Latin American experiences in the democratization of biodigesters

Contributions to Ecuador

PROJECT: DESIGN AND SCALE-UP OF CLIMATE RESILIENT WASTE MANAGEMENT AND ENERGY CAPTURE TECHNOLOGIES IN SMALL AND MEDIUM LIVESTOCK FARMS - REFERENCE NUMBER: 2015000061

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Toda una Vida

EL GOBIERNO DE TODOS

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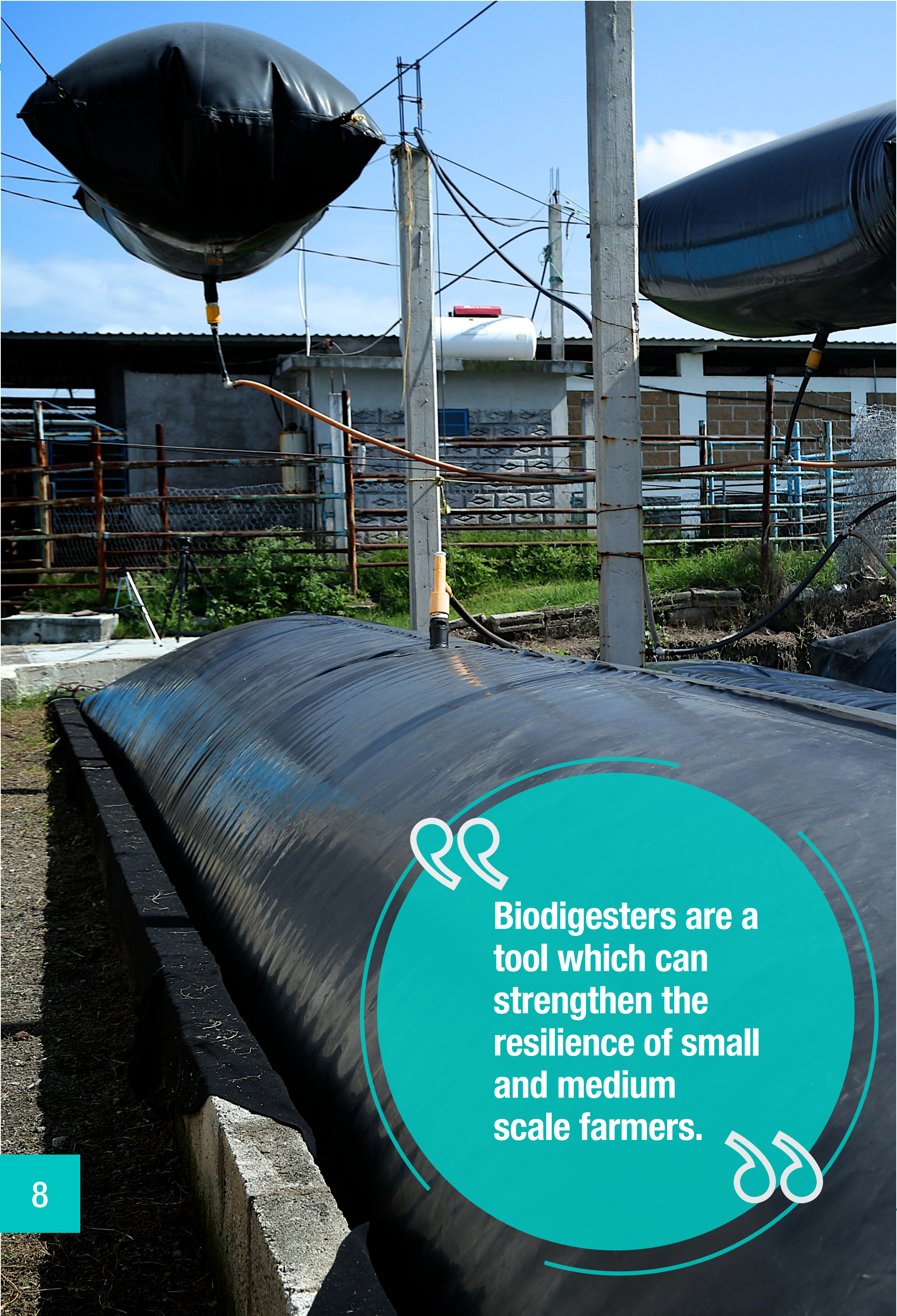
Latin America expiriencies in the democratisation of biodigesters:

Contributions to Ecuador

Contents

1. Objective of this document

The objective of this document is to present the international experiences, principally Latin American, with respect to the democratising strategies of biodigesters, directed at small and medium scale farmers. Firstly, the biodigesters will be presented; their function, products and types of system. Then the basis for national biogas programs and how they function will be explained. Following this, the only Latin American experience of this type of program, which took place in Nicaragua, will be presented, and will be augmented with descriptions of other initiatives of the democratisation of biodigesters outside the context of national programs, in countries such as Mexico, Costa Rica, Colombia and Bolivia. Finally, a variety of specific aspects of national biogas programs and regional experiences will be considered to evaluate the Ecuadorian context, with regard to the potential development of a strategy of democratisation of biodigesters among small and medium scale agricultural farmers.



> Biodigesters are a tool which can strengthen the resilience of small and medium scale farmers.

2. The resilience of small and medium scale agricultural producers.

At a worldwide level, small and medium scale agricultural farmers are found to be, in general terms, in a situation of vulnerability facing the effects of climate change (change within the normal cycle of rainy seasons, extreme climatic events etc.), confronted with fluctuations in fossil fuel prices (petroleum more than US$100 per barrel between 2011 and 2014), the fluctuation in prices of agrochemicals (tied in with prices of petroleum and gas) and faced with an inequality when in competition with short term production and market access from large scale trans-national agro-industry.

In this manner, the small and medium scale agricultural producer needs to strengthen their system of production, to make it resilient when faced with the effects of climate change, reduce their dependence on external supplies to the farm, give sufficient value to their products and to gain access to markets.

In this context, biodigesters are a tool which can strengthen the resilience of small and medium scale farmers.

Biodigesters are systems which produce biogas and fertiliser from organic material.

3. ¿What are biodigesters?

They are systems in which, through the absence of oxygen and presence of adequate bacterial consortiums, naturally develop anaerobic digestion and capture the biogas produced. The biodigester in its function, is similar to an animal's digestive system: organic material enters, is digested by bacteria, producing gases (biogas) and producing a liquid byproduct which has a high value as a fertiliser.

Biogas is the name given to the mix of gases produced in anaerobic digestion, and is characterised by containing 50% - 70% methane (CH_4), 40% - 20% carbon dioxide (CO_2) and traces of other gases among which is worth noting hydrogen sulphide (H_2S). The methane produced is combustible. In this manner the organic residues have the potential to produce a combustible gas: biogas. Furthermore, the capture of this methane and its combustion (transforming it into CO_2) reduces greenhouse gas emissions (GHG) which are produced in the decomposition of untreated manure.

Added to this is the fertiliser produced during the process of anaerobic digestion inside biodigesters called biol, effluent or digestate depending on the country. In the process of anaerobic digestion, the nutrients (Nitrogen (N), Phosphorous (P), Potassium (K) among others) contained in the organic residues which enter in their organic form, mineralise, and become available for plants. This process of mineralisation of nutrients also occurs when, for example, manure is spread on fields of crops, but in a much slower manner and with considerable loss of nutrients due to some elements (Nitrogen) being volatile, and with a risk of further loss due to rainwater runoff. Furthermore, phytohormones have been found to help strengthen plants and microorganisms which populate the cultivated soil and help to mineralise the nutrients present in the soil. In this manner biodigesters accelerate the production of fertilisers (nutrient mineralisation) avoid loss due to volatile elements and runoff, and provide enrichment in the form of phytohormones and microorganisms. In this way the recycling of nutrients which a biodigester promotes means that manure is managed and can be used to its full advantage in an agricultural context through use of its effluents, which in turn avoids contamination of water sources, something which can happen when manure is used without correct management.

In this manner, biodigesters are able to treat organic waste to produce biogas (combustible fuel) and biol (fertiliser). This service (waste treatment) with its associated products (biogas and biol) can be of great significance to strengthen the resilience of small and medium scale farmers, reducing GHG emissions and avoiding contamination of water sources.

Biodigesters are versatile tools which can strengthen small and medium scale farmers in many different ways.

4. What does a biodigester contribute to an agricultural producer?

Biodigesters are versatile tools which can strengthen small and medium scale farmers in many different ways.

4.1. Biodigester as a producer of fuel

Biodigesters are mainly recognised as biogas producers. The production in a farm or smallholding of a fuel (such as biogas) allows the user to cook with it, as well as using it in other ways such as powering milking machines, water pumps, mills, grass cutters, other thermal uses or electricity production for home use. This access to a new energy source expands the possibilities of use and improvement of the farmers processes, which might not occur if they were dealing with an increase in their energy bills. In this way, biodigesters, through the production of biogas, improve the energy self-sufficiency of the farmers enabling an increase in energy consumption on the farm or smallholding.

4.2. Biodigester as a producer of fertiliser

Further to this is the use of biol (fertiliser), a product largely ignored in the past, but one whose importance is being increasingly recognised. The use of biol in the crops themselves results in a true recycling of nutrients, making the producer more resilient and independent of agrochemical products external to the farm. The use of biol means that the farmers can fertilise their crops, saving costs incurred by buying in synthetic fertilisers and adding value to their own products by virtue of them being organic. There are many cases in which the use of biol has allowed farmers to adopt an agroecological production practice, becoming more sustainable and resilient. In this way, biodigesters, through the use of biol, help to increase the independence of the farmers with respect to external inputs, providing added value to their harvest and to the soil.

4.3. Biodigester as a treatment system

The anaerobic digestion that occurs inside the biodigester is an effective system to stabilise organic waste, giving it adequate treatment. In this way, the biodigester performs an environmental service by treating waste, offering two tangible products such as biogas and biol, compared to other systems that usually only provide the fertilisation component (composting, vermiculture, treatment plants, etc.) .

4.4. Biodigester as a tool for mitigating climate change

The manure produced by animals produces methane gas, which has a greenhouse effect 25 times greater than CO_2. If a biodigester is available, the production of methane from manure becomes more efficient, while at the same time it is captured for use. When biogas is combusted, methane is transformed into CO_2 and water, which reduces, therefore, the impact of the greenhouse effect.

Furthermore, the production and use of biogas replaces the use of other fuels, such as firewood or natural gas or liquefied petroleum, which reduces deforestation and the use of fossil fuels. In addition, the recycling of nutrients from the use of biol, reduces or eliminates the use of agrochemicals, manufactured in processes that require fossil fuels as raw material (natural gas for urea), as a source of energy and for transport and distribution. In this way, the biodigester allows the farmers to reduce the carbon footprint associated with their energy consumption and fertilisation of their crops.

4.5. Biodigester as a tool for adapting to climate change

A biodigester allows the farmers to have access to their own fuel, making them independent of external energy sources, a dependence on which in the face of extreme events produced by climate change could break their distribution chains or raise their costs.

Additionally, by producing a fertiliser and encouraging the recycling of nutrients on the farm, the farmers is also independent of external agrochemicals, which could see an interruption in their distribution chains and their prices due to their dependence on fossil fuels. The integration of a biodigester and agricultural activities associated with it, in addition, often lead to the farmers becoming involved in agro-ecological practices, where the diversity of crops, the integration of agriculture and livestock, the care and conservation of the soil, are key in the production process, which reduces pests (as well as the use of agrochemicals) and improves their resilience to extreme climatic events such as droughts (because biol increases the percentage of organic matter in the soil and due to less evaporation in the soil by having vegetation cover).

5. How do biodigesters work?

The anaerobic digestion that occurs inside a biodigester is developed in several stages and by a multitude of different bacteria that make up the bacterial consortium. These stages of anaerobic digestion work as a chain production, the waste generated in the decomposition of organic matter by a group of bacteria becomes the raw material of another group of bacteria, which degrades again and generates other waste which is then taken advantage of by others.

Bacterial consortia necessary for the development of anaerobic digestion are present in the fresh manure of any animal. Manure from cows, pigs, chickens, etc. can be used as a biodigester feed substrate, to produce biogas and fertiliser at the end of the process. The same does not happen with other organic materials such as crop, food industry or domestic waste, since they do not have the required bacterial consortium. However, these inert organic substrates can be digested if an initial consortium of bacteria is added (initiating the biodigester with manure or inoculum from another biodigester that already has the

> **The efficiency of anaerobic digestion depends on two parameters that are compensated: temperature and digestion time.**

bacterial consortium) or co-digesting the load of the biodigester with manure. In this way, all organic matter can be digested anaerobically producing biogas. It is also true that each type of organic matter has different potential for biogas production, and normally polygastric animal feeds have lower potential than those of monogastric animals and these less than organic residues that have not previously passed through a stomach, such as crop residues, household or food industry waste.

Being a process that occurs in nature (such as in the bottom of marshes) the efficiency of anaerobic digestion depends on two parameters being compensated for: temperature and time. When working at temperatures near 35°C, anaerobic digestion is faster, while at temperatures below 20°C longer times are required to degrade the matter and produce biogas and biol. This leads to two types of biodigester design: those that are heated to 35°C, to reduce the time the bacteria need to develop the anaerobic digestion process, which reduces the volume of biodigester, but increases investment and maintenance by heating, or those that work at ambient temperatures (usually lower than 30°C) increasing the volume of the biodigester, however, reducing the costs associated with a heating system.

> Low-cost biodigesters are those that do not use active heating or mixing devices, which greatly reduces investment and maintenance costs.

6. Types of technology appropriate to biodigesters

The anaerobic digestion that occurs within biodigesters develops more efficiently at 35°C. To reach this temperature, it is necessary in most climates to insert a heating system, which increases the investment and maintenance costs of the biodigester. In general terms, the types of biodigesters used by small and medium scale farmers do not use active heating systems, adapting to local temperatures.

Another issue is avoiding the formation of a "scum" or "crust" on the surface of the mud inside the biodigester. Active agitation systems can be used, which make investment and maintenance more expensive. In the case of biodigesters focused on small and medium scale farmers, passive alternatives have been sought to avoid the formation of this superficial crust, either by means of the pressure of the biogas itself to produce pneumatic agitation of it, adding manual agitators or diluting the load of the organic matter with water.

In this way, low-cost biodigesters are those that do not use active heating or mixing devices, which greatly reduces the investment and maintenance costs. They are known as low cost biodigesters, low technology, intermediate technology or appropriate biodigesters and are the most widely used in national biogas programs worldwide.

Household biodigesters are those that are capable of supplying the fuel needs for cooking of an average family. This means that a biogas production of at least 1000 litres of biogas per day will be necessary. If considered as a reference that 1 kg of cow manure has the potential to produce about 35 litres of biogas and 1 kg of pig manure about 50 litres, a household biodigester must be loaded with 25-30 kg of cow manure, or 20 kg of pig manure, per day. As a reference, four cows which sleep in a barn near the house, will deposit this amount of manure during the night.

In general, two types of appropriate biodigesters can be identified: fixed dome and tubular types.

6.1. Fixed Dome Digesters

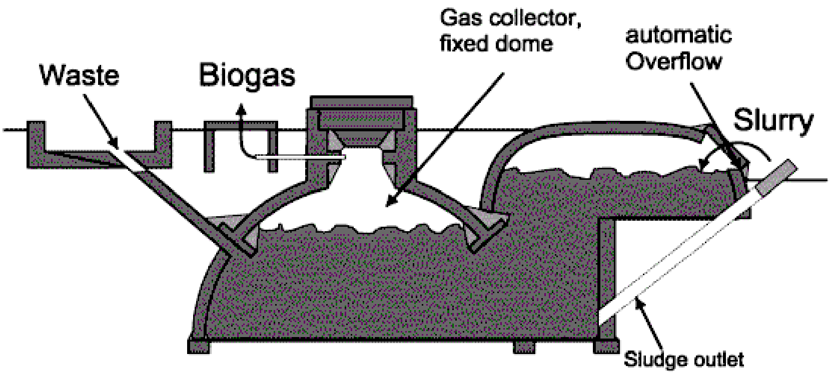


Figure 1: Top-Typical design of a double-chamber fixed dome biodigester (Model CAMARTEC, Tanzania). Bottom-Biodigester CAMARTEC built, prior to being plugged with soil (CAMARTEC, Tanzania)

Fixed dome biodigesters are usually built with cement and brick, which gives them a lifetime of up to 20 years, requires skilled labor for their construction and investment in the transport of large volumes of materials (sand, cement, bricks, etc.) to the place of installation. The fixed dome biodigester, at present, is usually made with two tanks, one main tank with a completely buried vault and a second smaller tank half-buried. The first tank is the main one where anaerobic digestion takes place, it is hermetic and the biogas produced is

http://www.thecitizen.co.tz/image/view/-/3047360/medRes/1236566/-/4p9d4n/-/project+pic.jpg captured within it. As it is buried, the temperature at which the anaerobic digestion takes place is similar to the temperature of the soil, very close to the annual average ambient temperature of the place (with seasonal variations). The second tank is open and serves as a compensation tank since, whereby biogas accumulates in the first tank, the pressure of the biogas increases until it moves some of the mud from the first tank to the second tank, hence the name ‘compensation tank’.

When the biogas is consumed it reduces the pressure of biogas in the first tank, thus returning the mud from the compensation tank to the main one, this generates a movement that produces agitation and avoids the formation of crust. These fixed dome biodigesters work very well in tropical and warm climates, but have limited function in cold climates, since soil temperature drops so low that anaerobic digestion is significantly slowed down. On the other hand, the two great advantages of these biodigesters are that the pressure of the biogas can reach up to a meter high column of water, and the load of organic matter (normally pig or cow dung) only needs to be mixed to a ratio of 1:1 with water. An example of a fixed dome biodigester with two tanks is shown in Figure 1, which corresponds to the CAMARTEC model, developed in Tanzania.

6.2. Tubular Digesters

Figure 2: Plastic tubular biodigesters (Ecuador) (top left), polyethylene geomembrane (Mexico) (top right), PVC geomembrane (Costa Rica) (bottom left)

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Tubular biodigesters are constructed of plastic, usually having cylindrical and elongated forms and being half-buried, the biogas dome that forms remains visible. Due to their shape they are also known as 'sausage biodigesters'. The plastic used in these biodigesters is usually greenhouse polyethylene (double layer) in the cheapest cases (with a lifetime of between 5-7 years if well protected) and geomembranes (with a lifetime of 10 to 15 years). The geomembrane can be made of PVC or polyethylene, with thicknesses greater than 0.75 mm. PVC geomembranes can be reinforced with internal nylon mesh or without it. In the latter case, the geomembrane is very elastic, characterising the biodigesters constructed with it as they have large biogas domes. In general, the companies dedicated to the sale of tubular biodigesters have opted for prefabricated tubular geomembrane (PVC or polyethylene) biodigesters, which simplifies the installation process. Plastic tubular biodigesters (made of tubular greenhouse polyethylene) must be constructed at the installation site. The transport of materials is, however, greatly reduced when compared to fixed dome biodigesters, the installation of the system is done in a single day and as with the fixed dome, skilled labor is required.

> **The tubular biodigesters are more versatile in its implementation in different climatic zones.**

These biodigesters operate at temperatures similar to those of the soil (such as with the fixed dome) because the mud is in the part that is below the level of the trench. As they are half-buried, leaving the biogas dome visible, they can be designed to take advantage of solar radiation so that

Figura 3: Biodigestor tubular de plástico adaptado a clima frío (Bolivia) .

the system is heated. In these cases, it is necessary to add insulation to the walls and floor of the trench so as not to lose the heat gained. If a compact greenhouse is included, which also serves as a protection for the system, it is possible to increase the working temperature of the biodigester, thus making functioning biodigesters possible in extreme climates (temperatures below zero degrees centigrade). This means that tubular biodigesters are more versatile in terms of the possibility for their implementation in different climates. These biodigesters work at lower biogas pressures, between 5 cm and 15 cm of water column, and for the mud to flow inside (since they do not have pneumatic agitation systems as in the fixed dome model) it is necessary for the manure to be mixed with water at a ratio of 1:3, which increases the volume of the biodigester (with respect to the fixed dome) and water requirements. In situations where water is scarce at certain times the liquid fertiliser produced can be reused for the mixture with the new incoming manure. Figure 2 shows several examples of plastic tubular and geomembrane biodigesters. Next table shows the advantages and disadvantages of these two types of biodigesters (fixed and tubular dome).

	Fixed dome	Tubular	Plastic tubulars	Geomembrane tubulars
Advantages	• Their lifespan is 20 years when constructed of brick and cement •They use little water (manure:water 1:1) when compared to tubular biodigesters •They don't take up a lot of space on the farm due to the fact they are buried, and no protection system is necessary •They attain far greater biogas pressures (water columns of 1m) than tubular biodigesters •A widely validated technology internationally (Asia and Africa)	• The best known technology in Latin America • It can be adapted to cold climates of the Andes with solar passive heating • Rapid installation (1 or 2 days) following the trench excavation • Any trained producer can be a tubular biodigester installer • The cost of transporting materials is low and because they are lightweight pieces and prefabricated.	• The cost / durability ratio (5-7 years) is appropriate for small scale agricultural producers • Materials available at local hardware stores	•They come prefabricated • They can be made to any size • 15-year lifespan • PVC geomembrane: very easy to repair • Polyethylene geomembrane: very durable and resistant
Disadvantag	• Greater cost than plastic tubular biodigesters • There is no previous consolidated experience in South America • This technology is not known in the region • They are not adapted to function in cold climates like the Andes • The transport of materials to communities can increase costs • Trained builders are needed to construct the biodigesters	• Due to being half-buried and having the dome visible, the area needs to be protected • They use more water in the load (manure:water 1: 3 to 1: 5) than the fixed dome biodigesters • They reach lower pressures of biogas (up to 15cm of a column of water) than those of fixed dome • External biogas reservoirs are often used to give more pressure and store biogas	• Limited in terms of size due to plastics available on the market • Holes of up to 20cm can be repaired	• Costs similar to adapted fixed domes • Geomembrane PVC: if it is not reinforced it reaches biogas pressures of around 5cm of column of water • Polyethylene geomembrane: holes of up to 20cm are repairable

Advantages and disadvantages of fixed dome biodigesters, and plastic and geomembrane tubular biodigesters

7. Antecedents in the democratisation of biodigesters in Latin America

In all Latin American countries, a similar process has occurred in the diffusion and implementation of biodigesters. In the 70s and 80s, in the majority of countries, the first installations of biodigesters, normally fixed dome, were carried out in projects sponsored by the German Technical Cooperation Agency (GTZ) and linked to public universities. These projects allowed for testing of the technology, developing research with regards the use of the fertiliser produced and adapting engines to work with biogas. At the end of the 80s and the beginning of the 90s support for these projects dwindled, due to lack of sustainability and replication of previous experiences, mainly due to the fact that the investment costs of new biodigesters (fixed dome) were high and there was inadequate control and monitoring of the biodigesters already installed.

In the first decade of the millennium there was a resurgence throughout Latin America in the field of biodigesters, again driven by projects linked to international cooperation funds and executed by NGOs. This time, the plastic tubular model of biodigester was used, and from 2006 the tubular geomembrane was introduced.

During this decade, small biodigester projects were developed throughout Latin America with very varied experiences in terms of results, ownership and sustainability. The main factor that determines the success or failure of these projects is the social strategy of implementation (the less subsidy provided and the more follow-up given, the better the results). In the transition between the first and second decade of the millennium there are already several universities involved in R+D in this type of low cost biodigesters in Latin America, with the number of universities involved increasing year by year. In this period the issues of how to democratise technology and make it accessible to the greatest number of small and medium scale farmers has begun to be explored. For example, Bolivia developed a national project (it did not include a program to generate a biodigester market) from 2008 to 2012, in which 750 domestic tubular biodigesters were installed all making use of a passive solar heating design, due to the fact that most of them were located in the Bolivian highlands.

The different experiences of installing biodigesters gave very different results and for this reason, in 2009, the Network of Biodigesters of Latin America and the Caribbean (REDBIOLAC[1]) was founded, as a pioneering space in which to share experiences and lessons learned. In this way, a bottom-up movement started at a regional level, involving NGOs, charities, universities, small and medium-sized companies, micro-finance companies and farmers associations throughout the continent. Based on the shared experiences, these participants began to give new impetus to the biodigesters in the region, with a focus on sustainability and not repeating the mistakes previously encountered in welfare assistance strategies. It is a diffuse process of democratisation of technology, carried out by a wide

> **The Biodigesters Network of Latin America and the Caribbean (REDBIOLAC) was born in 2009, as a pioneering space to share experiences and lessons learned**

[1]http://redbiolac.org/

variety of participants linked to the biodigester sector that, from below, develops unevenly in each country depending on the number of participants and local conditions. These are not national biogas programs because they are not covered by specific government policies, but rather are a heterogeneous and diverse group of connected movements that articulate participants with a comprehensive agricultural, economic and social vision. There are countries that have or have had much strength in this area, such as Mexico, Costa Rica, Colombia or Bolivia, which will be discussed later.

It is in these years, when two institutions of the Dutch International Cooperation (SNV and Hivos), with previous successful experiences in Asia and Africa in the development of sustainable biodigester markets, and before the breeding ground already advanced in Latin America, began to evaluate the implementation of National Biogas Programs (NBP) in the continent. These programs have a top-down approach, which is based on successful methodologies applied in Asia and Africa. In these cases, the structure and functioning of a NBP is already pre-established and validated by experience and it local participants are sought to make up the different components of the NBP. These NBP's are based on the development of a sustainable biodigester market. Honduras, Nicaragua, Bolivia and Peru were the first four countries in which the feasibility of developing a NBP was evaluated. Honduras was not considered to be feasible, while the other three countries were. Nicaragua started its NBP in 2012, based on African and Asian experiences, with the objective of installing 6000 biodigesters by 2018 (a target that was later reduced to 1500 units).

> The objective of the national biogas programs is to generate a sustainable biodigester market for small and medium-sized farmers.

8. National biogas programs

The objective of the national biogas programs is to generate a sustainable biodigester market aimed at small and medium scale farmers. All of these programs have different schemes according to local realities, but they share a series of characteristics in their approach:

- Market focus in which the clients themselves assume the majority of the investment costs.
- Participation of multiple participants in the program, each with their defined roles.
- Strengthen capacities of existing local participants.
- The development of a sector as such, going beyond the project rationale.
- Competition regulated by the supply side, ensuring the benefit of customers.
- Quality control system, designed and applied to protect the interests of families and gender equality.
- Medium to large timescale, since it takes at least 5-10 years to develop a sustainable and economically viable sector.

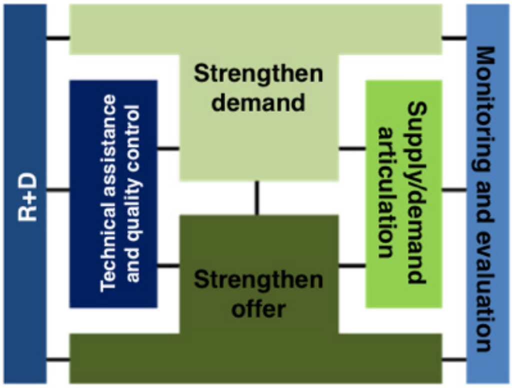

Figure 4: Scheeme of interaction between components of a national biogas program (source: SNV, 2013)

In these NBPs, two types of processes are defined: primary and secondary. The primary processes are those that are directly linked to the implementation of biodigesters (strengthening of demand, supply and articulation of demand-supply) and secondary processes that reinforce implementation.

8.1. Strengthening the demand

The claimants of biodigesters are the small and medium scale agricultural farmers. Strengthening these includes making them aware of this technology, its costs, operation and benefits (biogas, fertiliser and waste treatment). The activities of this component are based on *marketing* through radio spots, advertising through posters, calendars and bulletins, as well as visits to demonstration biodigesters. In the initial phase of the program, this is a component that requires a lot of effort since it is necessary to overcome the barriers of general ignorance of the producers about the technology that is offered to them. It is essential to have demonstration biodigesters that can be visited by interested producers. These marketing activities can be carried out by the NBP team, and complemented by the technology providers themselves, interested in placing their systems. In addition, other strategies can be employed, such as giving an incentive to people who bring prospective biodigester buyers in, making informal extension agents in the promotion.

8.2. Strengthening the offer

The suppliers are the technology providers: those who build fixed domes or are installers of tubular biodigesters. The suppliers can be from sole proprietorships to small and medium companies. This group also includes companies that provide accessories (ovens, lamps, motors, grass cutters, mills, milking machines, etc. All of which run on biogas), addition to the builders/installers.The task of strengthening the builders/installers in the initial stages involves training and certifying small and medium enterprises. In this way, the biodigesters implemented within the NBP are built/installed by people certified by the NBP itself. This encourages the implementation of validated technologies, through validated processes, and with the necessary quality control. At the start of the program, it is necessary to identify which technologies will be included within the program (more technologies can be added through the duration of the NBP, as long as they are validated), the materials, costs, installation protocol and final quality. With this established, generations of builders/installers can be trained for each technology. It is important to have training workshops periodically, as it is necessary to have a broad base of builders/installers distributed throughout the regions in which the NBP will intervene, considering the fact that not all certified builders/installers will end up by installing biodigesters, and others will opt out of this activity during the NBP. The training of builders/installers should also include: technical aspects, management aspects of small and medium enterprises, accounting, marketing and after-sales services.

8.3. Supply-demand articulation

This concerns facilitating the relationship between producers and suppliers of technologies, linking the component of strengthening the demand with the strengthening of the offer. Usually this component aims to develop mechanisms of access to credit lines specific to the NBP, by micro financing institutions. This is a very important issue in the NBPs of Asia and Africa: access to credit by producers to finance the purchase of the biodigester. However, as will be discussed later, in the Latin American experience this issue is not so clear. To reduce costs in credit, specific lines for NBP can be developed supporting the industries (for example, milk), as withholding agents. The management of subsidies also falls under this component. The subsidy is a key and complex aspect in a NBP as, if it is excessive it can undermine the market that is being developed, while if it falls short it may be insufficient to overcome barriers such as ignorance of technology or the ability of producers to pay themselves. In general terms, there has been a tendency to give a fixed (flat) subsidy regardless of the size of the biodigester implemented by a farmers. In this way, access to technology is made available to the most vulnerable farmers. This subsidy must maintain a balance between the payment capacity of the most impoverished producers and the cost of access to the smallest biodigester model. At the start of the program, mainly to stimulate demand and overcome the barrier of ignorance of technology, subsidies can be up to 50% of the cost of implementing a smaller model, to subsequently be reduced to 33% and thus, progressively, throughout the duration of the NBP.

8.4. Technical assistance

This component provides technical support to other components, such as the strengthening of supply and demand. In one way, this component must provide the tools to biodigester users so that they can take full advantage of the technology, both in the use of biogas and fertiliser, and in operation and maintenance. This component is also responsible for conducting meetings between farmers who are biodigester users (and non-users), to promote the exchange of experiences. In addition, technical assistance is also directed at technology providers, so that, with continuous training, their knowledge is deepened, they can stay updated and the transfer of knowledge to users is strengthened. These activities can be developed by NBP staff or be delegated to, or shared with universities, technological institutes and NGOs.

8.5. Quality control

Quality control is one of the keys to the success of NBPs. Each installed biodigester must reach quality control standards (or representative samples of these when installation rates of over 1000 biodigesters are reached per year), to ensure their final signing off and that the technical requirements established by the NBP are met. This guarantees the biodigesters installed within a NBP. To ensure the commitment of the constructor/installer, the last payment is made after the biodigester meets the quality control requirements. In addition to the quality control of installed biodigesters, this component also performs control of the processes of the NBP itself, such as technical assistance, training and certification of builders/installers, transfer of knowledge from technology providers to users, diffusion processes, etc. This is a key component, which it is recommended should always remain in the hands of the team that develops the NBP.

8.6. Monitoring and evaluation

This is a component that should provide information about the health of the NBP, through the collection of the data generated (number of facilities and providers, distribution of users in time and space and types and sizes of biodigesters), systematising them and identifying opportunities and weaknesses. Furthermore, this component should form a baseline which provides information regarding how the introduction of biodigesters has had an impact on the conditions of life, gender equality, economic, social and productive conditions of producers, comparing data with those who did not install biodigesters. The development of specific impact studies and representative surveys will be other activities to be developed. This component can be delegated to participants with previous experience such as universities or NGOs.

8.7. Research and development

Research and development is a component which does not feature in many NBPs, but rather is integrated within the area of Technical Assistance. However, in the case of Latin America, due to the strength of R+D in universities and other organisms, and the research needed to test technologies in different climates and the various applications of biol and biogas, it is a very necessary component. This component must provide input to Technical Assistance, collaborate in the measurement of impacts with Monitoring and Evaluation component and participate in the validation of installation processes and certification of builders/installers. It is a component that must necessarily be supported by research organisations, user producers and technology providers, for the development of a local R+D adapted to the real conditions of the country.

8.8. Governance models of national biogas programs

NBPs at an international level have formed similar models of governance in their general structure, but very varied at a lower level, to adapt to the local conditions. In general terms, a governance structure of NBPs similar to that shown in Figure 5 and described later can be identified.

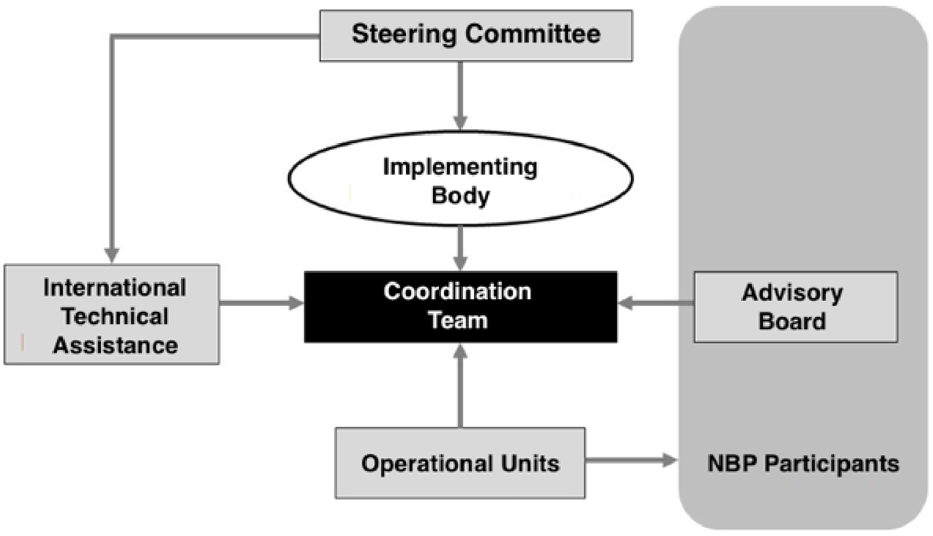

Figure 5: General governance structure of a NBP

- Steering Committee of the NBP: The steering committee is who will outline the strategic guidelines and to whom the NBP results will be reported as progress is being made. This Committee is formed, at the very minimum by the donor group and the Government. This committee will not participate in technical decisions, only in political and relevant issues for which an adequate environment for the implementation of the NBP is created. The Steering Committee will appoint, or form, an Independent Executing Agency, and will designate the experts of the International Technical Assistance.

-Implementing Agency of the NBP: This is an independent entity responsible for the coordination of the NBP and the hiring of professions who can lead and develop the components of NBP. This group of professionals will form the Coordination Team.

-Coordination Team of the NBP: This team is responsible for the implementation of the NBP in the country. It is responsible for following the guidelines of the Steering Committee and reporting progress. Professional experts in biogas, gender, promotion, micro finance, monitoring and evaluation, bio-inputs, etc. will participate in this team. It will receive International Technical Assistance to optimise the correct functioning all aspects of the NBP, consult with the Advisory Board and coordinate the Operating Units.

-International Technical Assistance: The International Technical Assistance will be formed by a Committee of International Experts that will be chosen by the Steering Committee. This will provide support to the NBP Coordination Team in order to adequately fulfil the proposed goals. This Technical Committee will evaluate the main activities carried out by the NBP and, together with the Coordination Team, should prepare a viable intervention strategy and execute it according to the different characteristics that the NBP may take over time.

-Advisory Board: The NBP Advisory Board should be a meeting place for the different actors involved in the program, constituting a consultative and proponent group at the same time. Ministries, NGOs, Universities, public research institutes, private entities, governments, municipalities and associations of producers can be part of the Advisory Council. To streamline processes, specific working groups can be formed: access to credit, promotion, R+D, quality control, etc.

-Operational Units: This is the execution unit most linked to the territory. There may be a single national unit, or several regional units, depending on the country and budget. These Operational Units report the progress made in their areas of intervention to the NBP Coordination Team. They carry out promotional activities, training, monitoring, coordination with the different executing institutions, technology providers, quality control, technical assistance and research in their intervention regions as well as the activities that are to be carried out to meet the different indicators of the NBP.

In Nicaragua a whole new market has been developed focused on the productive uses of biogas (systems fed biogas as mechanical milking machines, milk cooling, lawn mowers, mills, boilers, electric generators, water pumps, etc.).

9. Concrete experiences in Latin America

9.1. Nicaragua: First NBP in Latin America

Nicaragua is the only country in the continent that has developed a National Biogas Program based on the experiences of Asia and Africa. The NBP-Nicaragua[2] began in 2012, after the positive results of a feasibility study. The feasibility study identified a technical potential of 55,000 systems, which demonstrates the feasibility of developing a National Biogas Program. The socio-economic conditions of Nicaragua (27% of the population do not have electricity, which amounts to 64% in the rural areas), make the country close to the circumstances of African countries, where NBPs had been successfully developed. The program was funded by BID-FOMIN[3], Nordic Development Fund[4] and HIVOS[5], which was co-executor along with SNV[6] for the first two years. The initial objective was to install 6000 biodigesters by 2018, an objective that was reduced to 1500 in an intermediate evaluation of the program. By the end of 2017 they had reached 1200 installed biodigesters.

There are several achievements and challenges that the NBP-Nicaragua has had to overcome, which explains the low number of installations after 6 years compared to other Asian and African programs, however, it remains the program that has managed to install the most biodigesters in Latin America:

[2] http://programabiogasnicaragua.org/
[3] http://www.fomin.org/
[4] http://www.ndf.fi/
[5] https://www.hivos.org/
[6] http://www.snv.org/

• The formation of a team of people who coordinate the different components has been difficult due to the lack of previous experience in biodigester projects with a market focus in the region. In the case of Africa, the first continent to which the successful experiences of NBPs in Asia were transferred, personnel with experience were transferred from Asia to Africa, which allowed a transfer of knowledge to local teams. In the Nicaraguan case, the transfer of knowledge was more at the technical level (designs and construction of fixed dome biodigesters) and not so much in the management part of implementation strategies, which for the initial years had to be self-learned, which delayed the execution of the program.

• An important aspect was the decision regarding what type of biodigesters to consider for the NBP. Initially, with the Asian and African experience, the fixed dome model was opted for (CAMARTEC[7]) and the entrance to the NBP of tubular biodigesters of imported polyethylene geomembrane was allowed (Sistema Biobolsa de México[8]) and distributed by a local company (TECNOSOL[9]). The construction cost of fixed domes in Nicaragua tripled the investment of the other countries, while tubular geomembrane biodigesters were also expensive and did not achieve a good distribution. This caused serious problems in the promotion of the technology in the first years. Subsequently, adjustments and adaptations of the fixed dome model were made, in a joint venture between personnel with experience in Asia and local staff, which managed to considerably lower costs to reach USD$1,300 (for 6m^3 of biodigester). Also, after three years, a commitment was made to consolidate a technological range, which allowed for entry into the NBP of suppliers of tubular biodigesters of PVC geomembrane (VIOGAZ of Costa Rica[10]) and polyethylene geomembrane (Sistema Biobolsa de México), with similar costs. This ensured a better promotion of the technology, most of the biodigesters that have been installed are geomembrane tubulars. In this way, the NBP of Nicaragua has been a pioneer in consolidating a wide

[7] http://camartec.go.tz/
[8] http://sistemabiobolsa.com/
[9] http://www.tecnosolsa.com.ni/
[10] http://www.viogaz.com/

technological range (fixed and tubular dome) with respect to other NBPs, although this proposal was consolidated late.

• The bureaucratic level of management has been very high due to the requirements of the financiers, an aspect that has limited the execution capacity of the companies supplying the technologies involved.

• The high cost of the selected type of technology has implied the need to subsidise 62% of the construction cost of the smallest fixed dome biodigester (4m^3) to make it accessible (the producer pays USD $300 and the NBP contributes in the form of subsidy of USD $480). This flat subsidy implies 37% of the cost of an installed fixed dome biodigester (6m^3). The high subsidies, after five years of NBP, illustrate the difficulties that exist in the country to overcome the barrier of ignorance of technology and limited capacity of payment of producers.

• In other NBPs, access to credit from farmers has been the tool with which to overcome the barrier of farmers' limited payment capacity. However, in Nicaragua, around 80% of the farmers have paid in cash and many have not installed a biodigester due to not wanting to take on credit. The interest rate on loans to buy a biodigester is high (around 20%), which discourages producers. Lower interest rates can be obtained (around 10%), if the farmers requests a larger loan (up to USD $5,000) to make other investments besides the biodigester, which also discourages many potential users. Another aspect is the guarantee required in many of these credits, putting land ownership up as a guarantee for access to a biodigester also discourages the taking of credit by the potential user. The high cost of biodigesters (compared to other NBPs) and the difficulty of accessing attractive credit plans for farmers have been limiting factors in reaching the NBP goals for numbers of systems installed.

- Another pioneering contribution of Nicaragua's NBP has been the development of a whole new market (systems, technology suppliers, etc.), focused on the productive uses of biogas from much larger biodigesters (systems fed by biogas such as mechanical milking machines, milk cooling machines, grass cutters, mills, boilers, electricity generators, water pumps, etc.). Other NBPs focus on domestic biodigesters, leaving the productive uses of biogas for singular and demonstrative cases (since to use this type of machinery much larger digesters are needed that, at the same time, require much more food: manure or other organic matter). In this way, the NBP of Nicaragua has managed to make the productive uses of biogas accessible to farmers under a market logic. To develop this complementary market, it has been necessary to adapt technologies to biogas and validate the different systems considered, as well as to generate the interest of suppliers to display them in their windows and market them. This has made it possible to make technology interesting for medium scale agricultural producers who, in addition, have greater ability to pay and access to credit.

- Other aspects worthy of a mention are the successful development of the process of obtaining carbon credits by emission reductions before the CDM (Clean Development Mechanism) and the Gold Standard, the diffusion of the biodigester technology in the country, overcoming the previous ignorance or bad reputation of that technology and working out how to monitor and guarantee the functionality of the biodigesters installed in the program.

9.2. Costa Rica: Strong environmental policy

> **Costa Rica has a strong environmental policy that encourages the adoption of biodigesters as waste treatment systems that also produce biogas and fertilizer.**

Costa Rica, after Colombia, is of significance with regard the dissemination of plastic tubular biodigesters, thanks to Raúl Botero, professor at EARTH University who, in 1986, together with Thomas Preston, published the first manual of this technology. EARTH University, which has several tubular biodigesters operating in its facilities, promotes 100 students each year from Latin America and Africa, with knowledge of these systems. This has made the university a focal point in the dissemination of technology at a regional level. Several Costa Rican graduates of EARTH University[11] have carried out projects related to tubular biodigesters, replacing greenhouse plastic with geomembrane, normally PVC, giving greater durability to the system, such as the company VIOGAZ[12] or Biosinergia Alternativa[13]. These companies have become a Latin American reference with these types of systems, developing their activities with a market focus and without the support of international

[11] https://www.earth.ac.cr/es/
[12] http://www.viogaz.com/
[13] http://www.biosinergia.net/

cooperation. The intense environmental policies of the country's governments have encouraged the adoption of biodigesters as waste treatment systems that, in addition, produce other benefits such as biogas and fertiliser. The Ministry of Agriculture, the National Apprenticeship Institute and the public electricity company (ICE), have made efforts to disseminate biodigesters, with funds of all kinds for pilot projects, many of these initiatives are pushed by graduates of EARTH, but also by other actors and enthusiasts. Thus, without a specific policy for the development of a sector of biodigesters in the country, environmental policies catalyse this process based on the market.

9.3. Mexico: Business strategy with international support

It can be said that Mexico has achieved impacts similar to those of a national biogas program, while not actually having one. The NGO (IRRI[14]) and the social enterprise (BIOBOLSA[15]) are attaining similar results to the national programs of Africa and Asia, with more than 1000 systems installed per year As in the case of Costa Rica, the technology used is tubular geomembrane biodigesters, in this case polyethylene. Unlike in Nicaragua, there is no national program of biogas as such, nor of an effective application of environmental regulations that encourage the use of biodigesters as a waste treatment system for small and medium producers, as is the case in Costa Rica. Partial support has been obtained for the implementation of pilot projects by the government (Ministry of Environment, Livestock, Rural Development, Fisheries and Food) as in the case of Costa Rica.

> **In Mexico, the partnership between an NGO and a company is achieving similar results as national biogas programs in Africa and Asia.**

The innovative strategies of these two institutions in promotion (theatre, puppets, etc.), support in existing social networks (such as agricultural cooperatives, livestock unions, rural fairs and demonstration events), access to financing (microcredits at 0% interest), and their ability to attract large international cooperation budgets, has allowed them to subsidise biodigester installations, making this technology accessible to small and medium scale agricultural producers. It is important to note that less than 30% of the systems installed in Mexico have had subsidies (national or international) and when this has occurred, it has been up to 80%, and more often around 40% - 50%. This NGO-Company consortium is expanding to other countries in the continent (Nicaragua-Haiti-Colombia), Africa (Ghana, Ethiopia) and Asia (India), demonstrating a replicable business model.

9.4. Colombia: Consolidation of a biodigester sector

Colombia is a historic country in the development and diffusion of biodigesters among the small and medium scale agricultural farmers. It was in Colombia, in 1986, when the first installation manual for plastic[16] biodigesters was published (from minimal previous experiences in Ethiopia and Australia by Dr. Thomas Preston). This manual initiated the dissemination of this technology throughout the content. CIPAV[17] was initially, in the 90s, the institution that promoted the democratisation of plastic tubular biodigesters, but at the beginning of the new millennium the Foundation for Sustainable Tropical Agricultural Production -(UTA Foundation)[18] took the initiative in the implementation, training installers and research and development of plastic tubular biodigesters. This foundation convened in 2012 the meeting between actors for the formation of the Colombian Biomass Energy Network (REDBIOCOL[19]), today comprising 55 organisations of different types, NGOs, grassroots organisations, universities, social movements, rural and indigenous associations, urban collectives. The advantage of the tubular plastic biodigester is its low cost and the easy training of local technicians who can

[14] https://irrimexico.org/

[15] http://sistemabiobolsa.com/

[16] Botero, R., & Preston, T. R. (1987). Biodigestor de bajo costo para la producción de combustible y fertilizante a partir de excretas. Manual para su instalación, operación y utilización. Centro Internacional de Agricultura Tropical. Cali, Colombia, 353-362.

install it. This is why this technology spread so quickly throughout the country (and Latin America). It is worth noting the experience of ASPROINCA[20] which has more than 300 systems installed using its own original process, through which its members can access plastic tubular biodigesters and the necessary financing through a revolving fund and have their own installers. Another example is EL COMUN[21], an association of rural and working class organisations in Colombia which in the last two years have formed promoters through rural schools disseminating technology and obtaining support from the Ministry of Agriculture and international organisations for the installation of more than 100 biodigesters in the department of Santander, Colombia.

Colombia demonstrated a grassroots experience, managed by the local actors themselves, coordinated through a network of exchange of experiences and mutual support. In REDBIOCOL biodigesters are another tool to strengthen the sovereignty of small and medium farmers, considering, in addition, other aspects, such as the social and solidarity economy or the formation of new youth networks. The diversity of the institutions which participate in REDBIOCOL also results in a range of types of biodigesters being available, based mainly on tubular plastic and geomembrane biodigesters. Without concrete national policies for the development of a sustainable sector, nor environmental regulations making demands on small

> **Colombia shows its own process of technological democratization from a grassroot level, driven by local actors, coordinated through a national network of exchange of experiences and mutual support**

[18] https://utafundacion.wixsite.com/utafoundation
[19] http://www.redbiocol.org/
[20] http://www.semillas.org.co/apc-aa-files/5d99b14191c59782eab3da99d8f95126/libro_asproinca_espa_ol_2.pdf

and medium scale farmers, or big budgets from international cooperation, Colombia has managed to connect and consolidate a sector of biodigesters.

9.5. Bolivia: plastic tubular biodigesters in cold climates

Bolivia started a pilot biodigester diffusion pilot project in 2007, sponsored by the Endev-Bolivia[22] of the German Technical Cooperation (now GIZ[23]) and coordinated by CIMNE[24]. This project was extended every six months for five years depending on its results. The project closed in 2012 with 750 domestic plastic tubular biodigesters installed[25]. The nature of the project, with multiple extensions and a small team, meant that a long-term vision for the development of a biodigester sector in the country was never achieved. Among its achievements was the development and validation of the adaptation of tubular biodigesters to the cold climate conditions through a passive solar heating design, thus expanding the climatic working conditions of these low-cost systems. The positioning of plastic tubular biodigesters as the cheapest and most accessible technology, in line with the economic horizons of the most impoverished producers, was another of their contributions to the international scene. Another aspect was the incorporation of universities and NGOs in research and development under real operating conditions, both in the evaluation of biodigesters, designs and applications of biogas and biol. In 2011, the Research Centre for Biodigesters, Biogas and Biol (CIB3) was founded in the Bolivian Altiplano. Due to the fact that in Bolivia there is a subsidy for gas that makes it very accessible to families, the biodigesters lose part of their attraction (biogas) and it was decided to make a strong bet for the productive uses of biogas (although without specific results contrary to the case of Nicaragua) and uses of biol (fertiliser). This led to the existence of a large number of farmers interested in biodigesters, not because of biogas or their ability to treat waste, but for the fertiliser that was produced. Without specific policies from the government to promote the diffusion of biodigesters, but with the support of international cooperation, the project

[21] https://www.elcomun.org/
[22] http://www.endev-bolivia.org/es/
[23] https://www.giz.de/en/html/index.html

was always focused on the most impoverished farmers, the smallest and most vulnerable, with subsidies of 33% of the cost of the biodigester. In 2012-2013, the feasibility studies and plan for a national biogas program were carried out, but the necessary financing for its development was not granted. The case of Bolivia shows an intermediate point, indeterminate, in which there were no business ventures supported by environmental policies or international cooperation and neither did it have a strong social base organised through a network, nor a national biogas program with a long term vision, achieving impacts only while the project lasted, but with few subsequent replicas.

> **Bolivia developed and validated the adaptation of tubular biodigesters to cold climate conditions through a passive solar heating design**

[24] http://www.beegroup-cimne.com/biodigesters/

[25] http://beegroup-cimne.com/kt-content/uploads/2016/07/Biodigesteres-Lecciones-Bolivia-2014_compressed.pdf

It is important that there is a variety of types of biodigesters available to the farmers

10. Discussion and Conclusions

The democratisation of biodigesters among small and medium scale farmers has two approaches: one **top-down** based on national biogas programs, which has shown its success in Asia and Africa, but certain limitations in Latin America (as with the case of Nicaragua) and another **bottom-up** based on mutual support among different stakeholders linked to the biodigester sector, but that, despite the local impact, does not achieve the large national numbers of NBPs (as in the case of Colombia). In parallel, there are business initiatives that can be developed in contexts where governments have environmental policies (the case of Costa Rica) or when they have the support of international cooperation (the case of Mexico and Bolivia).

The ultimate goal of the democratisation of biodigesters is that they are accessible to any farmers who wishes to use one. For this, it is necessary that the small and medium scale agricultural producers know about the technology, its benefits, costs, operation and limits. In addition, they must be able to access quality technologies, technology providers and financing according to their socio-economic conditions when they need it. Continuous technical assistance (local R & D in real conditions), is a requirement for producers to take full advantage of this technology. With these considerations and experiences in the democratisation of biodigesters, several notes can be highlighted:

10.1. Technological range

It is important that there is a variety of types of biodigesters available to the farmers. A technology can offer greater durability based on greater investment (fixed dome, tubular geomembrane) versus more accessibility and shorter half-life (tubular plastic). The technological range also allows for covering more types of climates (tubular in tropics and cold, fixed dome in tropics and temperate climates), as well as conditions specific to each farmers (for example, the fixed dome hardly occupies space on the farm, but requires transportation of large volume of materials). For this reason, it is recommended to have in the technological proposal biodigesters of geomembrane (PVC or polyethylene) and fixed dome (if the necessary local adaptations are developed to make it competitive), which will normally be focused on the medium scale farmers, who have greater spending capacity, have already invested in agricultural infrastructure and have greater economic prospects. However, taking the experiences of Colombia and Bolivia as examples, to attend to the most vulnerable small scale farmers, with low spending capacities, without previous investment in infrastructure and an uncertain economic prospects, the possibility of being able to access cheaper plastic tubular biodigesters (with 7-year lifespan averages) represents an opportunity.

> **Accesibility of biodigesters by any farmer is the ultimate goal of the democratization of biodigesters.**

10.2. Market focus

A sustainable biodigester market can be developed, focused on medium scale farmers (as is the case in Costa Rica), but this will leave out the most impoverished farmers if subsidies are not available (as is the case in Mexico). Therefore, it is necessary to consider that the development of a sustainable biodigester market among small scale farmers requires appropriate technologies and other types of business dynamics. For example, it should not be about developing companies of professional builders/installers (only dedicated to the installation of biodigesters), but rather trained in a range of broader activities. In this way, these builders/ installers will be more resilient to high and low demand cycles, and be compensated by being able to offer other services.

> **The development of a sustainable biodigester market among small producers requires appropriate technologies and other types of business dynamics**

Another important aspect in the development of a sustainable market is that when the national biogas programs are finished or their subsidies are reduced, the small scale farmers may be left out of the market due to being unattractive to the technology suppliers, who will surely focus on the medium scale farmers, being a more profitable option for them.

10.3. Builders/installers, small and medium scale farmers

The builders are identified as the labourers who build the fixed-dome biodigesters, which are more labor-intensive; and installers as the operators who install tubular biodigesters (prefabricated if they are geomembrane) and which occupy less local labor. There are two different approaches depending of the companies offer one or other type of biodigester. While the labourers, due to their training, in addition to making fixed dome biodigesters will be able to do other building work, the companies that install tubular biodigesters usually only focus on this one item. This makes tubular biodigester companies more vulnerable in the case of a decrease in the demand for facilities, as they have no other activity to offer with which to compensate themselves. This is why these companies have developed more in the sector of medium scale producers, with a more stable investment capacity throughout the year and not being so dependent on the harvest cycle or vulnerable to droughts and other disasters. This is why, in order to develop a market for biodigesters, the potential of technology suppliers among medium farmers must be taken into consideration, but also their vulnerability (when it comes to tubular biodigester installers) among small scale farmers. In this case it is recommended to generate a large group of producers

> **The companies of tubular biodigesters are more vulnerable to a decrease in the demand of facilities, because they have no other activity with which to compensate**

who, in addition to carrying out their normal activities, are able to install tubular biodigesters when the demand exists, without depending on this as their only form of employment.

10.4. Team and participants

The formation of a team of people capable of carrying out a strategy of democratising biodigesters is one of the greatest challenges. Both in the case of Nicaragua and Bolivia, it has been seen that this may be a limiting process in operability. It is not easy to form a team with varied backgrounds who consider and know the reality of the agricultural producer with whom they will collaborate, with a market focus and understanding of the day-to-day difficulties of the most vulnerable farmers, with an opening to include the largest number of participants linked to the biodigester sector, not only universities and companies, but also associations of small and medium-scale farmers. The case of Colombia shows how a strong connected social base can trigger very interesting processes of democratisation of technology and a national biogas program must be able to work with these processes, reinforcing them. While it is always more complicated to work with a large number of actors, if considered from the initial stages, positioning a national biogas program as a tool that strengthens existing processes and develops new ones will mean that it is a more inclusive and sustainable process itself in the long term.

> **NBP can become a tool that strengthens and consolidates existing processes**

10.5. Access to credit and revolving funds

Access to credit has been considered key in national biogas programs so that producers can implement a biodigester. However, in the case of Nicaragua (80% paid cash) and in Bolivia (where the 750 domestic biodigesters were paid for in cash, despite offering accessible loans at 6% interest), it shows that there are cultural barriers, and social and economic conditions for access to credit in the continent. Some aspects that affect the most impoverished small producers are the following; often they do not have title of their lands, they fear getting into debt with the bank because of with a technology they do not feel entirely safe with, the interest is too high for small loans andit is reduced only if they get into debt for higher values. As an alternative to loans granted by micro-finance institutions, there is the possibility of loans granted by the collection companies (for example, milk collection companies) to their suppliers who pay in kind by withholding payments. Another little-explored alternative in national biogas programs is revolving funds, of which many associations of producers already have experience in their management (as is the case ASPROINCA in Colombia), and that allow financial access under local management. In this way, just as a technological range is proposed, it is recommended to have a range of financing tools to access biodigesters such as loans, revolving funds and loans from collection companies.

11. Notes for a NBP in Ecuador

Ecuador has a similar history, in terms of the development and implementation of biodigesters, to other countries in the region, but has not yet given a boost to the democratisation of the technology. Two national factors that can help explain why a process of democratisation of biodigester technology has not been activated in Ecuador is the gas subsidy that exists in the country, which, as in Bolivia, makes it very accessible to farmers and, the high level of nationwide coverage of the electricity grid.

In Ecuador there are previous experiences in the democratisation of biodigesters, mainly plastic tubulars, among small groups of agricultural producers. Generally these have been linked to agroecological approaches and connected through the Ecuadorian Coordination of Agroecology (CEA[26]). There have been successful experiences in Imbabura, Pichincha, Napo, Azuay and El Oro.

In Ecuador there are at least three suppliers of tubular geomembrane biodigester technology and some non-professional plastic tubular biodigester installers. This is a strength of the Ecuadorian biodigester sector, one that, for example, was not available in Bolivia or Nicaragua at the beginning of their processes.

Universities such as the National Polytechnic School (EPN), Amazon Regional University Ikiam or the San Francisco de Quito have lines of research active in anaerobic digestion, which, together with the National Institute of Energy Efficiency and Renewable Energy, form a basis for the development of R&D in the country.

[26] http://www.agroecologia.ec/
[27] https://www.facebook.com/redbioec/

In Ecuador, a network of participants linked to biodigesters was formed (REDBIOEC[27]), as a replica of the Biodigesters Network of Latin America and the Caribbean (REDBIOLAC) or the Biomass Network of Colombia (REDBIOCOL). It which developed a single event presentation and exchange of experiences in 2016 in Quito, in which more than 100 people participated. At present, the activities of this network are being resumed through the development of tubular biodigester installation workshops in Imbabura, Azuay and Guayas, aimed at small and medium scale farmers.

The national policies of Ecuador have addressed the democratisation of biodigesters from several ministries, since this process is aligned very well with the National Plans for Good Living:

• **The Ministry of Electricity and Renewable Energy** produced the first Bioenergetic Atlas of the country, which shows the potential of biogas production according to different waste (manure and crop residues) and its geographical distribution. Furthermore, this ministry encouraged the holding of informative workshops among small and medium scale farmers on biodigester technology, and has supported the installation of geomembrane plastic tubular biodigesters in different provinces (Guayas and Orellana) as demonstrations. Currently, the ministry is focused on the implementation of renewable energies for the production of electricity and does not have specific policies (although it is interested) in the development of another type of project, such as a national biogas program focused on small and medium scale farmers.

• **The Ministry of the Environment** has developed the GENCAPER project. In the first stage, it produced a manual for the analysis of technologies and experiences of biodigesters in Ecuador in the area of medium scale farmers and food processing industries. In a second stage, it focused on small and medium scale farmers, developing a manual for the installation of tubular geomembrane biodigesters and implementing six systems in the provinces of Santo Domingo de los Tsáchilas and El Oro, as demonstrations. In addition, this ministry asked the CTCN for technical assistance for the development of a national biodigester program (project in execution) and of which this document is a part.

- **The Ministry of Agriculture and Livestock**, in its commitment to a change in the productive matrix, has shown interest in biodigesters and has developed a program of production of bio-inputs in different parts of the country, among which is biol (the fertiliser produced by the anaerobic digestion). In addition, this ministry led the formation of an inter-ministerial table to which various institutional bioenergy stakeholders were invited, where biodigesters were also considered. At present, this ministry does not have specific policies for the democratisation of biodigesters.

- **The Ministry of Industries and Productivity,** has approached the topic of biodigesters by supporting specific projects of sewage treatment of slaughterhouses, but whose results have not been satisfactory.

In this way, in Ecuador there are previous experiences regarding biodigesters, there are technology providers, research organisations and an incipient network of participants, as well as interest and various projects from the ministries in the field of biodigesters. This breeding ground raises a baseline more strengthened than other processes developed in Nicaragua or Bolivia, but with components still in consolidation (companies, networks and R&D) with respect to other countries such as Colombia, Costa Rica or Mexico.

> Ecuador has the ingredients for the development and implementation of a strategy for the democratization of biodigesters among small and medium-scale agricultural farmers.

12. Conclusions

International experiences show that Ecuador has the ingredients in place for the development and implementation of a strategy for the democratisation of biodigesters among small and medium scale agricultural producers. Ecuador has incipient networks of participants in the biogas sector, with young companies installing tubular biodigesters, with previous experiences at the level of associations of producers and different ministries that have an interest in the diffusion of the technology.

The challenge facing a strategy of democratising biodigesters is how to combine a top-down approach, typical of national biogas programs with successful endorsement, with bottom-up approaches that consolidate the sectors and make them sustainable and independent long term. The learning processes of Nicaragua and Colombia are key in this aspect, in making an integrative proposal adapted to the context and potential of Ecuador. Considering and evaluating the previous experiences developed by small and local organisations and taking advantage of the brand new Biodigester Network of Ecuador, can be a starting point for the strategy of democratisation of biodigesters to be positioned as a support tool for the existing processes heading in this direction.

In addition, the strategy to be developed must consider a wide range of types of technologies that can be installed in different climates (highlands and tropics, such as the Bolivian experience), and that offer different relationships between durability and investment, always assuring the quality of the systems. This is why, due to its own national experience, it is recommended that Ecuador starts with geomembrane tubular biodigesters (such as Costa Rica, Mexico and Colombia) and plastic (such as Colombia and Bolivia), taking advantage of local capacities already developed in local companies and installers. Although tubular biodigesters are more widely known and seem to be preferred by producers in all countries of the region, there is a challenge between the sustainability of the companies dedicated to this area and the attention to the most vulnerable small scale farmers. To overcome this challenge, it is suggested to increase the diversity of types of companies that install biodigesters, considering consolidated and professional companies that will surely serve the sector of medium scale farmers, and non-professional, informal companies that will serve the needs of small scale farmers.

Accessibility to financing mechanisms must also be broad, considering the development of specific lines of credit, from micro-finance and banks (such as the Nicaraguan case), but also taking advantage of local processes such as revolving funds between producers (Colombian experiences).

Finally, the different experiences of several ministries with regard to biodigesters provides a basis for coordinated actions that contribute to a national strategy for the democratisation of biodigesters among small and medium scale agricultural farmers.

THE CLIMATE TECHNOLOGY CENTER AND NETWORK (CTCN) promotes the accelerated development and transfer of climate technologies for energy efficient, low carbon and climate resistant development. In its role as the implementing arm of the Technological Mechanism of the United Nations Framework Convention on Climate Change, the Center for Climate Technology (CTC) is hosted and managed by the United Nations Industrial Development Organization (UNIDO) and UN Environment and supported by more than 450 network partners around the world.

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