Washiriki's Guide to Biogas

Part 1 and 2
Biogas

Teach yourself how to build and use a biogasunit to get free energy and save the environment. Improve your livestock keeping with zerograzing, improve your smallholding with fertilizer:

Part 1
Biogas Basics

Part 2
Build your biogas unit

Part 3
Improved farming


Part 4
Use biogas


H.Kuijpers
Chanjale, Tanzania 2003
[1.1]

1 Welcome to biogas technology

What is biogas technology?

Biogas is gas that originates from animal dung and vegetable waste (organic waste). Microorganisms present in urine and manure of cattle produce it. Biogas will come out of the manure by itself when you keep the manure, mixed with water, in an airtight tank. You collect this biogas in a gasholder or reservoir. This reservoir should be adjustable to keep pressure according to the amount of biogas that comes in or leaves the gasholder.

Biogas technology is the way in which you create the conditions to gain biogas from organic waste ready to use for cooking and lighting. If you buy firewood, charcoal or kerosene, biogas technology can save you money. Once your biogas unit is operational, it will save a part of your expenses for fuel and energy.

The advantages of biogas technology are:
- improve your standard of living if you have to buy fuel for cooking and lighting
- save the environment from deforestation and the greenhouse effect
- improve your own environment because:
    - the biogas unit will keep flies, diseases and bad odor away by locking of the manure from the air.
    - biogas burns without smoke. Smoke affects eyes and lungs and also the interior of the kitchen.
    - digested manure has very good fertilizing qualities and can increase your harvest
- save time on fetching firewood or oil, as well as pasturing and collecting manure or fertilizer.

Conditions to use biogas technology

Biogas technology described in this manual is meant for tropical areas with average temperatures above 15 degrees Celsius. If you have a water source and a smallholding nearby, some animals and access to money, you can use the biogas technology to produce fuel from manure. In part 4 you can learn more about how to use biogas. However, before you start using biogas, you need to understand the conditions:

To collect **enough clean manure**, you keep your animals in **a clean stable** day and night. This is called **'zero grazing'**. Your stable should have smooth floors and troughs. You clean the stable every day and you bring food (grass, crop residues) to the stable, which you grow near the outlet of the biogas unit. The biogas unit will produce good fertilizer! The food you cut in little peaces.
When you clean the stable you collect manure and urine. This manure and urine you mix with **enough water** and put it in the biogas unit every day. You need a **nearby water source**: for every bucket with manure (one cow), you will need two buckets of water or urine every day! Without water a biogas unit will not work optimal.
When the manure leaves the biogas unit has better quality. It will improve your harvest. To really benefit from the biogas unit, you should **use the fertilizer**. This improved farming is explained in part 3.

You need money to pay for the materials and labor for the biogas unit and the appliances (stove or lamps). The costs for the cheapest biogas unit with a stove and lamp are about 150 dollar (1-1-2004). This biogas unit can last for 5 years. A more advanced and durable unit with a bigger capacity will cost around 1500 dollar and may last 10 to 15 years. How to build these units you will find in part 2.

First of all: Before you decide to use biogas technology, you calculate **the costs and benefits** over the period that biogas unit will last. The benefits should be bigger than the costs! The costs depend on the money you spend on energy, the benefits will depend on how much of this energy you will replace by free biogas. How much biogas you can produce depends on how much manure you can collect from your animals.
In part 1 you can learn how to calculate this. Only if you buy firewood, charcoal or kerosene you may expect enough financial benefits from biogas after investing money in a biogas unit. After working through part 1, you will know. If this is the case, you should be able to get **access to money** like a loan from the micro finance bank or funding by a local environmental organization with help of your community leaders.

Summary: Before you decide to build and use a biogas unit, you must have
1. Daily enough water from a nearby water source
2. Daily enough clean manure from a clean stable (and food to bring to the animals)
3. The intention to use the fertilizer
4. The information about your benefits and costs
5. Access to money

Washiriki's Guide to Biogas Part 1 – Biogas Basics

First, write down your energy demand. This means how much fuel like firewood, charcoal, kerosene, oil, etc. you are using right now and for which purpose (cooking, lighting). Calculate how much money you will spend on this fuel each year with table 1.
Second, calculate how much biogas you could produce with your biogas unit with the manure you collect with table 2.
Table 3 will help you to estimate how much biogas you will need for lighting and cooking.

Table 1. Is an example how to estimate your energy demand and the money you spend on energy sources each year. You need this to find out if you can save money by replacing your energy source with biogas. Use of peace of paper to copy this table and fill in the information about your own situation.

Table 1.

Energy demand

	example1	*example2*	14. Total
1. use of energy	*cooking*	*lighting*	
2. energy source	*firewood*	*kerosene*	
3. used in what appliance	*three stones*	*oil lamp*	
4. used in how many appliances	*1*	*3*	
5. how many hours per day			
a. morning	*½ hour*	*-*	
b. afternoon	*1 hour*	*-*	
c. evening	*3 hours*	*-*	
d. night	*-*	*3x3=9*	
Total	*4½ hours*	*9 hours*	
6. for how many people	*10*	*10*	
7. unit of energy source	*bundle*	*gallon*	
8. how many units per month	*20 (4 a week)*	*2 gallon (10 liter)*	
9. unit price (Tsh)	*150*	*3.000*	
10. costs per month (Tsh)	*3.000*	*6.000*	*Tsh. 9.000*
11. annual total costs (Tsh)	*12x3.000 = 36.000*	*12x6.000 = 72.000*	*Tsh 108.000*
12. other efforts per month (time to prepare energy source)	*8x4 hours walk to woodland, cutting*	*2x½ hours walk to petrol station*	*33 hours*
13. annual other efforts	*12x8x4= 384 hours*	*12x2x½= 12 hours*	*396 hours*
14. TOTAL COSTS AND EFFORTS	• *TSH 108.000 A YEAR* • *400 HOURS WALKING* • *1600 HOURS COOKING IN HEAT AND SMOKE*		

Fill in the table (write down):

1. For what purposes you use energy.
2. What energy source you use for each purpose.
3. In which appliance you use the energy source.
4. How many of these appliances do you use at the same time
5. How many hours you use these appliances.
6. For how many people you use them.
7. In which way you get the energy source. Example 1: a bundle of firewood, with about 10 branches of 1 – 2 meter. A bundle is then one unit.
8. How many units do you use in one month. Remember every time you have finished one unit for one month. Fill in the total.
9. The unit price, is the price you pay for the unit you filled in in 7.
10. Calculate the money you spend on each energy source by multiplying the quantity used per month (8.) with the unit price (9.)
11. Calculate the money you spend on each energy source by multiplying the costs per month with 12 months.
12. Write down any other efforts in one month. Example: the time you spend on collecting firewood, cutting firewood, starting the fire.
13. Calculate the efforts in one year from the previous row if applicable.
14. With the totals you can summarize your costs and efforts for energy in one year.

To see if you can save costs and efforts that you calculated in Table 1, you must estimate the amount of biogas you can produce.

Table 2.

Energy supply

1. source	2. how much	3. daily biogas-production	4. daily biogas potential	5. daily biogas choice
cows	*2*	400 liter	*800 liter*	*800 liter*
pigs	*2*	150 liter	*300 liter*	-
goats	-	100 liter	-	-
chicken poultry	*20*	8 liter	*160 liter*	-
human	*10*	100 liter	*1000 liter*	-
dry manure	-	200 liter		-
6. total			*2260 liter*	*800 liter*

Fill in the table:

1. Which animals do you own (source of manure)
2. How many animals of each sort.
3. If you add 2 buckets of water for each bucket of manure, this column gives you (as a rule of thumb) the amount of biogas you can produce per animal or human.
4. Calculate how much biogas you can produce by multiplying column 2 and 3 for each different sort of animal.
5. Choose which source of manure you want to use. You must consider the work you will need to do in order to collect all the manure without dirt, feathers or other particles that will disturb the biogas unit.
6. Calculate the totals of column 4 and 5.

Remember Table 1, where you filled in your energy demand. In Table 3. you calculate how much biogas you will need to get the same result. These are rules of thumbs.

Table 3.

Energy demand in biogas

	A. old	B. new
3. used in what appliance	*three stones*	biogas stove for 10 people (1 burner, 200 liters/hour)
4. used in how many appliances	*1*	1
5. how many hours per day (Total)	*4½ hours*	4½ hours
6. for how many people	*10*	
Total		200x4½= 900 liter/day

	old	new
3. used in what appliance	*oil lamp*	biogaslamp (120 liters/hour)
4. used in how many appliances	*3*	3
5. how many hours per day (Total)	*9 hours*	9 hours
Total		120x9= 1080 liter/day

Fill in the table:

1. Copy row 3. 4. 5. and 6. from table 1. to column A.
2. For a family you use a burner that uses 200 liters of biogas an hour and lamps 120 liters an hour. For institutions bigger burner of 2000 liters will be more efficient.

3. In column B you fill in the appropriate biogas appliance.

- to cook for 1 to 20 people: a burner which uses 200 liters of biogas in one hour (200 liter/h)
- to cook for more people: a burner of 2000 liter/h
- for lighting: a biogas lamp of 120 liter/h

Table 4.

Balancing supply and demand

	firewood	kerosene	total
1. table 1: annual total costs (Tsh)	*36.000*	*72.000*	*108.000*
2. table 1: annual total effort	*384 hours*	*18 hours*	*402 hours*
3. table 2: daily biogas choice	*800 liter*	*800 liter*	*800 liter*
4. table 3: daily biogas demand	*900 liter*	*1080 liter*	*2380 liter*
5. total balance choice-demand	*-100 liter*	*- 280 liter*	*- 1580 liter*
6. percentage choice/demand x100%	*88%*	*74%*	*33%*
7. annual cost reduction (Tsh)	*32.000*	*53.280*	*35.640*
8. annual time reduction (hours)	*237 hours*	*9 hours*	*132 hours*
9. return of investment in biogas (years)	*150.000 /32.000= 5 years*	*150.000 /53.280= 3 years*	*150.000 /35.640= 5 years*

1. Copy the total costs you calculated in table 1 here for each energy source
2. Copy the total effort you calculated in table 1 for each energy source
3. Copy the total of your biogas supply in the biogas choice from table 2. Fill this in in every column.
4. Copy the total daily biogas need from table 3.
5. Subtract row 3 from row 4. In the example this is negative: the demand is bigger than the supply
6. Calculate the percentage of coverage the energy demand by dividing row 3 by row 4 and multiply the outcome by 100%
7. Multiply the total costs of row 1 by the percentage in row 6. This is the money you save once you start using biogas.
8. Multiply the total effort (hours) of row 2 by the percentage in row 6. This is the time you save once you start using biogas.
9. For a tubular plastic biodigester you have to invest 150 dollar (150.000 Tsh). Divide 150.000 by the annual cost reduction in row 7. In case of another design you must change the costs of investment

Once you have calculated the period of return of the investment in biogas you can take a decision. If you want to pay for your biogas unit yourself by getting a loan the period should not be more than 5 years. It is better to have the investment returned after a shorter period!

2 Build your biogas unit

You decided to build a biogas unit. In this section you learn how to build the tubular plastic bio-digester and the floating dome bio-digester.

Planning the site

If your kitchen is not near your stable, you must choose:
Either to carry manure to the biogas unit near to the kitchen, or,
To spend more money on gas pipes (3/4 inch PVC class B, about 1 dollar for 3 meter), and build the biogas unit near the stable.

In general, the ideal site is situated:
- near the stable and water source, to reduce the distance to carry manure and water to the bio-digester
- below the level of your stable, to let the manure flow in the bio-digester by gravity
- below the level of your kitchen, to collect the condense in gas near the bio-digester
- above the level of your smallholding, to let the manure flow out there by gravity
- near the kitchen where you want to use biogas, to reduce the amount of gas pipe you need.
- for a floating dome digester there must be no trees nor tree roots growing near to the site.

For a bio-digester you can use different sizes, depending on your supply of manure and the amount of biogas you want to store. The advantage is that the bio-digester will work more efficient and according to your needs. However, in this manual only one size is explained to avoid difficult calculations, which are not that reliable as certain variables may differ from place to place. See the appendix for further reading.

Following steps must be taken:
- select local material
- prepare the site
- make a foundation (including the guide pole)
- masonry
- construction and installation of the gasholder, gas pipes and water trap
- installation of biogas equipment

The tubular plastic biodigester

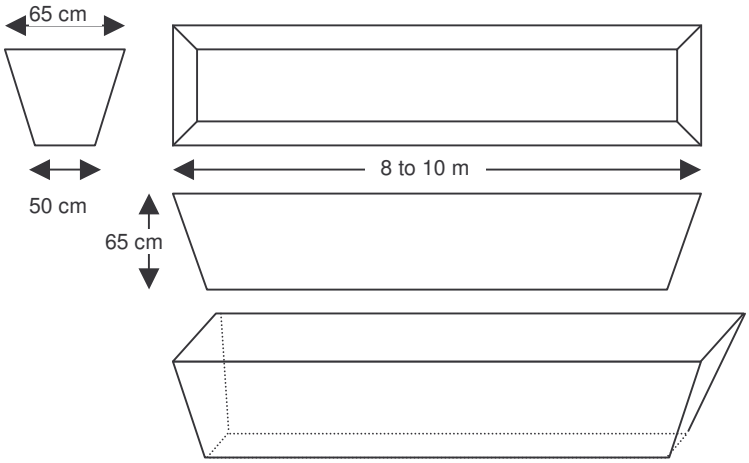
Select local material

1. Find out where you can get:
- transparent tubular polyethylene (also used for greenhouses).
  - diameter: 80-125 cm
  - circumference: 2,5-4 m.
  - caliber (thickness): 800-1000 gauge = 200-250 micron
  - length: 10+1 m for 8 pigs or cows.
- 2 pvc or ceramic tubes,
  - internal diameter (i.d.): 15 cm
  - length: 75-100 cm
- plastic (pvc) hosepipe
  - i.d.: 12 mm
  - length: determined by the distance to the kitchen
- two PVC adapter (male and female)
  - i.d.: 12,5 mm
- two rubber washers (from inner tubes of cars) with a 12,5 mm diameter central hole.
  - diameter: 7 cm
  - thickness: 1 mm
- two rigid plastic (perspex) washers with a 12,5 mm diameter central hole.
  - diameter: 10 cm
- PVC or PE pipe
  - i.d.: 12,5 mm
  - length: 2 m
- four used inner tubes cut into 5 cm wide strips
- one transparent plastic bottle (capacity 1,5 liters).
- one PVC elbow
  - i.d. 12,5 mm
- one tube of PVC cement.

① Prepare the site

1. Clear the site from vegetation and level the site.

2. Dig a trench with a length of the polythene tubing (8 to 10 meter), 65 cm deep, at the bottom 50 cm wide, up to 65 cm at the top. The trench must have a wider top to allow expansion of the polyethylene tube as the gas builds up. The bottom of the pit must be in level.

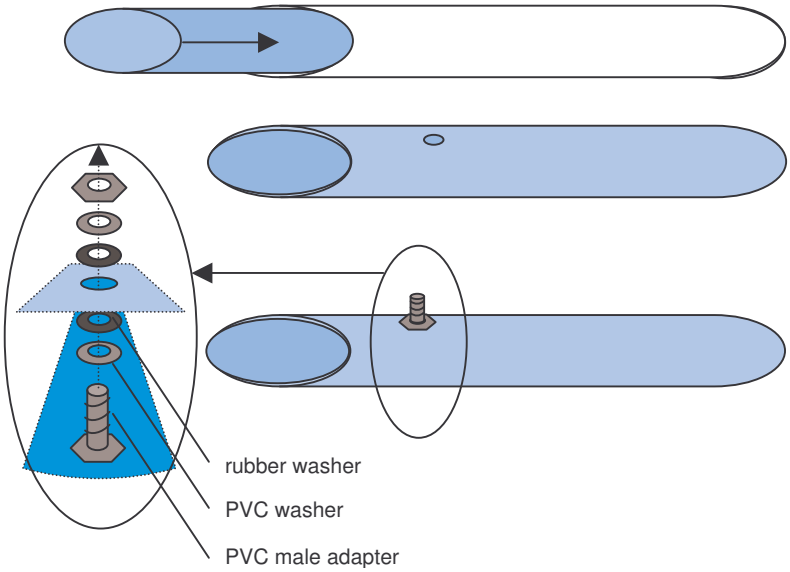


② Prepare the digester

1. First check the polyethylene tube for any holes especially around the corners and fold both ends to fit the width of the trench. Use 2 layers of polythene.

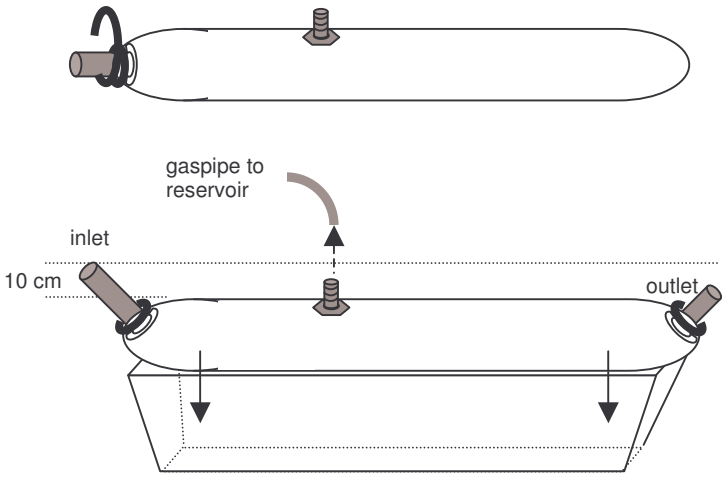
2. Take the cylindrical polyethylene tube and measure 8 meters or any appropriate length, leaving an allowance of half a meter both ends for fitting the PVC pipe.

3. Make small hole in the two layers of the tube, 1,5 meters from one end. Fit 1 PVC washer and 1 rubber washer on the flange of the male adapter. Then stick the flange trough the hole from the inside to the outside of the tube.
Put a second rubber washer and PVC washer on the flange of the male adapter from the outside of the tube. Secure the flange with a female adapter from the outside. Close the exit of the female adapter temporarily with a plastic film and rubber band.



4. Insert a PVC pipe to two thirds of its length. Fold plastic film around the pipe and secure it with 5 cm wide rubber bands. Wrap the bands in a continuous layer to cover the edges completely the edges of the plastic film, finishing on the PVC tube. For the outlet pipe you use the same procedure.

5. Put the digester into the trench. The inlet and outlet pipe make an angle of 45 degrees. The level of the inlet should be 10 cm above the top of the digester (tube) and 10 cm higher than the outlet. Fix the pipes in the inlet pit and outlet with cement and bricks.

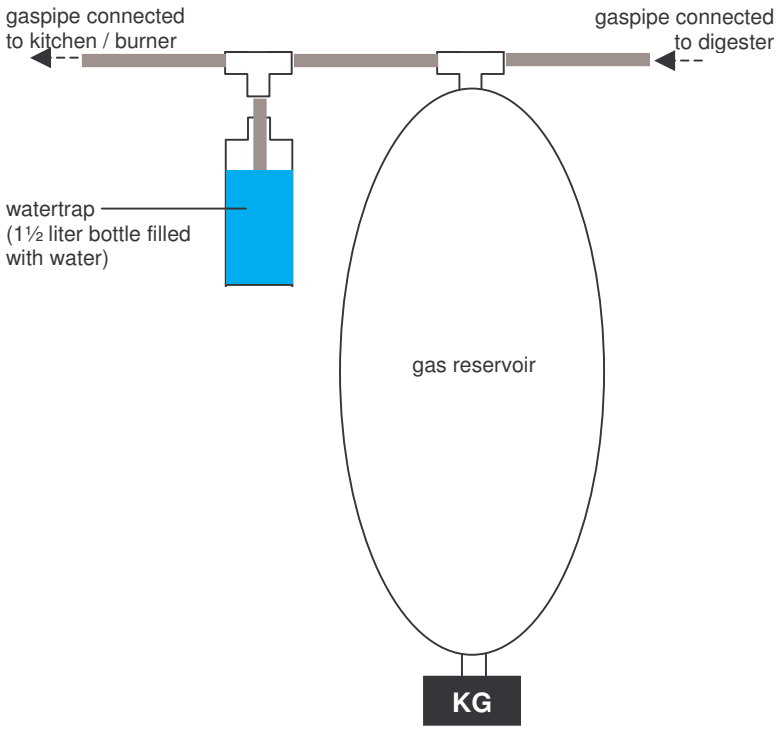


6. Use a polythene tube of 3 m to make a gasreservoir. Fasten both ends with tube (gastight!). Put a 'T' shaped pipe at the top of the reservoir. One end receives the gas from the digester and the other end takes the gas to the kitchen through a water trap.
The gasreservoir should hang in the shade, near to the kitchen. Put a weight at the bottom of the reservoir. This will pull the reservoir to keep pressure.

7. Use another 'T' shaped pipe for the watertrap. Put the 'T' shaped pipe in a 1½ liter transparent plastic bottle. Extend the pipe into the bottle with a PVC tube. Fill the bottle with water up to 3 to 5 cm above the mouth of the tube inside the bottle. This will watertrap operates as a safety valve. Once the pressure exceeds 3 to 5 cm water, the gas will pass outside through the water.

8. Fill up the biodigester with water up to two thirds of the depth. Connect a hose to the PVC flange to the gasreservoir. Use a 2 cm wide piece of tube to fasten the hose (gaspipe). Let the air inside flow out through the safety valve.

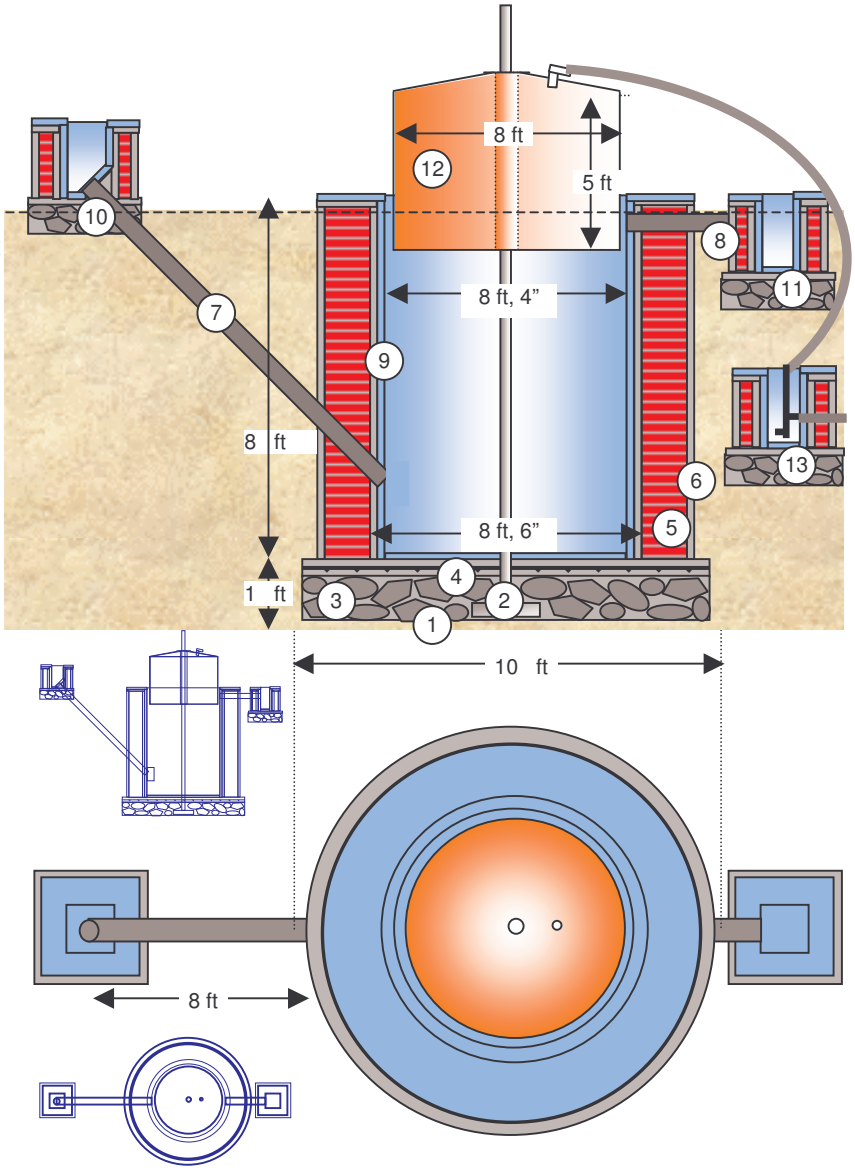
9. Fill up the biodigester with manure (ratio is one bucket of manure, two buckets of water). Make sure all the air has left the digester.



The floating dome bio-digester parts

1. Hole of 9 feet deep and 10 feet wide in a circular shape.
2. 14 feet metal guide pipe with diameter of 1½ inch with a foot at one side.
3. Foundation with stones and concrete.
4. Foundation with crossed steel bars and concrete.
5. Brick wall, inside diameter 8 feet and 6 inch
6. Outside plastering right form the first course of bricks
7. 12 feet x 4" pick Inlet pipe which is placed during masonry of the walls
8. 4" pvc Outlet pipe which is placed during the second last course
9. Plastering with cement in 2 layers of ½" each. Second layer with waterproofer
10. Mixing pit for water and manure
11. Outlet pit for digested slurry
12. Metal gasholder with diameter 8 feet, height 5 feet (a side), with guide pipe of 2 inch inside and connection for a gas pipe on top.
13. Control unit and condense pit at the lowest point between the bio-digester and the place of use.

-



Select local material

1. Find out where you can get:
- tools for digging, masonry, welding and carpentry
- stones (1 or 2 feet)
- aggregate (1 inch)
- cement
- sieved sand
- bricks (and which size)
- waterproofer
- galvanized pipes (3/4")
- metal gasholder
- biogas equipment

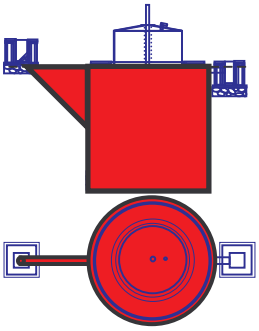
Everything must be available.
Consider the transport costs.

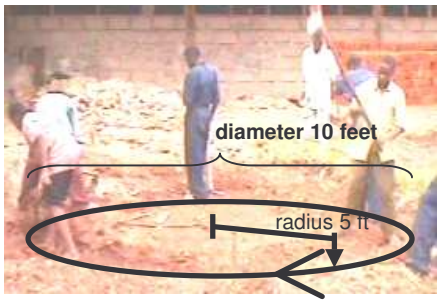
Prepare the site

① Pit digging

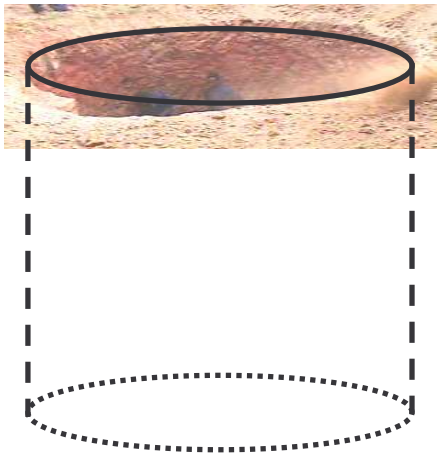
1. Clear the site from vegetation and level the site.

2. Put a stick in the center and use a rope of 5 feet (radius) to draw a circle that marks the outer edges of the pit. Mark the edges well in the ground and with sticks. The pit will have a diameter of 10 feet.

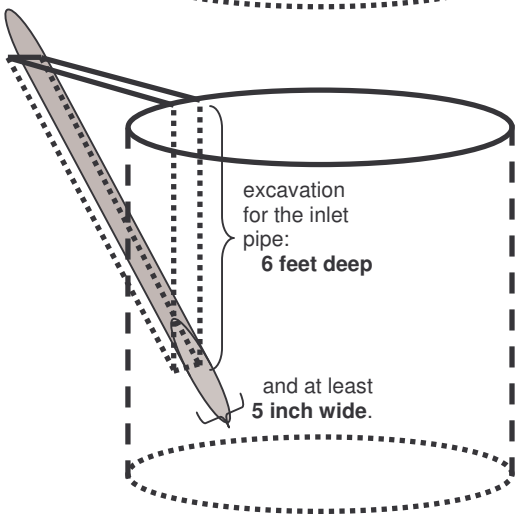




3. Dig a hole of 9 feet deep in a circular shape. Make sure that the edges are perfectly vertical.



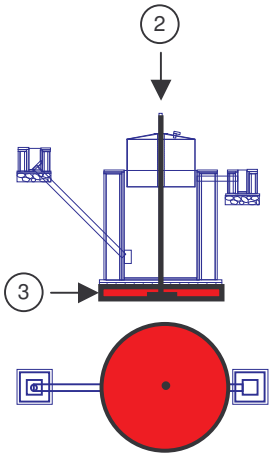
4. Excavate the place where the inlet pipe must enter the pit, somewhere between 6 and 7 feet deep, at least 5 inch wide. This excavation must surface the ground where you want to build the mixing pit, near the stable.



Make a foundation

(2) Guide pool

1. Weld a metal foot to a 14 feet metal pole with diameter of 1½ inch



(3) Foundation with stones

2. Lay stones on the floor of the pit. Leave space for the metal pole and foot in the center.
Prepare concrete with cement, aggregate and sieved sand (1:4:6)

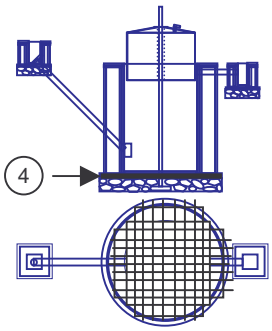
3. Place the pole on the floor in the center of the pit. Use a rope again to measure a circle that is the same distance to the edge of the pit everywhere.
Fix the pole with metal binding wire at four sides. Tie the binding wire both to the pole and a fixed object outside the pit.

4. Use a leveling rod to level the pole vertically. Fix the pole again with binding wires. Bind these wires tight to objects like big stones or steady poles outside the pit. THE POLE MUST STAND ABSOLUTELY VERTICAL AND STRAIGHT! This will avoid that the gasholder will hit the edges, which will destroy your gasholder soon.

5. Fill up the hole in the center with cement and aggregate.

(4) Foundation with steel bars

6. Put 5/8 inch steel bars on the floor with a distance of 6 inch square.
Use binding wire to fix the steel bars.
Fill up the hole with cement. Use a press to push and smoothen the cement.
Check the pole. When it's exactly straight and in the center, leave the concrete to dry at least one day.

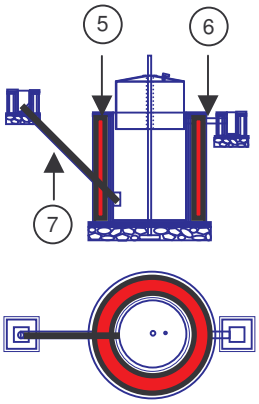


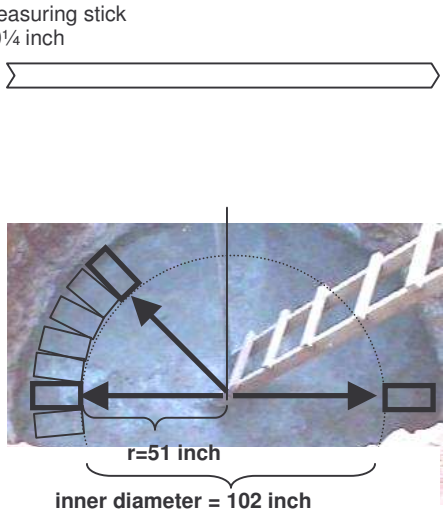
Masonry

(5) Bricklaying

1. Use stick of 50¼ inch to measure the inner circle for the bricks from the pole. The pole itself adds ¾ inch to the radius to 51 inch. The inside diameter must be 102 inch. The gasholder measures 8 feet (96 inch), the inside plastering 2 x 1 inch (on every side 1 inch) and there remains 2 x 2 inch to let the gasholder move freely.

2. Lay the bricks lengthwise, all pointing towards the center.





(6) outside plastering

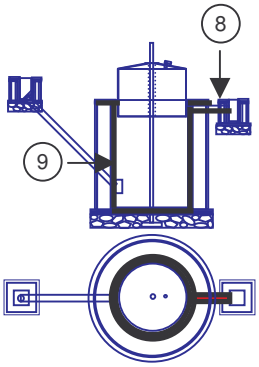
Start the outside plastering right away from the first course of bricks.

(7) Inlet pipe

3. Put a 4 inch pvc pipe into the excavation. Let it stick out slightly over the bricks inside the pit. Let is also stick out above the surface.
On the surface you will later build the mixing pit that should be on a higher level than top of the walls of the bio-digester.

(8) Outlet pipe

4. Finish the bricklaying up to 8 feet from the floor, but leave a space in last 2 courses for the outlet pipe, at the opposite side of the inlet. This outlet is a 4 inch PVC pipe, which you can connect to a channel in your smallholding, or in a reservoir. After you placed the outlet pipe, you can finish the final course.
Build a scaffold for the upper courses.



(9) Plastering inside

5. Make a first layer of plastering (½ inch) for the inside and floor. Start at the top.

6. Repeat the plastering but now mix waterproofer in the cement. The plastering does not need to be very smooth. A rough surface will even benefit the digestion.

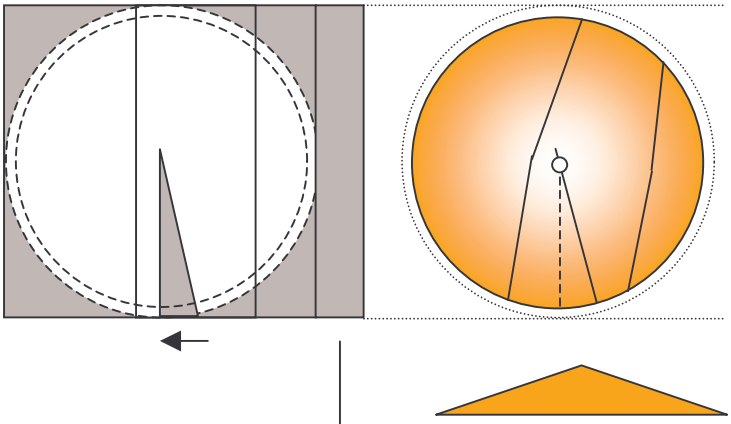
(10) (11) Mixing pit and outlet

7. Build the mixing pit and outlet with stones and concrete, bricks and cement. The inlet pipe should be at the lowest level inside. Cut of the remaining pipe at the bottom of the mixing pit. Finish the pits with waterproofer and cement.

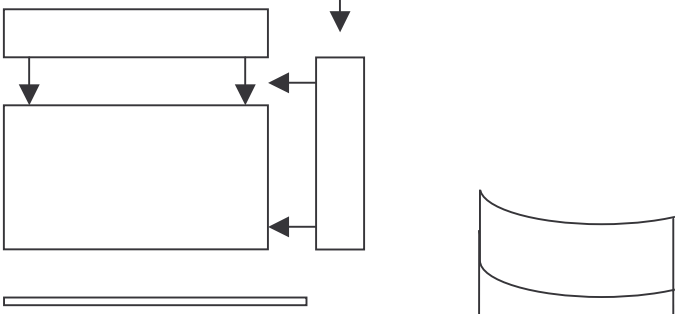
Metal gasholder

Advice: let an engineering company like NANDRA engineering in Moshi build this metal gasholder.
If you make the gasholder yourself, use a piece of paper to draw out the most efficient way to use the steel sheets.
Use 2 to 4 mm steel sheet.

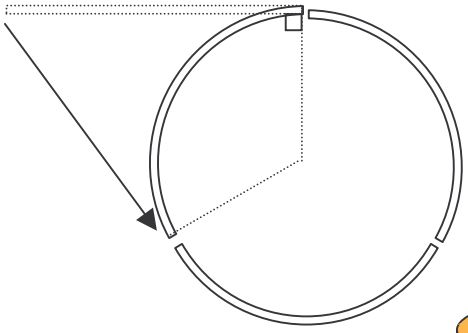
1. For the top weld three sheets (depending on the size). Cut a triangle to the center and fit the edges together again to make a triangular shape. This will improve the gas flow and increase the life span, since rainwater can flow of the top. Make a 2 inch hole in the center for the guide pipe and on 1/3 of the center a hole for a galvanized gas pipe (3/4 inch).



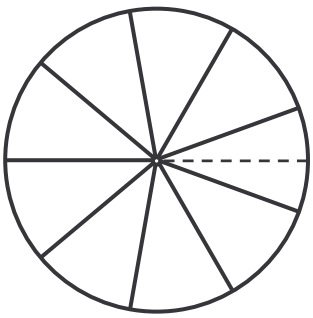
2. For the sides, use the remains of the top To get the height of 5 feet, weld a second piece. 3 pieces of 1/3 of the total circle (1/3 x 2 x pi x 4 feet).
Start with the sides.

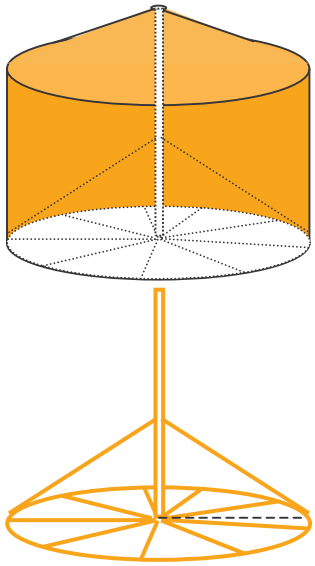


3. Make a can shape by bending each piece a 120 degrees and then weld the 3 pieces together.



4. The frame consists of a metal ring with nine steel bars connected to both the outside metal ring and the inside guide pipe (2 inch diameter). The steel bars make angles of 360 / 9 = 40 degrees.
The metal ring is also connected to the guide pipe with to steel bars for extra strength.
The frame is welded to the gasholder and 'folding' the sheets around the ring also closes the ring.





5. Paint the inside of the gasholder and ring with 4 layers of waterproof / gastight 'Marine paint'. Paint the outside with 2 layers of 'blackboard' paint for solar heating.

Installation

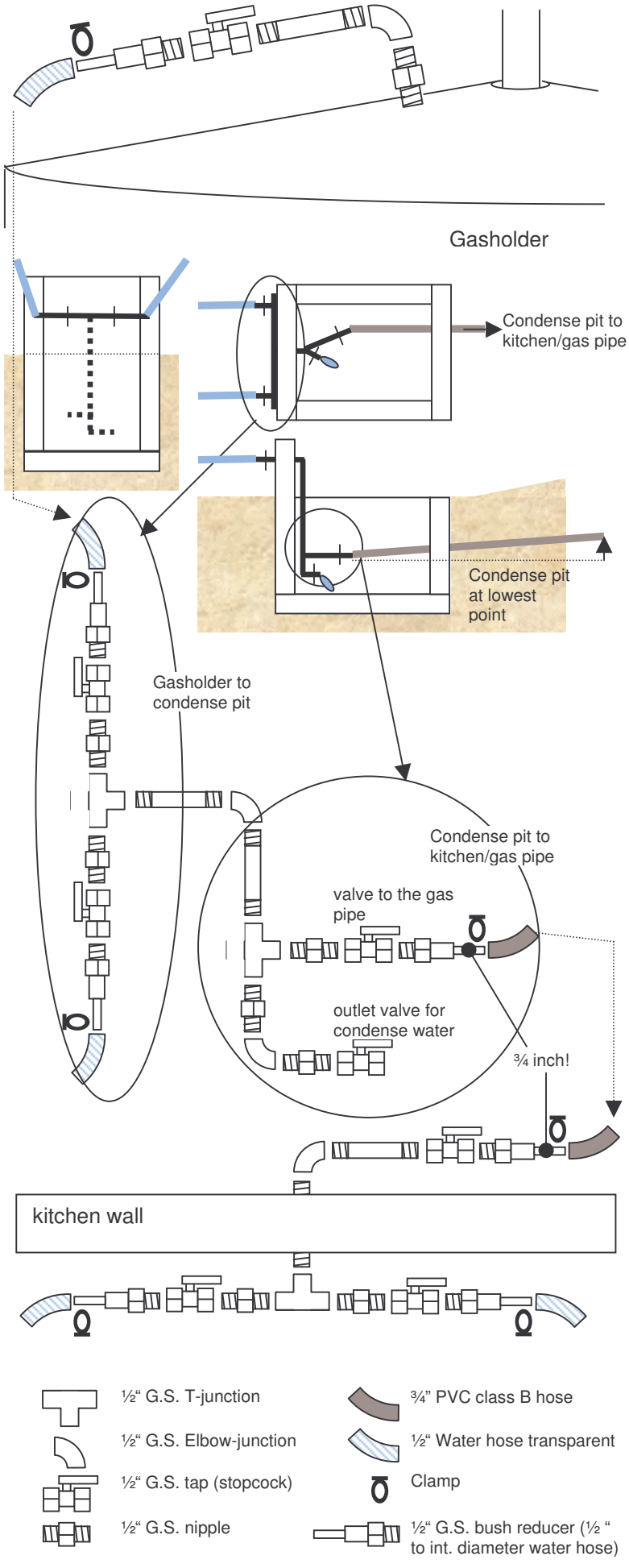
(13) Control unit / condense pit

1. Find the lowest point between the biogas unit and the place where you want to use the biogas. Dig a pit here (about 4 feet deep, 3 feet square).

2. Build a foundation with a concrete floor.

3. Build the wall facing the bio-digester above the surface, to connect hoses coming from the gasholders. Place a galvanized steel pipe in the wall to connect the hoses to taps on one side and the condense tap and gas pipe to the place of use on the other side.
The amount of taps depends on the amount of bio-digesters you want to connect now or in the future.

4. The connections, taps, bush reducers are explained in the figures.
The installation to connect a burner to the pipeline is exactly the same as that for the installation from a gasholder to the pipeline but without the inside (figure 5).
Use sealing tape to make airtight connections.



Washiriki's Guide to Biogas

Washiriki's Guide to Biogas is intended for people without building experience, but support of an equipped craftsman and credit of a third party is recommended. It explains how to plan, build and use a bio-digester to produce methane gas from organic waste. Washiriki's aim is to enable whoever is interested to learn about biogas technology.
Disclaimer: This copy has the purpose of promotion and further development. We do not accept responsibility for any damage. Feedback is welcome to: contact@washiriki.org

Part 1 – Biogas Basics

Introduces biogas technology and conditions to plan a biogas unit. Balance your energy demand and supply in terms of fuel, money and time. After finishing this part, you must be able to decide if biogas will benefit you within the period of investment.

Part 2 – Build your Biogasunit

Steps to build a floating dome bio-digester as well as a low cost tubular plastic bio-digester.

Part 3 – Improved farming (in preparation)

Provides knowledge about livestock keeping in a stable day and night (zero-grazing) and using digested manure to irrigate and fertilize a smallholding. Aim is to improve the soil and the harvest, especially to feed the livestock. This completes the cycle of feeding, collecting manure, producing biogas and fertilizer, growing food.

Part 4 – Using biogas (in preparation)

Provides basic knowledge and skills how to use biogas in appliances like burners and biogas lamps.

In cooperation with:

CHANJALE YOUTH VOCATIONAL TRAINING CENTER, Mwanga, Tanzania
The CYVTC, run by the brothers of Jesus the Good Shepherd, offers vocational training in the trades: Masonry, Carpentry, Motor vehicle mechanics, Electrical installation, Welding/Blacksmith and Tailoring. In 2003 the center has build their floating dome bio-digester, together with Rev. Jan Bosman, the students and the community. CYVTC, Box 39, Mwanga (Kilimanjaro), Tanzania. E-mail: broshepherd@yahoo.com

NANDRA ENGINEERING WORKS LTD, Moshi, Tanzania
NANDRA produces tailor made maize mills, hullers, grain storage tanks, wood burners with oven and antique garden lights. NANDRA has experience with metal gasholders and cooking pots with biogas burners. E-mail: nandra@eoltz.com

AFRICA 2000 Network Programme SURUDE SUA

The manual on the tubular plastic bio-digester is developed by the foundation for Sustainable Rural Development (SURUDE) through financial support from the Africa 2000 Network programme of UNDP. Special thanks to Sebastian V. Sarwatt and Simon Rwegyuera from Sokoine University of Agriculture in Morogoro, Tanzania, for providing the material for a demonstration unit for the Chanjale Vocational Training Center.