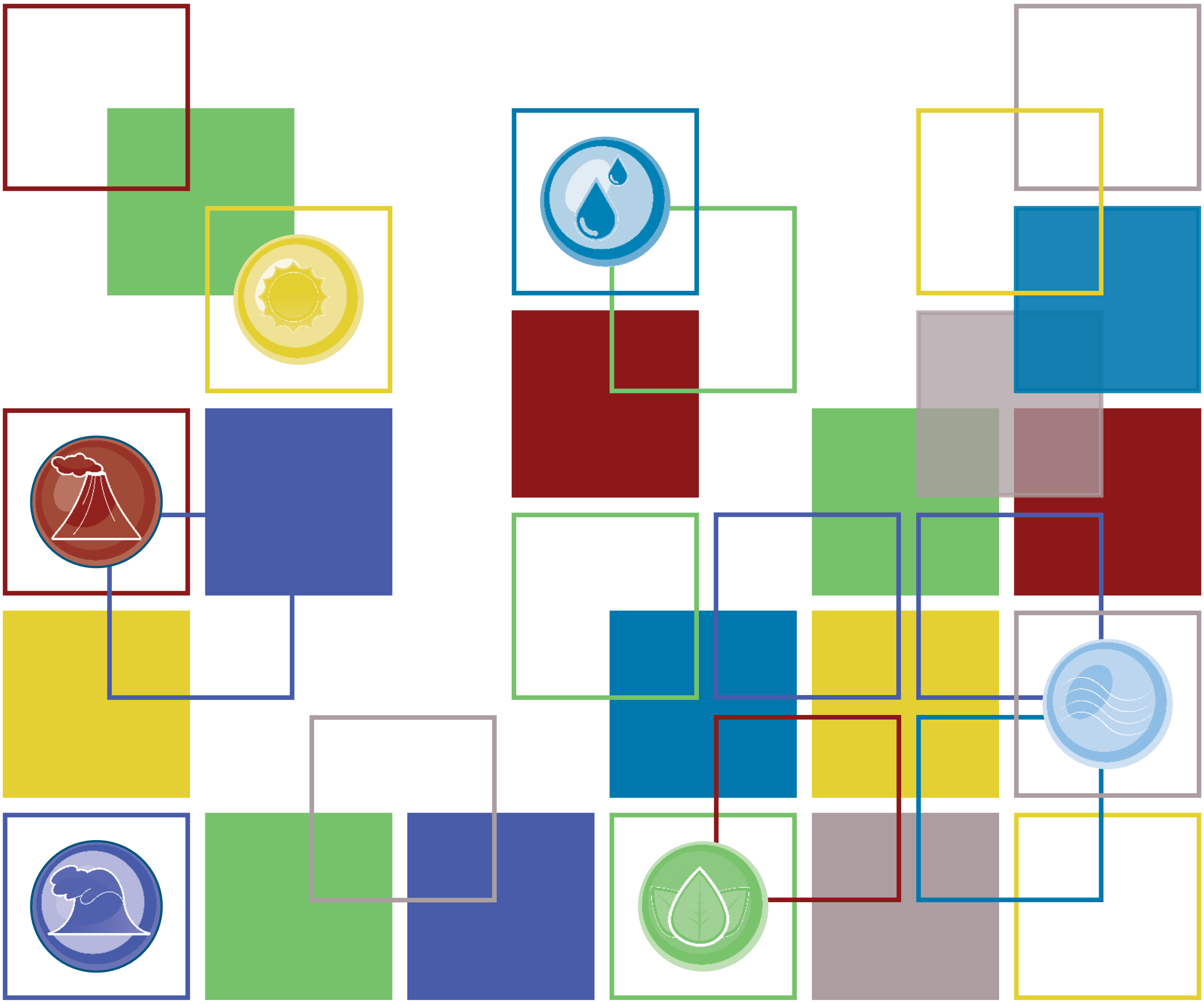
IRENA
International Renewable Energy Agency

Testing IRENA's biogas survey guidelines: Lessons learned in six countries



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About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity. www.irena.org.

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MAIN LESSONS LEARNED

Biogas surveys were implemented in six countries during 2017 to field-test a number of methodologies for collecting biogas data. The main lessons from this exercise were as follows:

- Participation: One of the major challenges was to locate existing biogas plants and persuade people to participate in the survey. Wherever possible, biogas data collection should be integrated with existing rural household surveys or, ideally, with programs to support the maintenance of biogas plants.
- Measurement: Biogas plants are frequently buried under ground and are difficult to measure. However, most are built to a limited number of models and sizes in each country. Collecting information about these standard sizes can be used to simplify measurement, by asking (and verifying) the type of biogas plant at a household rather than trying to measure every plant. This same approach can also often be used to collect data about the power rating of biogas appliances used (lights and burners).
- Age matters: The age of biogas plants in a country has a significant impact on the number of plants still operating. The relationship between age of plants and use also varies greatly, with some countries still achieving high levels of use for very old plants. This is a crucial variable that needs to be recorded to estimate biogas use.
- Daily gas production: The figures for plant sizes and appliance use (rating and number of hours per day) confirmed the commonly used assumption that daily biogas production is roughly one-third of the biodigester volume.
- Feedstocks: The amount of feedstock used in biogas digesters should be recorded in volume rather than weight and be converted to weight as part of the analysis. Volume measurement will usually involve asking about the number of bucket loads (or similar) used each day and multiplying this by the volume of the bucket.

1. INTRODUCTION

Biogas is becoming an increasingly important source of energy worldwide due to the availability of feedstocks and range of potential applications, such as: cooking; electricity generation; lighting; and transport. The gas, which is generated from the breakdown of organic materials, provides a clean alternative to fuelwood for cooking and the waste from biogas plants can also be used as fertiliser.

Governments, non-profit organisations and private companies are promoting the use of biogas digesters in areas where animal and other waste products are readily available. IRENA estimates that over 125 million people worldwide used biogas for cooking in their homes in 2017. While the majority of these users are in China and India, biogas use is also increasing in other countries.

The increased interest in biogas is also reflected in the many national and international targets that are related to biogas use. For instance, some countries have specific goals or targets for the deployment of biogas digesters as part of their renewable energy targets or Nationally Determined Contributions (NDCs) to combat climate change. Biogas can also be used to increase the proportion of the population using clean fuels and technologies, which is one of the targets of the Sustainable Development Goal for Energy (SDG 7).

Estimates of the number of people using biogas and the amount of gas produced are necessary to improve energy statistics and to monitor progress towards targets. However, the quality and availability of statistics about household biogas use are often limited due to the difficulties of data collection and some more specific problems related to the measurement or estimation of gas production and the length of time that biogas plants are used.

For example, data may be available about the number of biogas plants installed in a country over a long time period, but this alone can not be used to make an accurate estimate of current biogas production, because biogas plants are rarely used for their full design lifetime of up to 25 years. A lack of maintenance, incorrect operation or increased availability of other fuel sources can all reduce the amount of biogas production to a level below what was originally planned.

In the few cases where countries do publish data on the numbers of biogas plants installed, they often simply accumulate those figures without accounting for the decommissioning of older biogas plants or even the expected lifetime of the plants that have been built. In addition, while information about expected levels of gas production may be available, it will usually be based on assumptions about use that may not be verified by monitoring in the field.

Given the need for surveys to improve the quality of biogas data, IRENA published some guidelines for measuring small-scale biogas capacity and production in 2016.[1] In order to test the guidelines, IRENA then worked with local consultants in six countries to collect household biogas data following the methodologies proposed in the guidelines. The lessons learned from these surveys are presented here and can be used to complement the guidance given in the earlier report.

This report is structured as follows. Section 2 provides background information on biogas use in each of the six countries. Section 3 describes the experiences of the data collectors as they implemented the surveys following the IRENA guidelines. This includes a description of any challenges they encountered with specific questions suggested in the guidelines. Finally, Section 4 presents a summary of the survey results.

1 IRENA (2016), Measuring small-scale biogas capacity and production, International Renewable Energy Agency (IRENA), Abu Dhabi.

2. COUNTRY BACKGROUND

To pilot test the biogas survey guidelines, IRENA issued a call for proposals to implement small biogas surveys following the methodologies proposed in the guidelines. Countries with established and emerging biogas programmes were finally selected and surveys were implemented in 2017 in the following six countries:

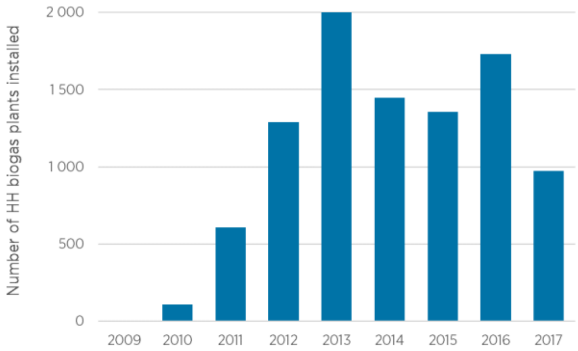
- Burkina Faso
- Cameroon
- India
- Nepal
- Rwanda
- Uganda

In total, almost 450 households were surveyed, but the selected households were not nationally representative. Instead the locations selected for the surveys were based on factors such as the availability of information from installers, known concentrations of households using biogas digesters and ease of access. Details of the locations surveyed are shown in Annex 1.

BURKINA FASO

Most household biogas plants in Burkina Faso have been installed under the Burkina Faso National Biodigester Program (PNB-BF). This programme is led by the Government of Burkina Faso with the support of the Africa Biogas Partnership Programme (ABPP), which is a partnership between the Netherlands Development Organisation (SNV) and Hivos.

Figure 1: Annual number of household biogas plants installed in Burkina Faso



The programme aimed to install 6 000 digesters during phase 1 (2010-2013) and 18 200 digesters by the end of phase 2 (2014-2019). By the end of 2017, over 9 500 plants had been built in Burkina Faso (see Figure 1).

All of the plants are of the fixed dome design, with digester volumes of 4, 6, 8 and 10 m^3. Two models have been installed: the GGC 2047 and FASO BIO 15. The GGC 2047 is a design from the Gobar Gas Company in Nepal and consists of a cylindrical pit with a concrete dome (see Figure 5). The FASO BIO 15 is similar to the GGC 2047 with the exceptions of the external shape and the inclusion of a small internal wall around one metre high that increases the hydraulic retention time by keeping the waste inside the digester for a longer period. Training is provided to local technicians on how to build the plants following the technical specifications.

Appliances used with the biogas plants include a gas burner and gas lamp supplied by the PNB-BF. In most cases the burners have been produced locally for use with LPG and are modified for biogas use. The gas lamps are imported from China.

Table 1 shows the minimum number of cows or pigs recommended by the PNB-BF for the operation of each size of digester.

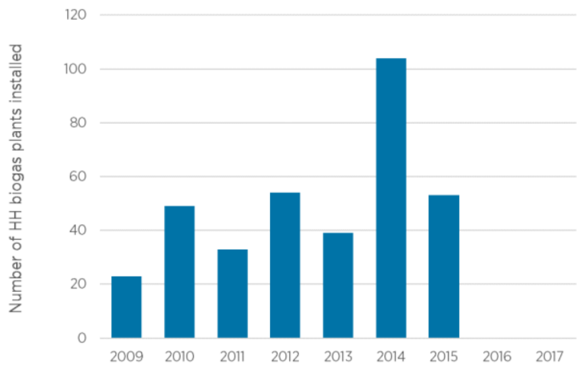
Table 1: Minimum number of animals recommended for digester operation

Animals	Digester size (m^3)			
	4	6	8	10
Cows	2	4	6	8
Pigs	4	8	12	16

Cameroon

The National Biodigester Programme in Cameroon is also supported by SNV, in collaboration with the Zoo-Sciences, Education, Empowerment and Development Group (a local NGO or Groupement d'Intérêt Economique – ZED-GIE). By the end of 2015, over 350 plants had been installed (see Figure 2).

Figure 2: Annual number of household biogas plants installed in Cameroon



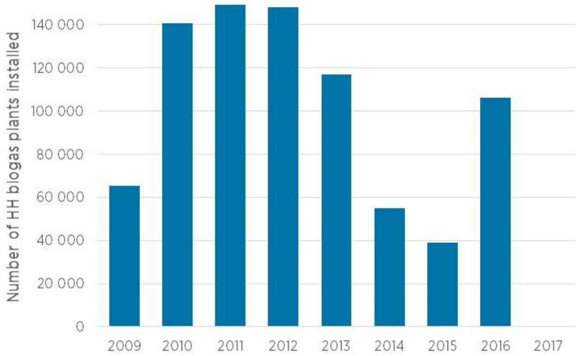
The GGC 2047 fixed dome design (see Figure 5) is most commonly used, with digester sizes ranging from 4-10 m^3 and 6 m^3 being the most popular.

Prior to the start of the National Biodigester Programme in Cameroon, there were also some private installations, including a number of floating dome plants, such as the one in Garoua Central Prison.

India

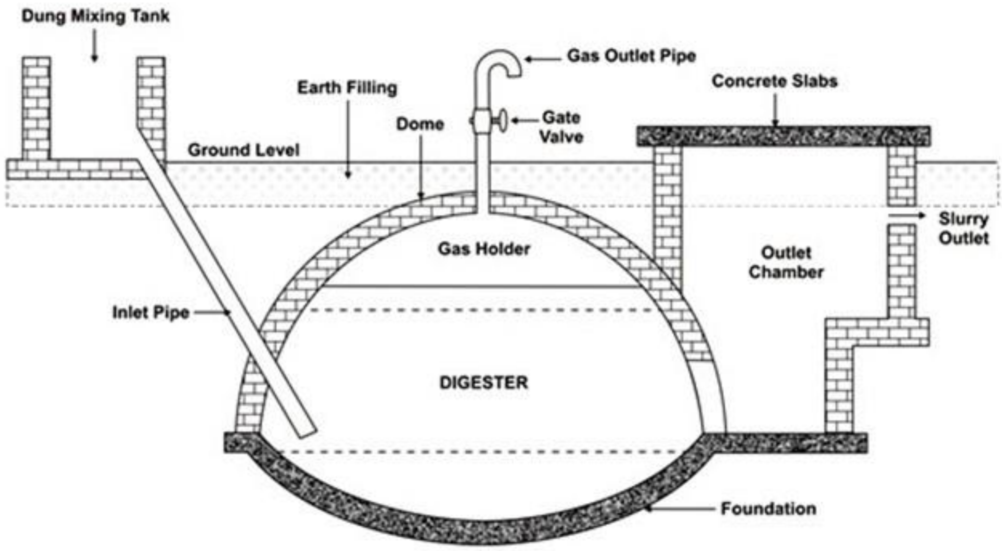
In India, the Ministry of New and Renewable Energy subsidises household biodigesters through its National Biogas and Manure Management Programme (NBMMP). By the end of 2016, over 4.9 million household plants had been built since biogas programmes were first introduced into the country in the 1980s.

Figure 3: Annual number of household biogas plants installed in India



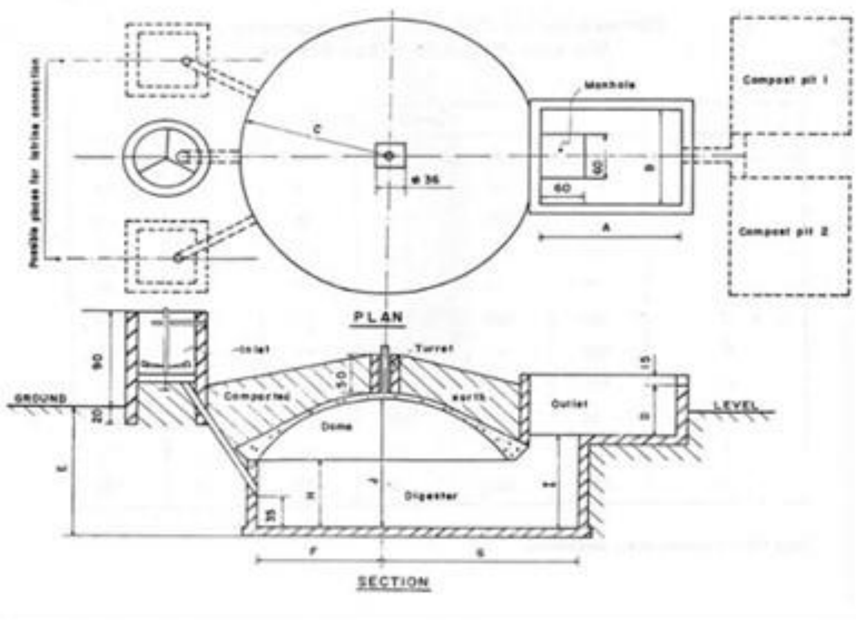
All of the plants surveyed were fixed dome Deenbandhu plants, as illustrated in Figure 4. The typical family type biogas plants ranged in size from 1 to 6 m^3. However, in the case of India, the size represents the daily gas production capacity as opposed to the digester volume.

Figure 4: Deenbandhu biogas plant layout



Source: Indian Council of Agricultural Research

Figure 5: Biogas plant GCC 2047 layout and dimensions



Components	Plant Size (m³)					
	4	6	8	10	15	20
A	140	150	170	180	248	264
B	120	120	130	125	125	176
C	135	151	170	183	205	233
D	50	60	65	68	84	86
E	154	155	172	168	180	203
F	102	122	135	154	175	199
G	195	211	230	243	265	293
H	86	92	105	94	115	115
I	112	116	127	124	132	137
J	151	160	175	171	193	203

Note : All dimensions are in centimeters.

Source: Energy Himalaya

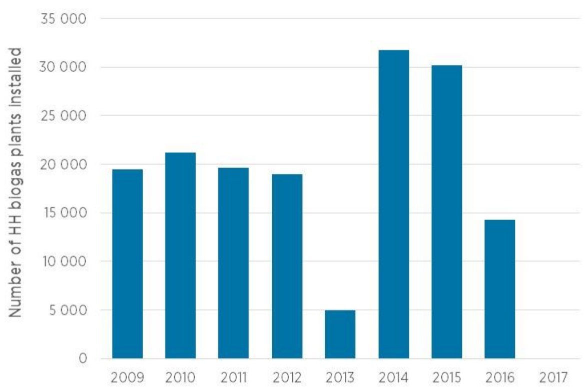
Nepal

The Alternative Energy Promotion Centre (AEPC) is the lead government institution responsible for promoting renewable energy in Nepal. Under AEPC, the National Rural and Renewable Energy Program (NRREP) certifies private biogas companies as qualified to disseminate information and install biogas plants. The origins of biogas plants encountered in this survey are shown in Table 2.

Table 2: Companies installing biogas plants in the survey area

District	Location	Installer	Sizes (m^3)
Nuwakot	Devighat	Kisan Gobargas Udhyog	6, 10
	Battar	Janabhawana Gobargas Udhyog	
Dhading	Mahadevbesi	Bhubaneshori Gobargas Company	6
Chitwan	Purbari	Janata Urja Bikash Company	6
Tanahun	Adhikari village	Pragati Bio Energy	4, 6, 8, 10
Kaski	Bhandardhik	Bageshori Gobargas Company	4, 6, 8, 10

Figure 6: Annual number of household biogas plants installed in Nepal



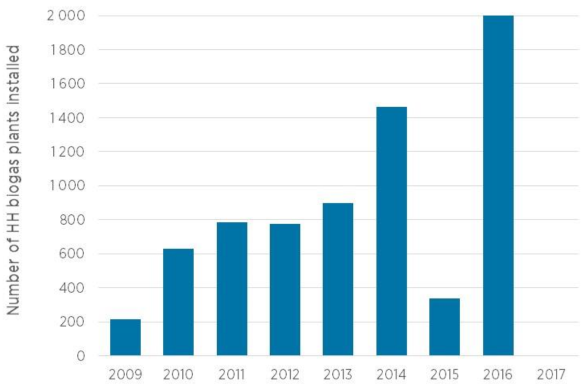
By the end of 2016 over 357,500 biogas plants had been installed in Nepal (Figure 6). Most of the plants installed in Nepal are of the fixed dome type and use a design called GGC 2047 that was developed by the Gobar Gas Company, a pioneering biogas construction company established in 1977. This model uses a cylindrical pit covered by a concrete dome. Figure 5 shows the layout and plant dimensions of the GGC 2047.

Rwanda

Biogas technology was first introduced into Rwanda in the 1980s and, from the early 2000s, the country has seen an increasing number of large-scale communal installations in prisons and schools.

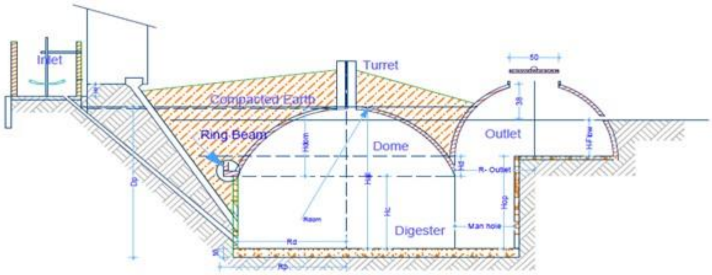
The Rwandan National Domestic Biogas Programme (NDBP) was launched in 2007, with the support of international partners such as SNV, GIZ and World Vision. Donor support ended in 2011 and the Government of Rwanda now provides subsidies for the further biogas development. By the end of 2016, over 7 300 plants had been installed in Rwanda.

Figure 7: Annual number of household biogas plants installed in Rwanda



The NDBP focuses on providing digesters to households with 2-3 cows. Most of the installed plants are locally modified versions of the GGC 2047 named RWA I, II and III and are available in sizes 4 m^3, 6 m^3, 8 m^3 and 10 m^3 (Figure 8). There are also a number of canvas digester plants (REG-EUCL), which are typically 520 cm long and 8 m^3 capacity.

Figure 8: Rwandan biogas plants (RW 1, 2 and 3) layout and dimensions



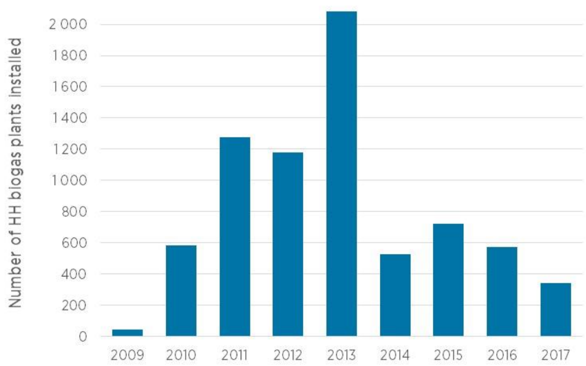
Dimensions of Different Models

Components	Symbol	RW 1&2				RW 3			
		4 m^3	6 m^3	8 m^3	10 m^3	4 m^3	6 m^3	8 m^3	10 m^3
Radius of Outlet	R_Outlet	80	90	100	110	85	95	100	110
Height of Overflow Level	H_Flow	40	49	51	54	40	44	51	54
Radius of digester	Rd	110	130	145	160	110	130	145	155
Radius of pit	Rp	140	160	165	190	140	160	175	200
Height of digester wall	Hc	80	85	90	100	80	85	90	100
Depth of pit (excavation)	Dp	175	202	228	242	165	175	185	200
Height of dome	Hdom	74	81	95	94	65	70	75	80
Curvature Radius of dome	Rdom	122	145	164	182	126	156	178	190
Inner height of digester and dome	Hall	154	166	185	194	145	155	165	175
Height of maximum slurry displacement	Hd	22	29	31	35	25	25	25	28
Height of outlet passage	Hop	102	114	121	135	105	110	115	128
Height of toilet hole from bottom of inlet	Ht	25							
Size of manhole	60x60								

UGANDA

Household biogas plants in Uganda are installed under the Uganda Domestic Biogas Programme (UDBP), which is the national implementation programme of the Africa Biogas Partnership Programme (ABPP), supported by Hivos and SNV.

Figure 9: Annual number of household biogas plants installed in Uganda



Biogas plants are installed by a private partner, Biogas Solutions Uganda (BSU) Ltd. Previous implementing organisations include Heifer Project International, CARITAS and other smaller local entities. Over 7 000 plants had been installed across Uganda by the end of 2017.

Most of the plants installed under the UDBP are fixed dome types and include the modified CAMARTEC design (MCD) adopted from Tanzania and a newer lower cost version of the MCD developed by BSU. The MCD is typically provided in four different sizes as summarised in Table 3.

Table 3: Design parameters for operation of biogas plants under the UDBP

Plant capacity (m^3)	Daily cow dung feed	Hours of gas availability		Suitable level of equipment	Suitable number of cows
		Cook	Light		
4	1.5	2	4	1 stove and lamp	1
6	2.5	4	4	1 stove and lamp	2
9	3.5	6	5	2 stoves and lamps	2-3
13	5.5	7	5	2 stoves, 3 lamps	4+

Note: A unit of cow dung feed is a 15 litre basin

3. EXPERIENCES WITH IMPLEMENTING THE SURVEY

The general challenges with implementing the survey are described below, followed by descriptions of challenges with specific parts of the survey and recommendations for improvement.

General challenges

The biogas survey teams faced quite similar challenges related to the overall implementation of the survey. These included:

- difficulties to obtain information about the locations of biogas plants;
- a reluctance of respondents to participate in the surveys;
- the dispersed nature of plants and distances between villages and accommodation;
- language barriers; and
- difficulties with measuring plants that were mostly buried underground.

One of the main challenges was the lack of readily available information about the location of households with biogas plants. In some cases, co-ordination with the official government entities or NGOs responsible for the installation of the plants was hindered by bureaucracy. To overcome these challenges, many of the enumerators relied on the assistance of a local stakeholder to identify suitable households.

In India, government records of households that had received subsidies for plants were found to be outdated and instead the survey team worked with a local person who had been involved in the installation of biogas plants. In Uganda, the enumerators used snowball (chain-referral) sampling where survey respondents would assist in identifying other households with biogas plants.

Another challenge was the reluctance of people to participate in a survey when they could see no direct benefit from doing this. Given the need for maintenance in many cases, households were hesitant to take part in a survey that was not tied to repairs.

In Nepal, for example, there had been a surge in the number of surveys in the region after the earthquake in 2015, but a lack of follow up activity had left many frustrated and wary of participating in additional surveys. Similarly, in Burkina Faso, households were cautious of strangers due to the threat of terrorism in the region.

The surveyors also faced difficulties related to the dispersed locations of households and villages, particularly in the African countries where the number of biogas plants was low.

The distance between sites in Uganda meant that a lot of time was spent travelling, resulting in a low number of interviews. Public transport was not available in Burkina Faso, making it difficult to move from one village to the next. Accommodation was also limited, leading to an increase in the distances travelled.

Language barriers also posed a challenge in some cases. In India, the enumerators found that specific local terms were used for measurement units as well as for livestock. Similarly, in Uganda, many households were only able to provide fuelwood consumption in terms of *"ekindwes"* (bundles) rather than in metric terms. In Burkina Faso, where the survey was conducted in multiple regions, the surveyors needed to change interpreters in order to translate questions into the local dialect.

Finally, given that most of the biogas plants were buried underground, it was difficult to measure their capacity. In many cases, the surveyors used the dimensions in the owner's manual rather than directly measuring the sizes of the plants.

Background information

In general, respondents were easily able to answer the background questions related to the number of people in the household and the installation year.

How many people are in your household?
(write in)

Number ________

When was the plant installed?
(write in)

Year ________

Have you used your biogas plant in the last year? *(tick one)*

Yes	☐	1
No – I stopped using it in last year	☐	2
No – I haven't used it for over a year	☐	3

In the case of Cameroon, the enumerators noted that, culturally, many people do not like to provide information on the size of their family or amount of property or livestock owned, so there could be some inaccuracies in the responses. Some households were also not sure about exactly which year their plants were installed, although in Uganda it was noted that in many cases the dates were actually indicated on the plants.

Plant details

Most households knew the size of their biogas plant, either from memory or by consulting the owner's manual. It was only in Uganda that respondents struggled to respond to the question on size. However, given that most plants were recently installed, they were able to recall the dimensions of the ditches they had dug and, from this, the surveyors were able to determine the size.

It was difficult for respondents to say whether the plant size represented the daily gas production or plant volume, but the way that plants are measured was the same in each country.

While it was usually easy to visually determine the type of biogas plant (i.e. fixed dome, floating drum, balloon, etc.), respondents often didn't know this. In most cases, the surveyors answered this question by reviewing the owner's manual or using information about the local biogas programme.

What is the size of the plant?
(write in or tick don't know)

size	☐	1
Don't know	☐	2

What does this value indicate?

Daily production (m^3 biogas/day)	☐	1
Plant volume (m^3)	☐	2

What is the information above based on?
(tick one)

Respondent knowledge	☐	1
User manual	☐	2

Indicate the type of biogas plant that is being measured. *(tick one)*

Fixed dome (hemisphere/CAMARTEC)	☐	1
Fixed dome (Deenbandhu)	☐	2
Fixed dome (Chinese design)	☐	3
Floating drum plant	☐	4
Balloon/bag digester	☐	5
Non-standard design (go to ....)	☐	6

Write in the dimensions of the biogas plant as indicated below. *(write in to the nearest cm)*

	cm	
Diameter	☐	1
Digester height (floating drum)	☐	2
Gas holder height (floating drum)	☐	3
Length (balloon/bag digester)	☐	4

If non-standard design, sketch the plant below and show the main dimensions.

In all countries, measuring the dimensions of the biogas plants was difficult, because they were usually buried underground. It was noted that the suggested method of doubling the distance from the gas pipe to the edge of the pit in order to estimate digester diameter gave unrealistic results.

Instead, the surveyors relied on a combination of the owner's manual, official information from the relevant biogas programme, details provided by installers and answers from respondents. However, respondents could only say how big their plants were in the case of recently installed plants

Given that most households were able to provide some information about plant size and that most plants are built to a few locally standardised dimensions, this part of the survey could be simplified to ask about which standard size of plant they have and its type, with an optional question for measuring and recording exact dimensions in cases where the size is unknown.

The dimensions and details of locally used designs can usually be obtained quite easily and are sufficient to estimate gas production. Furthermore, if biogas plants are built in a limited number of standard sizes that are well known to plant owners or can be easily recognised in the field, then it would be much easier to collect capacity data using a few simple categories rather than asking surveyors to try to measure exactly the dimensions of every plant.

Appliance use

Most people could easily answer the first question about the use of biogas lamps. Their main difficulty was to answer the question about the power rating of their lamp(s). In most cases, respondents were not able to answer this question, but this information was sometimes indicated on the lamp.

Most people could also easily answer the question about the average number of hours that the lamps were used each day, but there were some cases where people had electricity and only used their lamps during power outages.

Similarly, for biogas stoves, many respondents were unsure of their stove's power rating. In some cases, respondents also struggled to answer the question about the average number of hours each burner was used, due to variations in use (e.g. during school holidays).

To improve this section, surveys could ask about the sources or brands of appliances used by households, because stoves and lamps have often been distributed as part of a support programme or bought from a limited number of suppliers. Thus, the specifications of these appliances could be obtained from other sources and combined with simpler questions about the types of appliances used.

Do you use any biogas lamps? *(tick one)*

Yes 1
No (go to ....) 2

What is the average power rating of each lamp? *(tick don't know or write in number in litres/hour or watts)*

Don't know 1
Gas use in litres/hour 2
Power in watts 3

On average, how many hours per day do you use each lamp? *(write in no. of hours)*

hrs/day
Gas lamp 1 1
Gas lamp 2 2
Gas lamp 3 3

What is the power rating of each burner on your biogas stove? *(tick don't know or write in number in litres/hour or kilo-watts)*

Don't know 1
Gas use in litres/hour 2
Power in kilo-watts (kW) 3

Was this stove originally manufactured for use with biogas?

Yes 1
No (modified stove) 2

On average, how many hours per day do you use each burner for cooking and boiling water? *(write in no. of hours)*

hrs/day
Burner 1
Burner 2
Burner 3
Burner 4

Do you also burn excess biogas? *(tick one)*

Yes 1
No (go to ....) 2

On average, how many hours per day do you use each burner to burn excess biogas? *(write in no. of hours)*

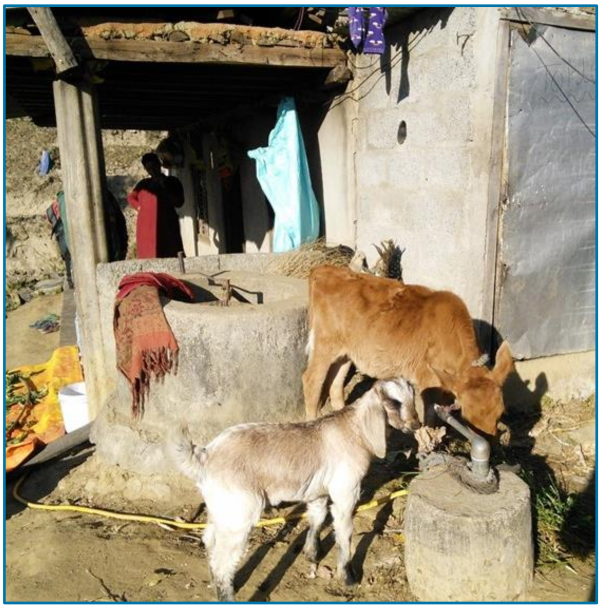
hrs/day
Burner 1
Burner 2
Burner 3
Burner 4

Feedstock use

In most cases, respondents were easily able to answer the questions about the main feed types and numbers of animals providing waste for the biogas digester. However, the surveyors in Cameroon noted that households were hesitant in some cases to provide exact information about their livestock and property ownership.

The main difficulty was the question about the weight of feedstock used. Very few respondents were able to answer this directly and surveyors often had to estimate these values based on the size of the container used to feed the digester.

To reduce measurement errors and make it easier to answer, this question should ask about of number of buckets or basins added daily and the volume of these containers. The conversion from volume to weight can then be done during the analysis, using the average density of each feedstock.



What is the main type of waste that this plant is designed to use? *(tick one or write in)*

Cattle	☐	1
Poultry	☐	2
Plant/food	☐	3
Don't know	☐	4
Other *(write in below)*	☐	5

Specify: ______________________________

Do you feed the digester with waste from any of the following animals? *(write in no. of animals providing waste for digester)*

	No.	
Buffalo		1
Cows		2
Calves		3
Sheep/goats		4
Pigs		5
Hens		6
Horses		7
Humans		8
Other (write in below)		9

Specify: ______________________________

How much of the following types of waste do you usually add to the digester each day? *(write in amount in kg)*

	Kg/day	
Cereals/grains		1
Rice straw		2
Wheat straw		3
Grass		4
Corn stalk		5
Fruit waste		6
Vegetable waste		7
Fats		8
Mixed food waste		9
Mixed organic waste		10
Other (write in below)		11

Specify: ______________________________

When you feed the digester, how much water do you add compared to the amount of waste? *(tick one, check that this includes the water added to animal wastes)*

Half as much water	☐	1
An equal amount of water	☐	2
Twice as much water	☐	3
Three times as much water	☐	4
Over three times as much water	☐	5
Don't know	☐	6

Fuel use

Where households purchased fuel, estimating the amount used each month was relatively easy. The main challenge was the estimation of fuelwood use when this was collected rather than purchased. This is because households were less likely to remember or be able to estimate how much was used.

Fuelwood measurement could be improved by having surveyors weigh a typical bundle of fuelwood and ask households how long it would last.

In addition, the amount of other fuels used varied depending on whether or not the plant was producing sufficient biogas. Here, the question could be improved by asking how much of each fuel is used when the plant is functioning at full capacity and adding a follow up question on how often the plant is not functioning.

How much of the following types of fuel do you currently use for cooking each month? *(write in amount in kg or litres)*

Fuelwood		Kg/month	1
Charcoal		Kg/month	2
Kerosene		Litre/month	3
Bottled gas (LPG)		Litre/month	4

How much of the following types of fuel did you use for cooking each month prior to switching to biogas? *(write in amount in kg or litres)*

Fuelwood		Kg/month	1
Charcoal		Kg/month	2
Kerosene		Litre/month	3
Bottled gas (LPG)		Litre/month	4

4. SUMMARY OF SURVEY RESULTS

A summary of some of the survey results is given below. Although the surveys were small and mostly intended to test the survey methodologies, these results highlight the importance of some factors (such as plant age) in the estimation of biogas use.

HOUSEHOLD SIZE

The average size of households using biogas varied from 4.8 in Nepal to 8.7 in Burkina Faso.

Table 4: Average size of households using biogas

Country	Average household size (people per household)
Burkina Faso	8.7
Cameroon	8.3
India	6.8
Nepal	4.8
Rwanda	6.1
Uganda	7.2

YEAR OF INSTALLATION

The ages of biogas plants recorded in the survey partly reflect the maturity of biogas programmes in the different countries. In Burkina Faso, Cameroon, Rwanda and Uganda, most of the plants were installed in the last seven years, whereas in India and Nepal some of the plants were over 20 years old.

Table 5: Years of installation

Country	Installation year
Burkina Faso	2010-2017
Cameroon	2010-2015 (+1 in 1997)
India	1995-2014
Nepal	1989-2016
Rwanda	2011-2016
Uganda	2008-2014

USE OF BIOGAS PLANTS

Households were asked whether they had used their biogas plant in the last year. In total, around 74% of the plants were used in the last year, although this figure varied greatly by country.

Rwanda, Uganda and Nepal all had a high rate of recent use. In the case of Rwanda and Uganda, their biogas programmes are relatively new, so this might be expected. However, high levels of use in Nepal were reported across a broad range of plant ages.

Table 6: Current use of biogas plants

Country	Share of households using their biogas plant in the last year (%)		
	Yes	Not in last year	Not in over a year
Burkina Faso	58	23	19
Cameroon	63	20	17
India	61	17	22
Nepal	94	2	4
Rwanda	93	5	2
Uganda	93	4	

In Burkina Faso and Cameroon, most of the plants were also installed in recent years, but more than one-third were not used in the last year. India also had a relatively low proportion of plants used in the last year, although some much older plants were included in the sample there. Additional questions in a biogas survey could explore the reasons why some plants are not currently used.

Figure 10: Biogas plant use by age of plant

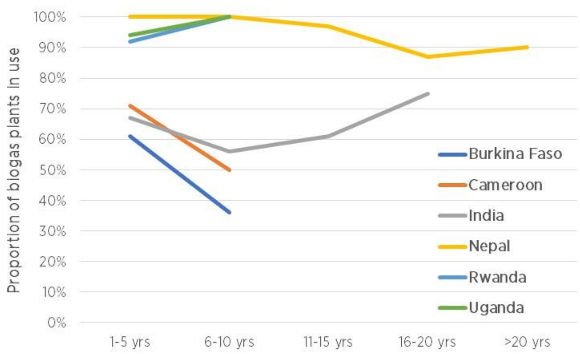


Figure 10 and Table 7 provide more details about the proportion of biogas plants still used in countries across different ages of biogas plants. The data shows how most biogas plants in Nepal are still used even if they are very old. In India, the use of biogas plants does not decrease as plants become older, as might be expected. Anecdotal evidence suggested that this was due to increased availability of LPG in some places where biogas plants had been recently built.

The data also clearly shows differences in African countries, where biogas plant usage has remained high in Rwanda and Uganda, but fallen rapidly in Cameroon and Burkina Faso.

Table 7: Biogas plant use by age of plant

Age of plant	Use	Burkina Faso	Cameroon	India	Nepal	Rwanda	Uganda	**Total**
1-5 years	In use %	61	71	67	100	92	94	**76**
	Not in use %	39	29	33	0	8	6	**24**
	No. of plants	*90*	*31*	*9*	*17*	*37*	*32*	***216***
6-10 years	In use %	36	50	56	100	100	100	**65**
	Not in use %	64	50	44	0	0	0	**35**
	No. of plants	*14*	*14*	*27*	*9*	*4*	*11*	***79***
11-15 years	In use %			61	97			**74**
	Not in use %			39	3			**26**
	No. of plants			*54*	*31*			***85***
16-20 years	In use %			75	87			**81**
	Not in use %			25	13			**19**
	No. of plants			*12*	*23*			***36***
21+ years	In use %				90			**86**
	Not in use %				10			**14**
	No. of plants				*21*			***22***
Total	**In use %**	**58**	**63**	**61**	**94**	**93**	**95**	**74**
	Not in use %	**42**	**37**	**39**	**6**	**7**	**5**	**26**
	No. of plants	***104***	***46***	***103***	***101***	***41***	***43***	***438***

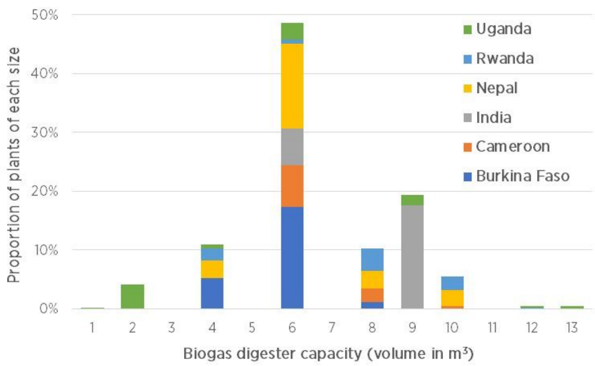
PLANT SIZE

Overall, the most frequently observed plant size (capacity) was 6 m^3. India was the one country where much smaller sizes where recorded, but this is because the definition of plant capacity there refers to the expected daily level of gas production (not the volume of the digester). Considering that the daily production level is usually about one-third of the true capacity, this suggests that most of the biogas plants there were 6-9 m^3 in volume, which is towards the higher end of the range of sizes recorded in the surveys.

Table 8: Average plant size recorded in the surveys

Country	Average plant size
Burkina Faso	5.7 m^3
Cameroon	6.7 m^3
India	2.7 m^3/day
Nepal	6.5 m^3
Rwanda	7.6 m^3
Uganda	5.2 m^3

Figure 11: Distribution of plant sizes (volumes)



Note: India data converted to true capacity (multiplied by 3)

Given that most digesters are buried underground, a major concern was that many households would not know the size of their digester. However, the data collectors could collect this information based either on the respondent's knowledge (in 41% of interviews) or by consulting their user's manual (56% of interviews). Information about digester size could not be collected in only 3% of cases.

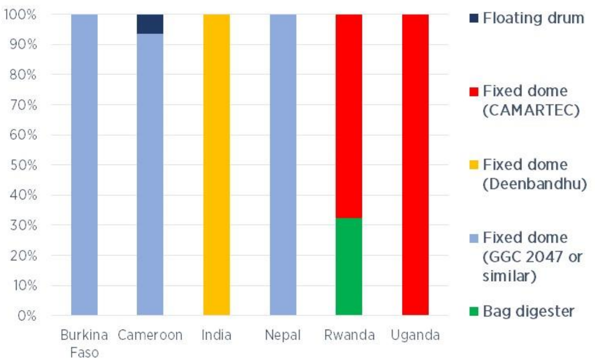
Plant type

The Gobar Gas Company 2047 (GGC 2047) fixed dome plant was used not only in its country of origin, Nepal, but also in Burkina Faso and Cameroon. In Burkina Faso, a local variation of the GGC 2047 called the BioFaso is also used and, in Cameroon, around 7% of plants were floating drum types.

The modified CAMARTAC, based on a Tanzanian design, was popular in the East African countries and almost one-third of plants in Rwanda were bag digesters.

In India, all of the plants were Deenbandhu fixed dome plants.

Figure 12: Plant types used in each country



Appliance use

Biogas lamps

In total, just over 20% of households were using biogas lamps. These households were mostly in Burkina Faso and Uganda. In India, the provision of biogas lamps in the survey area was discontinued in 2002 and the number of households still using them was low.

Table 9: Proportion of households using biogas lamps

Country	Propotion using lamps
Burkina Faso	63%
Cameroon	none
India	4%
Nepal	none
Rwanda	5%
Uganda	47%

Households were also asked about the power rating of each lamp. Around half of the households using biogas lamps were able to provide the power rating in Watts, a quarter knew the biogas use in litres per hour and the remaining quarter were unable to provide any information on the rating. The average figures provided were 65 W and 72 litres per hour.

All households (except one) had only one lamp, which was used on average for four hours per day.

Biogas stoves

Respondents were asked about the power rating of each burner on their biogas stove. Almost two-thirds (62%) did not know this information, 12% gave a value in kW and 27% in litres per hour. The most frequent answers were 4.3 kW and 500 litres per hour.

In India, Nepal, Rwanda and Uganda, all of the stoves were manufactured specifically for use with biogas. In Cameroon around 9% of the stoves were gas stoves modified to work with biogas and in Burkina Faso all of the stoves were modified.

Table 10: Proportion of households using one or more biogas burners in their stoves

Country	Number of burners used	
	1	2+
Burkina Faso	100%	0%
Cameroon	35%	65%
India	57%	43%
Nepal	90%	10%
Rwanda	85%	15%
Uganda	98%	2%

Households used their biogas stoves for an average of 3.56 hours per day. While most households (77%) only used one burner, around 23% used two or more. Only 3% of households produced excess biogas, which they removed from their biogas plant using the burner for an average of 1.4 hours a day.

Based on the average ratings of biogas lamps and stoves and average use (in hours), households consumed about 2 m^3 of biogas per day on average. Considering that the average digester size was about 6 m^3, this is in line with the commonly used assumption for fixed dome digesters that daily biogas production is about one-third of the total plant volume.

Feedstock use

In 94% of the households, the plants were designed primarily for use with cattle waste. Notably, none of the plants were designed specifically for the use of plant or kitchen waste.

In practice, many households used waste from multiple sources. Most of the households in Burkina Faso fed the digester with waste from cows (85%) and also pigs (33%). In Cameroon 93% of households used cow waste and 98% also added other types of waste including fats and vegetable waste.

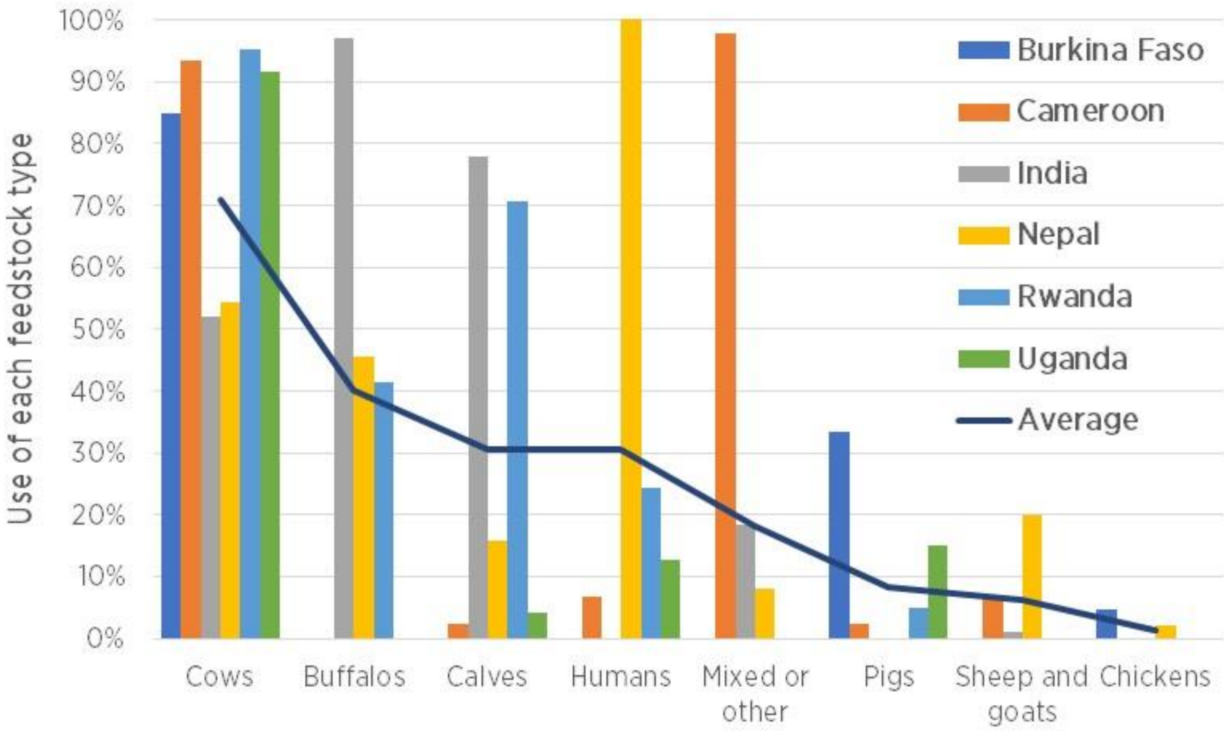
In India, most of the waste came from cattle, including buffalos (97%), cows (52%) and calves (78%). In Nepal, all of the digesters were designed to use human waste as well as waste from animals.

In Rwanda, in addition to waste from cattle and pigs, around a third of the plants also used human waste. In Uganda 91% of the plants used waste from cows and 15% also used pig waste.

The relative importance of each of the different waste sources used in the biogas digesters measured in the survey is shown in Figure 13.

Almost 80% of households followed the standard recommendation to mix equal amounts of waste and water in their biogas digesters. However, a large proportion of households added excess water in India (43%) and Uganda (42%).

Figure 13: Proportion of households using each type of waste in their biogas digesters



ANNEX 1: SURVEY LOCATIONS

Burkina Faso	
Region	**Villages**
Plateau Central (PC)/Ouagadougou	Gonse, Koubri, Gampela, Tanghin-Dassouri
Boucle du Mouhoun (BM)/Dédougou	Fara, Safane, Sabou Centre
Centre Ouest (CO)/Koudougou	Sylli, Bougnougnou, Cassou, Bakata
Sahel (S)/Dori	Dori, Djika, Lerbou, Gorgadji, Arbindo, Toukabayel, Djomga, Ocosambo, Lamdamol

Cameroon	
Region	**Villages**
Far North Region	Kaélé, Maroua, Yagoua
North Region	Garoua, Figuil
Adamaoua	Tibati, Ngaoundéré

India		
Region	**District**	**Villages**
Rajasthan	Sawai Madhopur	Ranthambore

Nepal		
District	**Municipality**	**Villages**
Nuwakot	Bidur Municipality	Battar, Devighat
Dhading	Thakre VDC	Mahadevbesi
Chitwan	Bhandara VDC	Purbari
Tanahun	Jamune Bhanjyang VDC	Adhikari
Kaski	Lekhnath Municipality	Bhandardhik

Rwanda		
Province	**District**	**Sector**
Eastern	Nyagatare	Rwempasha, Matimba, Karangazi
Northern	Gicumbi	Rubaya, Manyagiro, Nyankenke, Maya

Uganda		
District	**Subcounty**	**Parish/village**
Eastern	Nyagatare	Rwempasha, Matimba, Karangazi
Mpigi	Buwama	Mitala Maria, Magari, Jjalamba, Buwere, Nsangwa, Sango, Mugulu
	Mpigi TC	Mpigi Town Centre
	Mpigi	Mayembe, Nsamu, Kasamu
	Kituntu	Kitigi, Katiko
	Nkozi	Muge, Nabyewanga, Kitosi, Kikutuzi, Busesse
	Muduma	Busanyi, Mutumba
	Kamengo	Kiswabi, Buwe-butooro, Buweya, Kiwumu A, Koliseta
Butambala	Bulo	Ndeese, Trading Centre

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