BIOGAS TRAINING MANUAL

for use with CREATIVenergie's Expanding Gas Digester

CREATIVenergie

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"*God saw all that he had made and it was very good*" *(Genesis 1:31)*

Contents

Introduction

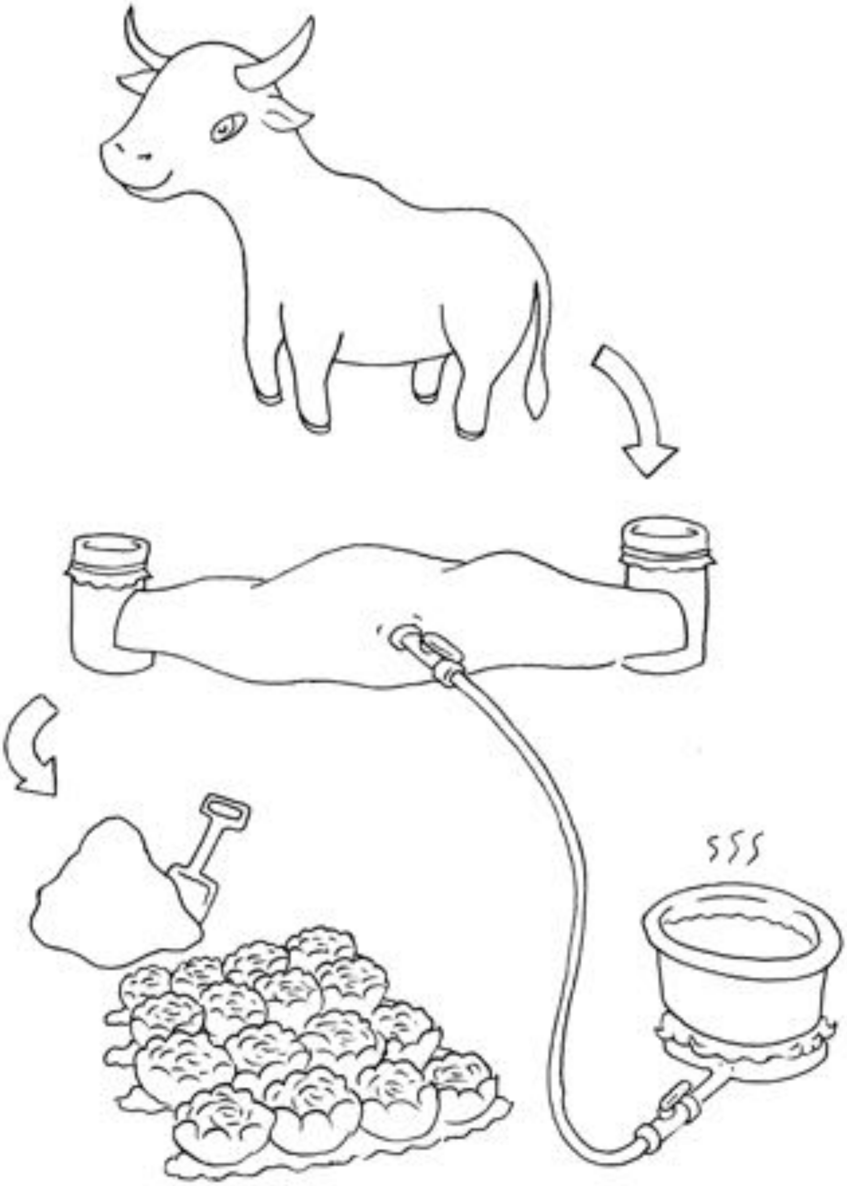
The Basics

Welcome to the CREATIVenergie biogas course. We want to make designing and building your own biogas plant as easy as possible and in this guide we will take you through each stage step by step. Whether your plan is to build your own biogas plant or to become an installer for others, we hope to guide you through everything you need to know. We have broken the process down into four key stages: principles, siting, sizing and safety, which are the topics of the first four chapters of this training manual. Wherever you design a biogas unit you should work through each of these steps. This manual will also assist you in understanding how to use the fertiliser (digestate) produced during the biogas digestion process to enhance the yield of your crops. There are additional resources in the appendices that you will find helpful at different stages: Appendix A is a step by step guide to assembling an expanding bag digester designed by the CREATIVenergie team; Appendix B contains a copy of CREATIVenergie's biogas operator's manual specifically for the expanding bag biogas plant. Teaching notes for biogas trainers are published separately.

What is biogas?

Biogas is the gas produced through the natural biological breakdown of organic matter (such as cow dung, chicken dung or food waste) in the absence of oxygen. Biogas is made up of 40-70% methane (CH_4) and 30-60% carbon dioxide (CO_2). It can be used as a source of energy, for example through burning the biogas. The technology that processes organic materials to produce biogas is referred to as a 'biogas plant' or a 'biogas digester' because of the way it digests material like a stomach.

A biogas plant is used to produce a clean gas fuel, similar in nature to LPG gas, which can be used for cooking, lighting, refrigeration and electricity generation.



The complete biogas system - organic matter in, gas and fertiliser out.

Why would I want biogas?

Save money

If you already buy LPG gas or charcoal, having a supply of biogas can reduce your fuel costs. After constructing the biogas plant, the supply of biogas is generated free of charge from cow dung or other animal or food waste.

Clean and modern

If you cook on an open fire, you will know how smoky it can be inside your home. Biogas burns with a clean flame and does not produce smoke. Not only will it help protect you and your family from the dangers of indoor air pollution (smoke), it will mean your cooking pots are easier to clean.

Easy to use

Biogas is easy to cook with; you just turn the gas on, light the gas hob with a match and start cooking right away. It is faster than cooking on wood too.

Produce high quality fertiliser

As well as producing a source of clean fuel, a biogas digester produces fertiliser that contains a lot of nutrients. You can compost it with other organic matter for use on your crops. If you are currently spending money on chemical fertilisers, using the fertiliser produced through the digestion process in the biogas plant could save you money.

Transform your waste into useful energy

If you produce a lot of household waste such as leftover food like rice or fruit and vegetable peelings, you can also put this into your biogas digester to produce fuel that you can cook with. This can help you manage your waste, putting it to good use, and which can also improve the hygiene around your homestead.

Good for the environment

Using a biogas plant is beneficial for the environment: it reduces CO2 emissions because the biogas is substituted for LPG gas as a source of fuel; it is beneficial for the forests/woodlands because using biogas reduces the need for collecting firewood or producing charcoal which often has a negative impact on forests.

Biogas can reduce the burden of collecting firewood

Chapter 01 - Principles

Principles of Biogas

"No Technology will be able to break the curse of poverty over the continent. Both Word and deed need to be applied"
(Farming God's Way, Field Guide)

Concept

Biogas is produced by micro-organisms breaking down organic matter. These micro-organisms are only effective at producing biogas under specific conditions. We need to understand what conditions the microbes like in order to design a biogas plant that works effectively.

What affects the performance of a biogas plant?

Temperature and airtightness

Key Point: One of the key factors that affects how well the microbes perform is the temperature. In order to produce biogas the organic matter needs to be warm enough; this is no problem in a warm country. Even more critically, the environment that the organic matter is in needs to be what scientists call anaerobic, meaning without oxygen. This is a more difficult condition to achieve but it is absolutely critical for the operation of a biogas plant.

Temperature

Biogas is produced by living micro-organisms, which are affected by temperature. If the temperature is too low, production of biogas will be slow. The microbes will become active only when they are warm enough, but if the temperature is too high the microbes can be killed which reduces biogas production.

A temperature range of 30-40°C inside the biogas digester has been found to be the best temperature for the microbes to convert organic matter into biogas. Within this temperature range you get a high degree of conversion of organic matter into biogas and also the stability of the whole system is much higher. This means the digester will be more tolerant to changes in what you put into the biogas plant. Because biogas systems are dependent on living micro-organisms, it is best to keep the temperature as constant as possible. A rapidly changing temperature inside the biogas plant can affect the overall stability and effectiveness of biogas production. If the temperature inside the biogas plant drops to 25°C or lower biogas production becomes very low and slow, because the microbes are not very active at such temperatures.

Airtightness: How do we create an environment without oxygen?

Father Saubolle, one of the early pioneers of biogas technology, said this is how he discovered biogas:

> *"I experimented and succeeded in producing cow dung gas in a coffee can, just sufficient to light a flame for five seconds. It was enough to satisfy me. I have grasped the principle."*

Father Saubolle put cow dung in a coffee can and sealed it. What was the prininciple that he had grasped? He had understood from his experiment that organic matter, left to decompose in a sealed environment (without oxygen) will produce a gas that is flammable.

A process that scientists call 'methanogenesis' transforms the organic matter into biogas. It is a process that involves live naturally occurring organisms, which thrive in environments without oxygen. The process occurs in the gut of humans and other animals, like cows. Without these micro-organisms, cattle would not be able to consume grass. The useful products of the process are absorbed by the gut into the blood stream, while the biogas is released in a belch. A typical cow belches 250 litres of biogas every day! That is a lot of methane! Understanding what happens in the stomach of a cow is helpful when we design and build a biogas plant.

In a biogas plant we create an environment without oxygen by putting the organic matter (cow dung, chicken dung or food waste) into water, and then sealing it in an airtight container, exactly as in Father Saubolle's experiment.

Explore for yourself

You can do a little experiment at home to see how these principles work in practice.

What you need: 2 small containers that fit neatly inside each other such as two old plastic bottles of slightly different diameters with the tops cut off (see diagram), a small piece of thin plastic tube, a little bit of sticky tape and a short length of string.

What to do:
(1) Stick the plastic tube to the inside bottom of the slightly smaller container.

(2) Now place this container into the larger one, so that the smaller one with the tube is upturned and the plastic tube comes out as shown in the diagram.

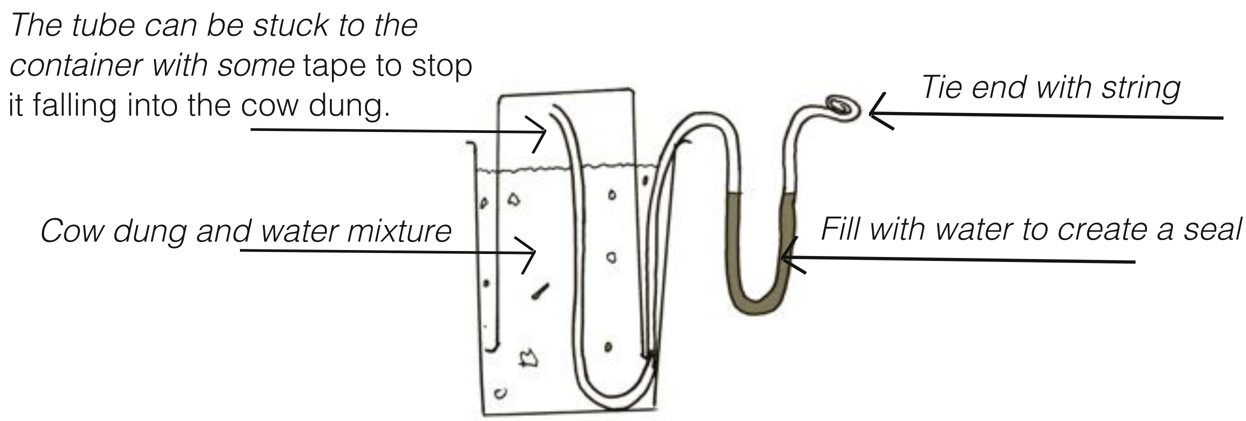
(3) Now fill the larger container with a mixture of half cow dung and half water (as shown in the illustration below) until it is full to just below the top of the small upturned container.

(4) Now try blowing down the tube (remember DO NOT SUCK or you will get a mouth full of cow dung!). You should see the container rise up.

(5) Let the container go back down again. Now arrange the tube so it creates a u-shape (as shown) and fill it with water to create a seal. It is this method of creating a seal with water that we use in a biogas plant design.

(6) Seal the top of the tube by folding over a couple of times and tying it with string, to stop the water evaporating.

(7) Leave the system in a warm place for a week or so (it takes a while for the biogas process to get started) and you should see the cup rise up. This will happen when gas is produced.


The tube can be stuck to the container with some tape to stop it falling into the cow dung.
Tie end with string
Cow dung and water mixture
Fill with water to create a seal

Properties of the feedstock material

So far we have seen that getting the temperature warm enough for the microbes will enhance performance, and when air is not present, organic matter will be broken down by bacteria to produce methane. Another important factor to enable the production of biogas is the carbon to nitrogen ratio inside the biogas digester.

Carbon is a very abundant chemical element, like oxygen. Combined with other elements it forms different molecules, which are the building blocks of living things, like humans and plants. Nitrogen, another element, is a colourless gas which makes up nearly 80% of the air we breath. It is essential for the growth, reproduction and functioning of living things, both in plants and animals. Nitrogen is used in amino acids to build proteins, and is present in every living cell.

The relationship between the amount of carbon (C) and nitrogen (N) present in organic matter is represented by the carbon to nitrogen ratio (C/N), giving the relative proportion of each element. The carbon nitrogen ratio is calculated by taking the amount of carbon in a material and dividing it by the amount of nitrogen. This is important because it has been found that the C/N ratio of a material has a significant affect on the amount and rate of biogas produced in a biogas digester. Optimum C/N ratios for a biogas digester are between 20-30. It is crucial to select materials in order to achieve this in the digester for efficient biogas production. A higher or lower C/N ratio will result in lower gas production.

Carbon is the major chemical element in the organic material. In order for the mircrobes to break this down and release biogas they require nitrogen to be present. A high C/N ratio means a very large amount of carbon compared to nitrogen; the result of this is that the nitrogen will all be used up before all the carbon is broken down and converted into biogas. On the other hand, if the C/N ratio is too low, there will be too much nitrogen compared to carbon; the effect of this is to produce too much of a substance called ammonia, which is toxic to the microbes that produce biogas. This means that we need to get the C/N ratio just right.

The table gives you an idea of the C/N ratio of different common materials, these are approximate values as they can vary.

Organic Material	C/N ratio
Cow Dung	20-30
Chicken Manure	7-10
Pig Droppings	13-20
Sawdust	200-500
Kitchen Food Waste	13-16
Human Faeces*	6-10

*Note: if human waste is used as a feedstock, the retention time should be increased from 40 to 95 days.

As you can see cow dung has a C/N ratio that is in the perfect range for effective biogas digestion, but sawdust has a C/N ratio that is much too high. It is possible to mix different materials in order to create a C/N ratio in the digester that is just right. You can use our calculation tool to find the correct mixture for organic materials that you have available to you. To keep it simple, however, if you have plenty of cow dung, you can use that without mixing it with anything else.

There are other material properties that affect the production of biogas, but discussing these are beyond the scope of this manual.

Summary of Key Considerations

A biogas digester works in the same way as a cow's stomach: when a cow eats grass, it produces gas. This happens because there is no oxygen in the stomach and it is the right temperature, which allows the bacteria that produce methane to live and do their work. This type of bacteria dies when exposed to oxygen.

Consideration	Consequences
Airtightness You need to create an environment that is airtight (that oxygen cannot get into) for a biogas plant to work.	If you do not create a sealed airtight biogas digester, it will not work. This is why it is essential that you build it to a high standard and maintain it well.
Temperature About body temperature is ideal - 30°C is a stable temperature for the bacteria to work efficiently.	Biogas production is efficient at 30-40°C Gas production becomes slow below 25°C. If the temperature drops below 10°C then biogas will not be produced.
Carbon to Nitrogen Ratio You need about 25 units of carbon to each unit of nitrogen for efficient production of biogas. Cow dung is an ideal material, but you can also mix different materials together to achieve the correct C/N ratio.	If the Carbon to Nitrogen balance becomes too high (>35) or too low (<18) then gas production will be reduced and the system may become toxic, reducing the efficiency of or killing the microbes that produce methane.

Impact

Critical

Desirable.

Important

Introducing the CREATIVenergie Expanding Bag Digester

Now that you understand the principles of biogas production we can introduce the biogas plant design for this course: CREATIVenergie's Expanding Bag Digester.

The design of this biogas plant is based around a bag digester. This is how it works:

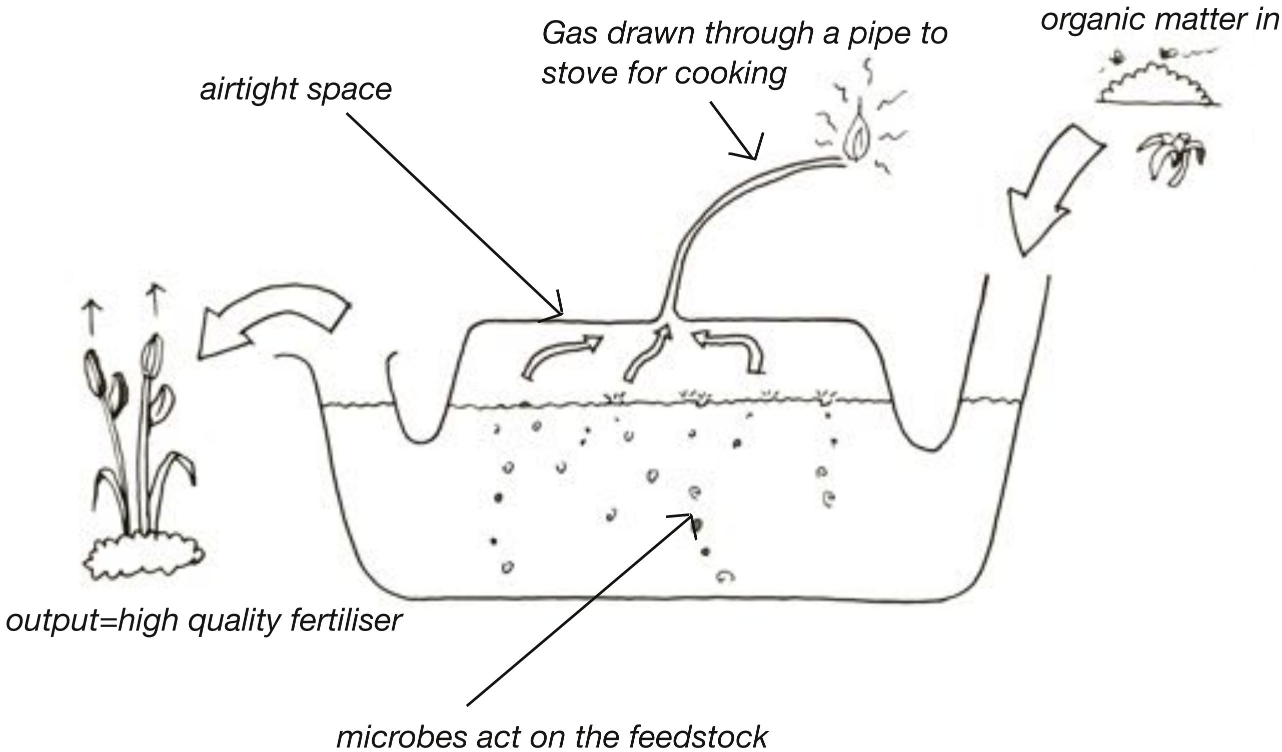
1. Feedstock (e.g. cow dung) enters a plastic or rubber bag that is made airtight (preventing oxygen getting in).

2. Over time the microbes act on the feedstock. Biogas is produced and the bag expands.

3. The gas can be drawn off through the gas pipe and used for cooking.

4. As more feedstock is put into the bag it forces old feedstock to flow out of the end of the biogas plant.

5. The old feedstock takes about 30-40 days to flow through the biogas plant, to be digested by microbes and come out at the other end. It can be composted or put on your fields as fertiliser.



Key Point Summary

In order to efficiently produce biogas you need:

- A sealed airtight environment for the microbes to digest the organic matter.
- A temperature of 30-40°C.
- A feedtock or mix of feedstocks with an average C/N ratio of 20-30; cow dung is ideal.

Chapter 02 - Sizing

Sizing a biogas plant

""Suppose one of you wants to build a tower. Won't you first sit down and estimate the cost to see if you have enough money to complete it?" (Luke 14:28, NIV)

Concept

It takes time for the organic feedstock that you put in the biogas digester to be broken down by the microbes and produce biogas. The size of the digester affects the amount of biogas that you will generate; it should be neither too large nor too small.

How big should a biogas plant be?

It is important to get the volume (size_ of your biogas plant right: if the plant is too large, it will cost you more to build, and the microbes won't have enough to feed on, meaning you'll have a low gas production. On the other hand, if the plant is too small, there won't be time for the feedstock to completely digest, the overall gas produced will be low and you won't achieve the full gas potential of the organic matter. This is illustrated on page 31. It is important to get the size correct.

In order to determine the size, the most important question you need to answer is: how much feedstock (e.g. cow dung / food waste) will you have available each day to feed the digester?

How much feedstock do you have available?

There are two main ways to determine the answer to this question:

1) The simplest and most accurate method is to weigh how much feedstock you have each day. If you are using cow dung, you need to weigh the total amount of cow dung that you have available each day to put into the biogas system. If you graze your cows, and they spend a large part of the day in the fields, this might reduce the amount of cow dung that is close to the biogas plant and therefore available. Make sure you work out how much you will actually have to feed your digester. When you do this estimation try and think about whether the amount of feedstock you have available varies throughout the year. A biogas plant should be fed every day.

2) If you cannot access a scale to weigh the cow dung you will need to estimate the amount available to you. This method gives you a rough idea of the amount of feedstock available and should only be used if your situation means that the first method is impossible or as a starting point to provide an approximate sizing for a prospective client. This is how you do it:

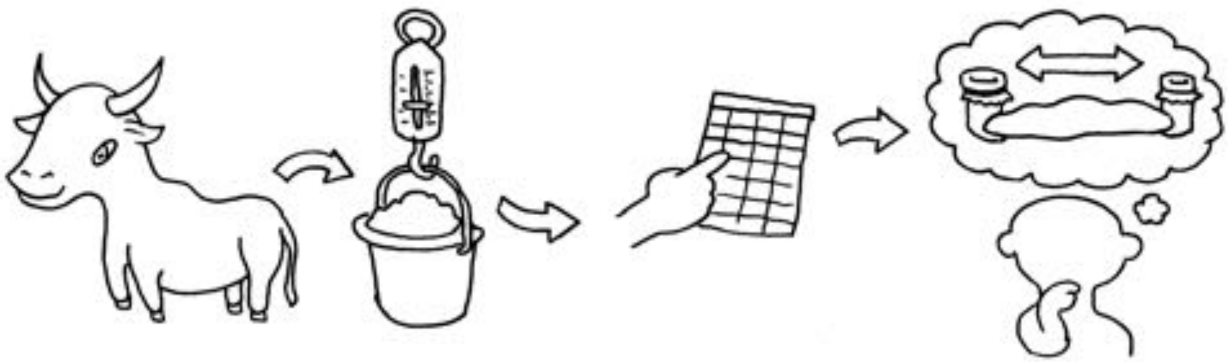
(1) On average a cow produces 10kg of dung per day, so multiply the number of cows you have by 10.

(2) Work out how many hours a day on average the cows spend in the cowshed - it is only when the cows are in the cowshed that it will be easy to collect the dung.

(3) Use the following equation to work out how much cow dung you have available per day:

10kg x ______________ x (__________________________ / 24) = _______kg per day
10kg x number of cows x (hours of cows in shed per day / 24) = kg cow dung per day

Now you know the amount of dung available we can calculate the size of your biogas plant.



It's important to size your biogas digester by weighing the amount of feedstock available.

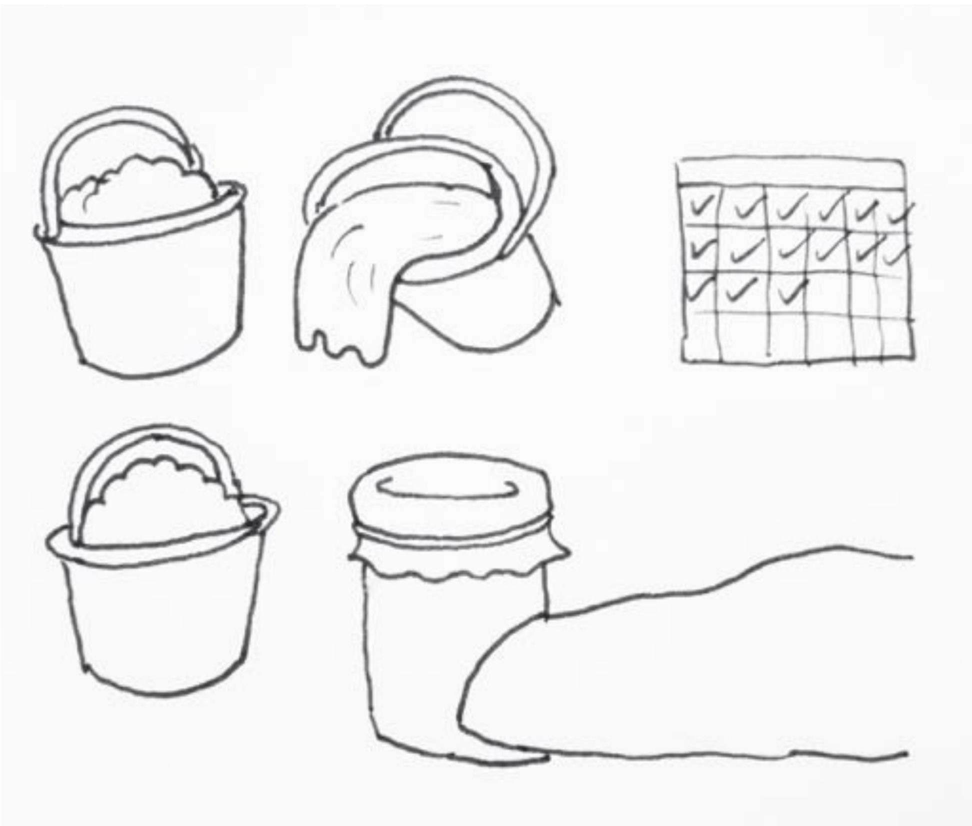
Calculation of the volume of the biogas digester

Feeding Rate

In order to stay healthy humans need to eat regular meals, not consuming too much or too little. Similarly a biogas plant needs to be fed regularly with roughly the same quantity of cow dung or food waste each day. We cannot leave it for a long period without feeding it. If we do not feed the biogas plant regularly it will not operate effectively.

The 'feeding rate' is a technical term for the amount of feedstock (e.g. cow dung) that you load into the digester each day. Your daily feeding rate will be the amount of dung that you measured (or estimated) earlier.

When you feed a digester, you need to mix the feedstock with water to make a slurry. As a rough guide we recommend mixing 1 bucket of cow dung with half a bucket of water to produce a thick sludge. Different feedstocks require different amounts of water; the aim is to achieve a thick sludge that can be poured into the digester. If you need to add more water to achieve this, add it little by little until when, if you tip the bucket up, the slurry flows out.



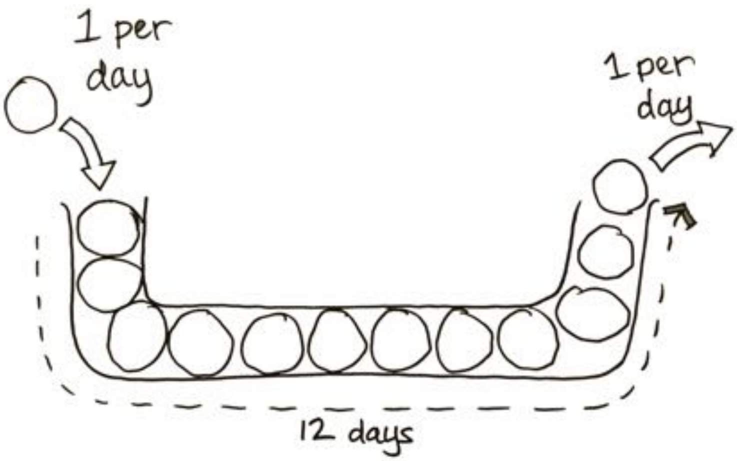
Remember to feed your digester regularly or it will stop working.

Retention Time

When you pour the feedstock (e.g. cow dung) into one end of the digester, the digestion process starts. Each time you add more dung, the dung you added previously will be moved along. After a number of days the dung you first added will find its way to the overflow, by which time it will have been broken down by the bacteria. This process is called digestion.

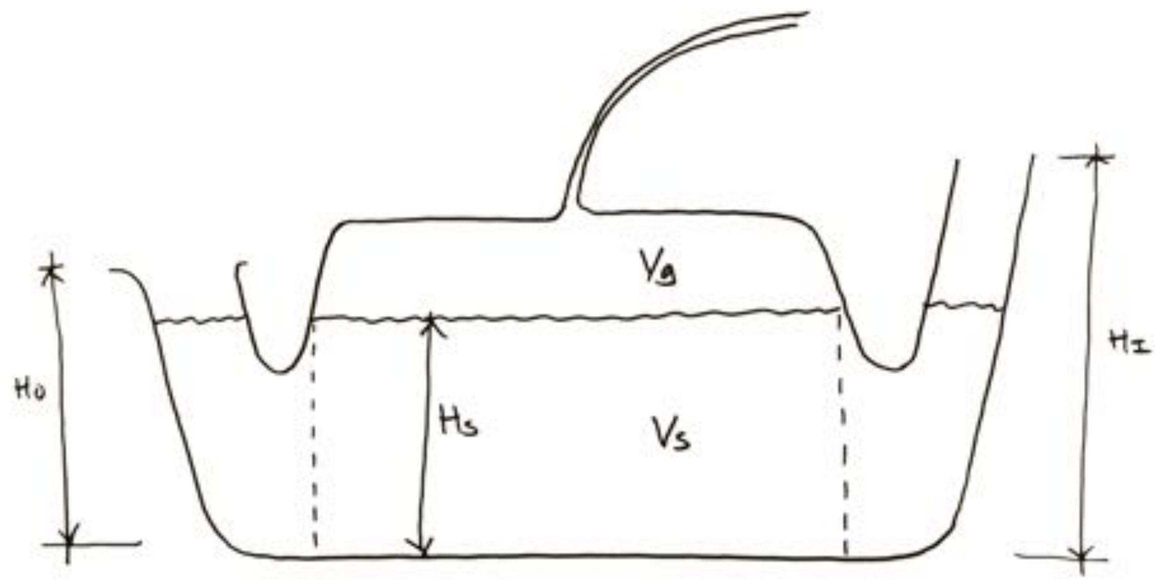
If something passes too quickly through the biogas digester it doesn't have time to break down and produce biogas. In order for the feedstock to be properly digested and to achieve the full biogas potential, it needs to be inside the system for a long enough time; the time that the feedstock stays in the digester is commonly referred to as the retention time.

How long something needs to spend in a biogas plant to generate the maximum amount of gas depends on the temperature of the plant. It has been found from experimental tests that for a biogas plant operating at internal temperatures of 30-40ºC, a retention time of around 40 days produces a greater amount of biogas, and results in a higher degree of decomposition of organic matter than shorter retention times. For practical purposes this provides us with a good guideline to use for designing our biogas plant.

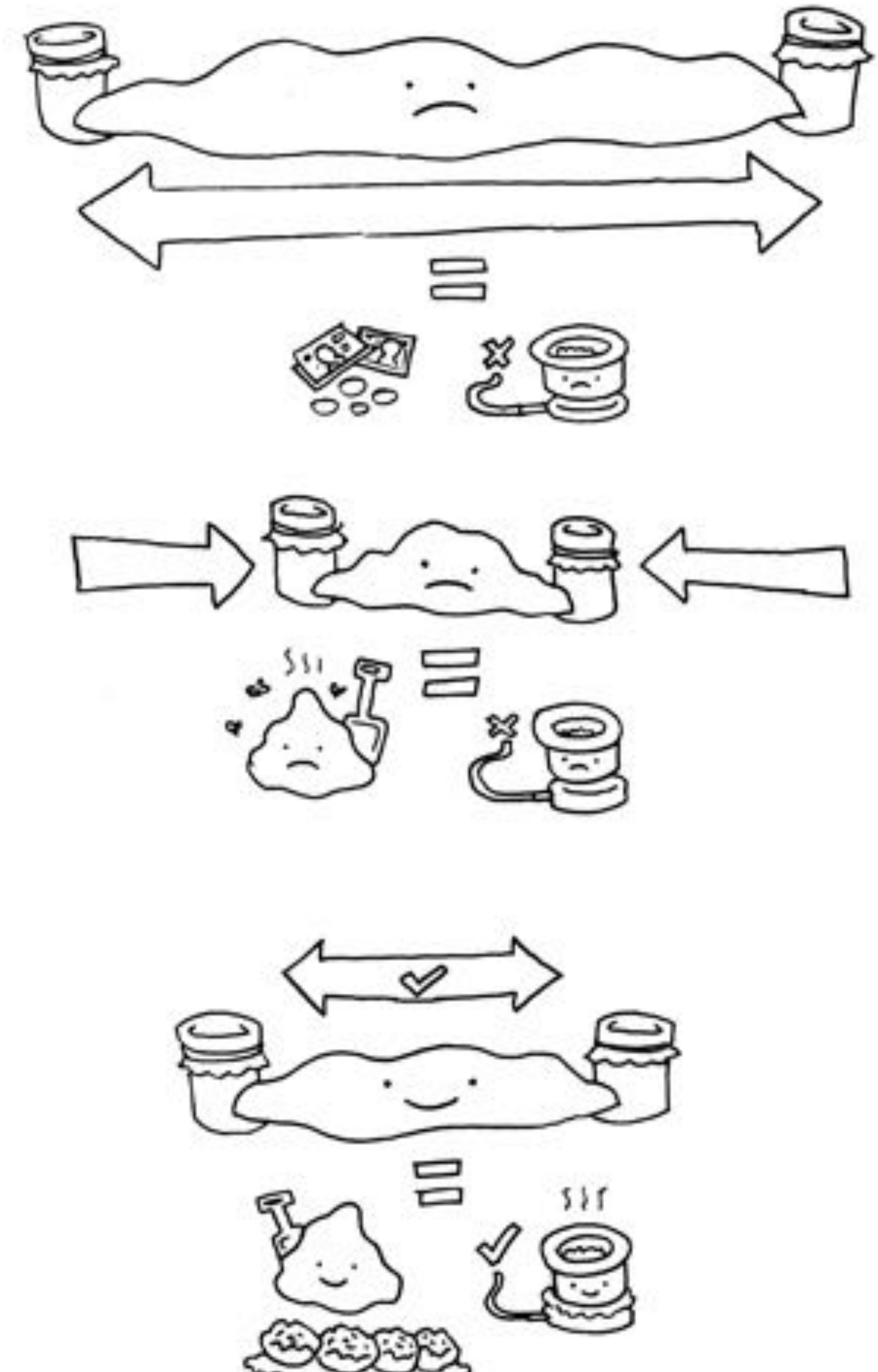


Retention time is how long the feedstock takes to pass through the digester. The picture illustrates how it works using balls in a pipe: if each day you added 1 ball to one end, then everyday 1 ball would also fall out the other end. In this example it would take 12 days for a single ball to pass from one end to the other. 12 days is therefore the ball retention time. The longer the pipe, the longer the retention time would be.

Volume Calculation
The size of a biogas plant is determined by two things: 1) the space where the slurry is, this is known as the the slurry volume (Vs), and 2) the space where the gas produced is stored, known as the gas volume (Vg). These two spaces (volumes) are illustrated in the diagram below.



A cross-section of a biogas digester showing the different volumes:
Vs is the volume taken up by the slurry
Vg is the volume filled with biigas
Ho is the height of the overflow
HI is the height of the inlet



You cannot just build a digester any size, for it to work properly you must size it correctly.

Calculating the Slurry Volume (Vs)

We already have all the information we need to estimate the slurry volume. It can be estimated using the following steps:

(1) Find the sum of the total slurry mass to be added to the biogas plant each day. This is the sum of mass of feedstock and the mass of water to be added.

e.g. you weigh 1 bucket of dung and this come to about 10kg
you then add ½ a bucket of water, which weighs about 5kg

Therefore total slurry mass = 10kg+5kg=15kg

(2) Now we assume that slurry has approximately the same density as that of water (the density of liquid is a measure of the amount of how much mass it has compared to the volume (or space) that it takes up). The density of water is 1000kg/m^3, meaning that if we had 1m^3 of water it would weigh 1000kg. To find the volume that 15kg of our slurry would occupy we divide 15kg by 1000 to give 0.015m^3 (that is 15 litres). In order to find the slurry volume to give a 40 day retention time, we need to multiply the figure that we just calculated by 40.

e.g. Slurry volume= $0.015 \times 40 = 0.6m^3$

So in this example the slurry volume of our digester needs to be 0.6m^3.

Calculating the Gas Volume (Vg)

Now we need to calculate the gas volume, that is the amount of space that the gas, when it is produced, will take up. Because it is likely that we will want to be using the biogas from our digester each day, we really only need to store 1 days worth of gas. In order to do this we need to know the amount of gas produced by the slurry everyday at the temperature of our biogas plant and with a 40 day retention time. Cow dung, as it comes fresh from a cow, would produce approximately 0.04m^3 of biogas per kg of dung added per day to the biogas digester.

To find the gas volume, we multiply this gas production figure by the amount of dung that we add each day, which in our example is 10kg. We do not include the amount of water added (5kg) because water does not produce biogas. The calculation looks like this:

$$\text{Gas Volume } (m^3) = 0.04 \text{ m3/kg} \times 10\text{kg} = 0.4m^3 \text{ of gas per day.}$$

So each day our biogas plant, designed for adding 10kg of cow dung each day would produce 0.4 m^3 of gas per day, which should approximately be enough to cook on a small single gas stove for an hour.

Now we can find the total volume of our biogas plant (which we are designing for 10 kg of cow dung per day - approximately 1 cow):

Biogas plant size (m^3)= Slurry Volume + Gas Volume = $0.6m^3 + 0.4m^3 = 1m^3$

These are the basic principles of how to calculate the size of the biogas plant's digester chamber.

The other key dimension that is important for this type of biogas plant is the height of the outlet (Ho), which should be just above the height of the slurry level and just below the level of the gas pipe and inlet. This will maintain a constant positive gas pressure, and ensures that slurry does not flow into the gas pipe or out of the inlet.

The calculations that are needed to work out these dimensions are beyond the scope of this manual and so in order to make this process much simpler we have produced sizing tables, which are given in the step by step construction guide in Appendix A. We also have produced a sizing tool computer & phone application, which you can download from our website.

Key Point Summary

- You need to work out how much feedstock you have to put into the biogas plant each day.

- The amount of feedstock available determines the size of the biogas plant. Making the plant either too big or too small will have negative consequences on the operation of the system and the production of biogas.

Chapter 03 - Siting

Siting a Biogas Plant

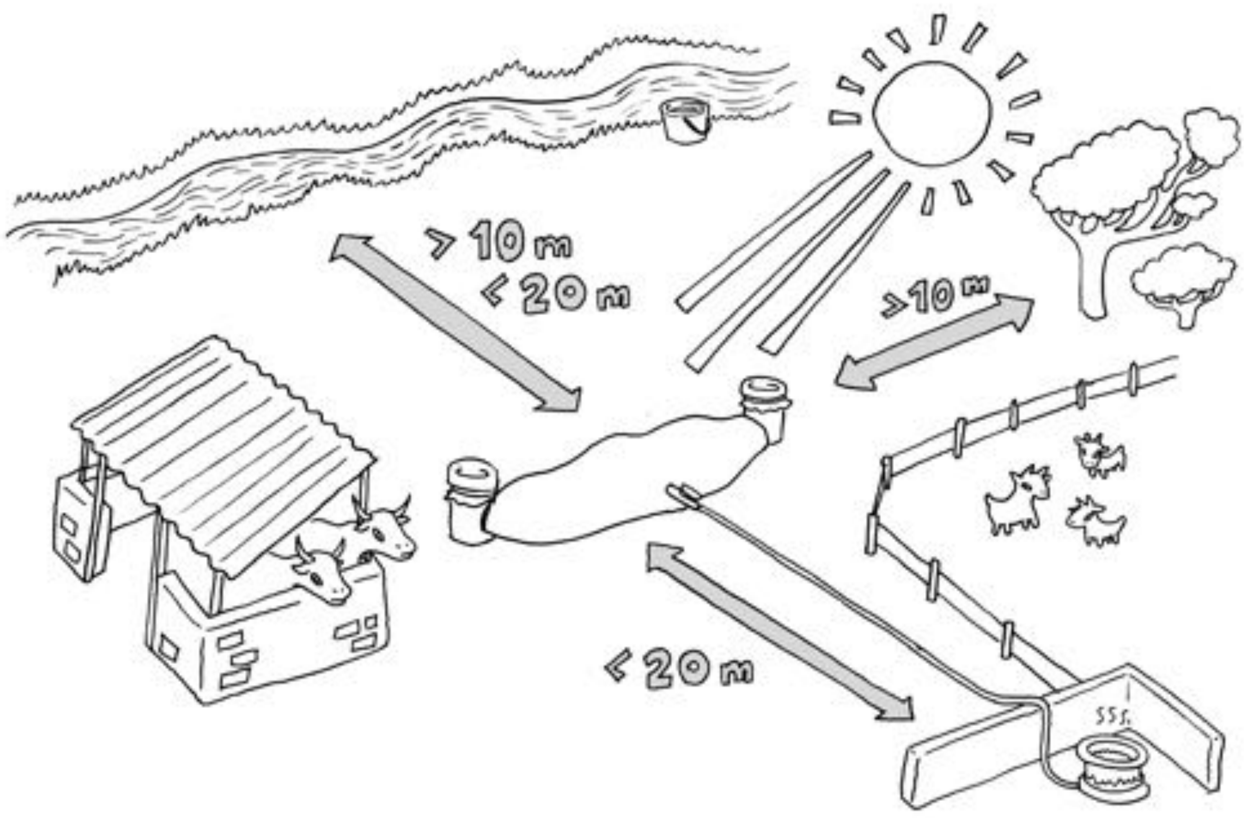
The House Built on Rock, Matthew 7:24

As with the parable of the 'house built on the rock' it is important that the biogas plant is built on a firm foundation. If we do not take consideration of the site seriously then we risk building foolishly like the house built on sand. This can have serious implications on the safety of the biogas plant as well as the likelihood of successful and efficient operation of the plant. Hence the principles of siting the biogas plant need to be followed diligently.

Concept

There are key considerations when deciding where to build your biogas plant. Many of the factors have safety implications and therefore it is important to carry out a thorough assessment of your proposed sites before beginning construction.

Assessing a potential site for building a biogas plant, a critical step in designing any biogas system.



The key factors concerning optimal location of the biogas plant. These are discussed in more detail in the pages that follow.

Siting - Key Considerations

Safety Factors	Consequences
Contamination of Water The biogas plant should be more than 10m away from any well or bore hole or open water source to reduce the risk of contamination should there be any leakage from the plant.	Risk to health and life if drinking water is contaminated.

Robustness & Difficulty of Construction

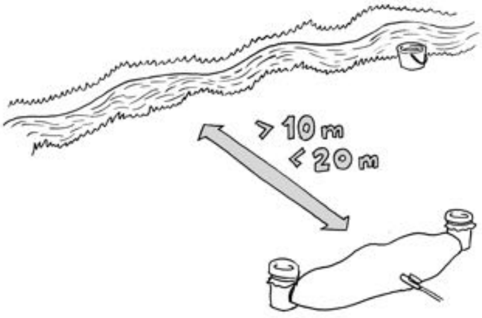
Trees and Vibration The biogas plant should be located away from any thing that has the potential to damage the plant through vibration or puncture. These include: - Tree roots (should be more than 10m away from the centre of a tree) - Vehicular access routes - minimum 10m away	Risk that the tank will be breached which can result in: - loss of gas and therefore risk of explosion - oxygen gets into the tank and stops the plant from operating - a tank leak that could cause contamination
Stones, Boulders, Pipes Take into account what you, or your client, already know of the ground conditions. For example, are there any drainage pipes in the area? Is it an area known to have large boulders beneath the surface?	Excavation of the ground could accidentally penetrate drainage pipes, or large boulders may make excavation hard work.

Inputs & Outputs

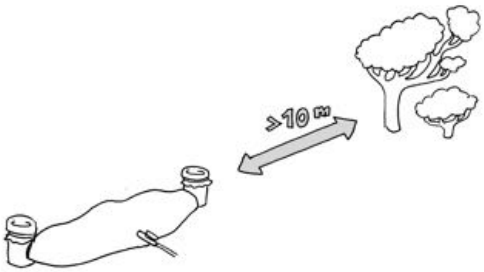
Water Sources Biogas requires a similar amount of water to be supplied as dung (i.e. 1/2 a bucket of water for every bucket of dung). Therefore the biogas plant should not be located too far from a water source. The suggested distance is 12-20m.	Too much labour required to keep the plant in operation.

Importance

Critical

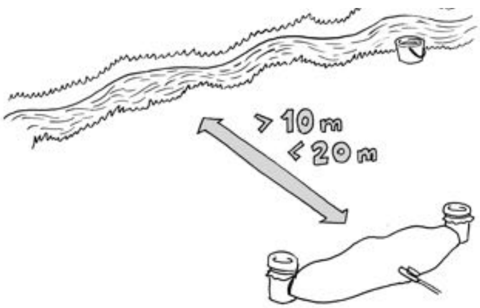


Critical



Important

Desirable



Feedstock

The biogas plant needs to be located close enough to the source of feedstock. Feedstock is what you put into the plant to produce the biogas, for example cow dung or food waste. You will need to load the plant once per day, so if the source is close it will make it much easier to do.

It is also helpful if your source of feedstock is from one location only, for example, if you keep your cows in a shed for part or all of the day, you can just shovel the cow dung from the shed into the digester. If you have to collect from a field it would make running the biogas plant harder work.

Consequences

Too much labour required to keep the plant in operation.

Gas Usage

Think about where and how you will use the gas. Ideally the biogas plant should be built as close to the point of use as is feasibly possible. However, if necessary, it is possible to pipe the gas greater than 20m.

If the point of gas use is more than 20m from the biogas plant then you will need to do a calculation to see if the gas pressure will be enough to push the gas along the pipe.

Operation

Sunlight / Heat

A biogas plant stops operating if the temperature drops below 10°C and reaches peak performance between 30-40°C, hence it is beneficial for the biogas plant to be placed in a sunny spot and to be protected from the cold.

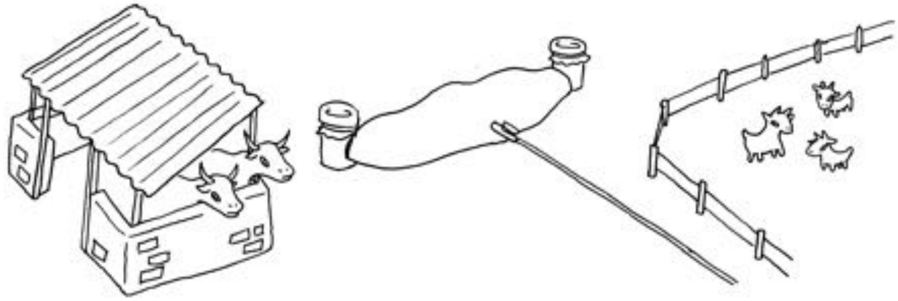
The plant will stop working for periods when its temperature is below 10°C, and efficiency of gas production will reduce as it nears this temperature.

Choosing the Site

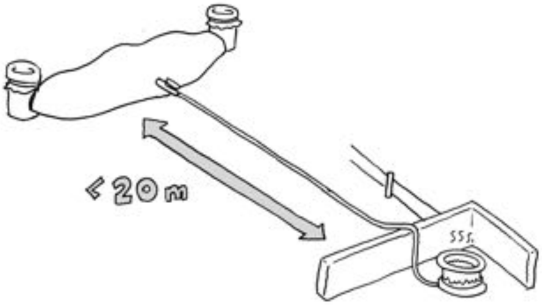
The decision making tree on the following pages can be used to safely locate a biogas plant based on the principles outlined above. It is important to note that in some circumstances it will **NOT** be possible to build a biogas plant. You will need to make this decision based on whether 'critical' and 'important' factors cannot be achieved and talk through with the owner if 'desirable' factors cannot be achieved.

Importance

Desirable

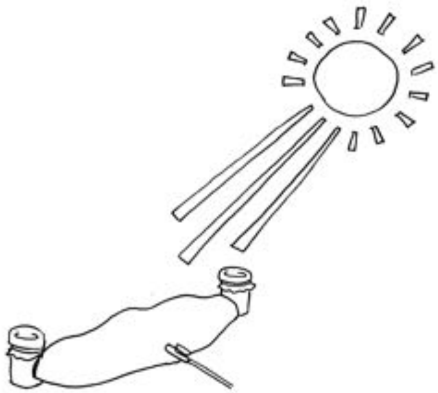


Important



Desirable

Critical if below 10°C



Before a biogas plant is constructed a Site Feasibility Report (given in Appendix A) should be completed and handed to the client. It is recommended to spend some time considering the potential site options without the client present to reduce pressure and give you space to think. The temptation might be to please your client but, as with the house built on the rock, if not built on a firm foundation ultimately your client will not be pleased. They could be left with a biogas plant that doesn't work or is at risk of a gas explosion. This would not be loving your neighbour!

Siting Decision Tree

Flow chart to determine appropriateness of potential sites

Key Point Summary

The factors that are used to determine the optimal location of the biogas plant include:

o safety factorso contamination of water
o robustness of construction
o efficient operation factors
o proximity to locations of inputs (water/dung).
o proximity of outputs (gas & compost) to point of use
o The Site Fesibility Report (see Appendix A) should be completed in conjunction with the flow chart.

Chapter 04 - Safety

How to Safely Operate a Biogas Plant

> "*Whatever you do, work heartily, as for the Lord and not for men*"
> *(Colossians 3:23, ESV)*

Concept

Like electricity, bottled gas and wood fires, biogas can be dangerous if not handled with care. However by being aware of the risks involved and taking the recommended precautions you should have a safe and happy biogas experience.

Be Safe

In this chapter we go through each of the possible risks associated with biogas and explain what precautions you should take to prevent hazards happening. The safe operation of a biogas plant is the responsibility of the user, and in the second part of this chapter we provide a daily operations guide to help you be safe when using the biogas plant. Anyone who wants to use a biogas plant MUST be trained in how to operate it safely.

Risk: Fire or Explosion

Biogas contains a large amount of methane, which is flammable, and under certain conditions can be explosive. This is very dangerous.

Precautions:

o The biogas digester should be constructed at least 3m away from existing buildings.

o No new buildings should be constructed within a 3m radius of the digester.

o All possible sources of ignition MUST be prevented.

o There should be a marked 3m exclusion zone around the digester.

o There should be no naked flames within the exclusion zone.

o People must not smoke within 20m of the digester.

o Using a cell phone (mobile phone) close to the biogas is forbidden.

o People must not light fires within 20m of the digester.

o People must not cook or use a charcoal coal pot within the exclusion zone.

- Electrical equipment should not be used within the exclusion zone including power tools, welding equipment, mobile phones.

- Iron or steel tools should also not be used in this region, for example you should not cut any metal near the biogas digester.

Risk: Asphyxiation

Biogas displaces air, which, if it was suddenly released reduces the level of oxygen available. This might happen if the membrane was pierced.

Precautions:

- To avoid any danger the area around a biogas plant should remain well ventilated.
- Do not cover up the inlet or the outlet of the plant with any plastic sheets.
- There should be a 3m marked exclusion zone with a fence around the unit with signs to make people aware of the dangers. Do not let goats come near the biogas digester.

Risk: Toxic Gas

Biogas can contain a small amount of Hydrogen Sulfide (H2S). It is a colourless gas with the characteristic smell of rotten egg. It is very poisonous, corrosive, flammable and explosive. Exposure to elevated concentrations of H2S is extremely harmful to your health.

Precautions:

- Keep a 3 meter exclusion zone around the biogas plant. Ensure the biogas plant is well ventilated.
- It is dangerous to enter a biogas unit, even after it has been recently emptied because poisonous gases can linger inside the digester. Never climb inside a biogas plant.

Risk: Disease

A biogas plant relies on a mixture of different bacteria, which are largely of unknown origin. There is a risk that the slurry within the digester could carry diseases.

Precautions:

- Care should be taken to avoid contact with the digester contents.
- After working with the digester you should wash your hands.
- Never climb inside a biogas plant. Do not let children play close to a biogas plant.

Safety Features of the CREATIVenergie biogas system

The biogas system described in Appendix A has a number of safety features. It is crucial that you are aware of these so that you understand the importance of their implementation in the construction process, and so you understand the importance of maintaining them.

The Biogas Plant Cover

This protects the unit from goats or other things that might damage the internal biogas digester bag. It prevents the bag from becoming pierced. It also protects the unit from the sun, which over time would damage the digester bag. The cover should be checked periodically for any substantial damage and should be patched up to ensure that the biogas unit remains protected.

Main Gas Valve

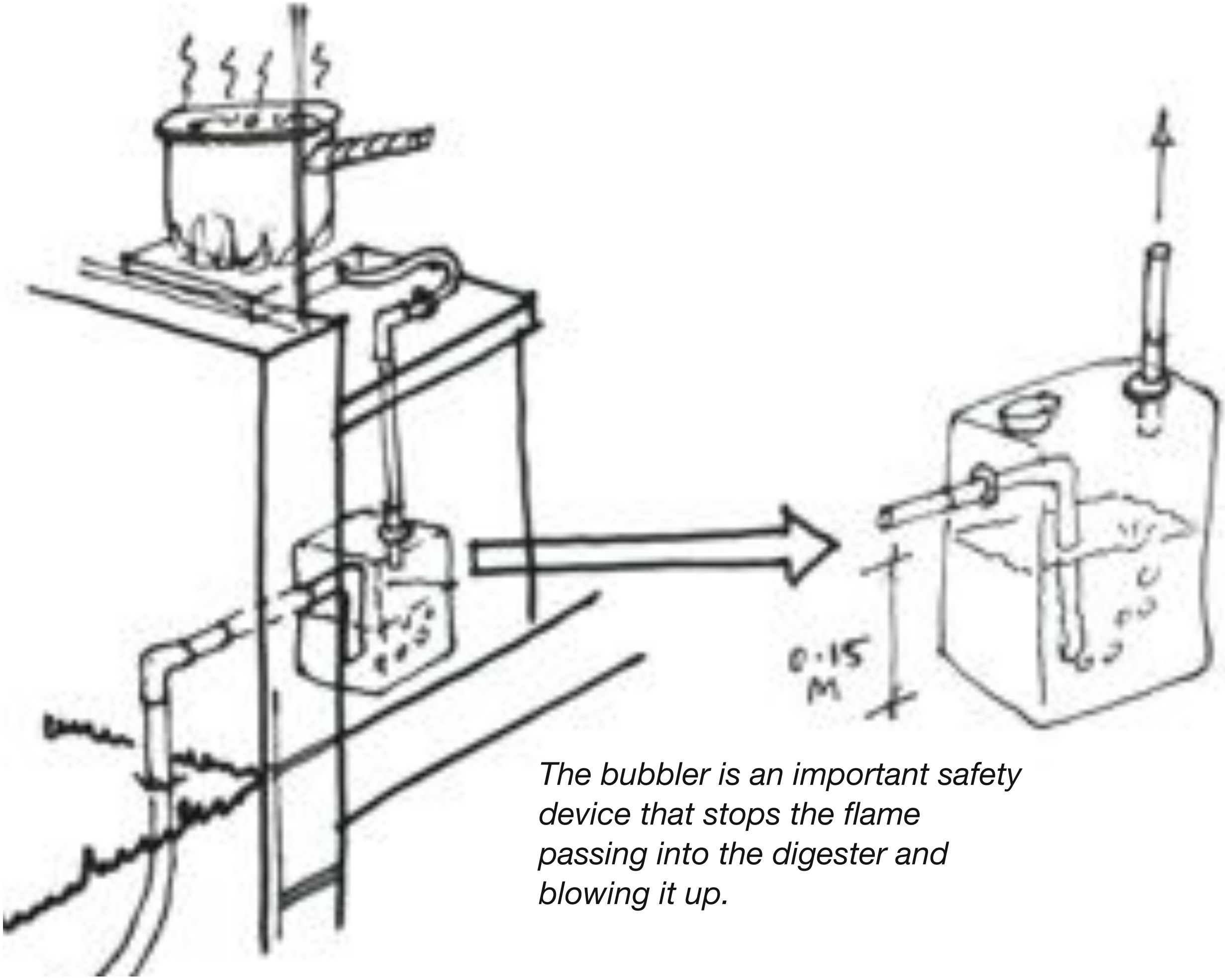
There is a valve to cut off the gas flow located next to the biogas plant. This isolates the gas supply so that if the gas pipe was to become damaged it would not cause a safety risk. It also means the plant can be cut off if any gas leaks in the pipe or stove are identified. The main gas valve should be closed when no gas is needed. Inspect the metal areas for corrosion. Carry out a leak test by filling a container with soap and water and using your fingers to cover the valve with it. If there is a leak you will see bubbles forming. If there is a leak you will need to repair or replace the valve.

Bubbler

Before the gas goes into the stove, it passes through a water bubble, as illustrated on the next page. In the unlikely case of flash-back, that is when the flame tries to pass back down the pipe, the flame will be stopped by the water before it can get anywhere near the biogas plant. Thereby stopping disaster.

Pressure Release System

If you did not use the biogas generated by the digester for a few days and the pressure was to build up, it would never get dangerously high. Instead, because of the way the system is designed the pressure would force the slurry to flow out of the overflow. If this happens you will have to feed the system with slurry until the biogas plant is full up again.



The bubbler is an important safety device that stops the flame passing into the digester and blowing it up.

Safe Operation

Operating a biogas plant safely is the responsibility of the user, but this need not be burdensome. There are a few key things you should remember to ensure you remain safe:

(1) Ensure that there is a 3m exclusion zone around your biogas plant and that nobody enters this area, except if trained to use the digester or authorised for maintenance. Make sure the fence around the unit remains in good order.

(2) Everyday, after using the biogas system, remember to turn the main gas valve off.

(3) Carry out regular visual inspections of the system. If anything is corroded or damaged, you will need to carry out maintenance or call a local biogas engineer to repair your system.

To help you remember this you can use the acronym EAT:

E=**E**stablish an Exclusion Zone
A=**A**ssess your biogas plant regularly for damage
T=**T**urn off the gas valve after use

Safe Operation of a gas stove

If you are a new user of a biogas system, you might never have used a stove before. Here are some guidelines on how to do this safely:

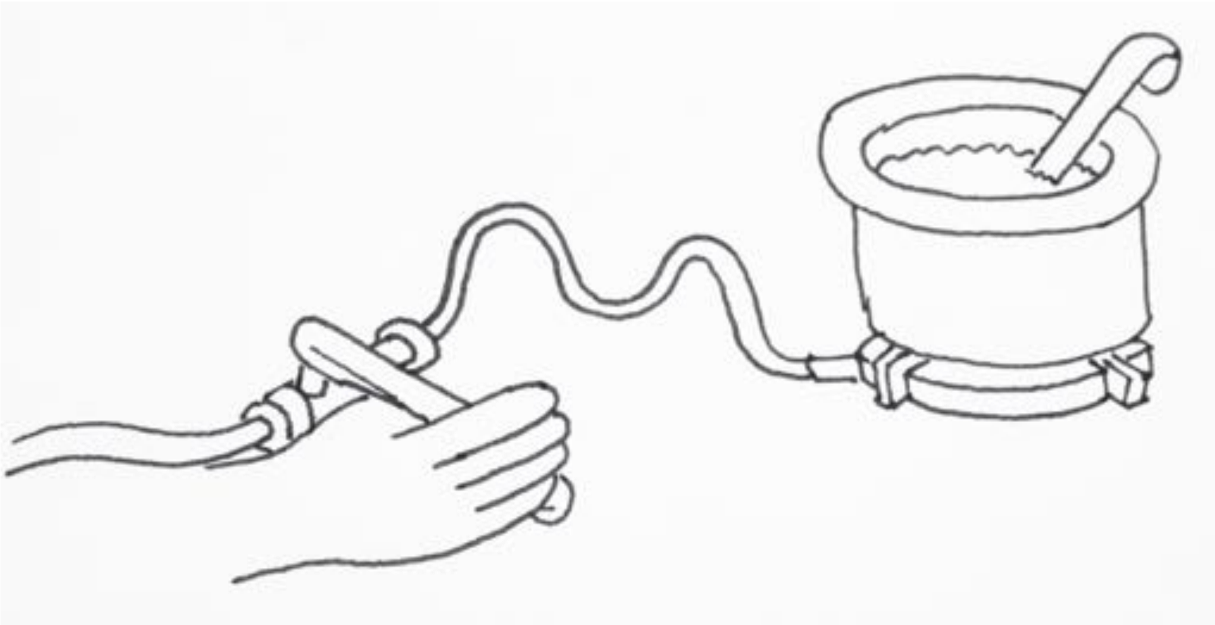
(1) Light a match and place it close to the burner of the stove.

(2) Slowly turn on the gas tap and make sure the gas lights into a flame.

(3) Place the pot on the stove.

(4) Adjust the flame for cooking: a good flame is short (1-2cm), makes noise, does not smell and has a blue color.

Note: there are more details on daily operations and maintenance in Appendix B.



Key Point Summary

o It it crucial that you establish a 3m exclusion zone around the biogas plant.

o Remember to turn the gas valve off at the end of cooking.

o Keep an eye out for any damage to the biogas plant and repair when required.

Chapter 05 - Digestate

Taking Advantage of Digestate

"I have come that they may have life, and have it to the full." (John,10:10, NIV)

Concept

Building a biogas system is not only about producing renewable energy. There is another significant benefit, the production of high quality fertiliser. The organic matter (digestate) that come out of a biogas digester can be composted and spread on your crops.

Introduction

The biogas process produces what is know as digestate, that is organic matter which has been broken down by the microbes in the biogas digester. Research has shown that the digestate can be used to replace man-made fertiliser without compromising crop yield. Furthermore, in field trials the quality of some crops has been shown to improve compared with commercial mineral based fertiliser. Investment in biogas is therefore not only about producing energy, it is also about helping to look after your land in a sustainable way, providing the nutrients so that your crops produce good yields.

As well as the benefits for the land, using digestate as a fertiliser is more sustainable in the long term, as it also reduces greenhouse gas emissions that are emitted when making more man made type fertiliser.

It should be noted that many of the studies on the use of digestate have been under specific lab conditions, often in Europe; your experience of using the digestate in real conditions is important in our global understanding of the benefit of its use.

The forms of digestate

If you look at the organic matter coming out of your digester you will notice it has both liquid and solid parts. The liquid we call the liquor and the solid part we call the fibre.

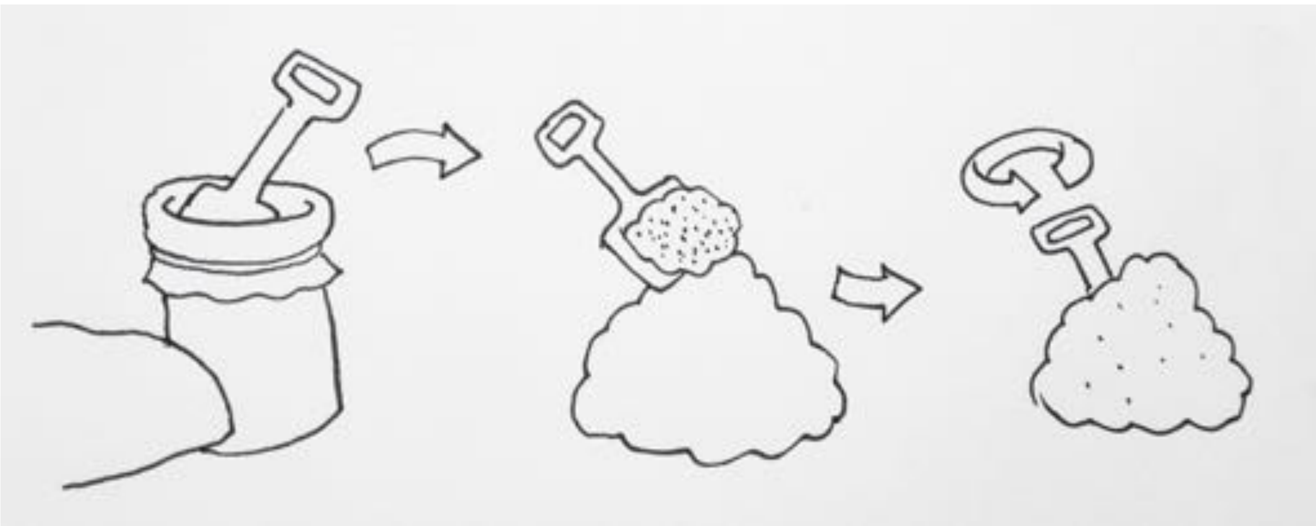
The benefits of digestate

The digestion process has been shown to increase the amount of nitrogen available from cow dung by around 10%, this is good for the crops. Digestate also contains useful amounts of phosphate and potash with small quantities of other nutrients, which will help maintain soil fertility.

How you process the digestate before putting it on your fields depends on the material that it is made from. In the course we have built a cow dung digester and so we will focus on using this in the best way possible. Other digestates are beyond the scope of this manual.

Composting

Composting the digestate, after it comes out of the biogas plant, is an effective way to process and store it ready to put on the fields when required. It has been shown that composting cow dung digestate for 100 days lowers its pH (reduces how alkaline it is) and improves its quality. After the composting process the digestate fibre has been shown to be as good as man-made peat fertiliser. The organic fibres provide a stabilised source of matter that is suitable for improving soil properties.



How to build a composting pit

A simple way to compost digestate is to dig a pit close to the overflow and a channel directing the digestate to the pit. Make sure that the pit is not too close to the digester so that it does not affect the structure, and result in it becoming unstable during heavy rains. Making it at least one meter away from the biogas plant should be sufficient.

After digging the pit, line it with some dry material, such as dry grass or banana leaves.
As you use your biogas plant, the digestate should flow out of the overflow and into the pit. Add some more organic waste. For example, this might be other crop waste, or dry material available locally. You can also add any food waste from your kitchen.
As the digestate flows out, continue to add organic material to the pit. Try and cover the compost pit so that is kept moist and does not dry out in the sun.

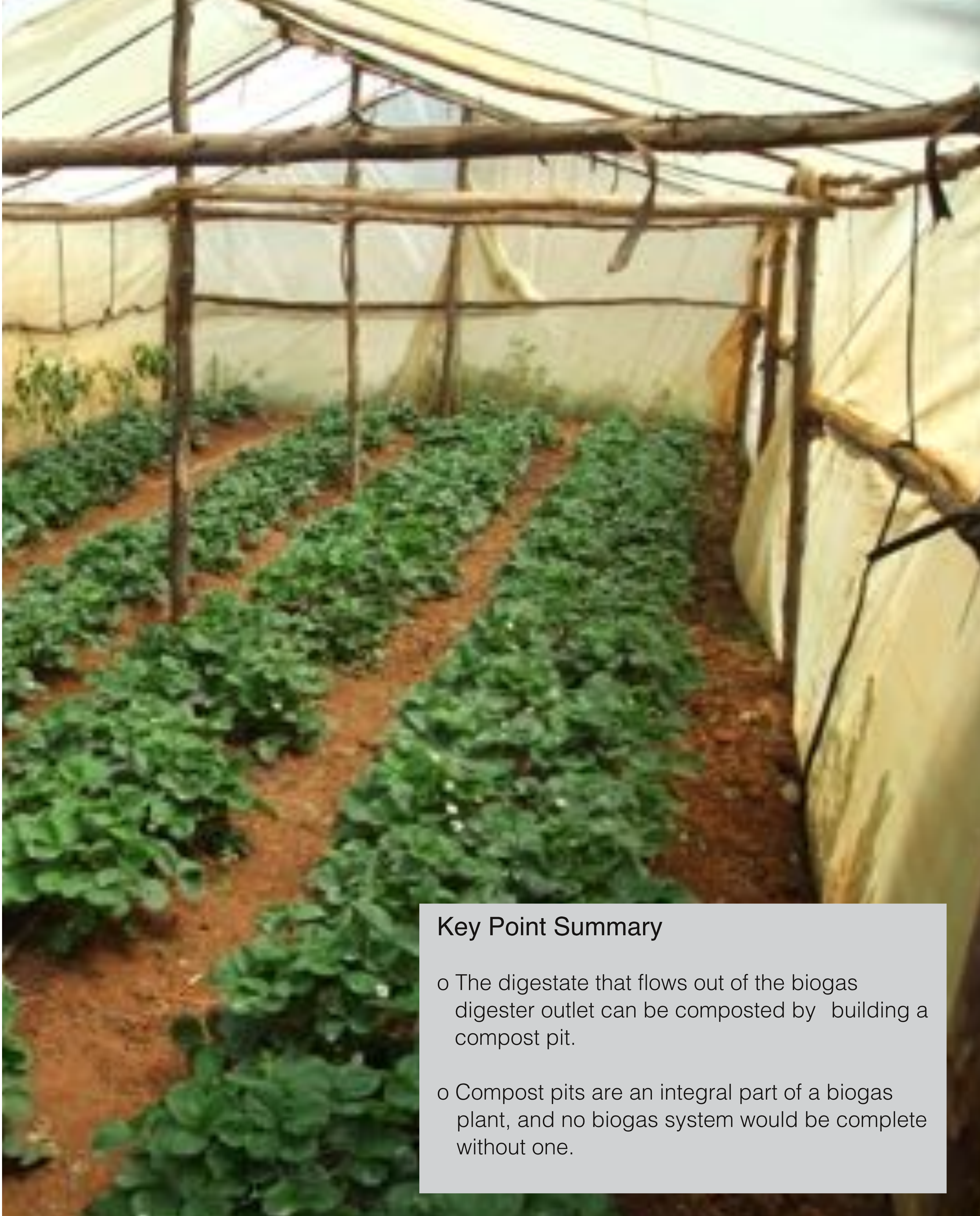
Every week or so aerate the compost by giving it a good mix using a fork.

Once the pit is full, dig another hole and dig a new channel to divert the slurry into it and repeat the same process. Leave the first pile to break down for around 100 days, after which you can start using this as compost on your crops.

If you get into a good routine with this composting process you will always have good quality compost to put on your crops.

Using composted digestate

To make optimum use of the composted digestate, you should apply it to the crops during the times when they are growing most rapidly. According to best practice, digestate compost should not be spread when heavy rain is forecast within the next 48 hours as a lot of the nutrients will be washed away. It should also not be applied to waterlogged soils. As a precaution, in order to avoid the contamination of water sources, the digestate should not be applied within 50m of any well, spring, borehole or reservoir that supplies water for human consumption. You should also make sure it is greater than 10m away from any surface water (such as a pond or lake).



Key Point Summary

- o The digestate that flows out of the biogas digester outlet can be composted by building a compost pit.
- o Compost pits are an integral part of a biogas plant, and no biogas system would be complete without one.

Appendix A
Expanding Bag Digester

CREATIVenergie Expanding Bag Digester

How to Build a CREATIVenergie Expanding Bag Digester - Step by Step Guide

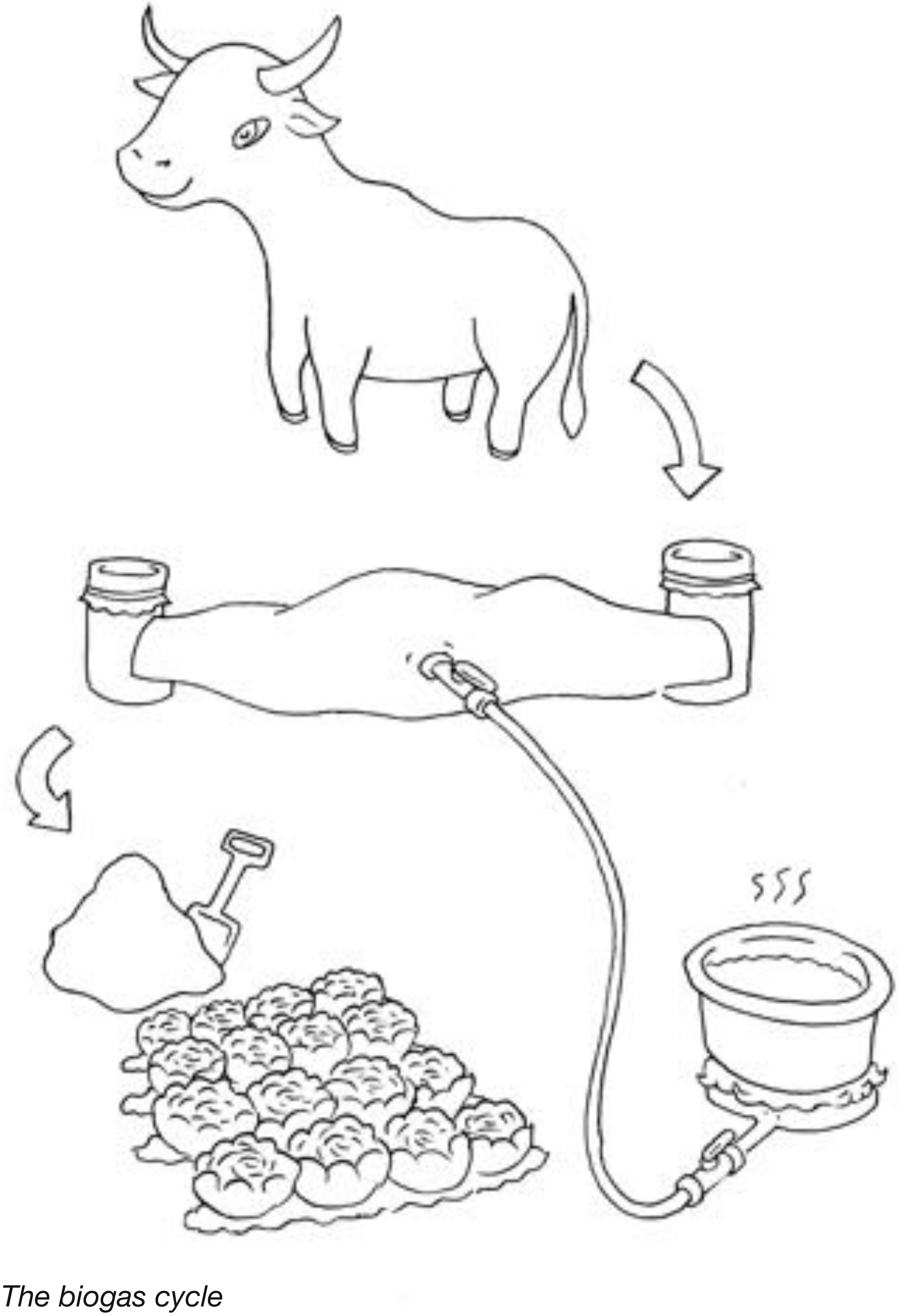
Introduction

This chapter takes you through the required steps to make the CREATIVenergie expanding bag digester. Please feel free to photocopy this guide and use it in non-profit work. If you use our design for profit we encourage you to make a donation to the charitable work of CREATIVenergie. You can find out how to do this by emailing info@creativenergie.co.uk

CREATIVenergie accepts no liability for the use of these designs/instructions. Use of these designs is at your own risk.

Safety

It is important that the builder is aware of all the safety implications of building and operating a biogas plant set out in CREATIVenergie's Biogas Training Manual: for use with the Expanding Bag Digester.



The biogas cycle

Expanding Bag Digester - Siting

It is important to pick a safe and efficient site for the biogas plant. Use the following diagram and checklist to determine that an appropriate site is available.

If you cannot meet the criteria in the diagram and the checklist it may not be suitable to build a biogas plant.

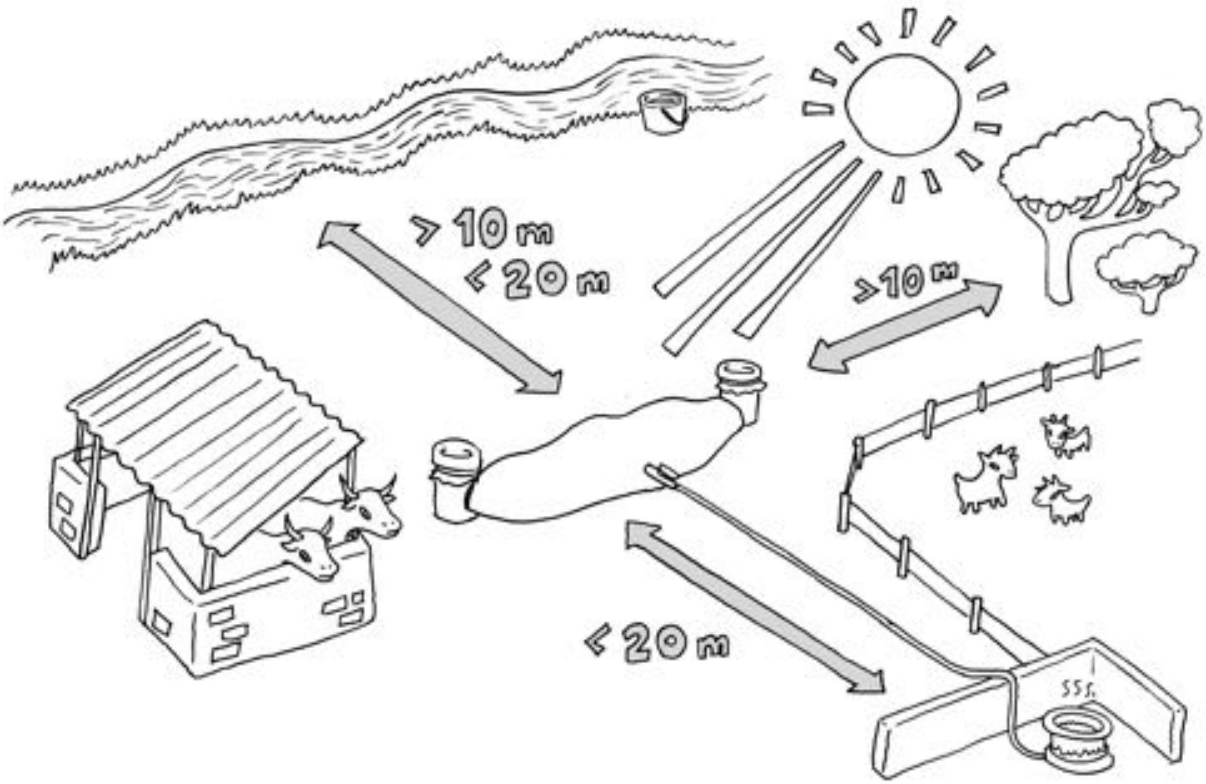


Diagram for correct site selection.

Setting up biogas: feasibility study

Name and contact details of interested farmer:	
Number of cows:	
Estimate kg of manure available per day:	
Climate of farm (is it in the valley (hot), or in the highlands (cool)	

Initial feasibility study- tick each box when each is confirmed

- ☐ There is sufficient raw materials to feed the digester every day over the whole year (min 10 kg per day)
- ☐ There is a water source close by that can be used to feed the plant each day
- ☐ The farmer is committed to look after the system and feed it every day or there is someone else who will be responsible.

Site selection: choosing the exact location to build the biogas

- ☐ A site has been chosen that is close enough to the source of manure.
- ☐ You are satisfied that the water source is close enough and sufficient and available for the whole year.
- ☐ The site is greater than 10m away from streams or wells to avoid contamination risk.
- ☐ You can confirm that there are no trees whose roots could damage the biogas plant. If there are trees, the farmer needs to agree to remove them before you tick this box.
- ☐ You can confirm that the ground is ok to dig
- ☐ The distance and root for the pipeline- between the biogas and where the gas will be used (kitchen) has been considered. And you can confirm that the suggested path for the pipe is feasible.
- ☐ You have discussed with the farmer the location of any other pipes/cables that might be around where you will dig the hole for the tank or the pipeline trench.
- ☐ The site is located in the sun (not essential but better)
- ☐ The farmer is happy with the suggested location

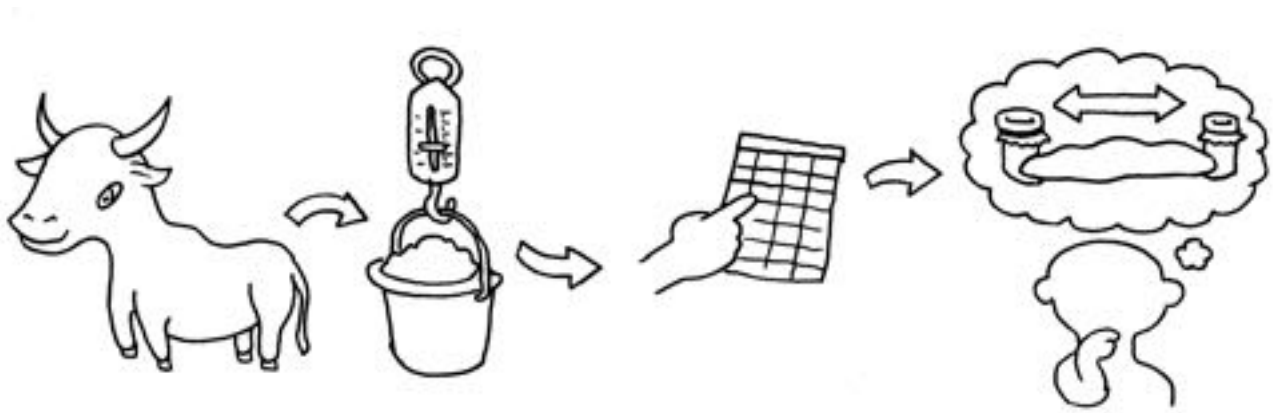
The farmer now needs to agree to collect dung everyday for 2 weeks and record each day how much he/she collects. The cow dung must be collected and stored in water (the farmed could dig a small hole and line with polythene plastic).

Kg of cow manure collected each day (as recorded by the farmer)	

This cow manure should be stored in water for at least 3 weeks prior to construction beginning.

Expanding Bag Digester - Sizing

It is important that you size the biogas plant correctly and this should be based on the weighed amount of dung that you can collect each day. Collect the dung for three days and take an average to find the daily amount.

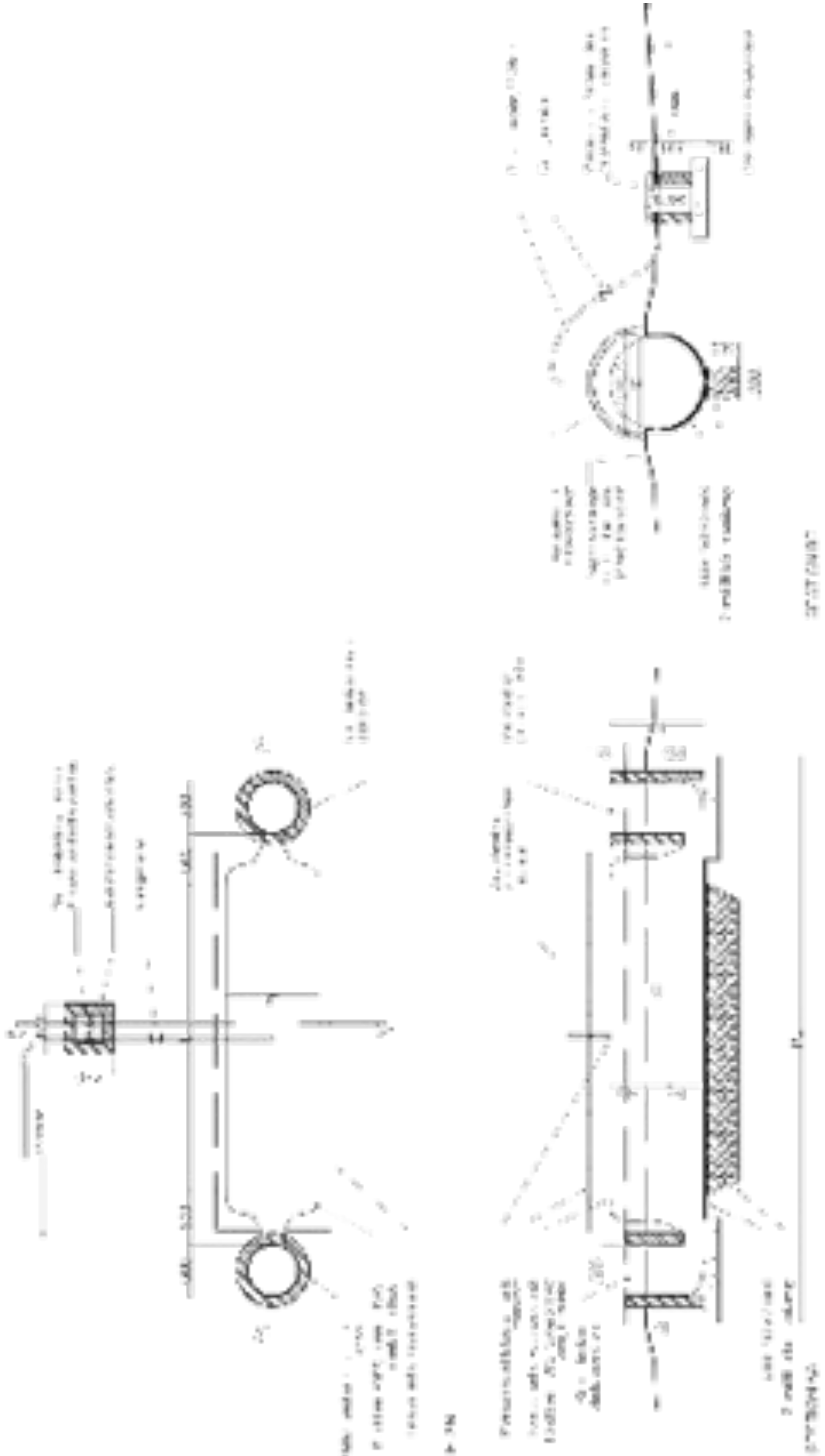


Once you know the amount of dung collectable each day you can then use the chart to determine the size for the digester. The dimensions are used with the drawing to build the correct size of digester. These are reproduced larger at the end of Appendix A.

Width of plastic sheet = 3 m

kg dung per day	10	15	20	25	30
Size of biogas plant, m3	0.92	1.37	1.83	2.29	2.75
Length of plastic sheet	4.48	5.23	5.97	6.71	7.44
L - Length of digester	1.47	2.20	2.93	3.67	4.40
D - Diameter of digester	0.89	0.89	0.89	0.89	0.89
Ho - Height of outlet	0.73	0.74	0.74	0.74	0.75
Hi - Height of inlet	0.88	0.89	0.89	0.89	0.90
PD - Depth of pit	0.56	0.56	0.56	0.56	0.56
PL - Length of pit	4.57	5.30	6.03	6.77	7.50
AL - Arch length	2.67	3.40	4.13	4.87	5.60
AD - Arch diameter	0.99	0.99	0.99	0.99	0.99

Table for sizing the biogas plant to be used with the sizing drawing



Exapnding Bag Digester - Materials Required

The chart to the right lists the amount of materials you will require in order to build the different sized biogas plants. The sizes correlate to the sizes in the chart on the previous page.

Materials charts

Width of plastic sheet = 3 m

kg dung per day	units	10	15	20	25	30
Width of plastic sheet (1mm HDPE, LDPE, Rubber or PVC)	m	3.00	3.00	3.00	3.00	3.00
Length of plastic sheet (1mm HDPE, LDPE, Rubber or PVC)	m	4.48	5.23	5.97	6.71	7.44
20mm internal dia. gas pipe	m	15.63	15.64	15.64	15.64	15.65
20mm, 90 degrees elbow	no.	1.00	1.00	1.00	1.00	1.00
20mm, tank connector	no.	1	1	1	1	1
1/2", female main gas valve	no.	1	1	1	1	1
1/2", female drain valve (same as gas valve)	no.	1	1	1	1	1
20mm to 1/2", 20mm plastic to 1/2" male gas pipe fittings	no.	1	1	1	1	1
20mm, tee	no.	6	6	6	6	6
1/2" female nozzle	no.	1	1	1	1	1
rubber gas hose (to fit nozzle)	m	1.5	1.5	1.5	1.5	1.5
PVC cement pot+brush	no.	1	1	1	1	1
Thread tape roll	no.	2	2	2	2	2

Table for ordering materials required

Materials charts

Width of plastic sheet = 3 m

kg dung per day	Units	10	15	20	25	30
bricks	no.	206	208	209	209	210
cement, 50kg bags	no.	7	7	7	8	8
sand	kg	953	1028	1115	1212	1319
aggregate	kg	375	375	375	375	375
mesh for ferrocement, 1/2"	m2	4.0	7.2	10.9	15.1	19.7
Mesh for ferrocement length	m	1.467	2.200	2.933	3.667	4.400
Mesh for ferrocement width	m	2.712	3.251	3.705	4.105	4.467

Expanding Bag Digester - Tools Required

The following is a suggested list of tools. If you can't find the same tool then you can try to substitute. Unless you are planning to build many biogas plants you may want to borrow tools rather than buy new.

For Setting Out

Tape Measure

Spirit Level

2 x 1.5m Sticks

Nylon cord

For Digging

Shovel

Pick

For Cement / Brickswork

Masons trowel

Spade

Finishing trowel - optional

For Pipework

Saw

Pliers or Molegrips

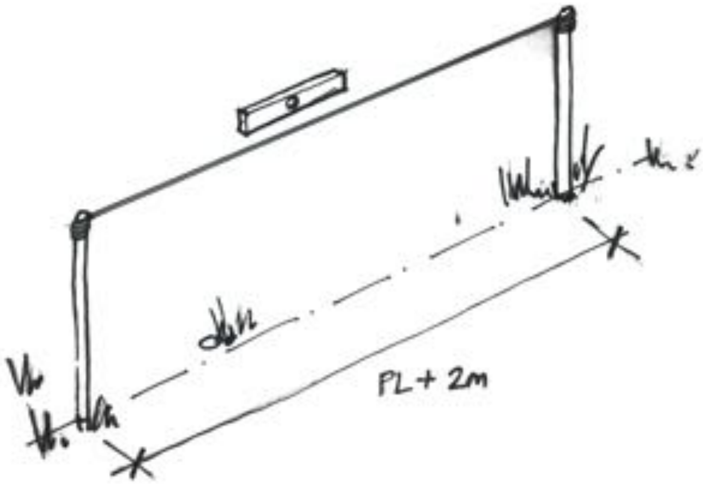
PVC Glue

Sharp Knife

2mm drill bit + drill

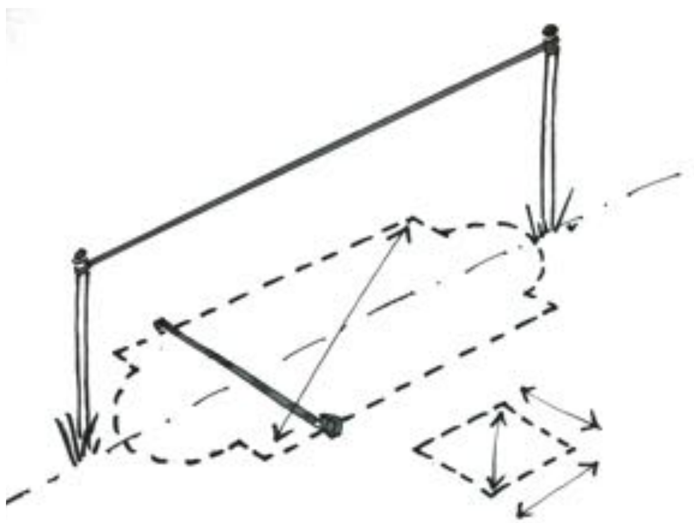
Expanding Bag Digester - Step By Step Process

The following is the step by step guide to build the CREATIVenergie expanding bag biogas digester. Before you start ensure that you have completed the siting and sizing assessments.



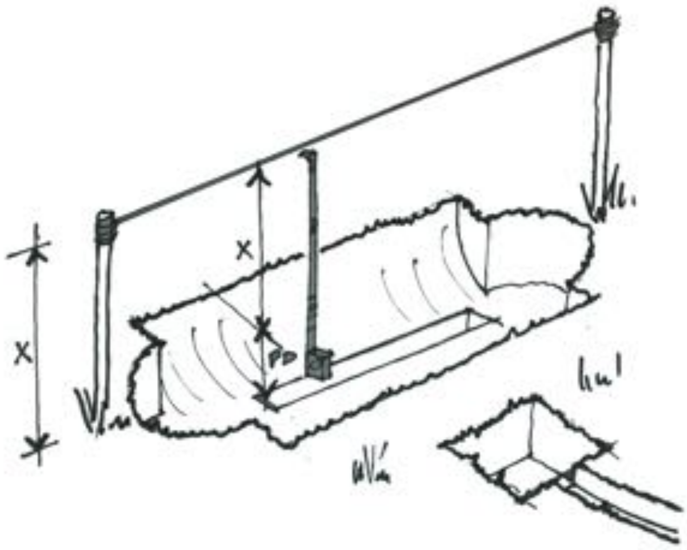
1) Set up the reference line

It must be level and longer than the total length of the biogas plant



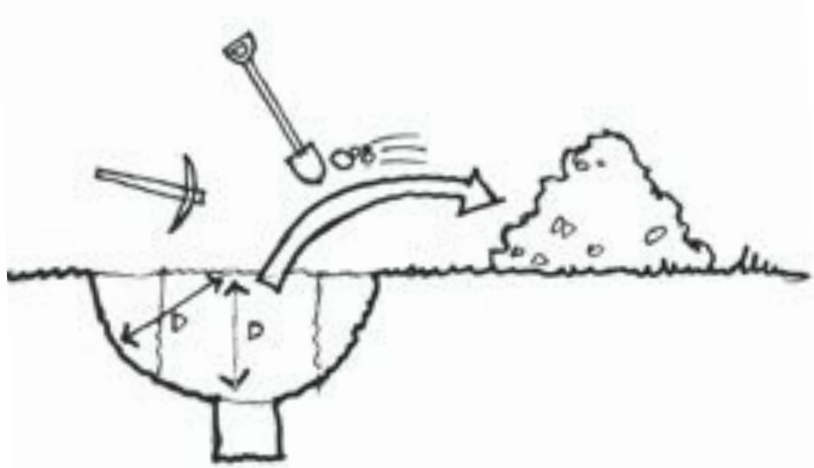
2) Mark out the area to be excavated

Check the setout is square by measuring the diagonals



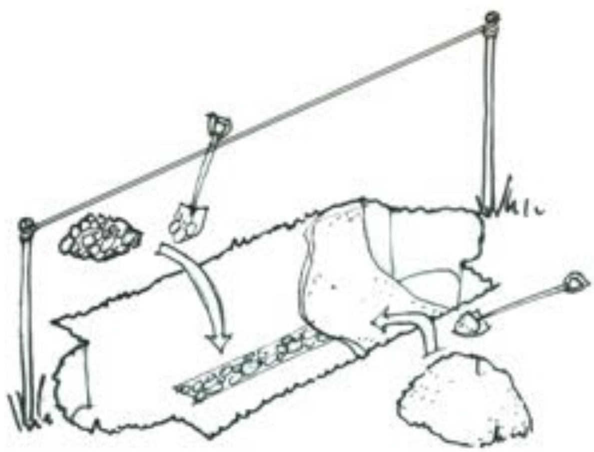
3) Excavate down to the required depth

Check that the depth is accurate by measuring back to the reference line



4) Dig out the soakaway channel

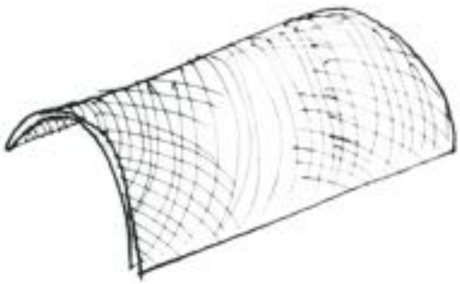
This will be filled with gravel and allow water that collects to drain away



5) Back fill gravel and layer of sand

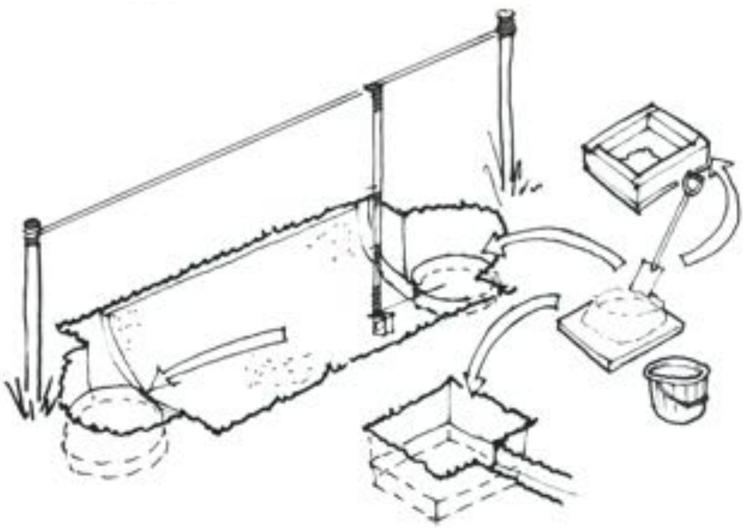
Put the gravel in the channel. Place a layer of sand over the ground and the gravel - this will protect the bag and allow free draining.

6) Prepare the mesh for the ferro cement covering



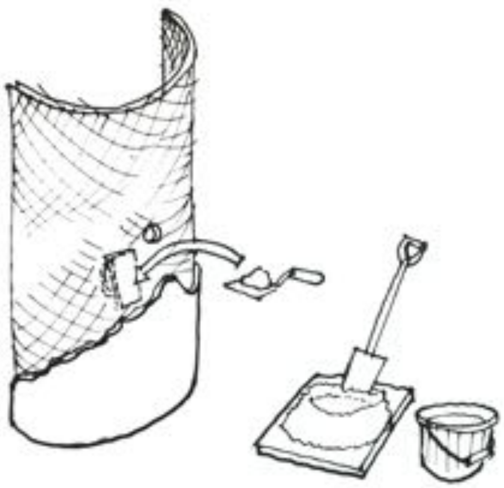
If you are unfamiliar with ferro cement the cover can also be made from corrugated iron sheets.

7) Prepare and lay the concrete inlet and outlet base, manhole base and manhole lid



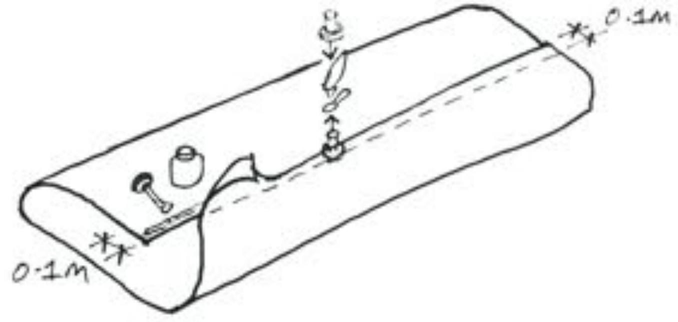
The mix for the concrete is 1:3:3
Cement:Sand:Aggregate

8) Prepare the ferro-cement & apply to mesh



The mix for the ferro-cement is 1:4, sand:cement.
Use the trowel & square trowel to daub the mix onto the mesh. You may need to build the arch in sections to ensure it is not too heavy.

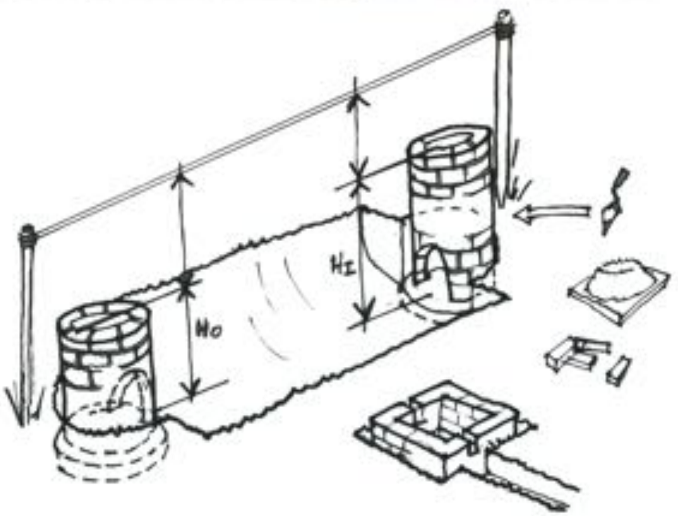
Leave a hole for the pipe to pass through.



9) Glue the sheet into a tube

If you cannot buy the membrane as a tube you will need to glue along one edge of a sheet to make into a tube. Use a glue suitable for the sheet you have bought.

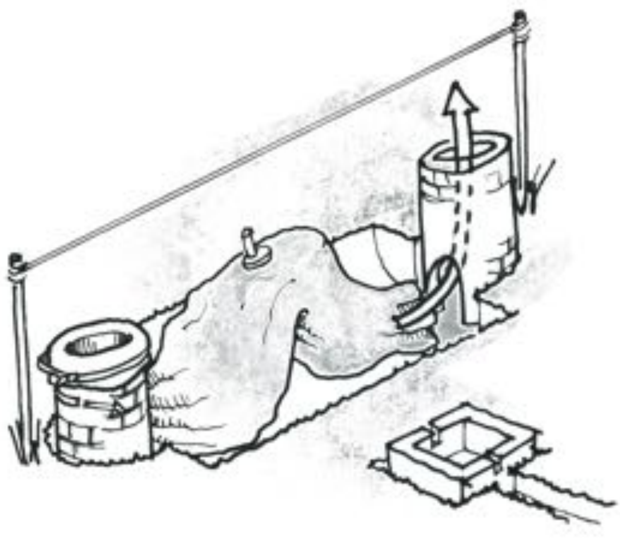
Cut a hole the diameter of the pipe on the opposite side to the join in the membrane.



10) Brick inlet and outlet and manhole

The mix for the mortar can be 1:4, cement:sand. It can be 1:6 with good quality sand.

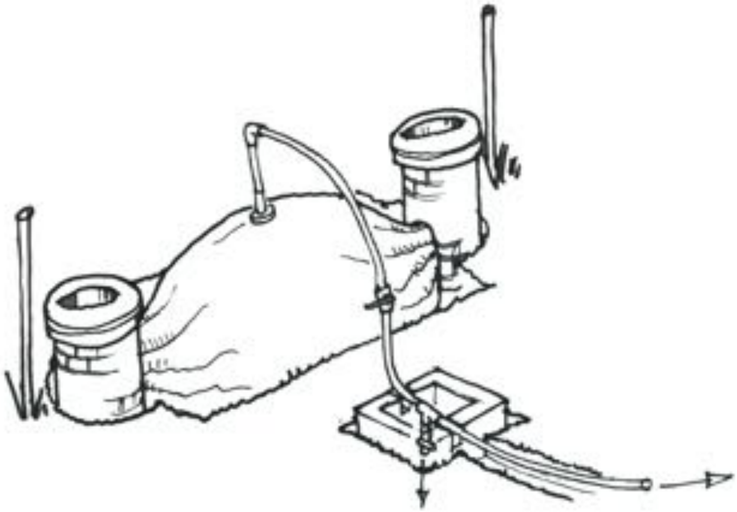
To save cost the brick inlet and outlet can be made from plastic bins of the correct dimensions.



11) Insert the bag into the inlet & outlet

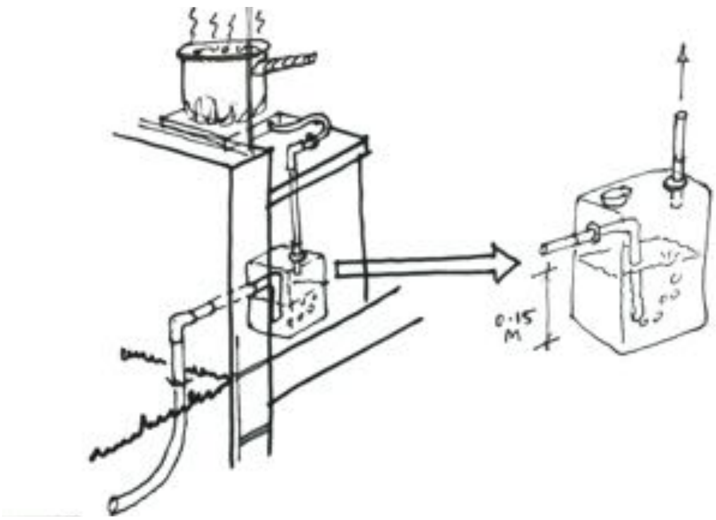
Ensure that the hole for the pipe is facing up and the seam is facing down. You will need to pleat the ends to get the bag into the inlet and outlet.

Use a strap to secure the ends around each chamber.



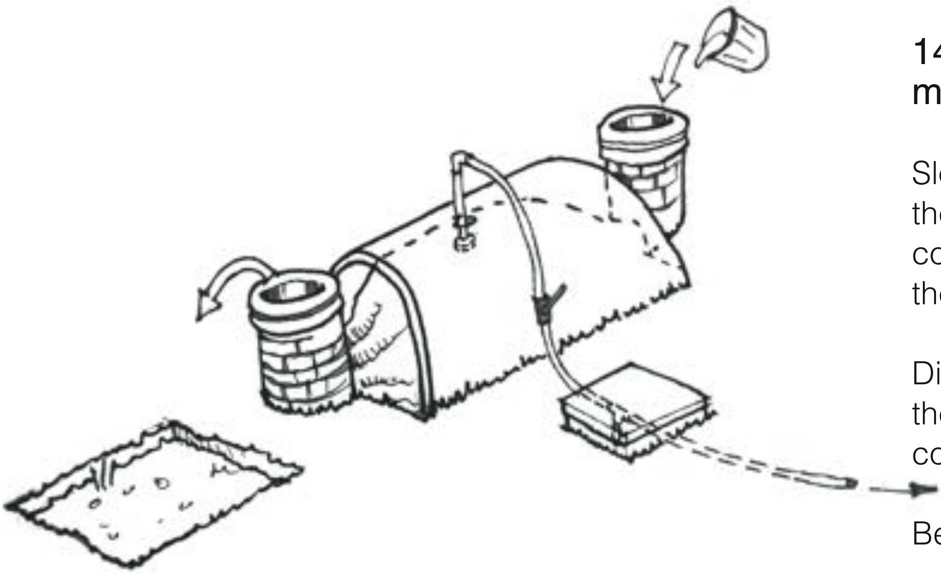
12) Attach the pipe, main gas valve and water drain

Fix the tank connector into the hole made in the top of the bag. Fix a pipe to this but do not fix to the elbow as the arch is still to be placed on top. Connect the main valve tee and water drain valve. Run the pipe underground to the house.



13) Connect the pipe work to the house with water bubbler

The water bubbler prevents flame from being able to pass back to the digester. This will protect your bag from burning down. The water bubbler should have 15cm of water in it.



14) Place the cover and manhole lids in place

Slot the pipe coming out of the digester through the cover hole and connect to the rest of the pipework.

Dig a compost pit next to the outflow and ensure you compost the outflow.

Begin feeding with slurry.

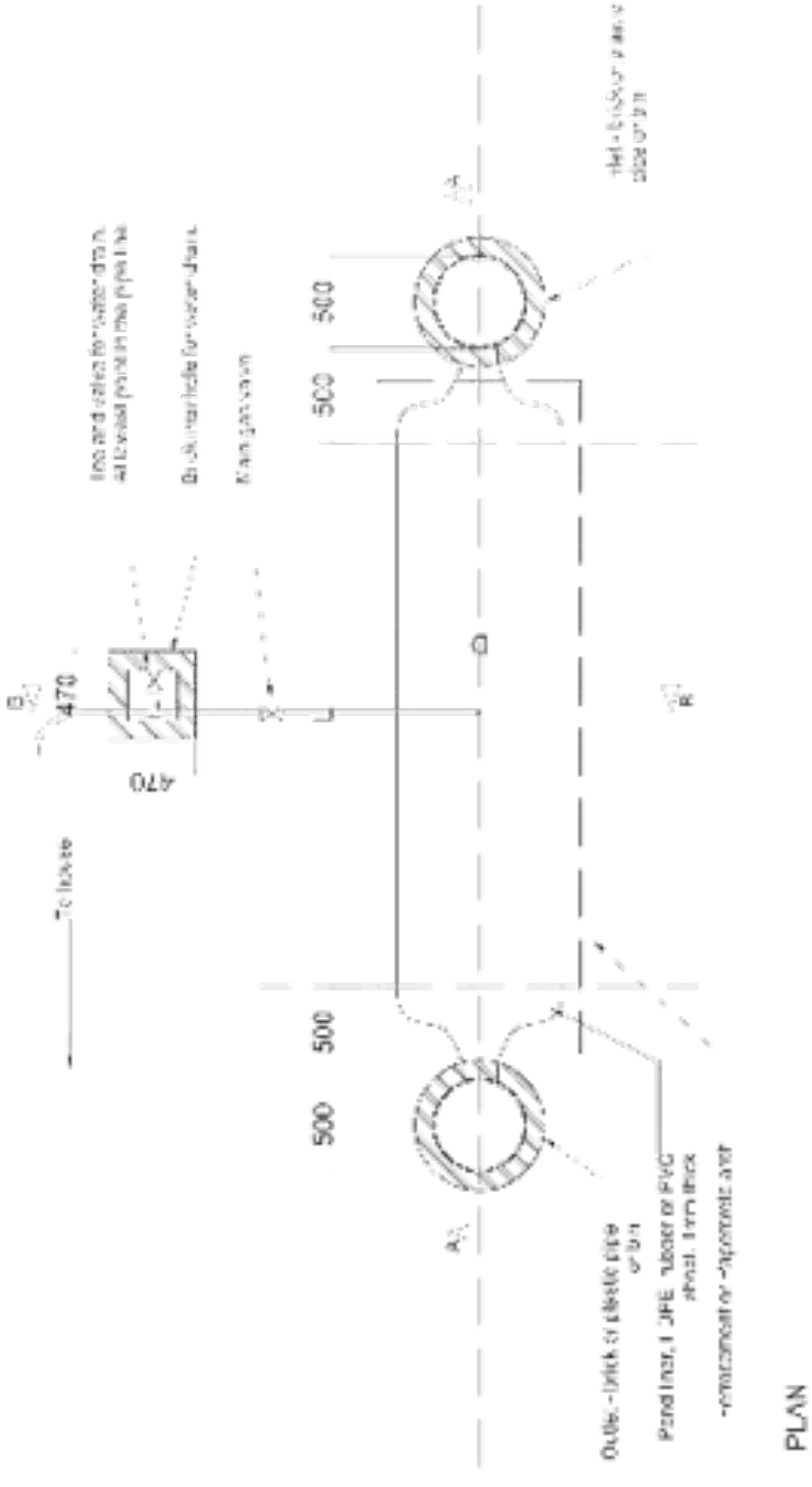
15) Prepare the stove

Increase the gas stove inlet nozzle to 2mm diameter to increase the gas flow to the stove. If this is not sufficient drill larger holes in 0.5mm increments until desired flow rate and flame is achieved.

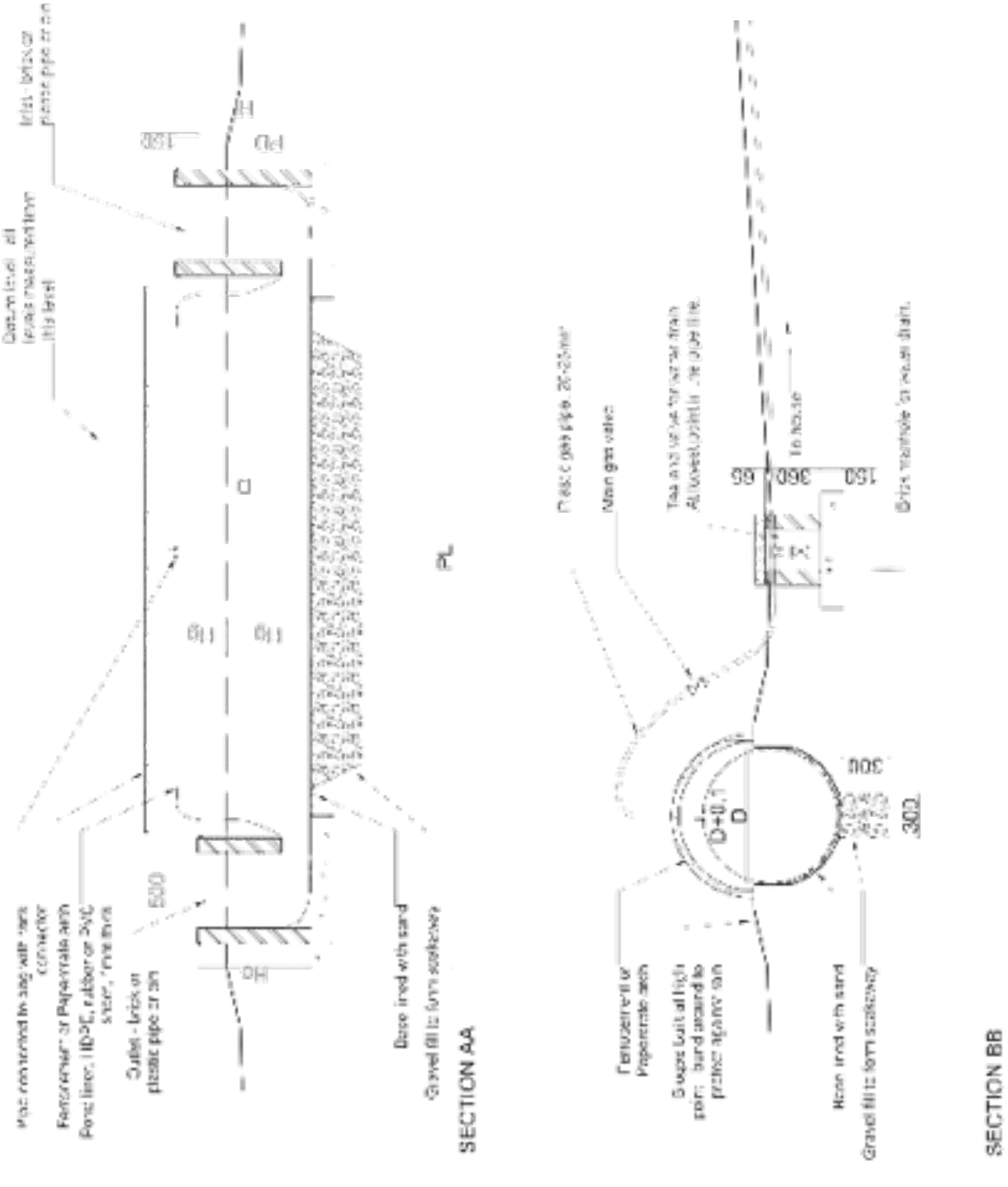
Expanding Bag Digester - Operations & Maintenance

Ensure that the operations and maintenance manual (Appendix B) is now handed over to the owner of the bag digester and that they are properly instructed on how to operate their biogas plant and how to maintain the safe operation of the plant.

Print and laminate the following warning sign and place by the biogas plant.



Plan view - to be used with sizing tables



Section views - to be used with sizing tables

Appendix B
Operations & Maintenance

Operation & Maintenance Guidelines

Operation

For the people feeding

- The digester should be filled with approximately the correct amount of cow manure and water everyday.
- These should be well mixed together to make a mixture of the consistency mala/porridge. This will reduce the risk of blockage of the inlet tube, and helps the gas production process.
- For the best result, prepare the mix in the morning and cover the inlet with a piece of black plastic. Allow the sun to heat the mix and only feed the mix in the afternoon.
- Severe under-feeding of the biogas plant will cause problems in its functioning.
- Avoid adding material that will not degrade (like polythene, glass, paper, wood). These should not be put into the digester.
- Try to avoid stones, mud or clay getting into the digester, these will reduce the volume and therefore reduce the amount of biogas produced.
- Never add chemicals to the mixture, this will be harmful to the bacteria.
- Filling can be done either once or twice a day, what is important is the total amount of dung added each day matches the size of your biogas plant; enter the size of your biogas plant here as a reminder ______________kg/day.
- Do not clean the inlet with water, this will increase the water content in the digester.
- If blockage does occur, it can unblocked by using a flexible rod.
- After feeding the digester, the inlet should be covered to ensure rain does not flow in and dilute the slurry (because it will reduce the gas output).
- Check that the outlet is also covered to stop rainwater flowing in and for safety.
- AFTER EACH USE THE MAIN GAS VALVE SHOULD BE CLOSED.

Tips of reducing gas consumption when cooking to give you maximum cooking time

1) Adjust the flames so they do not wrap around the cooking pot.
2) Cover the cooking pot with a lid, this will save a lot of energy.
3) When the pot is boiling, reduce the flame size so the you get a gentle simmer.

Maintenance

Daily checks

- [ ] The inlet, outlet and water storage tank need to be protected from rainwater flowing in. Ensure that they are covered at the end of each day before the rains.
- [ ] The main gas valve is placed immediately after the digester tank. In order to minimize the risk of accidents and gas losses, the main gas valve should be closed when no gas is needed. It should be closed off at the end of everyday.

Weekly checks

- [ ] From time to time the digested slurry will leave the outlet via the overflow and flow into the overflow pit. Dried slurry may obstruct the outlet overflow. Check the overflow weekly, and clean it when necessary.

- [ ] Check the water trap is filled and has not evaporated [use a dip stick] and refill with water using a tube and funnel if necessary.
- [ ] Inspect the system to ensure it has not been tampered with and is in good condition.

6 monthly checks:

- [ ] Main gas valve check for leaks.
- [ ] Check water level in the gas storage tank. Do this by letting the gas flow out of the storage tank (isolate the main digester tank and light the cooker and burn until the storage has emptied. Now check what the level of water is in the tube within the tank, it should be filled to the top. If it is lower than this, you need to refill the tank until it is covered.
- [ ] Check the gas taps and components for leakage with foam of soap and water.
- [ ] Check the rubber hose connecting the stoves is in good condition.

IMPORTANT: Ensure that all gas valves are closed when carrying out any maintenance or pressure testing. If pressure testing the gas system ensure to first burn off the gas in the pipes and leave the valve open for at least 20 minutes to drain off residual gas before pumping with air- to avoid the risk of creating a potentially explosive mixture of air and gas.

Troubleshooting

When the system does not work, it could be for a variety of reasons because of the many different factor that affect the digestion process and the production of biogas.

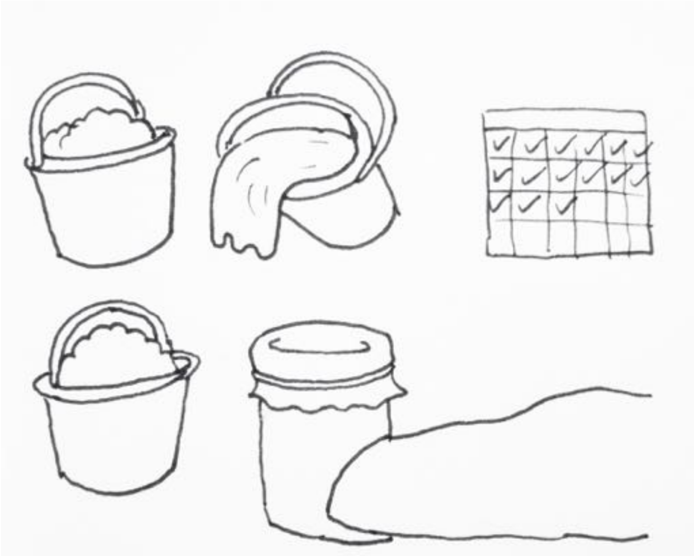
The first questions that should be asked are:

1. Is the digester water tight?
2. Is the digester gas tight?

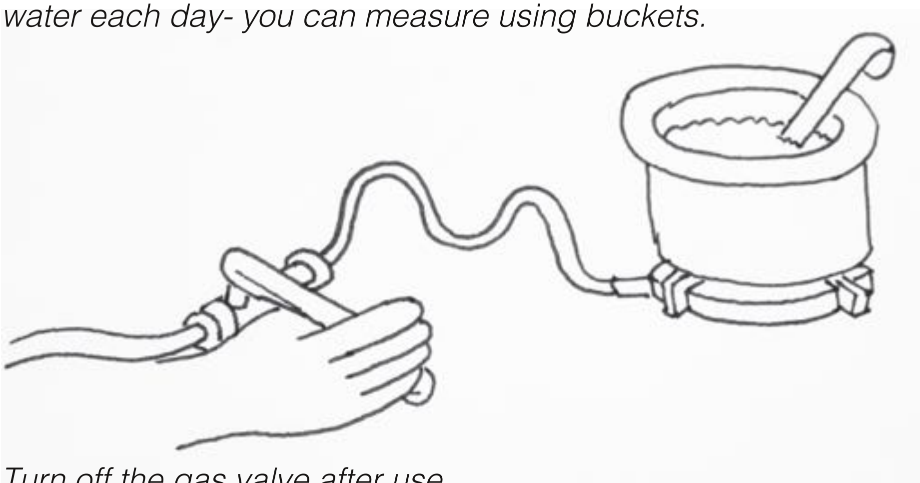
If the answer to either of these questions is yes, then this problem needs to be solved first. After that the digester should be fed as normal for a week or so and the situation re-evaluated.

What has happened	Likely reason	Most likely Solution
The gas coming out does not burn well:	There isn't enough methane in the gas mixture, it is mainly other gases that don't burn well.	Drain the gas from the system and then let the system refill and try again. It might be necessary to carry out this procedure several times.
The flame isn't blue, it is more orange in colour, and there is an odd sound	It could be water trapped in the system.	First turn off the stove and check the water trap. If there is water in there drain this out and try lighting the stove again. If this does not change anything you will need to turn the gas off at the main gas valve and drain all of the pipes.
The gas flow from the digester seems to be low	Either 1) There is water trapped in the system, 2) The gas level is low 3) There is a leak.	1. Check the water trap and drain if necessary. Once drained make sure you close the water trap valve on the system so that you do not loose gas. 2. Is the floating gas dome full? Leave

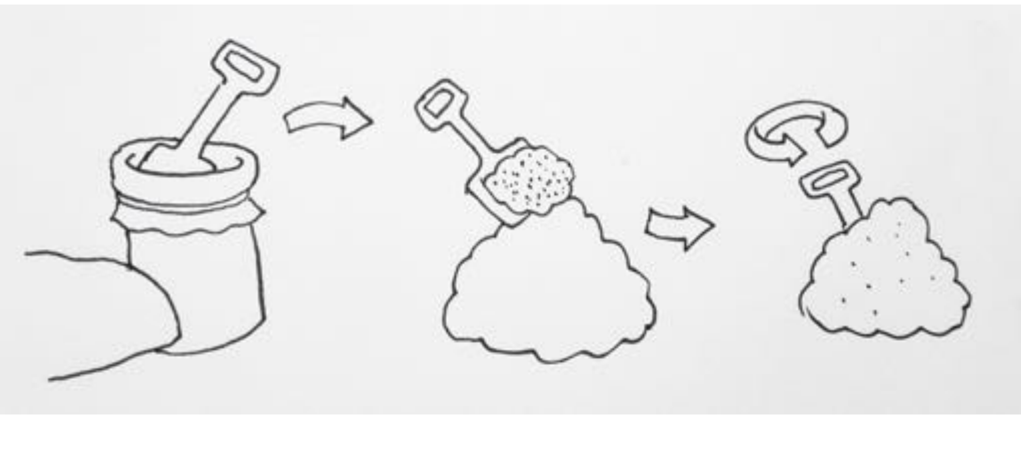
		the system for a few days to see if it refills. When this occurs the gas dome should rise. 3. If this does not solve it turn off the gas at the main valve (close to the digester) and inspect the pipework for likely leaks or blockages. Start in the obvious places (in the kitchen at each of the stoves, the bubbler, the connections to and from the bubbler, the connections coming into the house, each of the gas valves. If the gas storage dome shows that there is gas in the system you could use soapy water - fill a bucket with water and soap and use a rag to put this around the joins-bubbles rising will indicate the location of leaks. If the system has no gas left in it because of a major leak, ensure the main gas valve at the digester is turned off. Now pressurise the system with air by using a car tyre pump with the valve on the storage dome. Now use soapy water to locate the leak, checking all the pipe regions above the ground surface starting from the stoves.
The amount of gas we have each day is reducing	1) Gas leaking from the system 2) Not mixing the raw material or water properly before adding to the digester. 3) Cow dung solidifying inside the digester. 4) Wrong raw material has been added to the digester. 5) Sand and rock entering the digester.	1) Check for gas leaks using procedure given above and repair if found. 2) Check the water level of the digester. Is it below the minimum level mark? If it is the digester should be filled with a ½ water ½ dung mix until the level is reached. 3) If cow dung is solidifying the digester needs to be mixed. 4) Does anybody know of any other material that was added? In the next section we will look in more detail at analysing the situation to work out what best to do. 5) If a large quantity of sand and rock have enter the digester it may be necessary to consider a full clean out and re-commission. This is a very time consuming procedure and should only be used as a last resort.
Uh no! the digester seems blocked! I can't seem to add more cow dung.	The pipe used to load the material into the digester is probably blocked.	Use a wooden stick or bamboo cane to clear the blockage.



Load the digester with the same amount of dung and water each day- you can measure using buckets.



Turn off the gas valve after use.



Mix the digestate from the outlet with other dry matter and leave to compost.