by SET. SET also supplies a single burned biogas stove made of cast iron, and a gas cock. This set, consisting of the plumbing kit and a single burner biogas stove, costs Rs. 2350 (M.R.P. inclusive of taxes and transport anywhere in India). The total estimated cost of the compact biogas system for a typical household (around 1000-1500 lit capacity) is about Rs.10,000, but the actual cost may vary based on local prices of plastic tanks and local labour costs.

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What the numbers sayFrom 2003 onwards, about 1000 compact biogas plants have been so far installed by ARTI's trained personnel – covering both rural as well as urban households in Maharashtra. At least 1000 more plants have been installed by enthusiasts and hobbyists, using the instruction VCD widely produced and distributed by ARTI (click here for more information on our VCDs and booklets). In Maharashtra, several independent producers have copied the design for themselves. These existing plants are a useful advertisement for the advantages of biogas systems and consequently about 30-50 plants are now being installed per month.

In Maharashtra State alone, there are an estimated 500,000 potential users for this technology. ARTI aims to reach out to these potential users and more, with this revolutionary clean fuel technology. We also look to manufacture standardised feedstock in de-centralised units to facilitate ease in plant usage and set up sustainable entrepreneur chains for unit supply and maintenance.