Food Security and Climate Change

Biogas Energy Systems in Rwanda

Brian Hilton

Contents

Introduction

World Vision Rwanda works with the Energy, Water and Sanitation Authority of Rwanda (EWSA) to support farmers in establishing manure-based biogas cooking systems. These systems provide an energy-efficient alternative to firewood and reduce pressure on very limited forest resources.

In the Eastern Province of Rwanda, 128 households are taking part in the biogas systems project. EWSA was responsible for installing the biogas systems to create methane gas from dairy manure through a zero grazing system, which means forage is cut and carried to milk cows. All families received subsidies from both EWSA and World Vision Australia to jump-start the project.

Five households were visited and interviewed to assess the impact of the biogas cooking systems. Interviews focused on acceptability, reliability and ease of use of the biogas cooking systems; savings from reduced wood consumption; and use of supplementary wood cooking systems. Interviews also examined how households managed manure before and after digestion, and the impact on the value of fertilizer produced from biogas manure effluent.

All recipient families reported positively on their experiences with the biogas systems. They cited numerous benefits, including that biogas provided a clean, smokefree, rapid and reliable system of cooking compared to traditional wood stoves. Families also reported an increase in the fertilizer value of manure from the biogas system as a result of anaerobic digestion.

Families did not detect any ammonia nitrogen loss of manure through smelling the cooking gas. The cooking gas had an unpleasant odour, reminiscent of hydrogen sulphide or Mercaptan(the chemical put in commercial natural gas to give it a smell). But once ignited, it burned completely clean with an odourless bright blue flame.

Families also reported a decrease in biogas production in the dry season due to the difficulty of procuring forage for cattle.

Current biogas systems require two dairy cows producing 15 kg of manure each per day. New biogas systems from EWSA will have larger gas capacity and more plastic to retard gas escape. They will also require less manure, making them appropriate for families who have only one cow.

Brian Hilton
Food Security Advisor
Food Secuirty and Climate Change
World Vision Australia

Why biogas?

Biogas is produced through anaerobic (without oxygen) digestion of manure slurry, resulting in the release of methane gas. The gas can then be captured and safely stored underground to fuel a domestic cooking stove.

Biogas systems reduce greenhouse gas emissions by preventing methane gas from manure from being released into the atmosphere. They also contribute to the conservation of natural resources by replacing wood-based cooking systems.

Biogas systems are ideal for Rwandan farmers who own dairy cows, because they allow them to harvest energy for cooking at a very low cost.

How does biogas save forests?

Methane from biogas is essentially a free energy source that would otherwise go to waste. Wet manure naturally generates some methane gas. Soil bacteria usually oxidizes the remaining carbon in manure, which is released as carbon dioxide (CO_2). But in biogas systems, anaerobic digestion is encouraged. More carbon is liberated as methane gas (CH_4) and burned on the gas stove, also producing CO_2.

Rwanda is highly deforested, and pressures on firewood resources are enormous. Because biogas systems do not require wood, they save forest resources.

Intensive farming and the use of firewood for cooking are putting under pressure local forest resources

How does biogas integrate with farming systems?

Biogas systems integrate well with dairy farming systems. After processing, the manure used to produce methane gas retains at least the same fertilizer value as fresh or composted manure. The manure is suitable for the production of high value crops like banana, beans, Irish potato, and vegetables.

A local family's vegetable patch

The biogas system at work

The biogas system installed by EWSA consists of two buried concrete tanks: a digester and an outlet tank (see diagram below). Manure slurry is fed through an inlet into the larger tank, the digester, where micro-organisms reduce complex organic matter into methane gas and other organic compounds.

The build-up of methane gas in the digester creates pressure, channelling the gas into a pipe leading to the cookstove. A valve located overground allows for control of gas flow to the kitchen.

Gas pressure in the digester also flushes the system of spent manure, pushing it through a canal from the outlet tank to an overground pit.

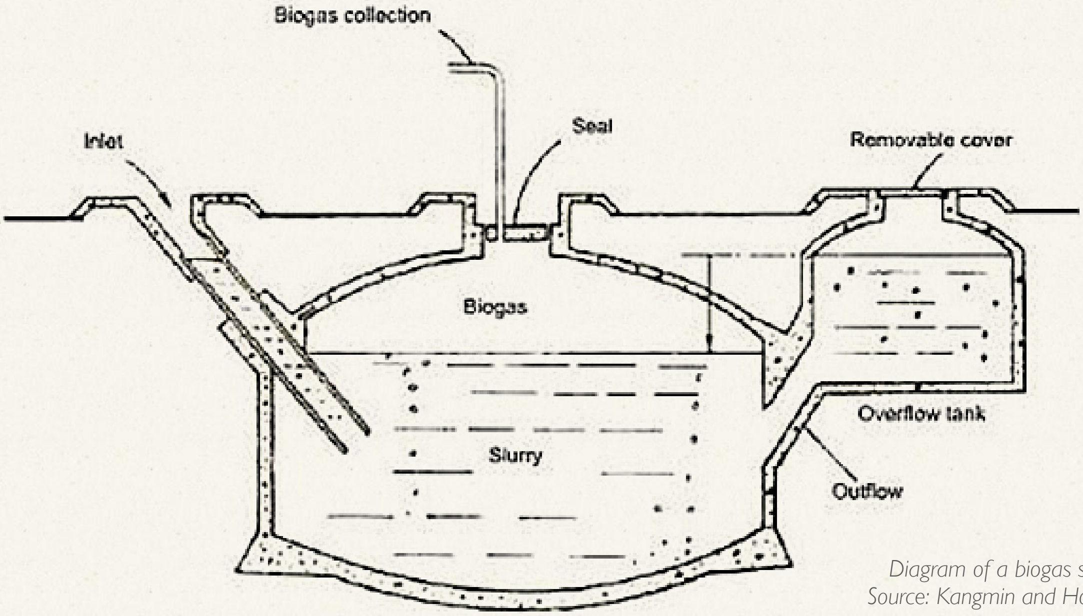


Diagram of a biogas system
Source: Kangmin and Ho (2006)

Biogas production steps

Step 1

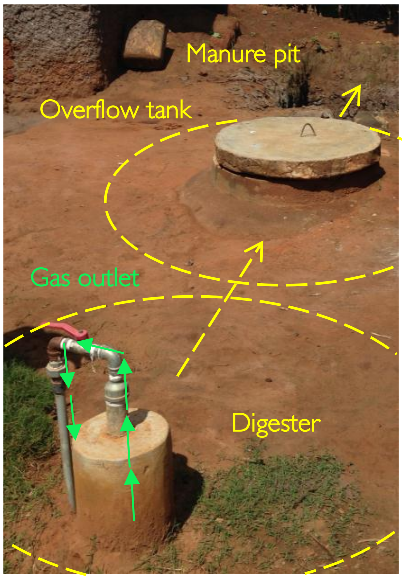
Manure is collected daily from two cows for a total of 30kg. Manure should not contain bedding straw or dirt. Zero grazing allows easy collection of manure because the cow is confined in a stall.

Step 2

Manure is mixed one-to-one with water in a mixer to form slurry. A plug at the bottom of a pipe leading from the mixer to the digester is removed, letting the slurry flow into the digester. The plug is then replaced.

Step 3

Once primed and fed daily with new manure, the digester produces methane gas. The more manure in the system, the more gas is produced. During cooking, a valve at the top of the digester tank is turned on to let gas into the kitchen through an underground pipe.



Step 4

Another valve in the kitchen is opened to the stove for cooking. The valve controls the size of the hot blue flame produced, and a gauge on a side tube indicates gas pressure in the tank.

Step 5

Methane pressure inside the tank pushes the spent manure slurry out of the overflow tank and into a manure pond.

Step 6

The manure slurry is removed from the pond and usually added in layers to dry leaves or straw to create a compost pile, which is spread during the next planting season.

Producing the manure slurry

Cement stall floors allow for easy collection of manure, because they prevent it mixing with dirt and straw.

Three of the five interviewed farmers had cement stall floors, but they were all in poor condition. The cows' stomping and continual drenching with urine weaken and break the cement over time, and replacement is expensive. Farmers also appeared to need help designing the slope and trough of the cement floors to enable efficient collection.

Cement stall flooring in poor condition making manure and urine collection difficult

The gaseous loss of nitrogen (through ammonification and denitrification) are concerns with anaerobic digestion. Manure is the only fertilizer applied to banana, beans, maize and other high value crops in these households. The gaseous loss of nitrogen in manure would have crop production consequences.

Significant denitrification is unlikely to occur because manure contains few nitrates. Ammonification also did not seem to occur, as the biogas did not smell of ammonia. Even the farmer using cow urine to create the slurry produced biogas with no detectable ammonia. The biogas had a sulphurous smell reminiscent of hydrogen sulphide. Once ignited, there was no smell or smoke. Biogas appears to burn just like propane.

All farmers reported that the manure slurry from anaerobic digestion was at least as effective at fertilization as undigested manure. Digestion allows manure to be applied directly in the field. Without digestion most farmers were composting the manure.

Farmers used different systems to handle the significant amount of effluent coming out of the digester. The effluent is a slurry, which makes it difficult to handle. Several farmers composted the effluent, while others applied it directly to their fields. One farmer used a technique to drain the liquid, producing a dry manure that was easier to handle.

Farmer who drains water from manure achieving a dry easy to handle product.

Water input

It was a challenge for farmers to collect 30 litres of water every day to produce the slurry. Several farmers solved this problem by installing water collection systems on the roofs of their houses. One famer installed a urine collection system, using urine instead of water to make the manure slurry.

Water collection system from roof (left) and urine collection system (right)

Results assessment

Cooking results

All families interviewed used biogas as the principle energy source to cook three meals a day. The smallest family interviewed had five children and the largest had nine.

The biogas generated from the manure of two cows was often insufficient to supply all the cooking fuel needed for a family of more than five children. These families maintained the use of wood stoves for foods such as beans, which require long cooking times.

Double burner biogas on the right, supplemental wood stove on the left

Families reported positively on their experiences with the biogas systems, citing the following benefits:

- clean with no smoke
- ignites quickly and enables efficient cooking
- cost-effective (no need to purchase firewood)
- user-friendly
- manure from the digester is more effective than untreated manure

Biogas production declines in the dry season, when families struggle to cut enough forage for cattle. One family simply did not cook beans during the dry season and frugally used the gas they had, while other families supplemented more freely with wood stoves.

The new EWSA biogas systems are more efficient and should produce more biogas with less manure. These new systems can be used by families who have only one dairy cow.

One family used biogas to boil drinking water, taxing the system to its limit. The other families used filters or chlorine to treat water before drinking.

Landholdings are small so famers grow forage which is mostly elephant grass. Reduced growth in the dry season means less forage for cows and less manure for biogas

Economic results

Biogas cooking systems are expensive but supply improved cooking in a smokeless environment. Subsidies appear to be necessary until the cost of biogas decreases.

Because biogas supplants wood cooking systems and involve minimal expenses, the benefits can be calculated almost exclusively against firewood savings. (Farmers were also expected to supply labour to dig deep holes in which to install the biogas tanks. This labour, estimated at approximately six to10 days, is not included in the analysis.)

Table 1: Break-even analysis for two biogas systems verses 3 stone cooking systems with and without subsidies in Eastern Province, Rwanda for a family of 7.

System	Total cost (USD)	Firewood cost per day* (USD)	Number of months needed to break even&
EWSA concrete tank	984	0.55	60
EWSA concrete tank, with subsidies	176	0.55	11
New EWSA plastic tank	735	0.55	45
New EWSA plastic tank, with subsidies	74	0.55	5

*Based on 1.45 kgs/day/person &Improved ceramic stoves use about 60% of the wood compared to 3 stone systems.

Table 2: Costs and subsidies for EWSA biogas system with concrete tank

Contribution	Cost (Rwandan Francs)	Cost (USD)
Government of Rwanda	300,000	441
World Vision Rwanda	250,000	367
Recipient farmer	120,000	176
Total	670,000	984

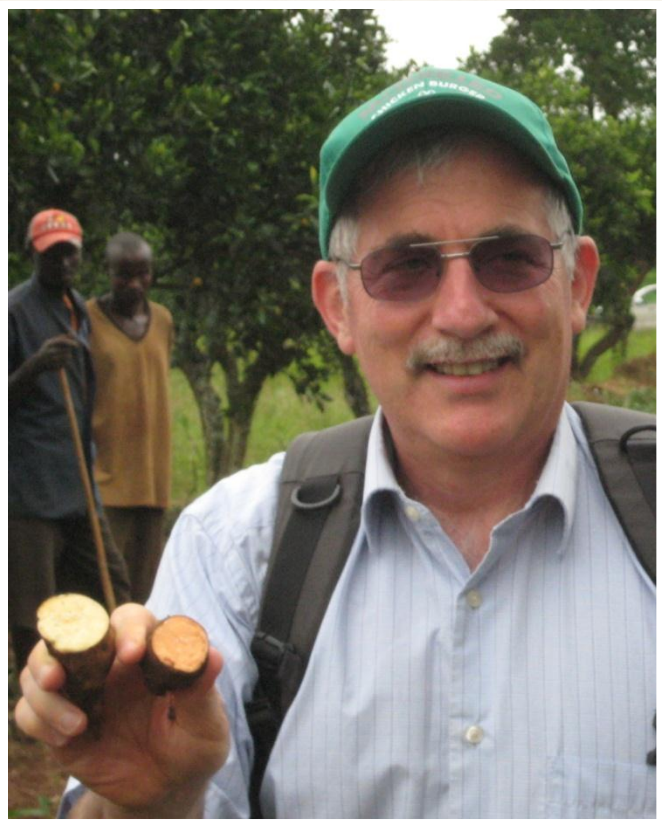
Table 3: Costs and subsidies for new EWSA biogas system with plastic tank

Contribution	Cost (Rwandan Francs)	Cost (USD)
Government of Rwanda	300,000	441
World Vision Rwanda	150,000	220
Recipient farmer	50,000	74
Total	400,000	735

The new biogas systems with plastic tanks appear to be very cost-effective and efficient. Because they require only one cow, the new systems will be able to reach more families.

Current biogas systems pay for themselves in firewood savings in 60 months , and in only 11 months for farmers receiving subsidies. New plastic biogas systems will pay for themselves in 45 months , and in only 5 months with subsidies.

About the author



Dr Brian Hilton joined World Vision Australia in 2011 after working internationally with World Vision for 17 years as an agricultural field manager and research and extension specialist.

In Mozambique, Brian worked with cropping systems in cashew, coconut, maize, vegetables and many other crops. Prior to Mozambique, Brian managed an animal traction training centre in Chad, where he also dodged bullets full-time during the civil war and many civil disturbances.

Brian has also worked as a lecturer at an Indonesian university and as a subcontractor for USAID.

For more information:
www.wvfoodandclimate.com