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DOMESTIC BIOGAS DEVELOPMENT IN DEVELOPING COUNTRIES

JULY 2013

A methodological guide for domestic biogas project holders in the early stages of setting up projects in developing countries

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1 Introduction

1.1 Context

Communities that rely mostly on agriculture and livestock farming in developing countries can face strong pressure related to:

- **Energy access:** for instance, in Africa, it is estimated that 68% of the population[1] live without clean cooking facilities [1]. Energy access plays a key role in poverty alleviation.
- **Resources depletion:** if a household uses firewood for cooking purposes, forests depletion in some areas makes firewood collection tougher.
- **Climate change mitigation:** agriculture (*i.e.* the production of crop and livestock products) accounts for 13.5%[2] of the global GHG emissions [2], and extensive systems are sometimes blamed for being less efficient than intensive ones when it comes to climate change mitigation (given that the later involve lower direct emissions per kg of product).

In this context, access to clean and sustainable energy through **domestic biogas production** can help rural communities alleviate current pressures on the environment.

In an urban context, domestic biogas in developing countries is also considered as a means for improving hygiene conditions (especially when it comes to public washrooms issues). This report only focuses on domestic biogas development within the frame of small scale agriculture and livestock production (*i.e.* in rural areas).

1.2 Objectives

The main objective of this document is to provide domestic biogas project developers with relevant information on the key issues to have in mind regarding national integration of such projects[3].

This document gives a general presentation of domestic biogas and its main environmental, social and economic benefits. It also browses the main aspects one should have in mind (checklist) in order to assess local risks and opportunities for domestic biogas development.

[1] International Energy Agency (IEA), 2010 data
[2] IPPC official figures for anthropogenic GHG emissions in 2004
[3] This document has been written after *ENEA Consulting* achieved a field mission in Rwanda on domestic biogas development, in partnership with the NGO *Vétérinaires Sans Frontières – Belgium*

2 Domestic biogas presentation

2.1 Value chain

2.1.1 General presentation

Biogas

Biogas is a gas produced through the digestion of organic materials in anaerobic conditions by specific bacteria, called methanogenic bacteria, or methanogens. Typical biogas composition is presented in the table below:

Component	Molar %
CH_4	45 to 65
CO_2	25 to 45
H_2O	2 to 7
O_2	Traces
H_2S	Traces
Cl	Traces
F	Traces

Table 1 Typical biogas composition

Biogas is mainly composed of methane (CH_4), and is thus a flammable gas. It can therefore be used as a fuel for heating, cooking and lighting. Biogas can also be used to feed engines to produce electricity.

The heating value of biogas – the amount of heat released during the biogas combustion – is approximately 6 kWh/Sm^3. In other words, the combustion of 1 standard m^3 of biogas produces the equivalent of 6 kWh of heat. For information, the following table compares the equivalence between biogas and other possible fuels in terms of heating value:

Fuel	Unit	Value
Charcoal	[kg/Sm^3 of biogas]	0.7
Firewood	[kg/Sm^3 of biogas]	1.3
Gasoline	[liter/Sm^3 of biogas]	0.75

Table 2 Equivalence between biogas and other fuels in terms of heating value [3]

It must be noted that the actual fuel consumption also depends on the fuel utilisation efficiency, such as cooking stoves efficiencies. The following table summarizes typical efficiencies for the possible uses of biogas:

Biogas use	Efficiency
Heaters	88%
Stoves	55%
Engines	24%
Lamps	3%

Table 3 Typical efficiencies for devices using biogas [4]

Bio-digester

The digestion process – or methanisation – is performed in a physical structure called digester or bio-digester. The main purpose of the digester is to provide the anaerobic condition required for the digestion of organic materials by methanogens. The bio-digester mainly consists in a water and air tight chamber. There are different types of bio-digesters characterised by their shapes, sizes and construction materials. The main types of bio-digesters for domestic biogas are described in paragraph 2.2.

The methanogenic bacteria required to perform the anaerobic digestion are generally present in the organic materials that feed the bio-digester. As a consequence, the methanisation is automatically performed without additional feed requirement, as long as the anaerobic condition is respected.

Bio-slurry

Besides biogas, the methanisation process produces an effluent: the bio-slurry. This by-product results from the digestion of the organic materials. It mainly consists in a mix of digested matter and water, with a high concentration of mineral substances and nutrients such as nitrogen (N), phosphorous (P), potassium (K) and magnesium (Mg).

As a consequence, the bio-slurry has valuable fertilising properties and is particularly interesting in a predominantly agricultural context. Several studies have been performed regarding the benefits of bio-slurry compared to traditional fertilisers such as manure and inorganic fertilisers. In Ethiopia, yield increases of 64% (wheat) to 72% (barley) after applying bio-slurry compost were reported [5]. In Rwanda, best performances were observed with bio-slurry combined to inorganic fertilisers, enabling yields to increase by 314.5% (irish potato in KARONGI District) [6]. In Asia, SNV has observed yield increases between 11% and 48% on vegetable crops such as cabbage, cauliflower and tomato [7].

2.1.2 Potential impacts

The dissemination of biogas plants has various environmental, social and economic benefits.

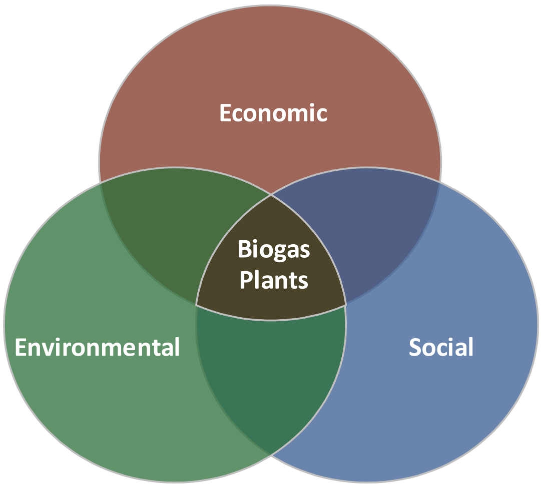

Figure 1 Domestic biogas plants: a triple win

Environmental impacts

- Reduction of the biomass resource depletion

Biogas plants can help tackle deforestation, especially in a context where households mainly use firewood or charcoal for cooking and heating. Indeed, an extensive use of firewood or charcoal may result in an unsustainable situation where the wood demand exceeds the sustainable wood production.

- Reduction of Green House Gases (GHG) emissions

The use of unsustainable wood for heating or cooking results in positive GHG emissions, whereas the use of biogas is generally neutral with regards to GHG emissions (provided that organic materials used to feed the bio-digester are renewable and that there is no methane leakage from the plant).

As a consequence, in a country where wood production is non-sustainable, biogas plants can displace the use of firewood or charcoal, resulting in a reduction of GHG emissions.

Social Impacts

- Quality of life

Biogas plants help improve beneficiaries' quality of life. First, they reduce the workload usually required for typical tasks such as firewood collection and fire tending. In addition, cooking with biogas stoves is more convenient and faster than with firewood or charcoal stoves.

Moreover, biogas is much cleaner than firewood or charcoal. Indeed, cooking with firewood or charcoal usually results in the production of soot which usually soils the kitchen and cooking utensils.

- Gender equality

Improved gender equality is a direct consequence of the previous point, since women are predominantly involved in the housework. Thanks to the reduction of their workload, women can spend more time on other activities and on education, hence a reduction of gender disparities.

- Health and sanitation

Indoor smoke pollution related to the use of firewood or charcoal may induce health risks such as respiratory diseases (no particulate matter emission unlike firewood or charcoal). In addition, bio-digesters reduce the pathogen content of organic materials. The sanitary condition of the household can consequently be enhanced thanks to domestic biogas units.

- Education

The installation of a biogas lamp can enable children to study later in the evening. Indeed, the lighting quality of biogas lamps is generally better than traditional lighting methods (e.g. kerosene lamps). Children that have access to a proper lighting can study up to 2 hours more per evening than children with poor lighting conditions.

- Food security

The use of bio-slurry as a fertiliser improves crop yields compared to traditional manure. It consequently contributes to food security for beneficiaries and the community in general.

Economic impacts

- Economic impacts for beneficiaries

By displacing the use of firewood or charcoal, biogas can help to reduce households' energy expenses. In addition, the increase of crop yield related to the use of the bio-slurry as a fertiliser can result in higher incomes for farmers. Properly used, bio-slurry can improve crop yield by 10% to 50% or more, compared to traditional fertilisers (e.g. compost) [8].

- Economic impacts for the community

The diffusion of biogas plants stimulates the national economy. Indeed, a large dissemination of biogas units results in job creation in the construction sector, or for specific training of masons or plumbers.

Note

Proper impacts studies have to be performed in order to assess the genuine social, environmental and economic benefits of domestic biogas on households. These studies can be carried out though survey campaigns on an appropriate sample of potential and actual domestic biogas users.

When assessing the potential impacts of a specific project, it is crucial to carry an analysis over the whole value chain of biogas production (approach similar to "life cycle analysis"[4]). This includes potential negative impacts resulting from farmers' decisions of implementing a digester: for instance, water availability must be taken into account to avoid conflicts (the organic waste must usually be diluted with water); similarly, biogas development policies can be blamed for increasing GHG emissions, if they encourage more people to switch from crop farming to livestock farming.

[4] *ENEA Consulting*'s partner, *Vétérinaires Sans Frontières Belgium* has decided to give priority to such holistic approaches when assessing the impacts of its activities, in order to set up a sustainable strategy for the next decades.

2.2 Technologies

2.2.1 Possible technologies for domestic biogas

As mentioned in paragraph 2.1.1, there are different types of bio-digesters with various shapes, sizes and construction materials. The most common technologies for domestic biogas – biogas production at a household scale – are presented hereafter:

- Plastic Tube Digester or Polyethylene Tube Digester (PTD): This technology has been particularly pushed by GTZ in South America, and more specifically in Bolivia. The main advantage of this technology is that the main material used for the digester – polyethylene – is relatively inexpensive. But on the other hand, polyethylene can be easily damaged. The technology lifespan is thus potentially short, depending on how careful the user is. This technology requires a specific training of users for the digester installation and operation.

- Plastic tank digester: This technology is mainly composed of two pre-built rigid plastic tanks: a first tank for the digestion of organic materials, and a second tank for the storage of the biogas that is produced. This technology is thus rather easy to install. The tanks are usually not underground, hence potentially damageable. This digester is derived from water tank technologies. Typical volumes are 1.8 m^3 for the digester tank and 1.5 m^3 for the gas storage tank. A lifespan of 20 years can consequently be expected by analogy with water tanks. However, it must be noted that the number of plastic tanks digesters currently installed is very low [9].

- Technologies based on the Fixed Dome model: This family of bio-digesters has been widely and successfully used in Asia, one of the most famous being in Nepal where more than 250,000 plants have been installed in 20 years [10]. It is thus the domestic biogas technology with the highest number of references. Fixed dome plants require specialised construction companies. Employment creation is therefore a side benefit of the dissemination of this type of technology. Typical domestic digester volumes generally range from 4 m^3 to 10 m^3.

- Floating drum digester: This technology was first introduced in India in the 50's. It is made of two chambers: the digester pit is located underground, and the generated biogas flows up to a reverse drum (made of steel, also called gasholder), that is floating (thus moving) over the fermenting slurry, or in a separate water tank. Since the drum can move, the gas pressure inside is constant, and its level aboveground indicates the amount of gas that is available. Such designs have been widely used in the past especially in India, but are considered as obsolete nowadays, compared to fixed dome models (due to a shorter lifespan and more maintenance requirements) [11].

Merits and demerits of these three technologies are summarised in the table below:

Technology	Pros	Cons
Plastic tube digester	▪ Inexpensive technology: Between € 100 and € 150 (USD 130-200)	▪ Very damageable ▪ Short lifespan: 4 years max. ▪ Relatively few successful installations ▪ Not very easy to operate ▪ Dismantling and recycling of the unit
Plastic tank digester	▪ Easy installation ▪ Quick biogas production start-up after installation (3-4 days) ▪ Small digester tank volume, therefore appropriate for limited livestock	▪ Expensive technology Approximately € 740 (USD 960) for the 1.8 m3 model ▪ Potentially damageable (not underground) ▪ Small digester volume available, hence low biogas production ▪ No employment creation ▪ Few existing installations, hence little feedback ▪ Dismantling and recycling of the unit
Fixed dome technology (Analysis based on the Rwanda design, see Box 1)	▪ Long lifespan: more than 20 years ▪ Not damageable (underground) ▪ Many references (e.g. 2,700 units in Rwanda, 250,000 units in Nepal for other fixed dome technologies) ▪ Easy to operate ▪ Job creation	▪ Expensive technology Between € 670 and € 1150 (USD 870-1500) ▪ Potentially long durations before the start-up of the biogas production
Floating drum digester	▪ Provides constant gas pressure at outlet ▪ Visual indication (floating gasholder level above the pit) of the amount of available gas	▪ Very expensive compared to fixed dome digesters ▪ Steel drum (gasholder) is subject to corrosion ▪ Lower lifespan than fixed dome technology

Table 4 Pros and Cons of 3 different types of domestic biogas plants

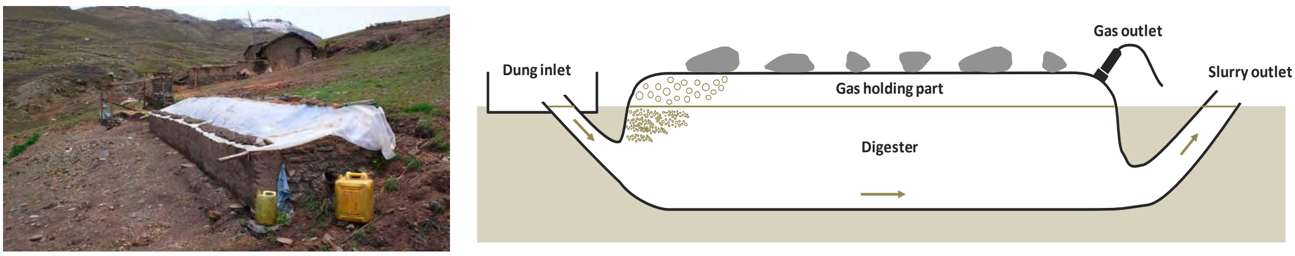

Figure 2 Plastic tube technology [3]

Figure 3 Plastic tank digester [9]

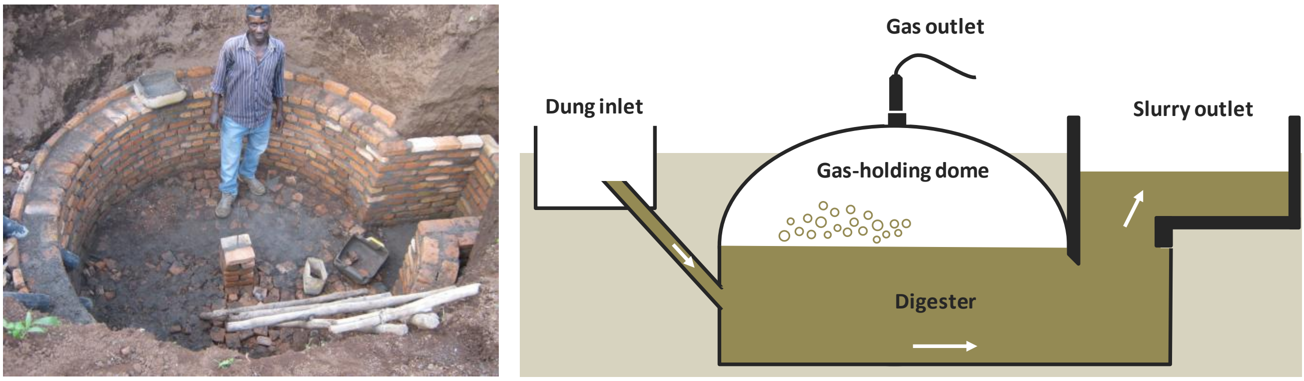

Figure 4 Fixed dome based technology

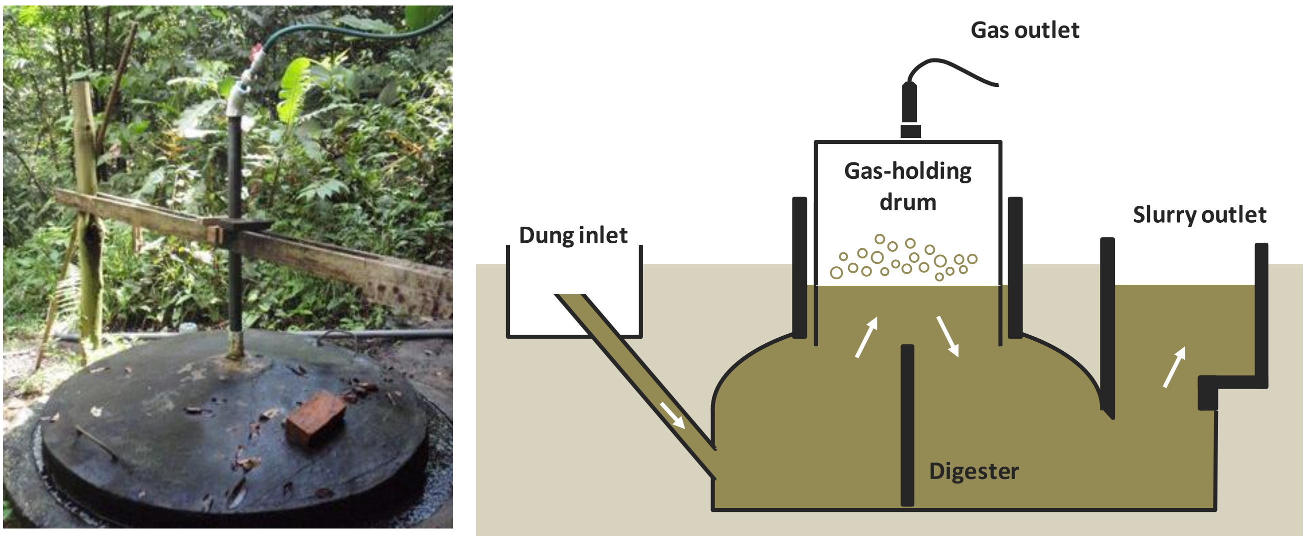

Figure 5 Floating drum technology [11][12]

2.2.2 Digester sizing

The sizing of biogas plants mainly consists in the definition of the bio-digester volume. The main parameters for the design of a bio-digester are listed in the table below:

Parameter	Symbol	Comment
Organic waste quantity	V_{Waste}	▪ It corresponds to the quantity of organic waste that feeds the digester generally on a daily basis. ▪ The biogas production mainly depends on the composition and quantity of organic waste that is sent to the digester. ▪ Typical organic wastes for domestic biogas are animal dung and human faeces
Water quantity	V_{Water}	▪ The organic waste must usually be diluted with water before entering the digester. ▪ It must be noted that urine can be used instead of water. Urine increases the biogas production, and enhances the fertilising properties of the bio-slurry. ▪ Typical organic "waste to water" ratios are between 1:1 for fixed dome technologies to 1:4 or more for plastic tube technologies.
Retention time	RT	▪ It is the time required by the bacteria to digest the organic waste and produce biogas. ▪ The retention time is usually between 20 and 45 days depending on the digester temperature.
Temperature	T	▪ The digester temperature has a direct impact on the retention time: the lower the temperature, the higher the required retention time. ▪ Ideal temperatures for a bio-digester are between 15°C – 30°C.
Acidity	pH	▪ The acidity inside the digester also has an impact on the biogas production. In the case of domestic biogas, the pH is difficult to monitor, but is usually not an issue. ▪ The ideal pH is around 7.

Table 5 Main design parameters for biogas plants

The digester volume has to be sized according to the quantity of waste and the retention time. The usual formula used to determine the required volume is:

$$V_{digester} = \frac{RT \times (V_{Waste} + V_{Water})}{1 - x}$$

Where $x = \frac{gas\ volume\ within\ the\ digester}{digester\ volume}$, is the volume fraction that will be occupied by gas within the digester. For dome or plastic tube digesters, a typical value is $x = 0.25$ since the gas volume in the dome or the tube usually represents around 25% of the total digester volume. When the gas is stored in a separate tank (e.g. floating drum or plastic tank technologies), $x \approx 0$ since there is almost no gas within the digester.

2.2.3 Biogas production and consumption

When the biogas plant is properly sized, it is possible to calculate the biogas production. It mainly depends on the composition of the organic materials that feed the digester. For domestic biogas, organic materials are mainly composed of animal dung.

The following table summarizes the biogas production as a function of dung quantity for different livestock:

Livestock	Dung production [kg/100kg of animal/day]	Biogas potential [liter of biogas/kg of fresh dung]
Cattle	8	35
Pig	4	51
Goat	4	35

Table 6 Dung production and related biogas potential for different animals [3]

The table below summarizes the typical biogas consumption for different biogas uses:

Use	Biogas consumption [liter/hour]
Cooking	220
Lighting	130

Table 7 Typical biogas consumption [3]

As a consequence, assuming that the biogas plant is properly sized, 40 kg of cattle dung would lead to the production of 1400 liters of biogas, which represents approximately a cooking duration of 6h30 (with one stove).

The minimum livestock required for a domestic biogas plant can be estimated according to the related cooking duration. As a result, a **minimum of approximately two cows** is required for a household to be able to cook properly with a biogas stove on a daily basis. The following table presents the equivalents in terms of dung production for adult livestock.

Livestock	Cow	Pig	Goat
Minimum number	2	4	20

Table 8 Minimum number of animals for different types of livestock

A combination of different livestock is also acceptable (e.g. one cow and two pigs instead of two cows).

It must be noted that these results assume that the biogas plant is properly sized to process 40 kg of dung every day. A smaller digester could fit lower cooking needs.

Box 1 An example of fixed dome design in Rwanda

The National Domestic Biogas Program (NDBP) in Rwanda has developed a specific model based on fixed dome technologies (the “Rwanda design”) which is currently the domestic biogas plant proposed to the NDBP beneficiaries.

The following table summarizes the investment costs for different domestic biogas models: the Rwanda designs, jointly developed by the NDBP, SNV and Tumba College of Technology at the end of 2012.

- RW1: fully made of burnt bricks
- RW2: made of stones and bricks
- RW3: made of stones, concrete and bricks

In addition to the Rwanda Design, the costs for the GGC (Global Gas Company) model that was formerly used in Rwanda until 2012 are also detailed.

Model/Size	4 m^3	6 m^3	8 m^3	10 m^3
GGC	650,000	800,000	950,000	1,100,000
RW1	545,000	624,000	712,000	827,000
RW2	555,000	658,000	745,000	827,000
RW3	617,000	743,000	833,000	933,000

Table 9 Domestic biogas investment costs [in RWF[5]] [13]

The following table summarizes the 4 different plant sizes for the Rwanda model.

Plant size [m^3]	Daily fresh dung [kg]	Daily water [l]	Head of cattle
4	20-40	20-40	2-3
6	40-60	40-60	4-5
8	60-80	60-80	6 8
10	80-100	80-100	8-10

Table 10 Plant size as a function of the available dung – Rwanda design [14]

Under these assumptions, a 4 m^3 digester could be suitable to provide a household with approximately 6h30 of cooking time on a daily basis.

[5] In July 2013, exchange rate was about RWF 1000 = EUR 1.2

3 Checklist to assess local risks and opportunities prior to get involved in a domestic biogas project

3.1 Political background (national)

The political background regarding energy and farming policies may be more or less appropriate for the development of domestic biogas projects in a given country.

The table hereafter summarizes the different political actors that can have a role in fostering domestic biogas projects.

Actor	Programs that can participate in domestic biogas development
Ministry of Agriculture	▪ **Food security programs** Such programs can consist in providing households with a head of cattle, hence allowing them to produce biogas, if livestock produces enough dung. When these programs focus on the poorest families, the latter may not have enough cattle to reach the minimum dung requirements of a domestic digester. ▪ **"Zero-grazing" policy** This means that cattle have to be kept in stables and fed with cut grass and other crops. Such policy is particularly suitable for the development of domestic biogas, since it facilitates dung recovery, compared to a context where cattle are allowed to roam and graze freely. ▪ **Direct biogas support** The Ministry of Agriculture can also provide direct support to biogas projects among farmers. This is mostly done by financing pilot projects (support to model farms) or spreading awareness (capacity building).
Ministry of Energy / Ministry of Infrastructure	▪ **Biogas sector development** In a context where small scale farming is very present, the Ministry of Energy can support national programs aiming at structuring the domestic biogas industry, namely establishing a sustainable and commercial biogas sector on a national basis.
Public sector institutions	▪ **Medium or large scale biogas implementation** Public institutions such as schools, hospitals, military camps or prisons can contribute to the promotion of biogas technologies by implementing biogas plants in their own sites.

Table 11 Typical political programs supporting biogas development

3.2 Current national biogas diffusion, and comparison among countries

Domestic biogas units are widespread in several countries, especially Asian countries such as Nepal or Vietnam, that are often taken as reference cases for biogas development in other countries. The German GIZ *(*Society for International Cooperation, formerly GTZ) and the Dutch SNV are the two main international organizations acting worldwide for domestic biogas promotion and providing technical support and documentation on the issue. The map below shows the countries where biogas projects were reported, according to these two organizations (NB: domestic biogas development is not the same in all countries: some countries like India, Nepal, and China host much more domestic biogas plants than others, like Ivory Coast, Colombia, or Morocco). Since biogas development must be assessed taking into account the whole value chain of agricultural production, areas where nomadism prevails and grazing (pastoral farming, e.g. in some areas of the Sahel region) is the main form of livestock farming do not appear as suitable to domestic biogas projects. Indeed, in these regions, dung collection would be a critical issue.

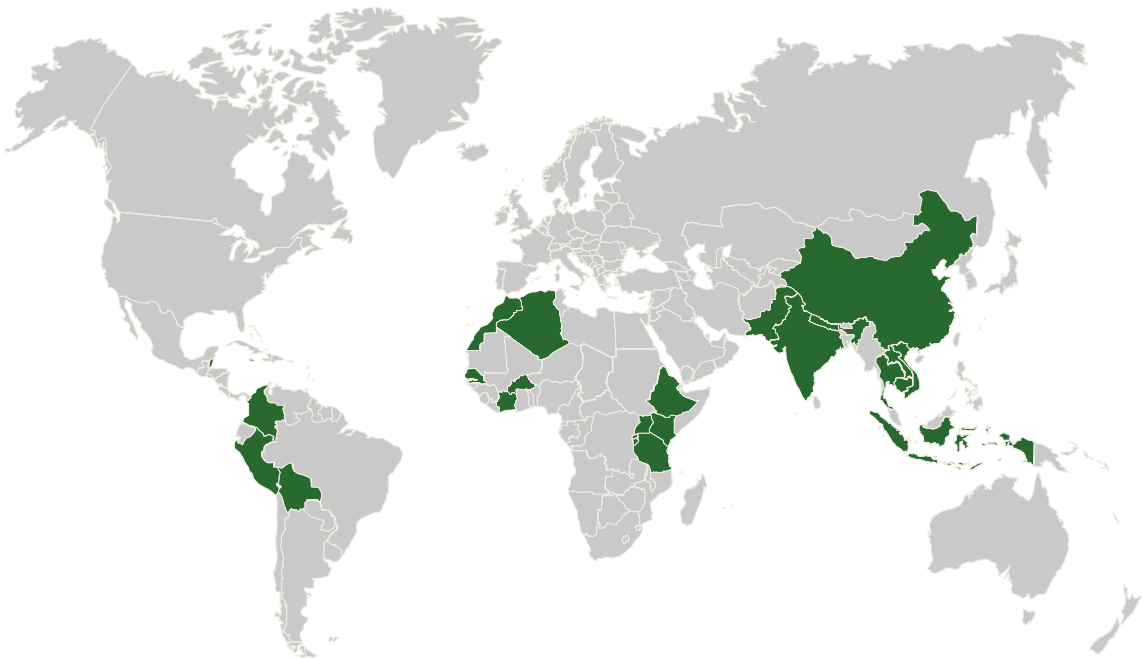

Figure 6 Countries with reported domestic biogas activity (according to SNV and GIZ)[15][16]

Prior to the development of domestic biogas projects in a given country, it is important to check the current biogas diffusion in this country, in order to guess the maturity of the sector. The definition of **national diffusion targets** (i.e. a targeted amount of biogas units that should be built within a specified time frame) by governments also gives information about the actual diffusion levels. In many countries already promoting domestic biogas, governments have implemented national programs aiming at establishing a proper biogas sector within the country. Such programs typically include financing schemes as well as training campaigns for local workforce, and provide technical support to project developers. They involve different actors (non profit organizations) that cooperate together with the local public institutions and private sectors in order to benefit from potential synergies.

Paragraphs hereafter deal with some examples of these programs across the world.

Diffusion in Nepal

With approximately 250,000 domestic biogas plants installed within the 20 past years, Nepal is one of the leading countries in terms of domestic biogas development. The average installation rate over the last 20 years is approximately 1040 units per month.

Diffusion in Vietnam

In Vietnam, the project "Biogas Program for the Animal Husbandry Sector of Vietnam" started in 2003 and aims at developing a commercial viable biogas sector in the country. It is managed by the Ministry of Agriculture and Rural Development (MARD), in partnership with international non-profit organizations such as SNV. The end of the last phase is planned for 2014. Over 2003-2012, 125,000 plants had been constructed [17].

Diffusion in Rwanda

Current midterm targets in Rwanda are as follows:

- National Domestic Biomass Program (NDBP, Ministry of Infrastructure): 12,500 installed units by 2016, which corresponds to an installation rate of 250 units per month [18]
- Government: 100,000 installed units by 2017, which corresponds to an installation rate of 1,700 units per month [18]

The Rwanda NDBP initial target was 15,000 biogas plants installed at the end of NDBP Phase I, in 2012 [14]. The actual number of domestic biogas plants installed until 2012 is approximately 2,700 units, which means that the program has only completed 18% of its initial target.

A revised objective of 12,500 units by 2016 has consequently been targeted by the NDBP as mentioned in the previous paragraph.

Diffusion in Kenya

A similar NDBP program is currently on-going in Kenya. The Kenya NDBP targets the installation of 8,000 domestic plants in a period of 4.5 years, which corresponds to an average installation rate of 150 units per month.

Diffusion in Peru

Domestic biogas development is at an earlier stage in Peru (as in other countries of Latin America), where no national program has been implemented so far. Yet, in 2013, the Dutch development organization SNV, in cooperation with Peruvian institutions and other non profit organizations, proposed to set up a national program (PNB, “Plan nacional de biodigestores”) that would last for 5 years, and target the construction of 10,000 domestic biogas plants (167/month on average)[19].

Diffusion in Tanzania

In Tanzania, the TDBP (Tanzania Domestic Biogas Programme) started in late 2008. Part of the funding came from a broader initiative named Africa Biogas Partnership Programme (ABPP), which covers six African countries[6]. The first phase will end in 2013 and 12,000 new domestic biogas plants have been targeted for the 2008-2013 period (200/month). The programme promotes a sectoral approach, enabling all potential partners (NGOs, public and private sectors) to cooperate on training, financing, and technical issues [20].

Comparing domestic biogas diffusion among different countries

It is possible to compare installation rates among the six countries (see Figure 7). Yet, one must take into account the fact that country sizes are different. Consequently, it can be useful to consider the size of the agricultural sector (e.g. through the GDP of agricultural production) or the number of inhabitants when comparing installation rates (see Table 12).

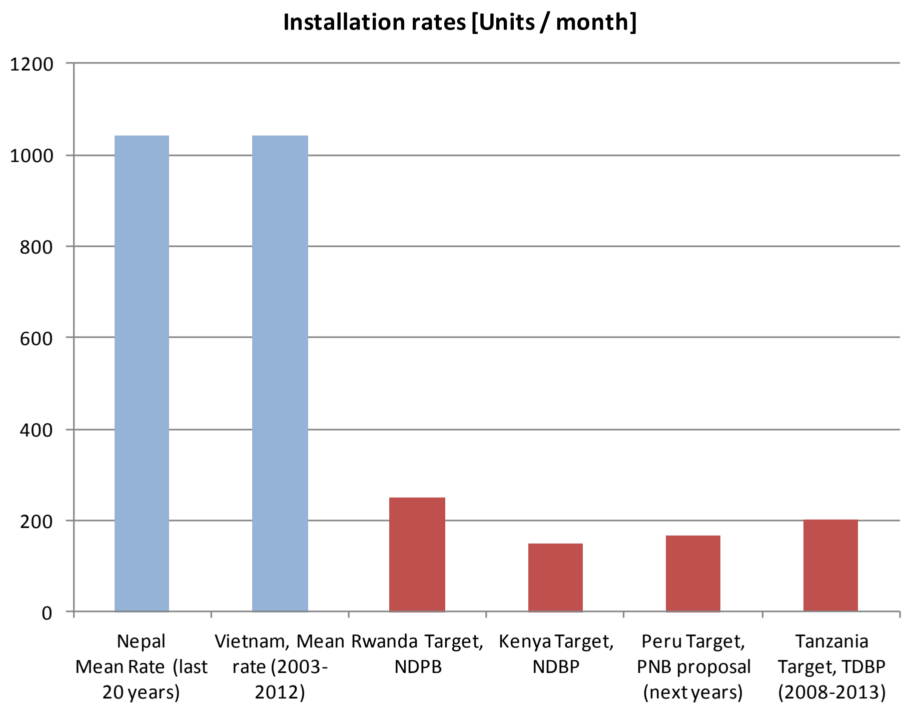

Figure 7 Summary of actual (blue) and targeted (red) installation rates – Nepal, Vietnam, Rwanda, Kenya, Peru and Tanzania

[6] Ethiopia, Kenya, Tanzania, Uganda, Burkina Faso, and Senegal

Period	Nepal	Vietnam	Rwanda	Kenya	Peru	Tanzania
Mean installation rate	1040 units/month (last 20 years)	1040 units/month (2003-2012)	250 units/month targeted	150 units/month targeted	166 units/month targeted	200 units/month targeted
GDP related to Agriculture	6.8 billion USD	29.7 billion USD	1 billion USD	5.1 billion USD	11.8 billion USD	7.9 billion USD
Population	30 million	89 million	12 million	43 million	30 million	48 million
Comparison ratio 1 Installation rate per unit of Agricultural GDP (units/months /billion USD)	153 (Index[7] 100)	35 (Index 23)	250 (Index 163)	29 (Index 19)	14 (Index 9)	25 (Index 16)
Comparison ratio 2 Installation rate per capita (units/months /million people)	35 (Index 100)	12 (Index 34)	21 (Index 60)	3 (Index 9)	6 (Index 17)	4 (Index 12)

Table 12 Comparison of actual installation rates of domestic digesters in Nepal, Vietnam, Rwanda, Kenya, Peru and Tanzania

3.3 Feedback from local actors (field mission)

It is essential to identify the main threats and opportunities to ensure a large diffusion of domestic biogas plants in a given country. As a consequence, feedback from domestic biogas stakeholders (including current and potential domestic biogas users, as well as local technology developers and designers) must be collected in a field mission.

The following section aggregates the key issues on which it is important to collect feedback from local stakeholders, prior to get involved in biogas projects in a given country.

3.3.1 Social aspects

Awareness

Awareness of biogas uses and advantages is a key aspect for a proper development of domestic biogas. Governments and local institutions can usually participate in raising awareness through:

- The media
  - Radio broadcasts
  - Articles in newspapers
  - Brochures
- The organization of visits
  - Visits to neighbours or family members that own a biogas plant
  - Exchange visits through the farmers' cooperative
- The support of "in-the-field" training (e.g. in partnership with local NGOs)
  - Meeting organization
  - Support of advisory groups and/or training sessions on best practices
- The financing of model plants, that can become a "showcase" for future biogas plants

[7] The Index is a comparative ratio (multiplied by 100) between the considered country and Nepal

It must be noted that decentralised and “in-the-field” awareness-raising is usually more efficient than centralised campaigns through the media, especially in rural conditions.

Public awareness on domestic biogas units should include general knowledge on the advantages of domestic biogas production (clean, environmental-friendly and efficient technology, reduction of workload, production of excellent fertiliser...) as well as technical (operational aspects such as minimum dung quantities, water or urine requirement, possibility for electricity production...) and economical (biogas plants costs) aspects.

Social acceptance

Social acceptance may constitute a possible constraint for a large diffusion of domestic biogas units in some societies. The social acceptance mainly concerns the use of biogas produced from animal faeces for cooking.

3.3.2 Technical aspects

Dung input during plant operation

As mentioned in paragraph 2.2, bio-digesters must be fed with a certain quantity of dung on a daily basis, and this quantity depends on the digester capacity. The minimum amount of dung, related to the smallest digester available in the country, is the minimum input required to produce enough biogas to cook properly on a daily basis.

Feedback can be collected from households that are already using a digester. Generally, the main issue that can occur is a lack of dung on a temporary basis, due to the death of one cow or any animal disease. As a consequence, issues relative to feedstock availability are more likely to occur among the most vulnerable households. In addition to a potential lack of dung for a few households, some domestic biogas users can also notice a slight reduction of the available dung, hence the biogas production, during the dry season.

Water and/or urine input during plant operation

As mentioned in paragraph 2.2, water is also required to dilute the inlet dung. Access to water can represent a significant issue, especially in dry countries. As a consequence, reliable local data on water scarcity (water stress indicators, as well as local feedback from beneficiaries) should always be collected by a biogas project developer, prior to get involved in a project. The typical available water for a household on a daily basis must be compared to the average water needs for the household and the requirements for a digester (e.g. a minimum water amount of 20-40 litres/day for a 4 m^3 digester in Rwanda, as illustrated in Box 1).

It must be noted that urine can be used instead of water and is actually more recommended than water for the dilution of the inlet dung. Indeed, using urine rather than water improves the biogas production, and enhances the fertilising properties of the bio-slurry. To be able to use urine rather than water, a urine collection system is required at the cows stable. As a consequence, awareness-raising and training regarding the construction of stables including a urine collection system can be essential to increase the use of urine rather than water at the digester inlet. Water harvesting can also be a good opportunity to avoid any travel to collect water.

Dung for biogas production start-up

After the construction of the biogas unit, it is necessary to fill the plant in order to start the biogas production. Indeed, the biogas production can only be performed in anaerobic conditions (see Figure 8).

Prior to get involved in a given country, it is important to have in mind the usual size of digester that will be used as well as the corresponding dung requirements for start-up.

For instance, for a fixed dome digester, the quantity of dung that is required for start-up can be estimated as follows:

$$Quantity\ of\ dung\ (in\ tons) = n \times V \times \frac{1}{1+\alpha} \times d$$

Where:

- n is the volume fraction of digester that will be filled in with the mix of water and dung (for a fixed dome digester, it is approximately 75%, see Figure 8)
- V is the digester total volume (in m^3)
- $1{:}\,\alpha$ is the dung to water ratio (one volume of dung for α volumes of water, typically, this ratio is 1:1)
- d is the dung density (in ton/m^3, usually about 1 ton/m^3)

Typically, a 4 m^3 biogas unit (fixed dome technology) will require about 1.5 tons of dung for the plant filling. This represents between 1.5 month and 3 months to fill the dome after the plant installation. For households with low dung availability, it is therefore advised to ask for additional dung from neighbours when possible.

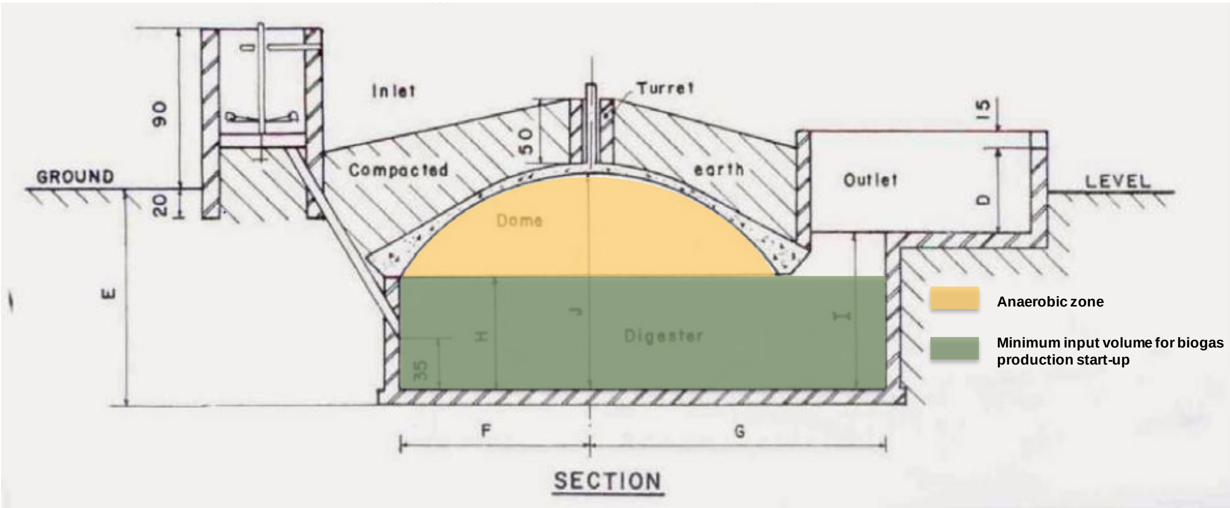

Figure 8 Minimum volume of dung and water for biogas production start-up (example of fixed-dome technology)

Plant construction/installation

The plant construction time can be obtained when interviewing local technology designers or local domestic biogas developers (for instance, construction usually lasts 16 days maximum for fixed dome technology in Rwanda), and depends on the plant capacity.

The selection of the digester capacity is usually a function of the number and type of cattle owned by the beneficiary: the higher the number of cattle, the higher the digester capacity. As a consequence, if the beneficiary acquires additional cattle after the plant construction, the quantity of dung that can be used for the gas production will be limited by the digester capacity.

Regarding construction materials, in some areas, materials might not be locally available (stones...). The availability of the required material may consequently impact the overall plant cost. Feedback from local technology designers can be useful.

Plant design

Project holders should paid attention to optimize the biogas plant design so that beneficiaries can benefit from the synergy between livestock farming, biogas production, and bio-slurry use for crop production. For instance, the stable design could be part of the whole plant design, so that their configuration minimizes dung or water handling issues (e.g. thanks to a urine collection system). Communal stables can also be designed in order to concentrate biogas production.

All these design options have to be discussed and found in collaboration with the local stakeholders, namely the potential biogas users. Project holders must keep in mind that issues related to biogas plants go beyond the plant itself.

Operation

Issues regarding plant operation can be related to:

- Inappropriate amount of water input.
- Low acceptance of dung handling (to feed the digester) resulting in inappropriate dung input. Dung handling can be performed either by a farmhand or by one of the family members of the household.
- Reluctance to use bio-slurry as fertilizer for food crops.

The digester technology must be chosen according to its reliability under local conditions. Indeed, reliability is a critical factor to take into account so that the users show confidence towards the technology.

3.3.3 Economic aspects

Construction companies

Structuring the biogas sector is a key success factor for domestic biogas development. Construction companies must be specifically trained for digester construction.

Feedback from local actors can be collected in order to determine:

- The number (or the proportion) of construction companies that have been trained and can implement biogas digesters, as well as the key private actors of the sector, that could become potential partners.
- The actual political support to training campaigns.
- The general behaviour of the private sector: depending on the country, the private sector can be relatively passive (waiting for a push from local governments) or proactive (companies getting into the biogas business by themselves).

Costs

Costs are the most important aspects for biogas development since they influence the final decision (on the farmer's side). A thorough assessment of biogas units costs must be done. It must be completed by an analysis of the existing subsidies and financing schemes, in order to confront the final cost to the average household incomes.

Field interviews of potential beneficiaries can be useful in order to determine the price that farmers would be ready to invest in such technologies. Appropriate loans can be imagined. Financing issues are further discussed in next section.

3.4 Financing issues

The price for unit construction can generally be paid through:

- Subsidies
    - There are generally existing subsidies from one of the national Ministries. Depending on the national policy, they can target specific households (e.g. with income thresholds)
    - International cooperation can provide governments with financial support. Money comes from governments in other countries through development aid agencies (e.g. the French *AFD*, the American *US Aid*), ministries (e.g. the Dutch *Ministry of Development Cooperation*), or local authorities involved in decentralized cooperation.
    - Regional districts can also provide subsidies
    - Finally, "top up" subsidies can be provided by NGOs
- Household contribution
    - A minimum direct material contribution may be asked by the subsidy provider: it corresponds to a minimum contribution that must be paid when the construction starts, in order to prove that the household is committed to the project
    - The rest can be paid cash or with a credit

As pointed out in paragraph 3.3.3, **access to credits** is a genuine stake to ensure an extensive development of domestic biogas in Rwanda.

Generally speaking, credits must be managed by an external financial institute and not directly by the project holder for several reasons:

- Financial knowledge: First, the project holder (e.g. NGOs) might not have the proper financial knowledge to handle financial credits.
- Follow-up after the end of the project: In addition, relying on a financial institute ensures a follow-up after the end of the project.
- Accountability of the beneficiaries: Finally, beneficiaries' accountability is stronger if they are committed to a financial institute rather than the project holder.

It is essential for project holders to assess the various existing structures giving access to credits prior to get involved in a project. Interest rates, loan durations, bank accessibility, and requirements on the borrower's side are the main issues that must be assessed.

3.5 Potential partners

There are several potential partners for project holders, with different characteristics. The type of partnership shall thus be specific to each stakeholder in order to optimise the possible synergies (e.g. geographical partners, technical partners...).

In addition, it is advisable to involve future partners in the project formulation.

4 Conclusion

Domestic biogas knowledge and technologies are not new. This means that significant work has been achieved over the last years: progress has been made on digester technologies and cost reductions, various political schemes have been tried at national level and different kinds of partnerships have been built in several countries. In addition, much information has been accumulated, providing today's project leaders with accurate data and extensive knowledge on the issues, especially when it comes to technical aspects and "Best Practices" for this kind of projects.

As a consequence, project developers are highly encouraged not to start from scratch: it is recommended to rely on existing structures (local and international) in order to benefit from potential synergies between different kinds of actors at each step of the process: local incentive framework, financing schemes, capacity building, technical design... A field mission at a very early stage of the project gives the opportunity to build up an efficient network that will be useful in the next steps.

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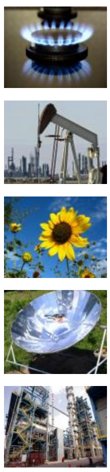

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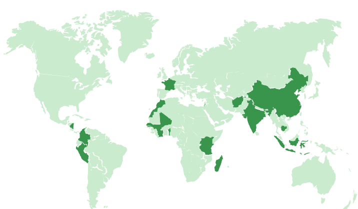

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