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Towards a sustainable biodigester sector in Ecuador: Inputs for a biodigester component of the PNBE

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

Jaime Martí Herrero (CIMNE-Ikiam)

(jaimemarti@cimne.upc.edu)

Paola Cuji (IIGE)

Valeria Ramírez (IIGE)

Luis Rodríguez (INIAP)

Duther López Domínguez (INIAP)

Jordi Cipriano (CIMNE)

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Contents

1. Objective, methodology and limitations of this document

This document falls within the framework of the DESIGN AND SCALE-UP OF CLIMATE RESILIENT WASTE MANAGEMENT AND ENERGY CAPTURE TECHNOLOGIES IN SMALL AND MEDIUM LIVESTOCK FARMS - REFERENCE NUMBER: 2015000061, financed by UNIDO, in the context of the Climate Technology Centre & Network (CTCN). The project is coordinated by CIMNE, with its local partners INIAP and the National Geological and Energy Research Institute – IIGE (the former INER), in collaboration with the Ministry of Environment and the Amazon Regional University, IKIAM.

The objective of the project is to provide technical assistance for the development of tools which sustainably promote the biodigester sector in Ecuador, and foster large-scale implementation of technology to exploit the potential of biomass from livestock farming.

This document corresponds to activity 4: systematization and communication of the information to produce inputs for the development of a National Biodigester Plan (NBP). The objective of this document is to have an operational and economic plan for the PNB in Ecuador based on information generated in the course of the project.

The specific objectives of the project are to:

- Contextualize biodigester technology in small and medium-sized livestock farms
- Analyse the current state of the technology, users, technology providers and the principal stakeholders
- Propose five-year goals, structure, functions, activities and budget of a National Biodigester Programme in Ecuador (PNBE).

The methodology used to achieve the proposed objectives has been based on the collection of information generated in the course of activities prior to the project, together with interviews and conversations with national and international actors.

The proposals which emerge from this document must be considered as reference guidelines, and must be subject to amendment and update as the PNB is implemented, adapting it to the specific circumstances of its execution.

PART ONE: Introduction and justification

2. Biodigesters and small and medium-sized farmers

2.1. Resilience of small and medium-sized farmers

At global level, small and medium-sized farmers are, in general terms, in a vulnerable situation in the face of the effects of climate change (change in rainfall patterns, extreme climate events, etc.), fluctuations in the price of fossil fuels (over 100 USD per barrel in the period 2011-2014) fluctuation in the price of agrochemicals (linked to oil and gas prices) and unfair competition in productivity in the short term and access to markets with a large transnational agroindustry[1].

Consequently, small and medium-sized livestock farmers need to strengthen their productive systems to build resilience to the effects of climate change, reduce their dependence on inputs from outside the farm, add true value to their products and access markets. In this context, biodigesters are a tool which can strengthen the resilience of small and medium-sized livestock farmers.

Figure 1: Botero & Preston biodigester operating for 3 years in Las Lajas in 2013 (El Oro).

[1] Martí-Herrero J. 2019. *Experiencias Latinoamericanas en la democratización de los biodigestores: Aportes a Ecuador*. CTCN-UNIDO. Ecuador. ISBN: 978-9942-36-253-7

2.2. What are biodigesters?

Biodigesters are systems which produce biogas and fertilizers from organic matter. They are systems in which, in the absence of oxygen and with the presence appropriate bacterial consortiums, anaerobic digestion occurs naturally and the biogas produced is captured. A biodigester is similar in the way it functions to an animal digestive system: organic matters enters and is digested by bacteria, producing gases (biogas) and producing a liquid by-product which has a high value as fertilizer.

Biogas is the name given to the mixture of gases produced in anaerobic digestion, and is characterized by containing 50 - 70% methane (CH_4), 40 - 20 % carbo dioxide (CO_2) and traces of other gases, notable among them being hydrogen sulphide (H_2S). The interesting part is the methane produced, which is combustible. Thus, the organic residues have the potential to produce a combustible gas such as biogas. In addition, the capture of this methane and its combustion (converting it into CO_2) reduces greenhouse gas emissions (GHG) which would be produced by decomposition in untreated manure.

In addition, there is the fertilizer produced during the anaerobic digestion process in the biodigester called bio, effluent or digestate, depending on the country. In the anaerobic digestion process, the nutrients (nitrogen (N), phosphorus (P), potassium (K) and other) contained in the organic residues which enter in organic form are mineralized, and thus become available to plants. This nutrient mineralization process also occurs when, for example, manure is applied to crops, but much more slowly and with greater loss of nutrients due to the evaporation of some elements (nitrogen) and the risk of loss through rainwater runoff. Moreover, phytohormones have been found which help to strengthen the plant and the microorganisms which populate the soil under cultivation and help to mineralize the nutrients present in it. In this way, biodigesters accelerate the production of fertilizer (mineralization of nutrients), prevent losses from evaporation, as well as being enriched with phytohormones and microorganisms. In this way, the recycling of nutrients encouraged by the biodigester means that manure is managed and used in agriculture through the use of effluents from the biodigester, which avoids the contamination of water sources which could occur from production of manure without appropriate treatment.

Thus, biodigesters are able to process organic waste to produce biogas (fuel) and biol (fertilizer). This service (waste treatment) and its two associated products (biogas and biol) can be of great importance in strengthening the resilience of small and medium-sized farmers, reducing GHG emissions and avoiding contamination of bodies of water.

2.3. What does a biodigester bring to a livestock farmer?

Biodigesters are a versatile tool which can strengthen small and medium-sized farmers in a variety of ways from different approaches. The following sections describe different ways in which a biodigester impacts on small and medium-sized livestock farmers.

2.3.1. Biodigester as a fuel producer

Biodigesters are best known for the production of biogas. The production of a fuel (such as biogas) on the farm allows users to cook with it and gives them other productive uses, such as powering milking machines, water pumps, mills, mowers, other thermic uses or production of electricity for own consumption. This access to a source of energy produced by the farmer himself expands the possibilities of use and improvement of his processes, which he would perhaps not consider if it meant an increase in his energy bill for the same activities. In this way, biodigesters, by the production of biogas, increase farmers' energy self-sufficiency by allowing a wider range of energy uses on his farm.

2.3.2. Biodigester as producer of fertilizer

Another aspect is the use of biol (liquid fertilizer produced in biodigesters), a product that was previously unnoticed, but is now taking on considerable importance. The use of biol in one's own crop growing means recycling of nutrients which makes the farmer more resilient and not dependent on agrochemical products external to the farm. Their use allows the farmer to fertilize his fields, saving the costs of buying synthetic fertilizers, and adding value to his production because it is an organic process. Indeed, there are cases of farmers where the use of biol has allowed them to get closer to an agro-ecological farming practice which makes them more sustainable and resilient. Thus, biodigesters, by the use of biol, help to increase the farmer's independence with respect to external inputs, adding value to his crop and the soil.

2.3.3. Biodigester as treatment system

The anaerobic digestion which takes place in the biodigester is an effective system for stabilizing organic wastes, and providing appropriate treatment. Thus, the biodigester provides an environmental service by treating wastes, providing tangible products such as biogas and biol, in contrast to other systems which typically only offer the fertilizer component (composting, vermiculture, treatment plants, etc.).

2.3.4. Biodigester as a tool to mitigate climate change

The manure produced by animals produces methane gas, which has a greenhouse gas effect 25 times greater than CO_2. If you have a biodigester, the production of methane from manure is not only more efficient, but at the same it is captured for use. When the biogas is burned, the methane is transformed into CO_2 and water which consequently reduces the greenhouse gas effect.

Furthermore, the production and use of biogas replaces the use of other fuels, such as wood, natural gas or liquid petroleum gas, which reduces deforestation and the use of fossil fuels[2]. In addition, the recycling of nutrients which are the product of biol reduces or eliminates the use of agrochemicals, manufactured in processes which require fossil fuels as a raw material (natural gas for urea), as a source of energy and for transport and distribution. Thus, the biodigester allows the farmer to reduce the carbon footprint associated with his energy consumption and fertilization of his crops.

[2] Martí-Herrero, J., Ceron, M., Garcia, R., Pracejus, L., Alvarez, R., & Cipriano, X. (2015). The influence of users' behavior on biogas production from low cost tubular digesters: a technical and socio-cultural field analysis. Energy for Sustainable Development, 27, 73-83.

2.3.5. Biodigester as a tool for adapting to climate change

A biodigester allows the farmer to have his own fuel, making him independent of external energy sources, which in the face of extreme events caused by climate change can interrupt his supply chains and increase his costs.

Moreover, by producing fertilizer and encouraging the recycling of nutrients on the farm, the produce also makes himself independent of external agrochemical inputs, which can interrupt his supply chains and his costs dependent on fossil fuels. The integration of a biodigester and faming activities, what is more, very often means integration of agriculture and livestock faming, where the diversity of crops, the integration of iatroculture and livestock farming, care and conservation of the soil, are the keys of the production process, which reduces pests (and the use of agrochemicals) and improves his resilience to extreme climate events such as droughts (because biol increases the percentage of organic matter in the soil and less evaporation in the soil because of the plant cover.

3. Background to the democratization of biodigesters in Latin America

In all Latin American countries, there has been a similar process in the spread and implementation of biodigesters. In the 70s and 80s, in the majority of the countries, the first biodigesters were installed, normally a fixed dome, in projects sponsored by German Technical Cooperation (GTZ) and linked to public universities. These projects allowed testing of the technology, research into the use of the fertilizer produced and adapting engines to run on biogas. In the late 80s and early 90s, the drive to support these projects disappeared, resulting in a lack of sustainability and replication of previous experiments due, primarily, to the fact that the costs of investment in new biodigesters (fixed dome) were high and there was a lack of adequate monitoring and control of the biodigesters already installed.

In the first decade of the new millennium, there was a resurgence of biodigesters in Latin America, once again driven by projects linked to international cooperation funds and executed by NGOs. This time, the type of biodigester used was the tubular plastic model and from 2006, geomembrane plastic tubes began to be introduced[3].

During this decade, small biodigester projects were developed throughout Latin America, with very varied experience in terms of results, farmers taking ownership and sustainability. The principal factor which determines the success or failure of these projects is the social strategy for implementation (the less the subsidy provided and the greater the monitoring, 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 biodigester in Latin America, and the number of universities has increased over the years. It was in this period that steps began to democratize the technology and make it accessible to a greater number of small and medium-sized farmers. For example, Bolivia developed a national project (it has not come to the idea of a programme which would generate a biodigester market) from 2008 to 2012, in

[3] Garfí, M., Martí-Herrero, J., Garwood, A., & Ferrer, I. (2016). Household anaerobic digesters for biogas production in Latin America: A review. Renewable and Sustainable Energy Reviews, 60, 599-614.

which 750 domestic tubular biodigesters were installed using a passive solar energy design, as the majority of them were located on the Bolivian Altiplano.

The various experiences of installation of biodigesters yielded very disparate results, and that was why in 2009 the Latin American and Caribbean Network of Biodigesters (REDBIOLAC[4]), became a pioneering space for sharing experiences and lessons learned. In this way, a ***bottom-up*** movement began connected at regional level, with the participation of NGOs, foundations, universities, small and medium-sized enterprises, microfinance institutions and farmers' associations across the continent. Supported by the shared experiences, these actors began to give a new impetus to biodigesters in the region which, from the bottom up, developed unequally in each country depending on the number of actors and local conditions. They are not national biogas programmes because they are not supported by specific government policies, but rather a heterogeneous and diverse movement, joined-up, linking actors with an integrated agricultural, economic and social vision. There are countries which have or have had great strength in this sphere, such as Mexico, Costa Rica, Colombia or Bolivia, more of which later.

It was in those years that two institutions of the Netherlands Development Organisation (SNV[5] and Hivos[6]), with previous successful experience in Asia and Africa in the development of sustainable biodigester markets and in the face of the already rapid advance of cultivation in Latin America, began to evaluate the implementation of National Biogas Programmes (NBP) in the continent. These programmes have a ***top-down*** approach based on successful methodologies in Asia and Africa). In those cases, the structure and functioning of an NBP is already established and validated by experience, and the aim is to find local actors who can develop the various component parts which make up the NBP. These NBPs 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 an NBP was evaluated. Honduras did not prove to be feasible, while the other three countries did so. Nicaragua started its NBP based on African and Asian experiences in 2012, with the objective of installing 6,000 biodigesters by 2018 (an objective which was reduced half way through the programme to 1500 units).

4. Background to biodigesters in Ecuador

Ecuador, which has a history similar to that of the rest of the continent in terms of development and implementation of biodigesters, has not so far given an impetus to the democratization of the technology. Two national factors may help to explain why Ecuador has not activated a process of democratization of the technology of biodigesters. One is the gas subsidy in the country which, like Bolivia, makes it very accessible to farmers and, secondly, the wide coverage of the electricity network.

In Ecuador, there is prior experience of the democratization of biodigesters, chiefly tubular plastic, among small groups of livestock farmers. Normally, these have been linked to

[4] http://redbiolac.org/

[5] Netherlands Development Organisation: https://snv.org/

[6] https://www.hivos.org/

agroecological approaches connected through the Ecuadorian Agroecology Coordinator (CEA).[7] There have been successful experiences in Imbabura, Pichincha, Napo, Azuay and El Oro.

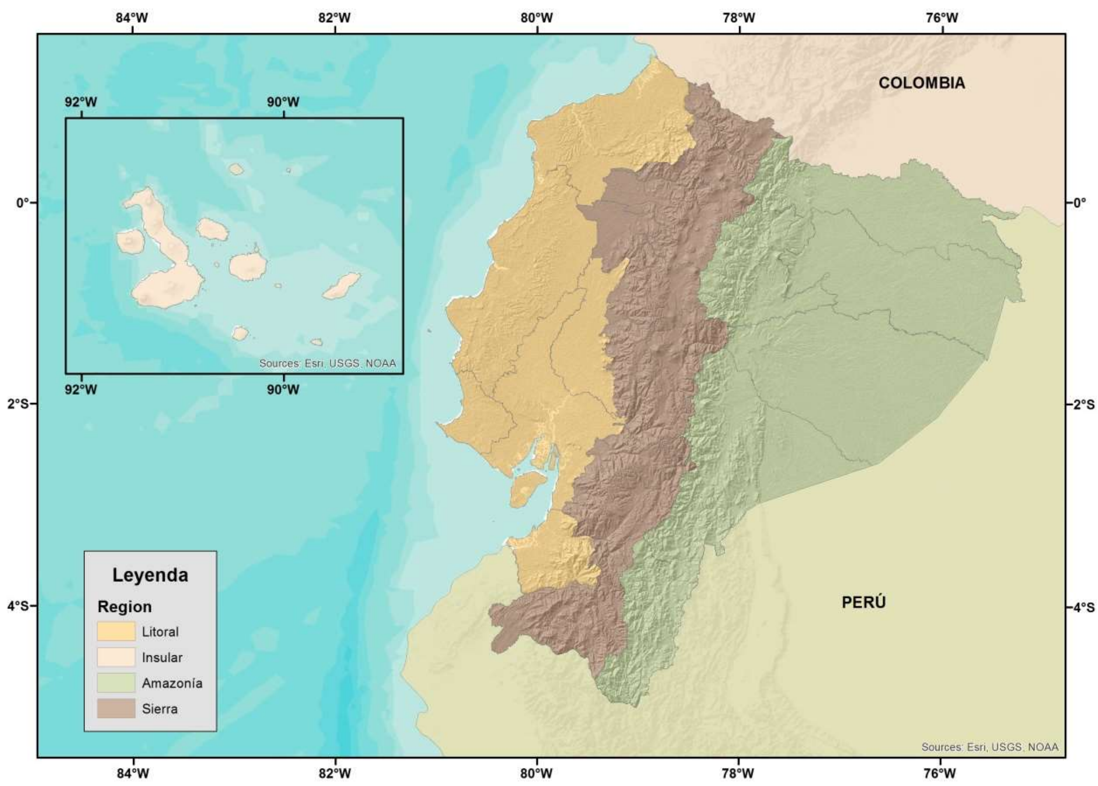


Figure 2 Map of Ecuador showing the three continental geographical regions: on the left, the coast; in the centre, the Andean Region and on the right, the Amazon Region, Source: ESRI, USGS, NOAA

In Ecuador, there are at least three suppliers of tubular geomembrane biodigester technology and some non-professional installers of tubular plastic biodigesters. This is a strength of the Ecuadorian biodigester sector.

Universities such as the National Polytechnical School (EPN), University of the Armed Forces (ESPE), San Francisco de Quito University (USFQ) or the Amazon Regional University, IKIAM, have active lines of research into anaerobic digestion which, together with the Geological and Energy Research Institute, form a base for the development of R&D in the country..

In Ecuador, a network of actors linked to biodigesters was formed (REDBIOEC[8]), replicating Latin American and Caribbean Network of Biodigesters (REDBIOLAC) or the Biomass Network of Colombia (REDBIOCOL[9]), which organized a unique event for presentation and sharing of experience in 2016 in Quito, attended by over 100 people. Currently, the activities of this

[7] http://www.agroecologia.ec/

[8] https://www.facebook.com/redbioec/

[9] https://www.redbiocol.org/

network are being resumed through the holding of workshops on the installation of tubular biodigesters in Imbabura, Azuay and Guayas aimed at small and medium-sized farmers.

Figure 3 Tubular plastic biodigester tubular (with protective plastic cover) installed in Valle de Intag by the ACAI in 2013 (Imbabura)

Ecuador's national policies have addressed the democratization of biodigesters through several ministries, as this process fits very well with the National Development Plans:

- The Ministry of Energy and Non-renewable Natural Resources, formerly called the MEER (Ministry of Electricity and Renewable Energy) produced the first bioenergy atlas of the country, showing the potential for production of biogas from different wastes (animal manure and crop residues) and their geographical distribution. In addition, this ministry encourage the holding of information workshops for small and medium-sized farmers on biodigester technology and supported the installation of tubular geomembrane plastic biodigesters in various provinces (Guayas and Orellana) for demonstration purposes.
- The Ministry of Environment (MAE) has developed the project on Capacity Building in the use of Energy from Livestock Waste (GENCAPER). In a first stage, it produced a manual of analyses of biodigester technologies and experiences in Ecuador in the context of medium-sized farmers and food processing industries. In a second stage, it focused on small and medium-sized farmers, developing a manual on 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, the MAE asked the Climate Technology Center & Network (CTCN) for technical assistance for the development of a national biodigester programme (implementation project), of which this document forms part.

- The Ministry of Agriculture and Livestock has shown interest in biodigesters and has developed a programme of bioinputs in different parts of the country, among them biol (the fertilizer produced by anaerobic digestion).
- The Ministry of Foreign Trade, Production, Investment and Fishing (formerly the Ministry of Industry and Productivity) has associated itself with biodigesters, supporting specific projects for treatment of waste water from slaughterhouses (abattoirs), but the results of which have not been satisfactory.

Thus, in Ecuador, there is prior experience of biodigesters, there are provides of technology, research bodies and an embryonic network of actors, as well as interest and various projects by ministries in the context of biodigesters. This niche of actors set a stronger baseline than other processes developed in Nicaragua or Bolivia, but with components which are still being consolidated (enterprises, networks and R&D) compared with other countries such as Colombia, Costa Rica or Mexico.

5. Results of the study of the potential for biodigesters in Ecuador

During 2017 and 2018, a study was carried out on "Baseline and potential technical demand for biodigesters in Ecuador: Analysis of the context and types of farmers"[10], as an initial result of the project "DESIGN AND SCALE-UP OF CLIMATE RESILIENT WASTE MANAGEMENT AND ENERGY CAPTURE TECHNOLOGIES IN SMALL AND MEDIUM LIVESTOCK FARMS" financed by UNIDO, in the framework of the Climate Technology Centre & Network (CTCN). The project is coordinated by CIMNE with local partners INIAP and the IIGE, with the collaboration of the Ministry of Environment and the Amazon Regional University, IKIAM.

The objective of the study was to contextualize Ecuador in socioeconomic terms, with emphasis on the energy sector and especially livestock, as an input for the generation of conclusions and recommendations for the sustainable development of biodigesters through the implementation of a national biodigester programme. The conclusions of the study are described below:

- **Regions of Ecuador:** Ecuador is divided into three continental regions (Costa, Sierra and Amazonia) and one insular (Galapagos). The livestock sector is concentrated in the Costa and Sierra regions, while Amazonia is characterized by a very low population density and Galapagos by its small population, but high visibility because of its natural assets.
- **Sectors and regions of interest:** A national biodigester programme focused on small and medium-sized farmers must begin by focusing on the livestock sectors and regions which offer the greatest potential for implementation of biodigesters. This means that the Costa and Sierra regions, and the pig and dairy sectors are the most suitable for starting a NBP. This does not mean leaving aside other regions and sectors which, in

[10] https://www.ctc-n.org/news/biodigestores-en-ecuador-lisis-del-contexto-y-tipolog-del-sector-agropecuario

specific circumstances, by their impact or visibility, nay be considered (such as the case of dairy farming in Napo or livestock farming in Galapagos, for example).

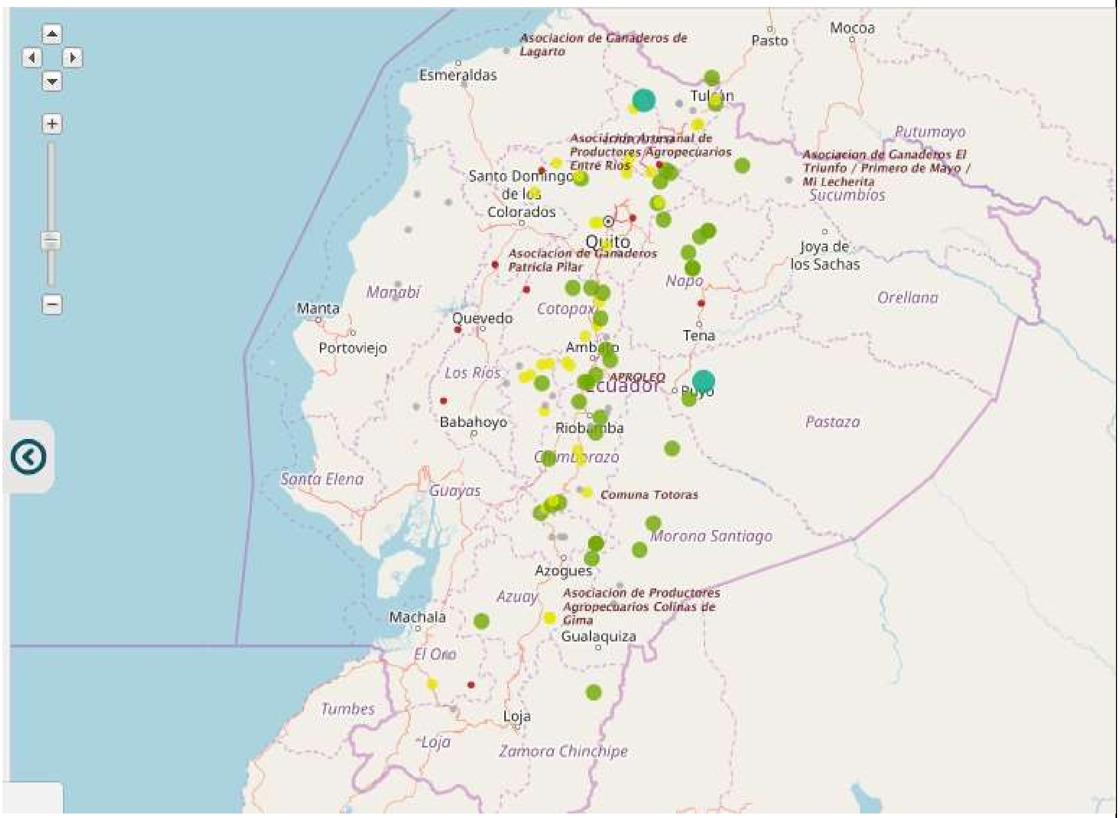
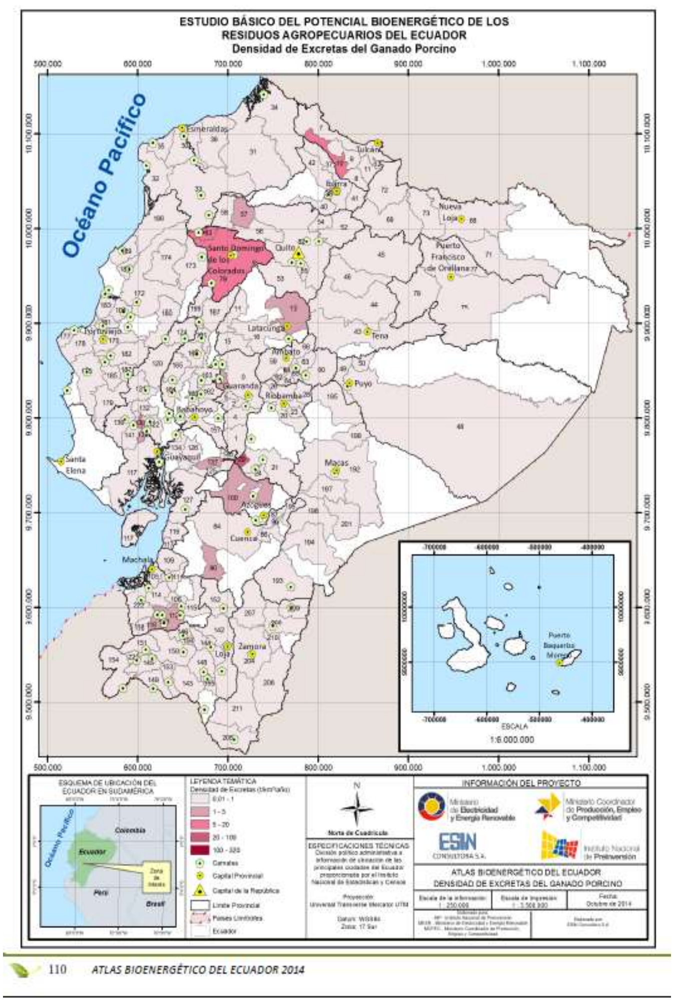


Figure 4. Distribution of milk collection centres listed in the Ecuadorian agro GEOPORTAL (http://geoportal.agricultura.gob.ec/)

- **Energy and biogas:** The country has very cheap energy prices, and accessible to the population, as LPG is subsidized, an average family can invest about 20 USD per year in LPG, which makes biogas produced by biodigesters less attractive. In this case, a national biodigester programme must consider expanding the use of biogas not only as a substitute for LPG for cooking, but also for other productive uses, such as operating milking machines, heating dairies, mowers, mills or generation of electricity for own consumption.
- **Biol:** It is known among the country's small agroecological farmers, and in part by farmers of intensive crops such as floriculture, broccoli growing and other crops. Given the lack of interest in biogas due to the LPG subsidy in Ecuador, a national biodigester programme must make enormous efforts to show the increase in yields from using biol, carrying out crop- and region-specific R&D.
- **Environmental mitigation:** Medium-sized pig farmers are faced with the need to take environmental mitigation measures with regard to the manure produced, and in this context, biodigesters become an opportunity to treat their wastes and comply with environmental legislation. In this case, the treatment is not an expense, because the generation of biogas can be used in food and heating for piglets, while the use of biol is subject to the availability of arable land of the medium-sized pig farmer or his capacity

to sell it. Small pig farmers, due to the small number of pigs owned by them, who also combine family agriculture and have space to use the manure, environmental mitigation is not an incentive, Something similar happens with dairy farmers (small and medium-sized) who also have pasture where they can apply the manure from their cows. In these last cases (small pig farmers and small and medium-sized dairy farmers) the focu9se must be on the use of biol and using biogas in cooking and productive uses on the farm.

- **Experience with biodigesters in Ecuador**: Ecuador has a similar history to other countries in the region with regard to the development of biodigesters. Currently, the technology most used in small and medium-sized farms is tubular biodigesters. Polyethylene tubular plastic (greenhouse gas plastic) is generally used for small farmers and PVC geomembrane for medium-sized farmers. There is experience of covered lagoons and sophisticated technologies, dedicated to large livestock farmers in the first case and treatment of organic wastes from the food industry in the second. The use of biogas is mainly happening on the farm for cooking and other thermic productive uses (heating for dairies, for example). The use of biol is widespread among small farmers. There are no known experiences in uses of biogas for operating farm machinery (mowers, grass choppers, etc.) or the production of electricity. There are a few informal suppliers of tubular plastic biodigesters, and two suppliers of tubular geomembrane biodigesters.



Established Figure 5 Bioenergy atlas of Ecuador showing the density of pig excrement (ABE, 2016)

- **Technical potential of biodigesters**: The analysis of the secondary information shows that between the Costa and Sierra regions, there are at least 201,000 small and medium-sized dairy farmers and 231,000 small and medium-sized pig farmers. As both sets of data may overlap (the same farmer can have dairy cattle and pigs), it is estimated that the technical potential of biodigesters focused on small and medium-sized farmers is at least 231,000 users. This figure indicates that it is feasible to develop a national biodigester programme, as experiences in other countries suggests that a potential above 50,000 users is sufficient.

Figure 6 Tubular geomembrane biodigesters: Left, the company "Biodigestores Ecuador" http://biodigestoresecuador.com), right, the company Biodigestores Mundo Intag (https://biodigestoresmundointag.blogspot.com)

- **Typology of farmers:** The typology of small and medium-sized farmers has been developed by sector of interest (dairy and pig farming) and by region (Costa and Sierra). A point to emphasize is the low investment in infrastructure of small dairy farmers who do not have a yard pen and mostly milk in the same field. (chiefly in the Sierra region). This is an aspect to consider, as without a milking shed, the collection of manure to feed a biodigester becomes difficult. In this case, it is necessary to consider complementing a national biodigester programme with incentives to improve infrastructure such as the prior installation of sheds for milking (and for supervision of the animals, possibility of treating individual animals, hygiene, convenience, etc.) in order to instal biodigesters.
  In the case of pig farmers, (small and medium-sized farmers in Costa and Sierra), they tend to keep the animals in pens, where in some cases the floor is earth. In this case, it is also appropriate to consider this aspect and complement the national biodigester programme with infrastructure improvement so that all pig pens have a roof and a cement floor, thus facilitating the loading of the biodigester by washing the pens with water.

6. Conclusions Part One

International experience shows that Ecuador has the conditions which allow the development and implementation of a strategy of democratization of biodigesters among small and medium-sized livestock farmers. Ecuador has incipient networks of actors in the biogas sector, with young tubular biodigester installation companies with prior experience at the level of farmers' associations and various ministries which have an interest in the rollout of the technology.

The challenges faced by a strategy of democratization of biodigesters is how to combine a *top-down* approach, typical of national biogas programmes with proven success, with *bottom-up* approaches which consolidate sectors and make them sustainable and independent in the long term. The lessons from the processes in Nicaragua and Colombia are key in this respect, to produce an integrated proposal suited to the context and potential of Ecuador. Considering and evaluating the prior experiences of small and local organizations and drawing on the brand new Biodigester Network of Ecuador, could be a starting point to position the strategy of democratization of biodigesters as a support tool for existing processes in this regard.

In addition, the strategy to be developed must consider wide range of types of technology, which can be installed in different climates (sierra and tropical, like the Bolivian experience), and which offer different ratios between durability and investment, always assuring the quality of the systems. It is for this reason, due to national experience, it is recommended to start with tubular geomembrane biodigesters (like Costa Rica, Mexico and Colombia) and plastic (like Colombia and Bolivia), taking advantage of local capacities already developed in local enterprises and installers. Although tubular biodigesters are better known and seem to be preferred by farmers in all countries of the region, there is a challenge between the sustainability of the companies dedicated to this category and looking after small more vulnerable farmers. To meet this challenge, it is suggested to increase the diversity of types of companies which install biodigesters, considering consolidated and professional enterprises which can certainly look after the medium-sized farmer sector, and non-professional, informal enterprises which will look after the small farmers.

Accessibility of financing mechanisms must also be broad, considering the development of specific lines of credit, from microfinance and banks (as in Nicaragua) but also drawing on local processes which can be revolving funds between farmers (Colombian experiences).

Lastly, the different experiences of various ministries of biodigesters offer a base to undertake coordinated actions which contribute to a national strategy of democratization of biodigesters among small and medium-sized livestock farmers.

PART TWO: Evaluation and potential of biodigesters in Ecuador

7. Types of farmer and regions targeted by the NBP

To better identify the typical farmers targeted by the NBP, they are classified into medium-sized and small[11]. The criterion for defining these various typologies between cattle or pig farmers, including by region, but also to achieve a classification common to the NBP, they are defined for this proposal as follows:

- Small dairy farmers are those who have less than 20 cows and produce up to 100 litres of milk per day, while medium-sized are those who have between 20 and 40 cows and produce up to 300 litres per day.
- Small pig farmers are those who raise less than 30 pigs, while medium-sized are considered those who raise between 30 and 300 pigs.

These criteria help to identify the spectrum of farmers targeted by the NBP, albeit flexible at the blurred borderline between which will exist in some cases in considering a farmer small or medium-sized, or even medium-sized or large. The following table summarizes the classification of the target farmers.

Table 1 Criterion for small and medium-sized farmers

	Pigs	Cows	
Small farmer	Less than 30 pigs	Less than 20 cows	Up to 100 l/d of milk
Medium-sized farmer	Between 30 and 300 pigs	Between 20 and 40 cows	Up to 400 l/d of milk

In terms of geographical distribution, two macro regions of interest have been identified to be prioritized in the implementation of biodigesters in Ecuador, due to the type of farmer and livestock concentrated there, The following table shows the provinces considered in these regions, called, for the purpose of development of the NBP, north region and south region. AS a matter of completeness, one additional province has been included in each region.

Table 2 Prioritized regions of Ecuador

	Pigs	Cows	For completeness
South	El Oro, Guayas, Los Ríos, Azuay, Cañar, Chimborazo	El Oro, Guayas, Los Ríos, Azuay, Cañar, Chimborazo	Bolívar
North	Santo Domingo, Pichincha, Imbabura	Pichincha, Tungurahua, Cotopaxi, Imbabura	El Carchi

[11] https://www.ctc-n.org/content/act-2-lisis-entrada-salida-de-los-biodigestores-en-el-contexto-ecuatoriano

Dividing the country into two working regions facilitates the decentralization of the process, This delimitation helps to focus efforts on spatial terms but does not mean exclusion of the other provinces from the development of the NBP.

8. Characterization and analysis entry/exit of the target farmers

By means of a field study[12] which considered 32 farms representative of the types of target farmer (Table 1) and distributed by prioritized regions (Table 2), a typical profile of a target farmer of the NBP was identified.

Thus profile identifies general characteristics of farmers, according to whether they are large or medium-sized and by type of livestock that they raise. The typical number of animals, typical infrastructure, management of manure and manure available for treatment and used in a biodigester.

In order to associate a type of biodigester with each type of farmer, types of biodigester have been classified according to the objective of their use:

- **Domestic biodigester:** Biodigesters which produce between 1 and 2m^3 of biogas per day, sufficient to cover all the fuel needed for cooking for a family.
- **Productive biodigester:** Biodigesters which produce more than 2m^3 of biogas per day and, therefore, cover the fuel needed for cooking and the biogas can also be used in other processes (heating for piglets or chicks, heating water to clean milking equipment, grass croppers, electricity generators, milking machines, motor pumps, etc.)
- **Environmental biodigester:** Biodigesters whose priority is total treatment of available organic residues, irrespective of the need for biogas or its potential use. In some cases, where more biogas is produced than can be used on the farm, the excess biogas is burned in a flare.

Finally, the economic value of the implementation of the biodigester in each type of farmer was evaluated, considering saving of fuel and purchase of synthetic fertilizers. More detailed information are set out in Table 32 and Table 33 in the annexes.

The acquisition values of LPG cylinders can vary from one type of farmer to another due to their accessibility and transport costs. On average, small dairy or pig farmers say they pay 2.90-2.95 USD, while medium-sized report figures of 3.13 to 5.75 USD per 15kg cylinder of LPG[12].

The typical small dairy farmer has some 8 cows, 5 of them in production, with total production of 50 litres of milk per day. He usually has a shed and milks in it. He obtains some 60 kg of manure per day, which he collects and later spreads on the pasture (recycling of nutrients). He consumes 1.5 cylinders of LPG per month, assuming a cost of around 50 USD per year because

[12] https://www.ctc-n.org/content/act-2-lisis-entrada-salida-de-los-biodigestores-en-el-contexto-ecuatoriano

it is subsidized (180 USD per year of State subsidy). He spends some 260 USD per year on fertilizers.

- With a domestic biodigester, he could treat 30kg of manure per day, mixed with 90 litres of water, producing 1m^3 of biogas per day, enough for cooking. The economic value of the fertilizer generated would be some 66 USD[13]. By using the biogas and biol properly, he would save some 116 USD per year in LPG and fertilizers, and the State would save some 180 USD per year in gas subsidy.
- With a productive biodigester, he could treat 60kg of manure per day, mixed with 180 litres of water, producing 2m^3 of biogas per day, enough for cooking. The economic value of the fertilizer generated would be some 132 USD. By using the biogas and biol properly, he would save some 182 USD per year in LPG and fertilizers, and the State would save some 180 USD per year in gas subsidy.

The typical medium-sized dairy farmer has some 47 cows, 24 of them in production, with total production of 336 litres of milk per day. He does not have a shed and milks in the pasture. He obtains some 140 kg of manure per day, which he collects and later spreads on the pasture (recycling of nutrients). He consumes some 3.2 cylinders of LPG per month, assuming a cost of around 220 USD per year because it is subsidized (400 USD per year of State subsidy). He spends some 2780 USD per year on fertilizers.

- With a productive biodigester, he could treat 120kg of manure per day, mixed with 360 litres of water, producing 4.2m^3 of biogas per day, enough for cooking. The economic value of the fertilizer generated would be some 310 USD. By using the biogas and biol properly, he would save some 530 USD per year in LPG and fertilizers, and the State would save some 400 USD per year in gas subsidy.

The typical small pig farmer has some 22 animals, 4 of them mothers and a breeding pig. He keeps them in a pen with a cement floor. He obtains some 30 kg of manure per day, which he collects and later spreads on crops. He consumes 2.1 cylinders of LPG per month, assuming a cost of around 73 USD per year because it is subsidized (260 USD per year of State subsidy). He spends some 400 USD per year on fertilizers.

- With an environmental biodigester, he could treat 30kg of manure per day, mixed with 150 litres of water, producing 1.5m^3 of biogas per day, enough for cooking and provide heating for some piglets. The economic value of the fertilizer generated would be some 190 USD. By using the biogas and biol properly, he would save some 263 USD per year in LPG and fertilizers, and the State would save some 260 USD per year in gas subsidy.

The typical medium-sized pig farmer has some 50 animals, 9 of them mothers and 2 breeding pigs. He keeps them in a pen with a cement floor. He says he obtains some 35 kg of manure per day, but considering the number of animals, this figure could be as much as 60 kg per day. IN many cases, he does not grow crops where he can use the manure, and this is an environmental problem. He consumes some 2 cylinders of LPG per month, assuming a cost of around 75 USD

[13] https://www.ctc-n.org/content/act-2-lisis-entrada-salida-de-los-biodigestores-en-el-contexto-ecuatoriano

per year because it is subsidized (260 USD per year of State subsidy). If he grows crops, he spends some 400 USD per year on fertilizers.

- With an environmental biodigester he could treat the 35kg of manure per day which he says he has, mixed with 175 litres of water, producing 2m^3 of biogas per day, enough for cooking and provide heating for some piglets. The economic value of the fertilizer generated would be some 180 USD. By using the biogas and biol properly, he would save some 255 USD per year in LPG and fertilizers, and the State would save some 250 USD per year in gas subsidy.
- With an environmental biodigester he could treat the 60kg of manure per day which it is estimated that he actually produces, mixed with 300 litres of water, producing 3.5m^3 of biogas per day, enough for cooking and provide heating for some piglets. The economic value of the fertilizer generated would be some 300 USD. By using the biogas and biol properly, he would save some 375 USD per year in LPG and fertilizers, and the State would save some 250 USD per year in gas subsidy.

9. The most suitable biodigester design

Because there is previous experience in the country and there are providers of the technology, it is not necessary to define and introduce new biodigester designs for the implementation of an NBP (as has happened in other countries). Consequently, **the principal biodigester model will be the tubular biodigester**, whether manufactured using plastic (for small volumes up to 12m3), PVC or polyethylene geomembrane (for volumes up to 100m^3)

It will, however, be necessary to consider design aspects to adapt these biodigesters to colder climates, as occur in the Andean Sierra, chiefly where there is dairy farming.

- In climates with average ambient temperatures below 20°C, it will be necessary to require dark colours for the manufacture of the biodigester.
- In climates with average ambient temperatures below 17°C, in addition to the above, insulation will be required (5 cm foam) in the trench.
- In climates with average ambient temperatures below 15°C, in addition to the above, a compact greenhouse.

10. Sizes and costs of biodigesters

The analysis of the costs of the biodigesters currently being offered by the established technology suppliers in Ecuador can be divided into three headings:

- Skilled labour which excludes daily wages for construction of the trench
- Logistics, which covers travel and visits
- Biodigester, which includes trench, reactor, reservoir, protection, accessories, digester, H_2S filter and overflow valve
- Other accessories, which can include input and output tanks, solid waste separators, heaters for piglets, etc.

An analysis of supply and installation of biodigesters by different technology suppliers in Ecuador shows that the cost of skilled labour is some 500 USD per installation, more or less irrespective of the size of the biodigester.

On the other hand, the logistics, depending on the location of the user and the number of journeys and visits undertaken, range from 40 to 210 USD, and the average can be considered as 150 USD.

According to this model, biodigesters manufactured from geomembrane, regardless of whether it is PVC or polyethylene geomembrane, have a cost per cubic metre ranging from 139 USD/m^3 for volumes around 10m^3, to 65 USD/m^3 for volumes of 40m^3. It should be noted that PVC geomembrane and plastic biodigesters incorporate a protection system with a cover that varies between 20 and 30 USD/m^3 of biodigester, while in polyethylene geomembrane biodigesters, the protection is minimal (because of the robustness of the material) and the costs is less than 5 USD/m^3 of the biodigester. Figure 7 below shows the costs by volume of geomembrane, biodigesters, supplied by the various established technology suppliers in Ecuador

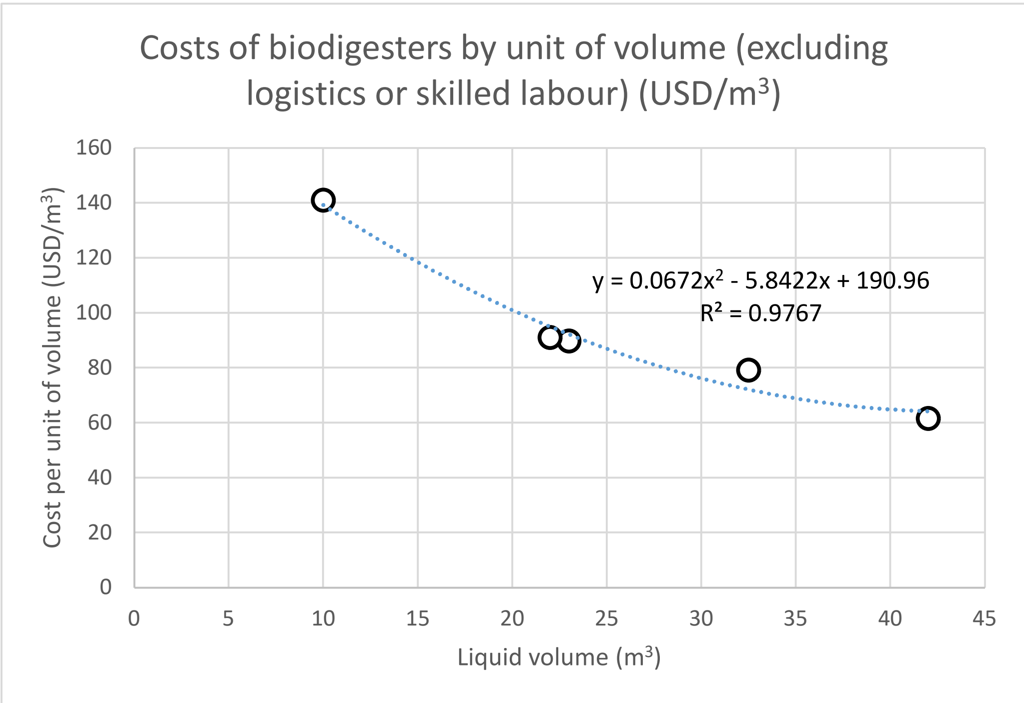


Figure 7 Costs of biodigesters per unit of volume (excluding logistics or skilled labour) (USD/m^3)

Applying this adjustment to specific values, as a reference, a geomembrane biodigester of 10m^3 costs 1390 USD, while one of 40 m^3 will cost 2600 USD.

Plastic biodigesters are cheaper and have a costs of some 100 USD/m^3 for biodigesters of 10 m^3 (1000 USD per 10m^3) and 75 USD/m^3 for 20m^3 systems (1500 USD for two biodigesters of 10m^3 each in series), to which must be added the logistics and skilled labour. In these cases, the logistics is less when the biodigesters are installed by more local engineers, estimated at 50 USD. Skilled labour can also be up to 200 USD cheaper per biodigester.

Table 3 shows the reference costs of geomembrane biodigesters for different liquid volumes, including labour and logistics.

Table 3 Current reference costs of biodigesters

Liquid volume of geomembrane biodigester (m^3)	Biodigester cost per unit of volume (USD/m^3)	Total biodigester cost (USD)	Cost of skilled labour (USD)	Logistics (USD)	Total (USD)
Geomembrane 10	139	1 390	500	150	2 040
Geomembrane 20	101	2 020	500	150	2 670
Geomembrane 30	76	2 280	500	150	2 930
Geomembrane 40	65	2 600	500	150	3 150
Plastic 7.5	100	750	200	50	1 000
Plastic 10	100	1 000	200	50	1 250
Plastic 20	75	1 500	200	50	1 500

In the installation offers analysed, in some cases other accessories or supplementary items are different as shown in Table 4. Such additional items are not specific to each installation (for example, heaters for piglets) or each supplier (solid waste separators).

Table 4 Costs of accessories, supplementary items

Accessory/supplementary item	Cost
Biogas heater for piglets (x2)	USD 130
Solid waste separator	USD 300
Input and output tanks	USD 150
Extra biogas reservoir(1.5 to 2 m^3)	USD 100

11. Challenges of the current biodigester technology

Installation prices of biodigesters in Ecuador, according to Table 3, are expensive chiefly for smaller volumes. The ability to pay of a small livestock farmer is less than the 1000 USD which is the cost of the cheapest domestic biodigester (plastic). The costs of geomembrane biodigesters are higher, but normally aimed at medium-sized farmers who have an urgent need to solve the waste treatment problem and avoid fines or closure of the operation because of environmental regulations.

In the cost analysis, the installation of covers on **PVC geomembrane biodigesters** can involve between 20 and 25% of the total budget for the installation of the biodigester. Due to the properties of this PVC material, it is necessary to protect it from solar radiation and to do this, zinc covers are constructed. This, moreover, is a limiting factor on the use of PVC membrane for the reactor in cold climates, where it is necessary to consider solar heating criteria and put the biodigester in compact greenhouses, since this material stretches considerably in the heat and makes it difficult, or more expensive, to build appropriate greenhouses. As an alternative to continuing to use PVC geomembrane and reduce costs and be able to use it in a cold climate, the alternative, to be validated by the R&D component of the NBP, is to cover the biodigester with a covering of a resistant material which contains the expansion of the dome of the biodigester, protects them from solar radiation and eliminates the need, to have a cover. This material can be a polyethylene geomembrane layer of 500 microns.

In **plastic biodigesters** of 10m^3, the investment in protection and cover also come to around 20 to 25% of the total budget. To reduce these costs, the proposal, to be validated by the R&D component of the NBP is to change the use of plastic to build the reactor for polyethylene geomembrane of 500 microns. In this way, the costs of manufacture of the reactor are reduced, and the need to build a cover is eliminated. Due to the dark colour of this simple and flexible geomembrane, the biodigester can increase the internal temperature by up to 3°C, thus improving its productivity. The objective is to achieve domestic biodigesters of 7.5 m^3 for a total cost of installation of around 750 USD to make them accessible to the majority of small livestock farmers.

In the case of **polyethylene geomembrane biodigesters**, the cost is higher than PVC geomembrane biodigesters, but because they do not require a cover, the total budget is similar to the other alternatives. Because it does not need a cover, it has a certain gain in internal temperature (around an extra 3°C, due to the black colour of the polyethylene geomembrane).

A challenge for any of the proposed systems is to consolidate and work in cold climate conditions, such as those that can be found in the dairy farming regions. For this, it is necessary to incorporate solar heating designs through dark colours, insulation in the trench and greenhouse. Only one of the three established technology providers in Ecuador have had experience of using these solar heating designs, so it is necessary to strengthen the suppliers' capacity in this aspect.

12.Implementation of biodigesters

The implementation of biodigesters has been effected through two different processes depending on whether it involves small or medium-sized farmers.

In the case of small farmers, the biodigesters have normally been linked to cooperation projects or developed where they have been heavily subsidized, at times 100%. Based on previous experience, this financing tends to involve a high risk of abandonment of the biodigesters, which can only be avoided if there has been a good selection of beneficiaries prior to installation and strong follow-up work subsequent to installation. Due to this situation, it is essential, in order to reach small farmers, to have an installation subsidy.

In the case of medium-sized farmers, although some biodigesters have been installed in the framework of projects with subsidies, the majority are being installed fully paid for by the users. This is chiefly due to the need for pig farmers to have adequate treatment of their wastes and avoid closure of the business or fines.

13. CO_2 emissions avoided by the implementation of biodigesters

The kilogrammes of CO_2 which have not been released into the atmosphere thanks to the introduction of a biodigester in a farming activity can be estimated. For that purpose, it i0s necessary to consider:

- the CO_2 emissions associated with the construction of the biodigester
- the emissions avoided by displacement of the use of LPG or fossil fuel which it replaces,
- the emissions avoided by displacement of the use of synthetic fertilizers,
- the emissions avoided by the change in the management of manure (which from being piled up is now introduced into a biodigester).

Table 5 shows the result of this analysis for each of the types of farmer identified on the NBP. Further details of the CO2 estimates are set out in the annexes (page 70).

Table 5 Balance sheet of CO_2 emissions associated with each type of produced with a biodigester

	Added	Avoided (kg CO_2/year)				Total kg CO_2 avoided Year 10
	Construction (kg CO_2)	Fuel	Fertilizers	Manure	Total avoided	
Small dairy	150	510	223	29	763	7 477
Medium-sized dairy	600	2 142	673	117	2 933	28 729
Small pig	150	765	300	494	1 560	15 445
Medium-sized pig	300	1 785	558	988	3 382	33 010

14. Expenditure on LPG subsidy avoided by the implementation of biodigesters

The introduction of biodigesters in livestock farming has an economic impact on the displacement of LPG as a fuel, as biogas is used by farmers. According to Martínez et al (2018)[14] the LPG subsidy in Ecuador is 18.60 USD of each 15kg cylinder of LPG when compared with selling prices to the public in Peru and Colombia The Hydrocarbon Regulation and Control Agency[15] publishes on its website the price of (subsidized) domestic LPG at figure of 0.106667 USD/kg LPG, and the (non-subsidized) price of industrial LPG at a figure of 0.6505470 USD/kg LPG. These values indicate that a 15kh cylinder of LPG has an associated subsidy of 8.16 USD. Thus, based on the expected biogas output by type of farmer with a biodigester, the quantity of cylinders displaced per year, and the associated subsidy, can be estimated, as shown in Table 6.

[14] Martínez, J., Martí-Herrero, J., Villacís, S., Riofrio, A. J., & Vaca, D. (2017). Analysis of energy, CO2 emissions and economy of the technological migration for clean cooking in Ecuador. *Energy Policy*, *107*, 182-187.

[15] https://www.controlhidrocarburos.gob.ec/precios-combustibles/

Table 6 Expenditure on LPG subsidy by type of farmer					
	Manure (kg/d)	biogas (m^3/d)	LPG Equivalent (kg/d)	Cylinders LPG(#/year)	Subsidy[16] (USD/year)
Small dairy	30	1	0.40	9.64	78.63
Medium-sized dairy	120	4.2	1.66	40.48	330.23
Small pig	30	1.5	0.59	14.46	117.94
Medium-sized pig	60	3.5	1.39	33.73	275.19

Thus, the State can save between 78 and 118 USD per year per small farmer, and from 275 to 330 USD for medium-sized farmers, when they have a biodigester.

The expenditure already incurred by the Ecuadorian State subsidizing LGP can be an investment if it is used to subsidize an NBP in Ecuador. In this way, families who incorporate a biodigester in their productive systems will be generating a saving for the State.

15. Description of the biodigester sector in Ecuador

15.1. Network of biodigesters of Ecuador

In Ecuador there is a network of biodigesters called RedBioEC[17] which has already held two national meetings with stakeholders in the sector and various practical workshops on the installation of biodigesters. The meetings were primarily attended by engineers from municipalities, farmers, NGOs, university students and teachers. In the workshops held (in Imbabura, Los Ríos, Azuay and Pichincha) the domes were always completed, showing the interest that exists in the technology. The workshops were directed by the NGO GreenEmpowerment (US), with financing from WISIONS Germany), and the participation of CIMNE (Spain), The Amazon Regional University, IKIAM (Ecuador) and Biodigestores Mundo Intag (Ecuador). Through the network, several biodigesters were installed, replicating the workshops, thanks to the efforts of the NGO GreenEmpowerment.

The network has a very clear focus on small farmers, with a considerable involvement of farmers or associations linked to agroecology. Up to now, the technology suppliers Biodigestores Mundo Intag and Biodigestores Ecuador have regularly collaborated in the network.

15.2. Technology suppliers

In Ecuador, it has mainly been tubular biodigesters that have been implemented. Up to 2014, tubular biodigesters made of tubular plastic polyethylene (plastic type for greenhouse) have been installed. Due to the dimensions which may be encountered (up to 4 metres circumference), the scale of the biodigester which could be i0nstalled was limited (up to some 12 m^3 of liquid volume). From 2014, national PVC geomembrane began to be used for the manufacture of biodigesters, expanding to the possibility of volumes up to 100m^3 per

[16] It was considered that each 15kg cylinder of LPG has an associated subsidy of 8.16 USD based on data from https://www.controlhidrocarburos.gob.ec/precios-combustibles/

[17] https://es-la.facebook.com/redbioec/

biodigester. In general, the rule is not to build biodigesters greater than 100m^3, and if larger volumes are required, it is necessary to connect two or more biodigesters of up to 100m^3 in series. In 2018, biodigesters manufactured with polyethylene geomembrane in sizes up to 60m^3 began to be built in the country.

During 2018 and 2019, an analysis was carried out of existing technology suppliers in Ecuador, as part of the project "DESIGN AND SCALE-UP OF CLIMATE RESILIENT WASTE MANAGEMENT AND ENERGY CAPTURE TECHNOLOGIES IN SMALL AND MEDIUM LIVESTOCK FARMS" financed by UNIDO, in the framework of the Climate Technology Centre & Network (CTCN). To carry out this analysis, an open invitation was issued to technology suppliers to instal biodigesters which would be evaluated. Six technology suppliers entered and four of them were selected. Each selected supplier installed two biodigesters, making a total of 8 biodigesters to be evaluated. After several months' operation, three technology suppliers were identified as having sufficient technical capacity and support in the installation of biodigesters. These three established technology suppliers are:

- **Biodigestores Mundo Intag:** This initiative was born of experience of biodigesters in the Intag valley (Imbabura) since 2002. It supplies tubular plastic and PVC geomembrane biodigesters. Its experience is primarily with small and some medium-sized pig farmers. It has chiefly worked in the north of the country, The size of the biodigesters is adapted to each specific installation.
- **Biodigestores Ecuador:** Started in 2015 in the south of the country, in Machala, after various experiences with plastic biodigesters, it currently offers PVC geomembrane biodigesters. It mainly works with medium-sized and some small pig farmers. It is primarily focused on the south of the country. The size of the biodigesters is adapted to each specific installation.
- **Sistema Biobolsa:** Thus is an initiative based on the international experience of the Biobolsa company, formed in Mexico in 2010, and now with a presence in a great many countries. It offers polyethylene geomembrane biodigesters, and, in the country, up to now, has made most of its installations in the dairy sector in the northern region. In general, it offers systems with a standard volume of 6, 8, 12, 16, 20, 30 and 40 m^3.

There are other non-professional technology suppliers, who work sporadically in the installation of biodigesters, specifically in the north of the country, in Carchi, in the centre in Riobamba and Ambato, and in the south in Azuay and Loja.

15.3. Universities and public research institutes

In Ecuador, there is incipient research and development activity in biodigesters, but it is disjointed.

Among the universities, mention should be made of the National Polytechnic School (EPN), the University of the Armed Forces (ESPE) and San Francisco University in Quito , with laboratory experience, and now beginning to extend to installation of biodigesters. The National Geological and Energy Research Institute – IIGE (the former INER), which has participated in projects on monitoring and implementation of biodigesters with CIMNE (Spain), an international actor which has also driven R&D in the EPN and the Amazon Regional University, IKIAM.

Away from Quito, in Ambato (Tungurahua), Ambato Technical University (UTA) has emerging experience of tubular polyethylene geomembrane biodigesters, and the Technical University of the North (UTN) has developed biodigesters with a fixed concrete dome. The Amazon Regional University, IKIAM, in Tena (Napo) does research, development and implementation of biodigesters in treatment of waste water and treatment of solid organic waste (it has five working biodigesters on its campus), as well as in collaboration with CIMNE (Spain).It also has scientific staff with experience in the design and adaptation of biodigesters to cold climates.

INIAP has participated in biodigester projects (with the IIGE, CIMNE and IKIAM), and is about to instal biodigesters at its experimental farms. This institute has great potential for contributing agronomic and zootechnical research to the development of biodigesters in the country.

15.4. Other institutions linked to the biodigester sector

The Ecuadorian Agroecology Coordinator ((CEA) is a body which interconnects at national level local actors involved in agroecology, and for over 15 years it has been connected with the development and promotion of biodigesters among small livestock farmers. It is an active part of the RedBioEC network, and has participated in the development of the workshops organized by the Network. In addition, it was a pioneer in facilitating the sharing of experiences and transfer of biodigester technology from farmers in the Intag valley (Imbabura) to Loza and Azuay. Having contacts with a great many local actors, it has access to small farmers throughout the country.

The NGO GreenEmpowerment, from the United States, has developed projects for implementation of biodigesters throughout the country since 2014. It participates actively in the RedBioEC network, it has been a catalyst with management capacity of the Network's training workshops and the replication of biodigester installations. The institution monitors the new biodigesters installed by other actors which are not established technology suppliers, and has a register of biodigester experience, background and non-professional installers.

CIMNE is a Spanish public research centre with a presence in Ecuador since 2014. It has transferred knowledge to the IIGE (former INER) and to the EPN in specific projects for implementation and monitoring of biodigesters. It participates in the RedBioEC network, providing courses in the workshops organized by the network. It has provided technical assistance to various of the established technology suppliers in the country, and is currently working closely with the Amazon Regional University IKIAM. CIMNE has experience in the development of national biodigester programmes in Bolivia and Peru (it coordinated the GIZ biogas project in Bolivia with the installation of 750 biodigesters). It is the coordinating body for the execution of technical assistance to the CTCN for the development of the plan of the National biodigester programme of Ecuador.

The Ministry of the Environment of Ecuador is the government institution which is most involved in the biodigester sector, driving projects for promotion and implementation since 2014. It is the body requesting technical assistance to the CTCN for the development of the plan of the national biodigester programme of Ecuador, and currently advises and evaluate the results of this project.

The Ministry of Energy and Non-renewable Natural Resources (former MEER) was also active in the promotion and implementation if biodigesters in the country from 2014 to 2017, together with the IIGE (then the INER), but at present it does not have any activities in this area.

15.5. Other institutions not linked to the biodigester sector

The Ecuadorian Vocational Training Service (SECAP) is the State institution which provides occupational and professional training and can play an important role in the certification of new biodigester installers trained under the NBP.

Livestock farmers’ associations will also have a strategic role for the NBP, as it is through them that knowledge of the technology can be disseminated. In the pig-farming sector, the principal interest is treatment of wastes to comply with environmental legislation and, accessory to that, using biogas for heating for piglets. In the dairy sector, the major interest is improving yields from pasture, and secondary to that, using biogas to clean milking equipment, heat water and, in some cases, power mechanical milking by biogas. Chiefly in the dairy sector, collector companies are also interesting, since by means of biodigesters, they can enlist the loyalty of their farmers, increase the amount of milk collected, and improve quality processes. These companies and associations can facilitate credit processes to their partners to acquire biodigesters.

The financial sector, such as banks and credit cooperatives will participate in the development of the NBP by providing specific lines of credit for the acquisition of biodigesters, which being in the framework of the NBP, will ensure the quality of the installations and use of the systems by the users, and thus reducing late payments. This could be reflected in reduced levels of bank interest for the credit and payment facilities.

PART THREE: Operating and economic plan of the proposed National Biodigester Plan

16. Aim and objective of a National Biodigester Programme

The aim of the National Biodigester Programme of Ecuador is to establish the foundations for the consolidation of a viable biodigester sector, through the implementation of 3500 biodigesters in small and medium-sized farms in Ecuador, directly benefiting at least 17, 500 people within a timeframe of five years.

The development objective is to contribute to the sustainable technification of the livestock farming activities of medium-sized and small producers in Ecuador, taking advantage of the residues generated from the livestock activity to produce energy and recycle nutrients, increasing the resilience of families to climate change and avoiding possible contamination of the soil, water and air, thereby avoiding a negative impact on human health and biodiversity.

The general objective is the development and establishment of a sustainable biodigester sector in the long term in Ecuador, which promotes its implementation, consolidates the sustainable development of small and medium sized livestock farms, increases energy sovereignty and self-sufficiency and nutrients of farmers, increase productivity, stimulates protection of the environment and improves people's quality of life.

The specific objectives are:

- Develop and consolidate a biodigester sector, considering the entire ecosystem of the actors, allowing participation of micro-enterprises in rural and urban areas
- Implement 3500 quality biodigesters in Ecuador in 5 years
- Guarantee the quality, operation and use of the installed biodigesters
- Research, develop and disseminate biodigester technology as a system of organic waste treatment in food processing and treatment of urban waste water by the implementation of demonstration pilot plants
- Maximize the benefits to users of the installed biodigesters, especially reduction in pollution, maximum benefit from biol and biogas, and their positive impact on livestock farming.

17. Expected results of the NBP in five years

Summary of the expected results at the end of five years of implementation of an NBP. These results are substantiated in subsequent sections of the document.

- 3500 families have a biodigester in which they suitably treat livestock residues producing biogas and biol.
- 189 tonnes of manure a day treated suitably in biodigesters(69,000 tonnes per year).
- Some 8016 m^3 of biogas produced daily, equivalent to 47.9 MWh. In a year, the primary energy generated is 17475 MWh.
- Displacement of the use of at least 77260 cylinders of LPG per year
- Saving of around 1.13 M USD per year in LPG subsidy
- Recycling of 434 tonnes of nitrogen (N), 194 tonnes of phosphorus (P) and 158 tonnes of potassium (K) per year.
- Avoiding emissions into the atmosphere of 6523 tonnes of CO_2 each year
- Increased livestock production, and thus income (by application of biol), estimated at an average 15%.
- Generation of rural micro-enterprises and employment through training and certification of some 71 non-professional installers.
- Improved environment in farms and rivers through proper treatment of livestock residues.

18. Political and legal framework of the NBP

The Constitution of the Republic of Ecuador states:

Art. 14.- *The right of the population to live in a healthy and ecologically balanced environment that guarantees sustainability and the good way of living (sumak kawsay), is recognized. Environmental conservation, the protection of ecosystems, biodiversity and the integrity of the country's genetic assets, the prevention of environmental damage, and the recovery of degraded natural spaces are declared matters of public interest.*.

Art. 15.- *The State shall promote, in the public and private sectors, the use of environmentally clean technologies and non-polluting and low-impact alternative sources of energy. Energy sovereignty shall not be achieved to the detriment of food sovereignty nor shall it affect the right to water.*

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18.1. Articulation with national planning

Art. 280.- *The National Development Plan is the instrument to which public policies, programmes and projects, the programming and execution of the State budget, and the investment and allocation of public resources shall adhere. It shall coordinate the exclusive areas of competence between the central State and decentralized autonomous governments. Observation of said Plan shall be mandatory for the public sector and recommended for other sectors.*

Alignment of the project with an objective of the National Development Plan

Objective 5. Stimulate productive and competitiveness for sustainable economic growth in a redistributive and supportive manner.

Policy 5.6 Promote research, education, training, development and technology transfer, innovation and enterprise, protection of intellectual property, to drive change in the productive matrix by linking the public and productive sector and the universities.

Policy 5.7 Guarantee energy supply with quality, timeliness, continuity and security, with a diversified, efficient, sustainable and sovereign energy matrix as the pillar of productive and social change.

Goals

- Increase from 98.9 to 112 the national agricultural productivity index by 2021
- Increase from 68.8% to 90% the generation of electricity from renewable energy sources by 2021.
- Increase fuel savings by optimizing electricity generation and fuel efficiency in the hydrocarbons sector from 9.09 to 26.6 barrels of oil equivalent by 2021.
- Increase the percentage of economic activities which use resources of biological origin as an input for the supply of goods and services by 2021.

Contribution to sectoral objectives and policies

- **Intersectoral Coordination Agenda**, *National Territorial Strategic Guidelines*: d.15. Promote research, education, training and retraining programmes which reflect territorial potential and needs, promoting entry into the labour market in an efficient manner
- **National Energy Efficiency Plan (PLANEE) 2016 – 2035**, General objective: Increase the efficient used of energy resources through the execution of energy efficiency programmes and projects in sectors related to supply and demand for energy, to reduce the importance of oil derivatives, contribute to the mitigation of climate change and create a culture of energy efficiency supported by a sound legal and institutional base.
- **National Climate Change Strategy of Ecuador 2012 – 2025:**
    - Strategic Line: Mitigation of climate change

      Specific Objective 1: Identify and incorporate appropriate practices to mitigate climate change in the livestock sector, which may also strengthen and improve productive efficiency and competitiveness.

      Specific Objective 3: Strengthen the implementation of measures to foster energy sovereignty, and gradual change in the energy matrix, increasing the proportion of energy generation from renewable sources, thus contributing to the mitigation of climate change.

      Specific Objective 4: Foster the application of practices which allow a reduction in GHG emissions in processes related to the supply of services and generation of goods, from their manufacture, distribution, consumption to final disposal.

      Specific Objective 5: Promote the transformation of the productive matrix, incorporating measures which contribute to reducing GHG emissions and the carbon footprint, sustainable use of renewable natural resources and responsible use of natural or renewable resources.

19. Targets of the National Biodigester Programme

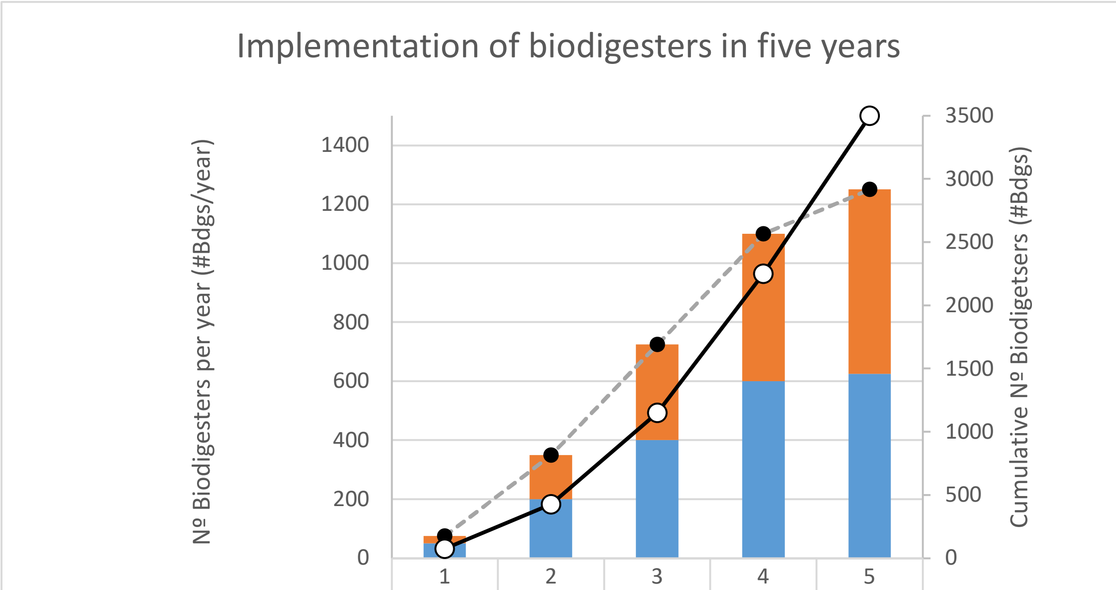
19.1. Installation of biodigesters

The installation of biodigesters is the indicator of progress in implementation of the National Biodigester Programme. The objective established is 3500 installations in 5 years. In NBPs in other countries in Asia and Africa, it is usual to consider targets of over 5000 units installed in 5 years, but the recent experience of the NBP of Nicaragua, where 1200 biodigesters were installed in 5 years (despite having a much higher target originally)[18], leads to adopting more modest and achievable goals, learning from the lessons of other countries.

Two sectors have been identified (dairy farming and pig farming) and two priority macro-regions for the implementation of these 3500 biodigesters. These sectors and macro-regions are the cornerstones for directing efforts and focussing activities, but this does not mean excluding other sectors and provinces if they help to achieve the objectives of the NBP.

Figure 8 shows the expected pace of installation of biodigesters to achieve the proposed targets. It should be highlighted that the number of biodigesters installed each year will increase progressively to achieve a platform of around 1200 in the final years. This is because in the first years, it is necessary to devote much more effort from the NBP to break down barriers of lack of knowledge of the technology among farmers and to consolidate the processes and strategies developed. There is also a difference in the pace between the south and north regions, and this can be explained by two reasons: in the north region, there are two established technology suppliers and there is a strong dairy sector in Pichincha and a strong pig farming sector in Santo Domingo de Tsáchilas, while in the south there is only one established supplier but although it has a strong pig farming sector, it also has small dairy and pig farmers in the south Sierra zone. For this reason, it can be expected that the pace of implementation will be somewhat slower in the south region.

[18] Martí-Herrero J. 2019. Experiencias Latinoamericanas en la democratización de los biodigestores: Aportes a Ecuador. CTCN-UNIDO. Ecuador. ISBN: 978-9942-36-253-7



	1	2	3	4	5
Ecuador Sur (#Bdgs/año)	25	150	325	500	625
Ecuador Norte (#Bdgs/año)	50	200	400	600	625
Total/año (#Bdgs/año)	75	350	725	1100	1250
acumulado (#Bdgs)	75	425	1150	2250	3500

Figure 8 Pace of installation of biodigesters by year and region, cumulative biodigesters

Of the 3500 biodigesters, it is expected that 40% will relate to medium-sized farmers (1400), and 60% to small farmers (2100). This differentiation is due to the fact that the number of small farmers is much higher than medium-sized, both in the dairy sector (233,000 dairy farmers with 10 cows against 40,000 with 25 to 40 cows) and pig farming (160,000 small farmers against 82,000 medium-sized)[19].

The pace of implementation of one or the other will be different, as medium-sized farmers have greater ability to pay and are more pressured by environmental legislation to resolve treatment of residues. As has been noted above, small farmers have normally been installing biodigesters in the framework of projects with subsidies, which means that it is necessary to break down barriers of lack of knowledge of and access to the technology. For that reason, it is expected that the pace of installation of biodigesters in medium-sized farmers will be more rapid than in the small. Table 7 shows the expected pace of installation of biodigesters by year and typology of farmer.

Table 7 Pace of installation of biodigesters by year and type of farmer

Year	**1**	**2**	**3**	**4**	**5**	**Total**
Small farmers (#bdgs/year)	25	150	325	725	875	2 100
Medium-sized farmers (#bdgs/year)	50	200	390	380	380	1 400
Total/year (#bdgs/year)	75	350	725	1 100	1 250	3 500
Cumulative Total (#Bdgs)	75	425	1 150	2 250	3 500	

[19] https://www.ctc-n.org/content/l-nea-base-y-demanda-potencial-t-cnica-de-biodigestores-en-ecuador-lisis-del-contexto-y

19.2. Certified non-professional installers

To achieve the pace of installation shown in Figure 8 and Table 7, it is necessary to have a number of technology suppliers able to deliver the proposed pace.

It must be borne in mind that when the pace of installation exceeds 350 biodigesters per year, it means that, more or less, it is necessary to install one biodigester a day somewhere in Ecuador. This brings with it the need to have several teams of biodigester installers operating in the country at the same time. In the first two years, the existing, and already established, technology suppliers will be able to achieve the proposed targets, but from the third year, it will be necessary to have new technology suppliers who are able to cope with a growing number of small farmers incorporated in the NBP.

Incentives will be offered to non-professional installers, i.e. personnel with the capacity to carry out installations of quality biodigesters, where this activity is in addition to the other economic activities in which they already engage. Thus, the installer's livelihood does not depend solely on the installation of biodigesters. The training of new installers will be based on tubular plastic biodigesters.

A trained non-professional installer can be expected to instal some 12 biodigesters per year (one a month). For the third year of the NBP, it is intended to instal 725 biodigesters, 325 of them in small farmers, so it will be necessary to have at least 20 trained non-professional installers at that time. Thus, during the second year, it will be necessary to train and certify 12 installers who will have the capacity to instal 144 biodigesters in the third year. During the third year, a further 14 non-professional installers will be trained, who will start to operate in the fifth year. The progression of trained and active non-professional installers, and biodigesters installed by them is shown in Table 8.

Cases may arise of synergies between new non-professional installers and existing technology suppliers, where the former become subcontractors of the latter, but the independence of these new installers will be encouraged to have a greater range of technology and actors. The case may also occur where non-professional installers become established professional technology suppliers, in which case they must be certified by the R&D component of the NBP.

Table 8 Number of certified non-professional installers per year and biodigesters installed by them

Year	1	2	3	4	5	Total
Number of new non-professional installers per year	0	12	14	33	12	71
Cumulative total active non-professional installers	0	0	12	26	59	71
Bdgs estimated installed by non-professional installers	0	0	144	312	708	1 164
Number of certification workshops for installers	0	2	2	3	2	9

19.3. Training and certification workshops for non-professional installers

To train and certify non-professional installers, it is necessary to hold workshops. From experience, 80% of the trained personnel replicate what they have learned. If it is considered that groups of 10 to 15 people are trained in each workshop, and considering that the NBP is rolled out in two macro-regions, at least two workshops will be held per year, and in the fourth year at least three workshops (see Table 8). In total, at least 9 workshops will be held throughout the NBP.

These workshops will take place over 5 days when there is technical training in biodigesters, practice, complemented by training in accounting and business. To ensure quality of opportunities, the workshops will offer places to look after children, so that women and men can participate on equal terms. These workshops could be held in INIAP facilities in collaboration with the Ecuadorian Vocational Training Service (SECAP) for certification of the training .

19.4. Products of learning and knowledge

To generate a sustainable biodigester sector in Ecuador, it is very important to provide access to updated information which serves as a reference for the installation, operation and benefit of biodigesters.

For this reason, during the first year, a manual on installation of tubular biodigesters adapted to the Ecuadorian context will be produced, and will serve as the basis for the training workshops for non-professional installers from the second year. This manual will be revised during the third year, and an updated version published.

In addition, a biodigester and biogas and biol applications manual will be prepared in the first year and updated in the third.

To encourage better and greater use of biol and other aspects of biodigesters, pamphlets of the results of R&D will be published every six months with new progress in the results of research into the application of biol to different crops and ecoregions, starting from the second year it is hoped to produce 8 pamphlets.

To foster sharing of experiences among users, technology suppliers and other stakeholders, a national annual event will be held from the second year.

To report progress in the NBP itself in terms of execution, training, research, monitoring, etc., a seminar will be held every two years with the participation of stakeholders in the sector, government and the media. In the first year, this event will serve to present the NBP, its objectives, mechanisms and challenges. The third year will serve to show the progress and possible changes in strategy, and the fifth year will serve to show the final results and evaluation of the NBP.

Table 9 Products of learning and knowledge

Year	**1**	**2**	**3**	**4**	**5**	**Total**
Manual on installation of biodigester	1		1			2
User Manual	1		1			2
Printing of user manuals	1 200		2 800			4 000
Pamphlet on R&D progress		2	2	2	2	8
Printing of pamphlets		300	900	1 200	1 500	3 900
Seminars on NBP progress	1		1		1	3
Experience sharing event		1	1	1	1	4

19.5. Providers of applications

Around the biodigesters there are a diversity of accessories which contribute to drawing the benefits of biogas and biol, and also the pre-treatment of residues. Solid waste separators (both for influent and effluent), cookers, boilers, heaters, lamps, milking machines, generators, hydrogen sulphide filters, fertilization-irrigation systems, hydroponics and biogas reservoirs, are just some of the accessories which complement biodigesters.

The established technology suppliers offer some of these accessories. To make access to these accessories more universal, it is important to incentivize the existence of other technology suppliers, who may be associated with hardware supply chains (to deliver the accessories to users and suppliers) or may have direct contact with technology suppliers or non-professional installers.

Some of these accessories can be imported from Brazil, Colombia or China, but others can be manufactured in Ecuador by companies which already make accessories which operate on gas (such as cookers, lamps, boilers, etc.).

Indeed, it may be considered in this regard that there is the capacity to send prefabricated biodigesters to any part of the country, to be installed by non-professional installers. This chain would facilitate the penetration of technology into rural areas. Suppliers of installation kits can be new or the same already established technology supply companies.

19.6. Quality of the processes

The quality of the processes, not only in the installations, is one of the keys to achieving the proposed objectives. In this respect, it is necessary to certify their quality, the quality of the training of the non-professional installers, the quality of the accessories of the biodigesters and the quality of the use and application of the biodigester.

- Assistance will be provided to users of biodigesters making visits from the BP twice a year to all biodigesters installed during that year. This imposes a very heavy burden of monitoring of users, necessary for adequate appropriation and benefit from the technology, making 7000 visits. These activities will carried out within the technical assistance component.
- A quality control check will be made of each of the biodigester installations carried out within the NBP, making a total of 3500 visits. This will also guarantee the quality of the training of the non-professional installers. This activity is carried out by the quality control component.
- Follow-up visits will be made to 5% of the existing systems each year to evaluate appropriation by and the impact on the user families, making a total of 336 visits. These visits will allow obtaining indicators of the development and progress of the NBP.
- 30 biodigesters a year will be monitored to assess their functioning in terms of production of biogas, temperature, operation and some physiochemical parameters[20].

[20] A proposal has been developed on "Assessment and method of monitoring of biodigesters" available at https://www.ctc-n.org/system/files/dossier/3b/e3.1a_monitoreo.pdf

The monitoring of each biodigester will be at least one full year, so that at the end of 5 years, 150 systems have been monitored. This activity will be in the charge of the R&D component.

Table 10 Number of visits to biodigesters per year, by NBP component						
Year	**1**	**2**	**3**	**4**	**5**	**TOTAL**
Technical assistance visits	150	700	1 450	2 200	2 500	7 000
Quality control visits	75	350	725	1 100	1 250	3 500
Monitoring and evaluation visits	0	21	58	113	175	367
Monitoring of biodigesters	30	30	30	30	30	150
Biodigesters per year	75	350	725	1 100	1 250	3 500
Total biodigesters installed	75	425	1 150	2 250	3 500	3 500

20. CO_2 emissions avoided by implementation of the NBP

The introduction of biodigesters in livestock farming has a direct impact on the reduction of emissions from the activity. This reduction comes from the displacement of the use of fossil fuel (LPG in the case of Ecuador) by biogas, displacement on the use of synthetic fertilizers by the application of biol, and by the change in the management of manure, which goes from being accumulated to being introduced into the biodigester. In the Annex “Estimate of CO_2 emissions avoided by the use of biodigesters” (page70), the methodology and calculations are set out in detail. Table 5 shows the CO_2 emissions avoided by type of farmer, and this can be linked to the pace of installation of biodigesters in Table 7. If these values are considered, and it is assumed that the pace of installation of biodigesters between dairy farmers and pig farmers is 50%-50%, then the tonnes of CO_2 emissions avoided each year can be estimated, as shown in the following table.

Table 11 CO_2 emissions avoided by the implementation of the NBP, by year and type of farmer						
Year	1	2	3	4	5	**TOTAL avoided (tCO_2)**
Small dairy (tCO_2)	6.1	53.6	164.1	409.0	732.6	**1 365.3**
Medium-sized dairy (tCO_2)	58.3	306.6	821.5	1 381.8	1 939.0	**4 507.3**
Small pig (tCO_2)	21.1	129.1	370.1	902.0	1 576.2	**1 998.6**
Medium-sized pig (tCO2)	75.8	386.5	1 007.7	1 642.2	2 275.3	**5 387.4**
TOTAL avoided (tCO_2)	**161.4**	**875.8**	**2 363.4**	**4 335.0**	**6 523.1**	**14 258.6**

This shows that at the end of 5 years of the NBP, 14,000 tonnes of CO_2 emissions into the atmosphere will have been avoided.

21. Saving in gas subsidy through implementation of the NBP

Implementing the NBP with the goal of achieving the installation of 3,500 biodigesters will have an impact on reducing consumption of LPG by farmers.

Table 6 shows the expenditure on LPG gas subsidy by type of farmer which can be saved by installing a biodigester, and this can be linked to the pace of installation of biodigesters in Table 7. If these values are considered and it is assumed that the pace of installation of biodigesters is 50%-50% between dairy and pig farmers, then the saving in LPG subsidy each year under the NBP can be estimated, as shown in the following Table 12.

Table 12 Saving in LPG subsidy through implementation of the NBP						
	1	2	3	4	5	**Total (USD)**
Small dairy	786	6 683	20 206	56 138	118 173	**201 988**
Medium-sized dairy	8 255	41 278	11 3928	22 6205	452 410	**842 077**
Small pig	1 769	10 614	31 607	86 802	182 450	**313 243**
Medium-sized pig	6 879	34 398	94 940	188 504	377 008	**701 731**
Total USD	**17 690**	**92 974**	**260 682**	**557 650**	**113 0042**	**2 059 040**

Thus, the in the first year of functioning of the NBP, the State would save some USD 17,000, but in the third year, the saving would be around USD 370,000. In the fifth year, the saving would be around USD 1.1 million. In total, over the five years if the NBP, savings of over USD 2 million would have been generated.

22.Subsidy to biodigesters installed

The implementation of a subsidy scheme is necessary to break down the barriers of initial lack of knowledge of the technology, to consolidate the sector and to optimize processes and the economic value to the technology suppliers and, above all, make the technology accessible to the most vulnerable small farmers.

The estimated costs of the biodigesters, shown in Table 3, means that the smallest domestic biodigesters require investment of USD 1,000. To make these systems accessible to small livestock farmers, the investment needs to be lowered to at least USD 600, thus the need for the NBP to contribute USD 400 per biodigester. These figures for capacity to pay vary from region to region in the country, but USD 600 is an average reference value for capacity to pay.

The principal objective of the subsidy is to make biodigesters accessible to the most vulnerable farmers, and this will set the benchmark for the subsidy for all other farmers. Consequently, an initial level of subsidy of USD 400 is proposed for each system installed, irrespective of the size of the biodigester. From the third year, it is proposed to reduce this subsidy to USD 300 per system, .as by then the barrier of lack of knowledge of the technology will have been overcome

In addition, in the case of cold climate biodigesters, a bigger investment is needed to integrate the greenhouse and insulation. In this case, an extra subsidy of USD 200 is proposed for systems installed more than 2,800 metres above mean sea level (AMSL).

Table 13 Subsidy scheme for installation of biodigesters		
Period	Years 1 and 2	Years 3, 4 and 5
Per biodigester installed	USD 400	USD 300
Extra per biodigester more than 2,880 metres AMSL	USD 200	USD 200

Thus, considering that 20% of the systems will be installed each year more than 2,800 metres AMSL, and if the pace of installation of biodigesters shown in Table 7 is taken into account, the investment in subsidies per year can be calculated, as shown in Table 14.

Table 14 Investment in subsidies per year during the NBP						
Year	**1**	**2**	**3**	**4**	**5**	**TOTAL**
NBP subsidy (USD)	33 000	154 000	246 500	374 000	425 000	**1 232 500**
Total/year (#bdgs/year)	75	350	725	1100	1250	
Cumulative Total (#Bdgs)	75	425	1 150	2 250	3 500	3 500

The requirement in investment in subsidies for the entire NBP is less than USD 1.25 million, well below the USD 2 million of LPG subsidies saved by this NBP (see Table 12).

23. Components of a national biodigester programme

National biodigester programmes have the objective of generating a sustainable biodigester sector aimed at small and medium-sized livestock farmers. All these programmes have different schemes depending on local realities, but they share a series of characteristics in their approach:

- Market-oriented focus in which the same clients assume the majority of the costs of investment.
- Participation of multiple stakeholders in the programme, each with their defined functions.
- Building capacities of existing local stakeholders.
- Development of a sustainable sector, going beyond the framework of the project.
- Skills regulated on the supply side, ensuring the benefit to the client.
- Quality control system designed and applied to protect the interests of families and gender equality.
- Medium- or long-term time horizon, as it requires at least 5-10 years to develop a sustainable and economically viable sector.

Two types of process are defined in these NBPs: primary and secondary, Primary processes are those which are directly linked to the installation of biodigesters (strengthening of demand, supply and matching supply and demand) and secondary processes are those which reinforce implementation.

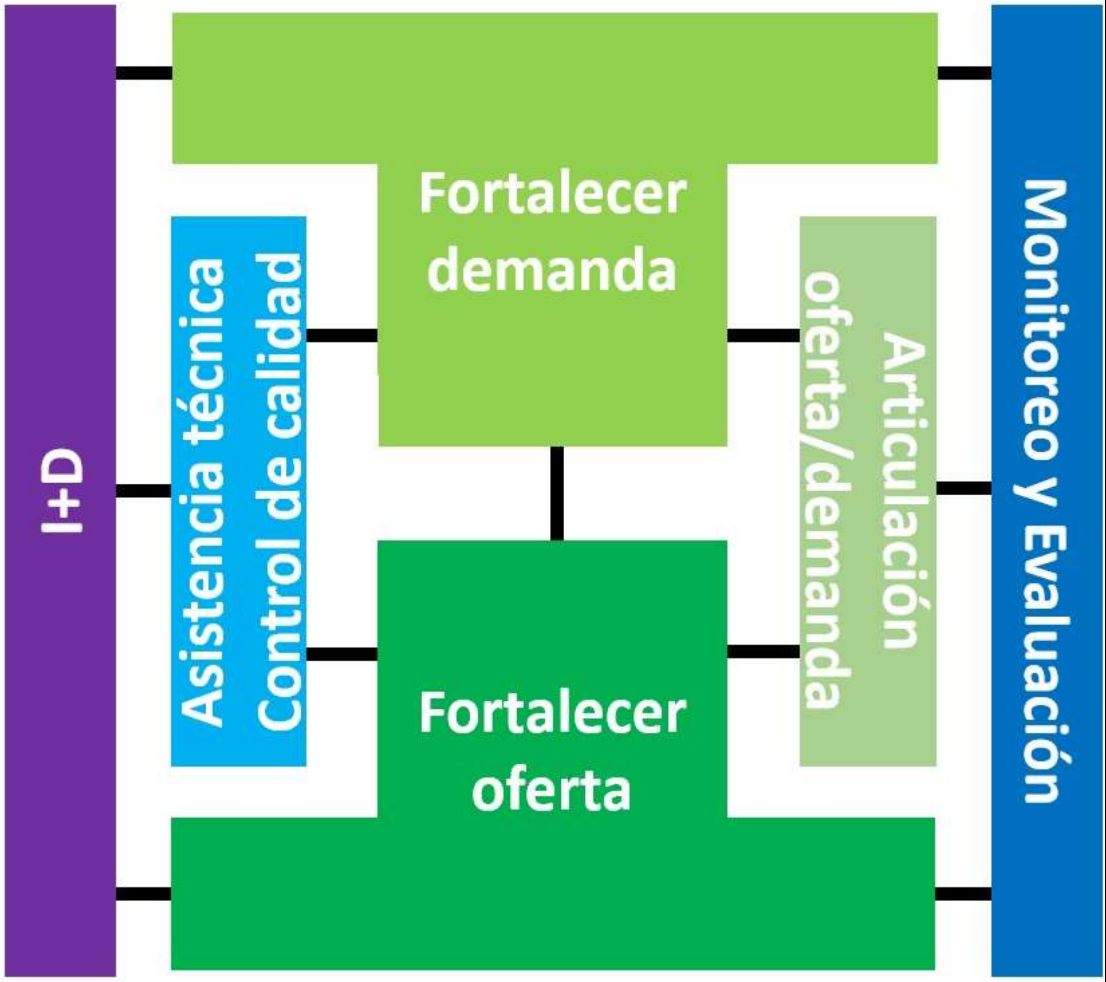


Figure 9 Chart of interaction between components of a national biogas programme (adapted from SNV, 2013)

Glossary:

I+D = R&D; Asistencia técnica = Technical Assistance; Control de calidad = Quality Control; Fortalecer demanda = Strengthening demand; Fortalecer oferta = Strengthening Supply; Articulación oferta/demanda = Matching supply and demand; Monitoreo y Evaluación = Monitoring and Evaluation

23.1. Strengthening demand

Those generating demand for biodigesters are small and medium-sized livestock farmers. Strengthening these includes providing them with knowledge of the technology, its cost, operation and benefits (biogas, fertilizer and waste treatment). The activities of this component are based on *marketing* through radio spots, poster publicity, calendars and pamphlets, as well as visits to demonstration biodigesters. In the initial phase of the programme, this is a component which requires a great deal of effort, but it is necessary to overcome the barriers of general lack of knowledge among farmers of the technology on offer. It is essential to have demonstration biodigesters which can be visited by interested farmers. These marketing activities can be carried out by the NBP team, and complemented by the technology suppliers themselves, who are interested in placing their systems. In addition, other strategies that exist, such as providing an incentive to people who introduce others interested in buying a biodigester, making them informal promotion agents.

This component will work by providing livestock farmers with the necessary information to allow them to decide whether it is appropriate to instal a biodigester. For this process, the component will be implemented in collaboration with the Ministry of the Environment and the Ministry of Agriculture and Livestock, but also with bodies such as INIIAP, which already has channels of communication with farmers. Governors, prefectures and municipal authorities in the region with a high level of livestock farming will also be agents for communication. NGPs, in many cases, work in places which other organizations find hard to reach, so it will be necessary to work with them, especially those which may become technology suppliers. Farmers' associations and collector companies are entities which have an interest in strengthening and improving the productivity of their members, so they will be able to help with disseminating the technology.

This component will have to work with the R&D component and the Monitoring and Evaluation component to generate objective and quality comparative information (concerning the various technology suppliers)

Activities – Strengthening of demand

- Develop a strategy of dissemination and promotion of biodigesters aimed at potential users
- Generate written, radio and television dissemination material.
- Implement campaigns to promote biodigesters through visits to demonstration biodigesters, workshops
- Train actors involved in the NBP to give clear, accurate and consistent information.
- Develop and printing of biodigester user manual.

23.2. Strengthening of supply

The suppliers are technology suppliers and non-professional installers. Suppliers can be single-person companies, NGOs or small and medium-sized enterprises. This group also includes companies which provide accessories (cookers, lamps, motors, grass choppers, mills, milking machines, etc., all running on biogas), which may be different from the technology suppliers. The activities to strengthen suppliers are aimed initially at training and/or certifying suppliers of technology and accessories and non-professional installers. In this way, the biodigesters installed within the NBP are installed by people certified by the NBP itself. This encourages the implementation of validated technologies, through validated processes, and with the necessary quality. At the start of the NBP, there already existed three companies validated as technology suppliers (see Section 15.2). Non-professional installers will be trained in training workshops from the second year. To have installers distributed throughout the country, independent workshops will be held (at least one per year) in each macro-region identified. The training of installers must also include, in addition to the technical aspects, aspects of the management of small and medium-sized enterprises, accounting, marketing and after-sales services.

This component can be supported by INIAP for the realization of workshops in it facilities, and the certification of engineers can be coordinated with SECAP. As an alternative, a university can certify the training (see universities in Section 15.3). The proposed subject matter of the training could be defined by institutions such as CIMNE and GreenEmpowerment, which have already held workshops in the installation of biodigesters in collaboration with RedBioEC, considering the universities involved in the sector.

This component will have to work with the R&D component to obtain comparative information and with the Quality Control component to identify weaknesses in the technology suppliers and non-professional installers that must be rectified.

Activities – Strengthening of supply

- Strengthening of previously validated technology suppliers
- Training of trainers of non-professional installers or tubular biodigesters, training of users, after-sales service and business plan.
- Development of training workshops for non-professional installers or tubular biodigesters, training of users, after-sales service and business plan.
- Strengthening of technology suppliers and non-professional installers.
- Development and printing of a manual on installation of biodigesters
- Installation of 3,500 biodigesters

23.3. Matching of supply and demand

This involves facilitating the relationship between farmers and technology providers, linking the strengthening of demand component with strengthening of supply. Normally, this component tries to develop mechanisms for access to lines of credit specific to the NBP, from banks and savings and credit cooperatives. This subject is considered to be very important in the NBPs of Asia and Africa: access to- credit by farmers to finance the purchase of biodigesters. However, in the Latin American experience of democratization of biodigesters, it has not been a key mechanisms[21].

For that reason, in Ecuador, as well as traditional channels for facilitating affordable access to biodigesters through credit granted by banks or credit cooperatives, it is necessary to explore other ways, To reduce costs of credit, specific ,lines can be developed for the NBP and supported by the collector industries (e.g. dairy), as extension agents of retention. Another successful mechanisms to facilitate affordable access of farmers to biodigesters has been revolving funds, managed by farmers' associations. In this way, with seed capital contributed by the NBP, a virtuous circle can be created within consolidated associations, so that ach farmer who access a loan at a very low interest rate repays it to the revolving fund, which other associated farmers can then access.

The management of the subsidies can also come into this component. The subsidy is a key aspect and a complex one for the NBP because if it is excessive, it can distort the market which it is trying to develop, and if it is too little, it may not be enough to overcome barriers such as lack of knowledge of the technology or farmers' capacity to pay. In general terms, the tendency has been to give a fixed (flat) subsidy, irrespective of the size of biodigester installed by a farmer. In

[21] https://www.ctc-n.org/system/files/dossier/3b/del_1.2_biodigestotes_latinoamerica_espanol.pdf

this way, access to the technology by the most vulnerable farmers is facilitated. This subsidy must maintain a balance between the capacity to pay of the poorest farmers and the cost of access to the smallest biodigester model. At the start of the programme, chiefly to incentivize demand and overcome the barrier of lack of knowledge of the technology, the su9bsidies may be as much as 50% of the cost of installation of the smallest model, and then subsequently reduced to 33% and thereafter progressively over the duration of the NBP.

This component must work with banks and credit cooperatives, and must explore other mechanisms for financing farmers through collector companies and farmers' associations.

Activities – Matching of supply and demand

- Develop and promote financial products taking advantage of synergies between different stakeholders to make credit more accessible.
- Implement and control revolving funds in associations to access biodigesters
- Implement the policy on subsidies and management of its payment.

23.4. Technical assistance

This component provides technical support for the other components, like strengthening of supply and demand. On the one hand, this component must provide the tools to users of biodigesters so that they can take full advantage of the technology, both in the use of biogas and fertilizer, and in operation and maintenance. This component, moreover, will be responsible for holding meetings between farmers who use biodigesters (and non-users) to promote sharing of experiences. In addition, the technical assistance is also aimed at technology suppliers, so that, through continuous training, knowledge is enhanced, kept up to date and the transfer of knowledge to users is strengthened.

These activities can be carried out by the NBP's own staff, INIAP, the CEA[22], municipal authorities and NGOs.

This component must be coordinated with the R&D component to update the information to be transferred to users, and the components of strengthening of supply and demand.

Activities – Technical Assistance

- Provide technical assistance in the use and benefits of biodigesters to users (workshops, visits, written material, radio, etc.)
- Generate synergies with other institutions to support the technical assistance to users
- Strengthen knowledge of technology suppliers and non-professional installers

23.5. Quality control

Quality control is one of the keys to the success of NBPs. Each biodigester installed must pass a quality control check (or representative samples when installation rates of biodigesters exceed

[22] CEA: Ecuadorian Coordinator of Agroecology: http://www.agroecologia.ec/

1,000 per year), to ensure that the final target is achieved and that it fulfils all the technical requirements established in the NBP. This guarantees the biodigesters installed through the NBP. A quality control protocol has been developed which are set out in the annexes: Quality (page 75).

To ensure the commitment of the constructor/installer, the final payment is made after the quality control has been passed. As well as quality control of installed biodigesters, this component also carried out checks of the NBP's own processes, such as technical assistance, training and certification of constructors/installers, transfer of knowledge from technology suppliers to users, dissemination processes, etc. This is a key component, and it is recommended that it should always remain in the hands of the same team that developed the NBP.

This component is a fundamental pillar of the NBP and must be executed by staff of the NBP itself. This component must work with the component on matching of supply and demand to allow payment of the subsidy after approval of the installation, the component on strengthening of supply to identify weaknesses and the rest of the component to provide feedback on the quality of its processes.

Activities – Quality control

- Development of a quality control system for installed biodigesters
- Quality control of installed biodigesters
- Quality control of the process and activities of other components of the NBP.

23.6. Monitoring and evaluation

This is a component which must be able to take the pulse of the NBP, by collecting the data generated (number of installations and suppliers, distribution of users over time and space, and types and sizes of biodigesters), process the data and identify opportunities and weaknesses. In addition, this component must establish a baseline which can then show the impact of the introduction of biodigesters on living standards, gender equity, economic, social and productive conditions of farmers, comparing data with those who did not install biodigesters. The development of specific impact studies and sample surveys are other activities that will need to be developed.

This component can be delegated to stakeholders with previous experience in the management, execution and monitoring of projects related to biodigesters in Ecuador, considering stakeholders identified in the section "Description of the biodigester sector in Ecuador" (page 28).

This component must coordinate actions with the component on strengthening of supply to provide information on users and the progress of appropriation and use of the technology by them.

Activities – Monitoring and evaluation

- Development of the NBP database and register of numbers to achieve the targets

- Reports of user satisfaction surveys, quantification of impacts and barriers to be overcome in dissemination, implementation and access to credit
- Publication of results and feedback to stakeholders
- Half-yearly seminars to present results

23.7. Research and development.

Research and development is a component which does not appear in many NBPs and remains integrated in technical assistance. In the case of Latin America, due to the strength of universities and ither bodies in R&D and the need for research to validate technologies in different climates and applications of biol and biogas, it is a highly necessary component. This component must provide technical assistance inputs, collaborate in measuring the impacts of the monitoring and evaluation component and participate in the validation of the processes of installation and certification of constructors/installers. It is a component which necessarily must be supported by research bodies, user farmers and technology suppliers, for the development of local R&D suited to the country's actual conditions.

Strong investment is required in research unto the use of biol on different crops and in different climates, since this is one of the great benefits of biodigesters in a country where gas is accessible and is subsidized.

Universities such as the Amazon Regional University, IKIAM, the National Polytechnic School (EPN) of the University of the Armed Forces (ESPE) can participate, together with public research institutes such as INIAP and the IIGE (former INER).

Activities – Research and development (R&D)

- Have experimental sites with different biodigesters fed with different types of manure and in different climates (on experimental farms of INIAP and universities)
- Validation of biodigester designs of technology suppliers and applications
- Monitoring of technical behaviour of biodigester in actual use (mitigation and adaptation to climate change)
- Optimization of technologies and advances in application of biol to different crops and ecoregions.
- Transfer or R&D results to suppliers and users through technical assistance.
- Validation and certification of new technology suppliers

24.Governance of the NBP

The governance structure of the NBP is centred in the Coordination Team, which is the group of professionals responsible for achieving the proposed targets. The components described are part of the Coordination Team of the NBP. This team is contracted by the Implementing Agency, in coordination with the public bodies participating in the plan, which is the independent institution charged with managing the NBP. The Management Committee of the NBP, formed of the Government and donors, is the body which designates the Implementing Agency and the international technical assistance which supports it.

The Coordination Team will have advisory support from an Advisory Council made up of stakeholders involved in the biodigester sector (users, suppliers, financing institutions, etc) and will in turn will have its own tools for collecting information through its R&D comp0onet, monitoring and evaluation, technical assistance and quality control components.

The coordination team, as well as the components described above, will have a local presence through operational units, a south macro-region group and another in the north macro-region.

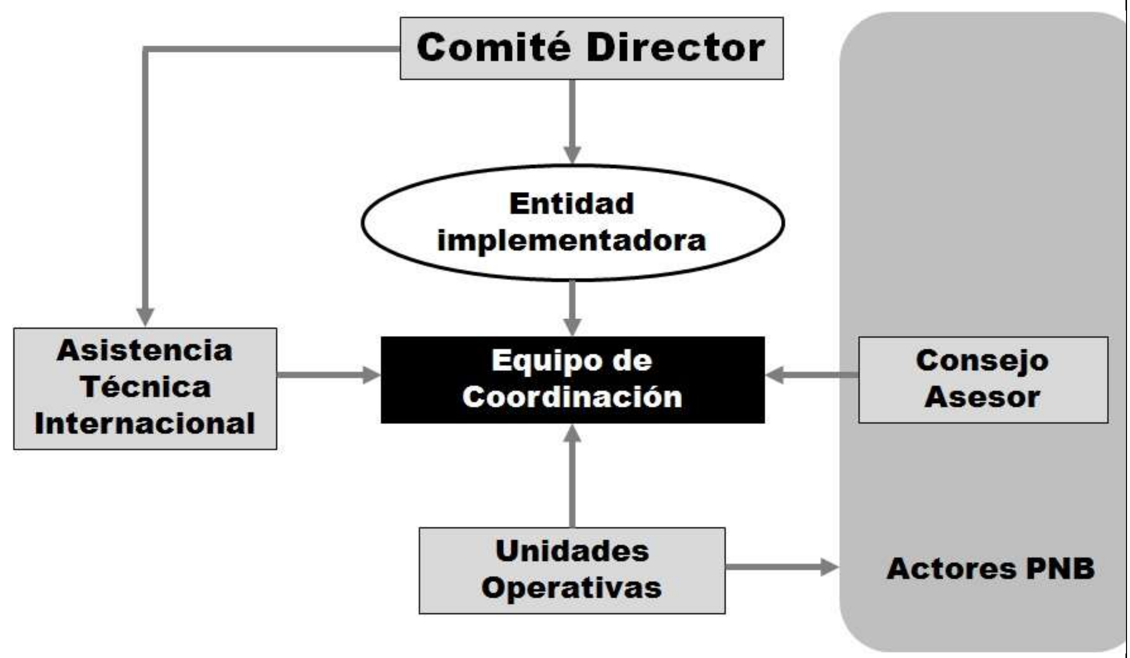


Figure 10 General governance structure of an NBP
Glossary:
Actores PNB = NBP stakeholders; Other translations, see headings in text below.

-Management Committee (*Comité Director*) of the NBP: The Management Committee will set out the strategic directions and to which the results of the NBP will be reported as its implementation progresses. This Committee is formed, as a minimum, of the group of donors and the Government. This committee will not participate in technical decisions, only on relevant policy issues to create an appropriate environment for the implementation of the NBP. The Management Committee will designate, or form, an independent implementing agency, and will designate the international technical assistance experts.

-Independent Implementing Agency (E*ntidad implementadora*) of the NBP: This is an independent entity responsible for coordination of the NBP and contracting of professionals who can lead and develop the components of the NBP. This group of professional will form the Coordination Team.

-Coordination Team (*Equipo de coordinación*) of the NBP: This team is responsible for the implementation of the NBP in the country. It is responsible for following the directions of the Management Committee and reporting progress. The team will include professionals expert in biogas, gender, promotion, microfinance, monitoring and evaluation, bioinputs, etc. It will call on international technical assistance to optimize the proper functioning of the NBP in all its aspects, it will conduct the Advisory Council and coordinate the operational units.

-International Technical Assistance: The international technical assistance consists of an international expert committee which will be selected by the Management Committee. It will provide support to the NBP Coordination Team in order to adequately fulfil the proposed targets. This technical committee will evaluate the principal activities undertaken by the NBP, and in conjunction with the Coordination Team, must prepare a viable intervention strategy and execute in accordance with the various characteristics that the NBP may acquire over time.

-Advisory Council (*Consejo Asesor*): The NBP Advisory Council must be a meeting space for the various stakeholders involved in the programme, in the form of a group for consultations and making recommendations. Ministries, NGOs, universities, public research institutes, private entities, governorates, municipalities and farmers' associations can form part of the Advisory Council. To make the processes more flexible, specific working groups could be formed: access to credit, promotion, R&D, quality control, etc.

-Operational Units (*Unidades Operativas*): Operational units are needed, one for each macro-region. They are the entities for execution of the NBP with local links. They are formed chiefly of field experts (promotion, technical assistance, monitoring, quality control, etc.). These operational units are coordinated by the NBP Coordination Team, to which they report progress made by them in their areas of intervention. They carry out promotion, training, monitoring activities, coordinating with the various executing institutions, technology suppliers, quality control, technical assistance and research in their regions of intervention, as well as the activities that they carry out to achieve the various NBP indicators.

25. Operability and budget

23.1. Overall budget summary

Table 15 Overall budget summary of the NBP over 5 years

Years	1	2	3	4	5	**TOTAL (USD)**
TOTAL PERSONNEL	309 900	300 198	339 415	345 603	351 915	1 647 032
Inputs	143 000	33 320	45 806	40 771	41 407	304 304
Subsidy	33 000	154 000	246 500	374 000	425 000	1 232 500
Strengthening demand	78 750	57 500	95 500	37 500	31 250	300 500
Strengthening supply	45 600	16 000	72 900	21 000	16 000	171 500
Matching supply and demand	20 000	54 000	93 000	77 000	0	244 000
Technical assistance and QC	9 750	52 100	62 779	91 817	103 792	320 238
Monitoring and evaluation	18 000	10 125	31 750	34 250	48 500	142 625
R+D	61 500	33 500	36 500	33 500	27 500	192 500
International tech. asst.	45 000	30 000	45 000	15 000	30 000	165 000
TOTAL (USD)	**764 500**	**740 743**	**1 069 150**	**1 070 441**	**1 075 364**	**4 720 198**

25.2. Coordination Team

The Coordination Team will be based in Quito, where it will be integrated in the operational unit which covers the north macro-region. The operational unit working in the south macro-region will be located in Cuenca.

The Coordinating Team consist of a programme coordinator with a legal adviser, an accountant plus an expert for each component, except the R&D component (which is organized differently). This team will determine the activities to be carried out in the country. It will carry out activities in the north macro-region, and will delegate execution of this in the south macro-region to a person responsible for the region.

Each macro-region will have a field expert, chiefly to support the strengthening of demand and technical assistance components.

From the third year, it will be necessary to have an additional expert per macro-region, due to the large number of biodigesters installed (725 new biodigesters in the third year).

A budget line is reserved for specific consultations, which the Coordinating Team cannot undertake. This budget amounts to 10 per cent of the total personnel budget of the NBP, and which can be identified as budgets for studies and/or "unforeseen" work.

The budget for the Coordinating Team for five years is shown in Table 16.

Table 16 Personnel budget by year

Personnel	1	2	3	4	5	TOTAL (USD)
Programme manager	39 400	40 188	40 992	41 812	42 648	205 039
Administration	22 500	22 950	23 409	23 877	24 355	117 091
Legal Adviser	22 500	22 950	23 409	23 877	24 355	117 091
Expert in strengthening demand	22 500	22 950	23 409	23 877	24 355	117 091
Expert in strengthening supply	34 200	34 884	35 582	36 293	37 019	177 978
Expert in monitoring and evaluation	22 500	22 950	23 409	23 877	24 355	117 091
Expert in matching supply and demand	22 500	22 950	23 409	23 877	24 355	117 091
Technical assistance and quality control expert	22 500	22 950	23 409	23 877	24 355	117 091
Consultancies	45 000	30 000	30 000	30 000	30 000	165 000
Responsible for south macro-region	23 800	24 276	24 762	25 257	25 762	123 856
Technician 1	16 250	16 575	16 907	17 245	17 590	84 566
Technician 2	16 250	16 575	16 907	17 245	17 590	84 566
Technician 3			16 907	17 245	17 590	51 741
Technician 4			16 907	17 245	17 590	51 741
TOTAL PERSONNEL (USD)	309 900	300 198	339 418	345 604	351 919	**1 647 033**

At the level of operating costs (see Table 17), the Coordinating Team and the operational units will be accommodated in spaces granted which do not require payment of rent. These spaces can be linked to the Ministry of the Environment or another ministry.

It is necessary, on logistical grounds, to buy one car and one motorcycle per macro-region. From the third year, with the contracting of two new technicians, a further two motorcycles will be purchased. The coordination of the logistics with decentralized autonomous governments will be one of the priorities.

Table 17 Operating budget						
Expenditures	**1**	**2**	**3**	**4**	**5**	**TOTAL**
Car purchase and maintenance	35 000	3 000	3 060	3 121	3 183	47 365
Car purchase and maintenance	35 000	3 000	3 060	3 121	3 183	47 365
Purchase of motorcycles (2x)	10 000	2 000	2 040	2 080	2 122	18 243
Purchase of motorcycles (2x)			10 000	2 080	2 122	14 203
Travel and subsistence	10 000	10 200	10 404	15 000	15 300	60 904
Office services (2x)	6 000	6 120	6 242	6 367	6 495	31 224
Refurbishing office (2x)	8 000		2 000			10 000
Office equipment (2x)	30 000	2 000	2 000	2 000	2 000	38 000
Office supplies (2x)	6 000	4 000	4 000	4 000	4 000	22 000
Other	3 000	3 000	3 000	3 000	3 000	15 000
TOTAL Operating expenses	**143 000**	**33 320**	**45 806**	**40 771**	**41 407**	**304 304**

25.3. Strengthening of demand

The activities and outputs considered in the component on strengthening of demand are set out in Table 18 and in the associated budget in Table 19. These activities and achievements are aimed at the dissemination of the technology and the opportunity represented by the NBP to access it among small and medium-sized livestock farmers.

For the promotion of biodigesters, as well as the specific mechanisms of each established technology supplier, the NBP will generate additional publicity and reference material, with clear and validated information.

One of the keys to promotion is “seeing is believing”. For this, a successful strategy is to develop workshops in farmers’ associations, and subsequently, for those interested, and inviting them to visit nearby biodigesters. In cases where there are no nearby biodigesters, it will be necessary to implement demonstration biodigesters.

Part of strengthening of demand is the development of a user guide, si0nce it helps to give assurance to future users of the existence of printed matter in support of operating and exploiting the benefits of the biodigester. The guide already developed by Hivos and CIMNE in Bolivia can be used as a reference and adapted to the Ecuadorian context[23].

A key message of this component is that the NBP guarantees the installations, since the suppliers are validated, and the non-professional installers are certified. Quality control of the installations will be key in underpinning this message.

Table 18 Activities and outputs by year of the strengthening of demand component						
Strengthening of demand	**1**	**2**	**3**	**4**	**5**	**TOTAL (#)**

[23] https://www.beegroup-cimne.com/sistema-bio-nati-manual-de-operacion-y-mantenimiento-en-zona-andina/

Development of promotional material	1		1			2
Reproduction of promotional material	2 500		5 000		2 500	10 000
TV, press and radio campaigns	2	2	1	1	1	7
Promotional and demonstration activities	1	1	1	1	1	5
Training of NBP stakeholders	1		1			2
Promotional and awareness raising workshops	10	20	30	30	30	120
Demonstration biodigesters	15	15	10	5		45
Demonstration tours	10	20	20	10		60
Development of user guide	1		1			2
Printing of user guide	1 200		2 800			4 000

Table 19 Budget by year of the strengthening of demand component

Strengthening of demand	**Unit cost (USD)**	**1**	**2**	**3**	**4**	**5**	**TOTAL (USD)**
Development of promotional material	10 000	10 000	0	10 000	0	0	20 000
Reproduction of promotional material	2.5	6 250	0	12 500	0	6 250	25 000
TV, press and radio campaigns	5 000	10 000	10000	5 000	5 000	5 000	35 000
Promotional and demonstration activities	5 000	5 000	5000	5 000	5 000	5 000	25 000
Training of NBP stakeholders	3 000	3 000	0	3 000	0	0	6 000
Promotional and awareness raising workshops	500	5 000	10000	15 000	15 000	15 000	60 000
Demonstration biodigesters	1 500	22 500	22500	15 000	7 500	0	67 500
Demonstration tours	500	5 000	10000	10 000	5 000	0	30 000
Development of user guide	6 000	6 000	0	6 000	0	0	12 000
Printing of user guide	5	6 000	0	14 000	0	0	20 000
Total Streng.demand (USD)		**78 750**	**57500**	**95 500**	**37 500**	**31 250**	**300 500**

25.4. Strengthening of supply

The activities and outputs considered in the component on strengthening of supply are set out in Table 20 and the associated budget in Table 21.

The supply of biodigesters initially comes from the established technology suppliers. It will be necessary to train and certify new non-professional installers who serve rural regions remote from commercial circuits and which, for logistical reasons, the established suppliers find it hard to serve.

The training of these non-formal installers will be the focus of this component, and for that purpose, the first task is to define the final model,, materials, adaptation to cold climates of the biodigesters on which they are to be trained. It was mentioned above that the model in this case will be the tubular plastic model. This first final definition of the reference biodigester must be undertaken in conjunction with the R&D component. For that purpose, the designs and manuals already produced in other countries of the region (by Hivos and CIMNE) will be adapted to the Ecuadorian context[24].

The development of training workshops will require generating reference teaching materials, and have materials and tools available. The first workshop can be developed for trainers, aimed at SECAP personnel who will subsequently be responsible for delivering courses and certifying the participants that they pass. The development of the workshop[s must be in the field, practical, linked to the local area, with an initial theory class followed by practical work in installation. This can be developed in conjunction with INIAP, as it already has spaces ready for the condu9ct of this type of activity with real infrastructure. The final certification of the installers will be after installation of a biodigester in a family which passes the NBP quality control.

It is important to consider training in accounting, marketing and after-sales service in future non-professional installers. It cannot be ruled out that non-professional installers (with sporadic involvement in installation of biodigesters) decided to become technology suppliers within the NBP (thus making it their primary or secondary business activity).

In addition, this component will be charged with helping to generate a sustainable, competitive and quality biodigester market in Ecuador. For this, it must also adapt and validate biogas devices (pumps, milking machines, grass choppers, generators, etc.) and ensure that they are available on the market to farmers who are users of biodigesters. In this r6esoect, i0t i0s important to reply on the progress already made in the NBP of Nicaragua (developed by SNV and Hivos) to promote biogas in productive uses on the farm[25].

This component will work closely with the R&D component.

This is a key component which requires and expert with previous experience in biogas technology.

Table 20 Activities and outputs by year of the strengthening of supply component

Strengthening of supply	1	2	3	4	5	TOTAL (#)
Strengthening of strategic partners	2	2	2	2	2	10
No. of workshops	0	2	2	3	2	9
Development of training material	1		1			2
Printing of material	40		60			100
Tool kit	40		60			100
Biodigester material kit	40		60			100

Table 21 Budget by year of the strengthening of supply component

[24] https://www.beegroup-cimne.com/sistema-bio-nati-manual-de-instalacion-en-zona-andina/

[25] https://www.youtube.com/watch?v=bBUf35ntSwQ

Strengthening of supply	Unit cost (USD)	1	2	3	4	5	TOTAL (USD)
Strengthening of strategic partners	3 000	6 000	6 000	6 000	6 000	6 000	30 000
Holding of workshops	5 000	0	10 000	10000	15 000	10 000	45 000
Development of training material	5 000	5 000	0	5 000	0	0	10 000
Printing of material	15	600	0	900	0	0	1 500
Tool kit	100	4 000	0	6 000	0	0	10 000
Biodigester training material kit	750	30 000	0	45 000	0	0	75 000
Total Strength.Supply (USD)		**45 600**	**16 000**	**72 900**	**21 000**	**16 000**	**171 500**

25.5. Matching supply and demand

The activities and outputs considered in the component on matching supply and demand are set out in Table 22 and the associated budget in Table 23.

This component has the objective of facilitating economic access of farmers interest in biodigesters. There will be three basic pillars which complement each other and which in some cases may have synergies: development of financial products through banking institutions, savings and credit and microfinance cooperatives; development of strategic partnerships with associations and/or collection companies to provide credit for their members; develop implementation and monitoring of revolving funds in farmers' associations.

In the dairy cycle, collection companies can provide credit to the farmers who supply them, acting as an extension agent which deducts an instalment with each payment of milk. Similar schemes can be evaluated ion the pig sector.

Consolidated farmers' associations with management capacity can manage their own revolving fund, so that a farmer can ask for credit from it, and replay it to the same fund so that the fund is maintained.

This component will approve payments of subsidies on each installation, as soon as the i0nstallation passes the relevant quality control. The component will work very closely with the demand strengthening component and the monitoring and evaluation and quality control components.

Table 22 Activities and outputs by year of the matching of supply and demand

Matching of supply and demand	1	2	3	4	5	TOTAL (#)
Development of financial products (multi-stakeholder meetings)	2	2	1	1		6
Development of revolving fund mechanism	1		1			2
Identification of implementation of revolving funds	1		1			2
Creation of revolving funds		2	3	3		8

Table 23 Budget by year of the matching of supply and demand

Matching of supply and demand	Unit cost (USD)	1	2	3	4	5	TOTAL (USD)
Development of financial products (multi-stakeholder meetings)	2 000	4 000	4 000	2 000	2 000	0	12 000
Development of revolving fund mechanism	8 000	8 000	0	8 000	0	0	16 000
Identification of implementation of revolving funds	8 000	8 000	0	8 000	0	0	16 000
Creation of revolving funds	25 000	0	50 000	75 000	75 000	0	200 000
Total Match.supply/demand (USD)		**20 000**	**54 000**	**93 000**	**77 000**	**0**	**244 000**

25.6. Technical assistance and quality control

The activities and outputs considered in the component in technical assistance and qu9ality control are set out in Table 24 and the associated budget in Table 25.

The technical assistance will ensure the proper functioning, correctly use and full benefits of biodigesters. It will focused on strengthening and monitoring biodigester users, with two visits per family using the biodigester. It must be borne in mind that this is a complementary activity to the after-sales service provided by the technology suppliers and non-professional installers. In this way, by these visits, it will be ensured that the users are kept up to date on the use, maintenance and exploitation of the benefits of the biodigesters.

Taking advantage of the logistics invested in these visits to farmer families who have biodigesters, the opportunity will be taken to inform them about the results of progress in research (R&D component) chiefly in the use of biol, through the R&D pamphlets. These visits will also serve to ascertain requests for research from users, which will be passed on to the R&D component.

A very useful tool is the holding of experience-sharing events among users from different regions, in which consideration can also be given to exchange of experiences among technology suppliers and non-professional installers. These events can be held at macro-regional and/or national level.

Technical assistance can be delegate or shared with the INIAP, as this public research institute already carries out this type of activity in the livestock farming sector and knows the dynamics. Specific training in biodigesters, use, maintenance and exploitation of the benefits will be necessary for the technicians who provide assistance.

The quality control visits will also come under this component. As has been mentioned, this is a fundamental tool of the NBP which ensures the reliability of the actions performed by the NBP. Thus, it ensures that each of the installations realized under the NBP will be visited to evaluate the quality. When rates of installation come close to 1,000 biodigesters per year (an average of 3 biodigesters a day), it is difficult to carry out this quality control because of the logistics involved, and this evaluation is made of a significant number of installations realized by each supplier or installer. It is important to ensure the effectiveness of these actions, since it is on quality control approval that depends the final payment of the su9bsidy and this process must be rapid.

Thus component will have to coordinate with the R&D component, the monitoring and evaluation component and the matching of supply and demand component.

Table 24 Activities and outputs by year of the technical assistance and quality control component

Technical assistance and quality control	1	2	3	4	5	TOTAL (#)
After-sales visits	150	700	1450	2200	2500	7000
Quality control visits	75	350	725	1100	1250	3500
Printing of R&D pamphlets		300	900	1200	1500	3900
Experience-sharing events		1	1	1	1	4

Table 25 Budget by year of the technical assistance and quality control component

Technical assistance and quality control	Unit cost (USD)	1	2	3	4	5	TOTAL (USD)
After-sales visits	*	4 875	22 750	31 417	47 667	54 167	160 875
Quality control visits	*	4 875	22 750	23 563	35 750	40 625	127 563
Printing of R&D pamphlets	2	0	600	1 800	2 400	3 000	7 800
Experience-sharing events	6 000	0	6 000	6 000	6 000	6 000	24 000
Total AS & QC (USD)		**9 750**	**52 100**	**62 779**	**91 817**	**103 792**	**320 238**

25.7. Monitoring and evaluation

The activities in this component are aimed at recording information which allows evaluation of the performance of the NBP. It starts from a baseline which identifies the initial situation of livestock farmers. Maintaining a broad focal group of farmers among those who can provide long-term monitoring of the whole NBP will allow an evaluation the impact on those who do or do not incorporate a biodigester in their productive system.

This component will monitor 5 per cent of the biodigesters installed, so that it is possible to see the progress of the first biodigesters installed during the first year, and compare them with the biodigesters installed in the third or fourth year..

The information obtained from this monitoring is of interest for all components of the NBP, since it allows activities to be corrected, others strengthened, based on the information generated. It is recommended that the monitoring and evaluation should be carried out by an external institution, with experience of field work, biodigester implementation projects and the capacity to enter regions which are difficult of access for monitoring.

Gender equity criteria must be considered in each of the results of this component, from the baseline to the impact study. This component, moreover, will ensure that gender equity is considered in the actions of all the other components of the NBP.

An annual monitoring and evaluation study of the NBP will be carried out, from the second year, plus an in-depth interim evaluation study of the NBP. It is recommended that the impact study should be done during the fourth year, taking advantage of the consolidation of families who have taken ownership of biodigesters with several years' experience, although some case studies may precede it.

For the purpose of transfer, this component will prepare a biannual event to report progress of the NBP.

Table 26 Activities and outputs by year of the monitoring and evaluation component

Monitoring and evaluation	1	2	3	4	5	TOTAL (#)
Monitoring 5% existing bdgs		21	58	113	175	367
Baseline study	1					1
M&E studies		1	1	1	1	4
Impact study				1		1
Interim evaluation			1			1
Final evaluation					1	1
Biannual seminar	1		1		1	3

Table 27 Budget by year of the monitoring and evaluation component

Monitoring and evaluation	Unit cost (USD)	1	2	3	4	5	TOTAL (USD)
Monitoring 5% existing bdgs			2 125	5 750	11 250	17 500	36 625
Baseline study	10 000	10 000	0	0	0	0	0
M&E studies	8 000	0	8 000	8 000	8 000	8 000	32 000
Impact study	15 000	0	0	0	15 000	0	15 000
Interim evaluation	10 000	0	0	10 000	0	0	10 000
Final evaluation	15 000	0	0	0	0	15 000	15 000
Biannual seminar	8 000	8 000	0	8 000	0	8 000	16 000
Total M&E (USD)		**18 000**	**10 125**	**31 750**	**34 250**	**48 500**	**124 625**

25.8. R&D

This component must generate and consolidate knowledge in the Ecuadorian context concerning biodigesters, use of biogas and biol.

A key aspect is to generate knowledge of the dosage and frequency of biol for the various crops and eco-regions of the country. This is one of the major potential uses of biodigesters (biol) in a country which subsidizes gas. Consequently, now, the key stakeholder can be INIAP, to systematically carry out studies of the application of biol in the different eco-regions and with different crops. These studies can also be carried out by universities which have experimental farms like the University of Cuenca or the Central University of Ecuador. Also envisaged within this component is the conduct of several research studies into biol each year, The results of this research must be set out in pamphlets and passed on to biodigester users through the technical assistance component.

The technology is already known and validated, but it is necessary to optimize the technology in climate conditions of which there has not been sufficient experience in Ecuador. During the first year, it will be necessary to implement activities on validation in a cold climate, and transfer this knowledge to the supplier companies, and include it in the subject matter of training of non-professional installers. During the first year will also be when work is carried out on 500 micron geomembrane (see Section 11), to validate this proposal (Ambato Technical University and the Amazon Regional University, IKIAM, have carried out experiments with this material). For this reason, other research in this component is under consideration (in addition to biol), And as mentioned above, the subject of this research can be defined by the livestock farmers themselves.

In addition, to generate a reference database on the technical behaviour of the biodigesters installed, their biogas output, recycling of nutrients achieved and their impact in reducing emissions of greenhouse gases, 30 biodigesters a year will be monitored, making a total of 150 systems by the end of the project.

As there are several universities and research centres which can contribute to this component, it is suggested that a consortium of interested universities with previous experience and public research institutes should be formed (see Section 15.3, page 29) for the decentralized conduct of the component activities.

Table 28 Activities and outputs by year of the R&D component

R&D	1	2	3	4	5	TOTAL
Equipping of the North experimental research centre	1					1
Reagents and analysis	30	30	30	30	30	150
Monitoring kits	30	5	5	5	5	50
Logistics	1	1	1	1	1	5
Research into biol	5	5	5	5	3	23
Other research	2	2	2	2	1	9
Meetings	1		1		1	3

Table 29 Budget by year of the R&D component

R&D	Unit cost (USD)	1	2	3	4	5	TOTAL (USD)
Equipping of the North experimental research centre	15 000	15 000	0	0	0	0	15 000
Reagents and analysis	250	7 500	7 500	7 500	7 500	7 500	37 500

Monitoring kits	400	12 000	2 000	2 000	2 000	2 000	20 000
Logistics	3 000	3 000	3 000	3 000	3 000	3 000	15 000
Research into biol	3 000	15 000	15 000	15 000	15 000	9 000	69 000
Other research	3 000	6 000	6 000	6 000	6 000	3 000	27 000
Meetings	3 000	3 000	0	3 000	0	3 000	9 000
Total R&D (USD)	**27 650**	**61 500**	**33 500**	**36 500**	**33 500**	**27 500**	**192 500**

25.9. International technical assistance

It is necessary to have experience of national biogas programmes in other countries in order not to repeat the mistakes already committed in other places and to be able to adapt successful strategies. It is about having advice, evaluation and strategic proposals from institutions with previous experience. Possible actors to be considered could be, at international level, the Netherlands Development Organization (SNV) which is the best known institution, as it started by implementing the first NBPs in Asia in the 1990s. When this type of programme began to be implemented in Africa (in the 2000s), the SNV did so in partnership with Hivos. And in the first experience of NBP in Latin America, in Nicaragua, SNV and Hivos were the ones who coordinated its execution. SNV and Hivos worked in Peru and Bolivia on the viability of NBPs, in association with CIMNE, with long experience in Bolivia coordinating the GIZ biogas project.

It is because of this previous experience that it is considered that the project must rely on these three actors to support and contribute to the process of development of the NBP in Ecuador.

Table 30 Activities by year of international technical assistance

International technical assistance	1	2	3	4	5	**TOTAL**
Hivos (month equivalent/year)	1.5	1	1.5	0.5	1	5.5
CIMNE (month equivalent/year)	1.5	1	1.5	0.5	1	5.5
SNV (month equivalent/year)	1.5	1	1.5	0.5	1	5.5

Table 31 Budget by year of international technical assistance

International technical assistance	**Unit cost (USD)**	**1**	**2**	**3**	**4**	**5**	**TOTAL (USD)**
Hivos (month equivalent/year)	10 000	15 000	10 000	15 000	5 000	10 000	55 000
CIMNE (month equivalent/year)	10 000	15 000	10 000	15 000	5 000	10 000	55 000
SNV (month equivalent/year)	10 000	15 000	10 000	15 000	5 000	10 000	55 000
Total International TA (USD)		**45 000**	**30 000**	**45 000**	**15 000**	**30 000**	**165 000**

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ANNEXES

Inputs and outputs of dairy farms

Table 32 shows the input/output analysis for dairy farmers. In the case of the small dairy farmer, on average they have some 60 kg of manure available per day which could be used to feed a biodigester, where the threshold of biogas production between a domestic biodigester and a farm biodigester is 2m^3 per day. For this reason, two scenarios are proposed for this type of small farmer, where in one case the introduction of a simple domestic biodigester is analysed and in the other, a farm biodigester

Table 32 Inputs and outputs of dairy farmers

INPUTS	Small dairy farmer		Medium-sized dairy farmer
Has a shed	No		Yes
Where he milks	In pasture/pen with fence		Milking shed
Total number of animals	8		47
Milk cows	5		24
Dry cows or other	3		12
Milk production per animal (litres/day)	9.6		14
Daily milk production (litres/day)	48		336
Management of manure	Collects manure and spreads on pasture		Collects manure and spreads on pasture
Manure available for biodigester (kg/d)	60		138
OUTPUTS			
Type of biodigester	Farm biodigester	Domestic biodigester	Farm biodigester
Manure available daily (kg/d)	60	30	120
Water daily (litre/d)ay	180	90	360
Potential biogas daily (m^3/d)	2	1	4,2
Uses of biogas	Cooking + uses on farm	Cooking	Cooking + uses on farm
Consumption of LPG (cylinders/month)	1.4	1.4	3.2
LPG cost (USD/year)	49.71	49.71	220.8

State LPG subsidy (USD/year)[26]	137.09	137.09	313.34
Reference cost of synthetic fertilizers (USD/year)	257.6	257.6	2787.5
Estimate price biodigester recycled nutrients (USD/year)	131.18	65.59	309.63
Nitrogen (N); Phosphorus (P); Potassium (K) recycled (kg/year)	68; 16; 62	34; 8; 31	223.4; 40.3; 60.1,3

[26] It was assumed that each 15 kg cylinder of LPG had an associated subsidy of USD 8.16, based on data from https://www.controlhidrocarburos.gob.ec/precios-combustibles/

Inputs and outputs of pig farms

For pig farmers, the input/output analysis is shown in Table 33. In this case, the quantity of manure assumed for medium-sized pig farms is 34.5 kg/d, lower than would be expected considering the average number of animals (57.4 kg/d of manure). Consequently, two scenarios have been considered for medium-sized pig farms.

Table 33 Inputs and outputs of pig farms

INPUTS	Small pig farm	Medium-sized pig farm	
Has pen	Si	Si	
Cement floor	Si	Si	
Total number of animals	22	50	
Mothers	4	9	
Piglets	11	35	
Breeding animal	1	2	
Fattening	6	4	
Management of manure	Collects manure and spreads on pasture	Collects manure and spreads on pasture	
Manure available for biodigester (kg/d)	29	34.5	
OUTPUTS			
Type of biodigester	Environmental biodigester	Environmental biodigester	Environmental biodigester
Manure available daily (kg/d)	29	34.5	57.4
Water daily (litre/d)ay	174	172.5	287
Potential biogas daily (m^3/d)	1.5	2	3.5
Uses of biogas	Cooking and farm uses (heating for piglets)	Cooking and farm uses (heating for piglets)	Cooking and farm uses (heating for piglets)
Consumption of LPG (cylinders/month)	2.1	2	2
LPG cost (USD/year)	73.08	75.12	75.12

State LPG subsidy (USD/year)[27]	205.63	195.84	195.84
Reference cost of synthetic fertilizers (USD/year)	405.6	Very variable from USD 0 to 40 000	Very variable from USD 0 to 40 000
Estimate price biodigester recycled nutrients (USD/year)	193.33	182.33	303.33
Nitrogen (N); Phosphorus (P); Potassium (K) recycled (kg/year)	86; 66; 33	105; 85; 31	167; 114; 23

[27] It was assumed that each 15 kg cylinder of LPG had an associated subsidy of USD 8.16, based on data from https://www.controlhidrocarburos.gob.ec/precios-combustibles/

Estimation of CO_2 emissions avoided by use of biodigesters

According to Harianto and Cahyani (2019), the tubular plastic biodigester construction is associated with the emission of 306,624 kg CO_2. The materials used to construct a biodigester vary from one place to another, and in this case the authors consider a biodigester 4 metres in length and include bricks and cement, which account for 66% of the CO_2 emissions associate with the construction. In the case of Ecuador, it is not usual to use cement or bricks, and the lengths of domestic biodigesters tend to be 8 metres, so it is considered that the use of double plastic offsets the lack of use of building materials, and a conservative value for CO_2 emissions associated with the construction of domestic biodigesters is 150 kg. To facilitate the approximation, this value can be extrapolated to other sizes of biodigesters, proportional to the daily load of manure that is fed into them. In other words, for a domestic biodigester fed with 30 kg of manure, 150 kg CO_2 is emitted, and for a farm biodigester which is fed with 120 kg of manure, four times as much CVO2 is emitted in its manufacture. These values are summarized in Table 34 below.

Table 34 CO_2 emissions associated with the construction of the typical biodigester associated with each type of farmer

	Manure/day (kg/d)	CO_2 emissions associated with the construction of the biodigester
Small dairy	30	150
Medium-sized dairy	120	600
Small pig	30	150
Medium-sized pig	60	300

To estimate the quantity of emissions which are avoided by substitution of LPG by using biogas, it is assumed that: small and medium-sized dairy farmers produce 30 and 120 kg of manure per day, and have a potential to produce 1 and 4,2 m^3 of biogas per day respectively. Small and medium-sized pig farmers have 30 and 60 kg of manure and have the capacity to produce 1.5 and 3.5 m^3 of biogas[28].

If it is assumed that the biogas has a methane content of 60%, this means that $1m^3$ of biogas has 21.5 MJ of energy. According to Martínez et al (2018), the energy contained in a 15 kg cylinder of LPG in Ecuador is 54.284 MJ, thus $1m^3$ of biogas is equivalent to 0,396 kg de LPG. According to IDAE (2010) 1 kg of LPG is associated with emissions of 3.5285 kg CO_2[29].

[28] https://www.ctc-n.org/content/act-2-lisis-entrada-salida-de-los-biodigestores-en-el-contexto-ecuatoriano

[29] $1m^3$ is equivalent to 0.0572 kg of LPG (Wang and Zhang, 2012)

1 kg of LPG has 54.2840909 MJ of energy in Ecuador (Martinez et al, 2018)

1kg of LPG is associate with emissions of 3.5285 kgCO_2 (IDAE, 2010)

Table 35 shows CO_2 emissions saved by substitution of LPG with biogas, if biogas is used for cooking and other farms uses where its replaces it.

Table 35 CO_2 emissions associated with the displacement of consumption of LPG by biogas, by each type of farmer

	Manure/day (kg/d)	Biogas/day (m^3/d)	Energy (MJ/d)	kg LPG equivalent (kg/d)	Kg CO_2/year
Small dairy	30	1	21.5	0.396	510.09
Medium-sized dairy	120	4.2	90.3	1.664	2142.39
Small pig	30	1.5	32.25	0.594	765.14
Medium-sized pig	60	3.5	75.25	1.386	1785.33

Thus a small dairy farmer avoids emission of 510 kg CO_2 per year, and a small pig farmer 765 kg CO_2 per year, while medium-sized farmers reach 2141 kg CO_2 per year in the case of dairy farms, and 1785 kg CO_2 per year in the case of pig farms.

In addition, there is a saving of emissions in the displacement produced by ceasing to use synthetic fertilizers, replacing them with recycling of nutrients which occurs when using biol from the biodigester. The emissions associated with 1 kg de nitrogen (N) are 2.79 kg CO_2, 1 kg of phosphorus (P) 0.74 kg CO_2 and 1 kg of potassium (K) 0.35 kg CO_2, according Jayasundara et al (2014). In this way, knowing the typology of the farmers, and the potential recycling of nutrients per year, the CO_2 emissions saved by avoiding the use of synthetic fertilizers can be estimated, as shown in Table 36. The values of nutrients recovered were extracted from the input/output analysis of biodigesters in the Ecuadorian context (CTCN, 2018)[30].

Table 36 CO_2 emissions associated with the displacement of synthetic fertilizers by recycling of nutrients.

	Nutrients recycled(kg/year)			CO_2 avoided (tCO_2/year)			Total (tCO_2/year)
	N	P	K	N	P	K	
Small dairy	68	16	62	189.72	11.84	21.7	223.26
Medium-sized dairy	223	40	61	622.17	29.6	21.35	673.12
Small pig	86	66	33	239.94	48.84	11.55	300.33
Medium-sized pig	167	114	23	465.93	84.36	8.05	558.34

The change in the management of manure avoids CO_2 emissions into the atmosphere. In the study by Hou et al (2017) it is shown how the accumulation of cow dung produces 2.68 kg of CO_2 equivalent for each tonne of manure (considering CH_4 and NO_2). In the case of pig manure, which is allowed to accumulate, the associated CO_2 would be 45.12 kg CO_2 per tonne of manure, linked to pig farmers. A case which will arise currently between some medium-sized pig farmers is when the pig manure goes to a septic tank, or open pond, where this treatment is associated with1737.14 kg CO_2 equivalent for each tonne of manure. In this case, it will be considered that all farmers only accumulate manure and later spread it on the crops, as shown in the results of

30 https://www.ctc-n.org/content/act-2-lisis-entrada-salida-de-los-biodigestores-en-el-contexto-ecuatoriano

the input/output analysis study of biodigesters in the Ecuadorian context[31]. Considering these values, Table 37 shows CO_2 emissions avoided by changing the management of manure.

Table 37 CO_2 emissions associated with the change in management of manure which now feeds the biodigester

	Manure/día	Kg CO_2/year avoided
Small dairy	30	29.35
Medium-sized dairy	120	117.40
Small pig	30	494.07
Medium-sized pig	60	988.14

Once we have the CO_2 emissions associated with construction and the savings associated with the use of biogas, displacement of fertilizers and management of manure, we can produce a balance sheet of CO_2 emissions for each type of farmer, as shown in Table 38.

Table 38 Total balance sheet of CO_2 emissions associated with each type of farmer with a biodigester

	Added	Avoided (kg CO_2/year)				Total kg CO_2 avoided/ year 10[32]
	Construction (kg CO_2)	Fuel	Fertilizers	Manure	Total avoided	
Small dairy	150	510	223	29	762	7 470
Medium-sized dairy	600	2142	673	117	2 932	28 720
Small pig	150	765	300	494	1 559	15 440
Medium-sized pig	300	1785	558	988	3 331	33 010

If these values are considered, and it is assumed that the pace of installation of biodigesters between dairy farms and pig farms is 50%-50%, then the CO_2 avoided each year can be estimated, as shown in Table 39.

Table 39 CO_2 emissions avoided by the implementation of the NBP by year and type of farmer

Year	1	2	3	4	5	**TOTAL avoided (tCO_2)**
Small dairy (t CO_2)	6,1	53,6	164,1	409,0	732,6	**1365,3**
Medium-sized dairy (t CO_2)	58,3	306,6	821,5	1381,8	1939,0	**4507,3**
P Small pig (t CO_2)	21,1	129,1	370,1	906,0	15781,2	**2998,6**
Medium-sized pig (t CO2)	75,8	386,5	1007,7	1642,2	2275,3	5387,4
TOTAL avoided (t CO_2)	**161,4**	**875,8**	**2363,3**	**4335,0**	**6523,1**	**14258,6**

31 https://www.ctc-n.org/content/act-2-lisis-entrada-salida-de-los-biodigestores-en-el-contexto-ecuatoriano

32 Total kg CO_2 avoided year 10 calculated as "Total Avoided (kg CO_2/year)" for 10, minus "Added by construction (kg CO_2)"

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Quality control of low-cost biodigesters

Low-cost biodigesters are those which avoid the incorporation of active agitation systems and/or heating[33]. In general, these systems try to use natural phenomena for the proper functioning of the biodigesters (gravity, hydraulic, solar heating, etc.) The best-known low-cost biodigesters are fixed dome, floating dome and plastic biodigesters[34].

Ein Ecuador, the low-cost biodigesters being installed are plastic, whether PVC geomembrane, polyethylene or greenhouse plastic. There have been numerous experiences of installation of biodigesters, by there has never been external quality control (QC) of them. This QC is now carried out in the field, with the installed system, and does not consider the internal protocols of each technology supply company or the manufacturers of the materials prior to the installation of the biodigester.

For the present project, two quality control activities will be carried out, one specifically to validate the installation through a visit, and another extended one of the type to evaluate the functioning of the biodigester by monitoring

Quality control of installation

The process of quality control of the installation will be carried out when at least one hydraulic retention time[35] has passed (established in the design of the biodigester) since installation. It may also be carried out earlier at the suggestion of the technology supplier.

- Verification of the quality of the material used for the biodigester:
    - Condition of the biodigester. If the biodigester is inflated, it is a good indicator of hermeticity. This parameter will also be evaluated in joints, fixings and welds. As a resource a mixture of water and soap will be used, and the presence of bubbles will be an indication of leaks .
    - Type of plastic (greenhouse plastic, PVC or polyethylene geomembrane). This will be evaluated in terms of what is offered (complies or does not comply).
    - Colour of the plastic or geomembrane. This will be evaluated in terms of what is offered (complies or does not comply).
    - Thickness of the plastic or geomembrane. This will be evaluated in terms of what is offered (complies or does not comply).
- Verification of biodigester protection measures (enclosure and cover).
    - If the biodigester uses polyethylene geomembrane, an enclosure and cover is not essential.
    - If the biodigester is over 3,000mAMSL, the cover must be translucent.

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[33] Martí-Herrero, J. (2011). Reduced hydraulic retention times in low-cost tubular digesters: two issues. *biomass and bioenergy*, *35*(10), 4481-4484.

[34] http://beegroup-cimne.com/kt-content/uploads/2018/06/Guia-Biogas-sector-lechero-2018.pdf

[35] Hydraulic Retention Time (HTR): Average length of time that the soluble compound remains in the system from its inflow to its outflow, or the arithmetic ratio between the (useful) liquid volume or solid of the biodigester and the average flow. (http://beegroup-cimne.com/kt-content/uploads/2018/06/Guia-Biogas-sector-lechero-2018.pdf)

    - Verify if the trench impedes access of small animals such as dogs.
- Verification of the dimensions of the biodigester:
    - Width, length and depth.
    - Estimated volume of the trench.
- Verification that the user knows about the operation and maintenance
    - Daily load (how much manure and how much water).
    - Maintenance activities (overflow valve, hydrogen sulphide filter and condensation water in pipes).
    - Check hydraulic retention time based on estimated volume of trench and daily load.
- Verification that it is producing biogas and that it is burned in the place of use.
    - Opening the tap at the point of consumption, light the biogas and check if the flame is stable .
- Verification that the biol does not produce smells
    - Take a sample of the biol and identify the presence of smells. They must not be the same as fresh manure.
    - Check the absence of flies around the biol outflow.
- Verification that the user knows how to use the biogas and biol
    - Use of biogas: Show burning and use by the user, potential use of biogas on the farm.
    - Use of biol: Show actual use of biol, and potential use.
- Verification of user satisfaction
    - Would he invest in a biodigester again? Has he recommended it to a neighbour, acquaintance of family member?

Quality control of functioning

A process of monitoring[36] the production of biogas, methane content and samples of inputs and outputs to the biodigester will be conducted over several months. To establish the functioning of the biodigester, it must be stabilized, and thus the measurements must be taken at least after there hydraulic retention times have elapsed (established in the biodigester design). This monitoring will require data for at least one full week, and preferably for a full month.

- The mass of manure(kg) and water (l) loaded daily in the biodigester will be recorded.
- The cumulative production of biogas (m^3) will be recorded.
- A sample of the biogas will be taken and its methane content will be measured (%CH_4).
- A sample of fresh manure will be taken and analysed to ascertain the total solids (% TS), volatile solids (%VS on a wet basis) and pH.

[36] For reference, consult the following article on monitoring and characterization of biodigesters: Martí-Herrero, J., Ceron, M., Garcia, R., Pracejus, L., Alvarez, R., & Cipriano, X. (2015). The influence of users' behavior on biogas production from low cost tubular digesters: A technical and socio-cultural field analysis. *Energy for Sustainable Development*, *27*, 73-83.

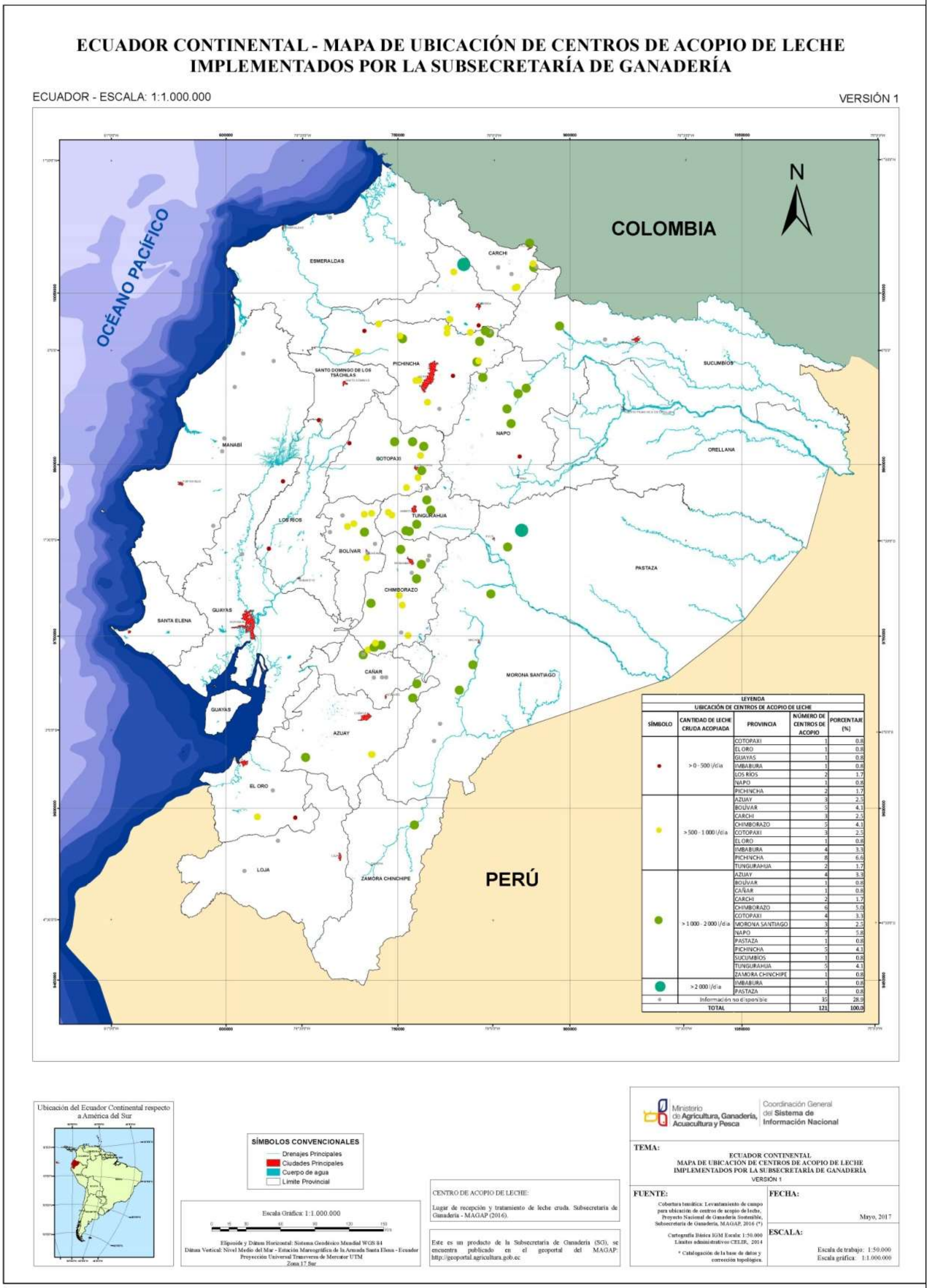
- A sample of the mixture entering the biodigester will be taken (water + manure) analysed to ascertain the total solids (% TS), volatile solids (%VS on a wet basis) and pH and NPK.
- A sample of the biol will be taken and analysed to ascertain the total solids (% TS), volatile solids (%VS on a wet basis) and pH and NPK.
- The ambient temperature and the temperature of the biodigester will be measured.
- The following parameters will be calculated[37]
  - Organic load rate ($kg_{SV}/m^3_{biodigestor}/d$)
  - Hydraulic Retention Time (d)
  - Specific biogas production (m^3_{biogas}/kg_{SV})
  - Biogas production rate ($m^3_{biogas}/m^3_{biodigestor}/d$)
  - Working temperature (°C)

[37] For reference, consult the following article on monitoring and characterization of biodigesters: Martí-Herrero, J., Ceron, M., Garcia, R., Pracejus, L., Alvarez, R., & Cipriano, X. (2015). The influence of users' behavior on biogas production from low cost tubular digesters: A technical and socio-cultural field analysis. *Energy for Sustainable Development*, *27*, 73-83.

CATTLE	SIZES OF Livestock Farm Units (LFU) (hectares)										
	TOTAL	< 1	1-2	2-3	3-5	5-10	10-20	20-50	50-100	100-200	<200
Total											
LFUs	427,514	93,839	57,747	40,295	47,143	52,574	44,793	51,434	24,803	9,948	4,939
Head	4,486,020	226,729	186,007	153,237	225,745	340,466	437,177	855,871	708,152	545,982	806,653
Criollo											
LFUs	359,305	88,510	54,397	37,695	43,140	46,016	35,584	34,015	13,730	4,279	1,940
Head	2,428,731	211,887	172,960	138,095	198,652	278,389	318,577	476,301	305,902	163,816	164,151
Unregistered mixed breed											
LFUs	71,632	5,594	3,474	2,730	4,285	7,010	9,860	18,019	11,651	5,889	3,118
Head	1,902,197	14,724	12,992	14,952	26,665	59,121	114,747	358,974	385,867	357,749	556,406
Mixed breed registered											
LFUs	649	23	9	27	30	25	43	192	105	98	96
Head	63,903	116	52	45	195	1,467	559	5,459	5,403	12,164	38,443
Pure-bred beef cattle											
LFUs	816	,	,	*	*	48	94	233	134	103	140
Head	36,436	,	,	*	*	209	882	3,179	3,003	3,769	25,212
Pure-bred dairy cattle											
LFUs	999	*	*	42	12	72	103	329	171	145	123
Head	39,173	*	*	123	60	1,131	2,198	10,269	5,833	4,778	14,780
Pure-bred dual purpose											
LFUs	472	*	*	*	*	14	42	137	79	80	112
Head	15,579	*	*	*	*	148	213	1,690	2,144	3,706	7,661
Production of cows' milk											
Head	808,856	52,232	45,558	39,396	54,720	80,210	87,353	151,665	119,962	87,581	90,179
Litres	3,525,027	224,469	191,574	160,288	227,188	327,755	345,282	644,654	531,871	432,847	439,098

Source: RRCNC, 2016

PIGS	SIZES OF LFU										
	TOTAL	**Less than 1 hectare**	**1 to 2 ha**	**2 to 3 ha**	**3 to 5 ha**	**5 to 10 ha**	**10 to 20 ha**	**20 to 50 ha**	**50 to 100 ha**	**100 to 200 ha**	**200 hectares and over**
Total											
LFUs	440,475	124,210	61,175	42,428	49,765	54,593	41,163	40,453	17,655	6,358	2,674
Head	1,527,114	289,951	149,021	111,806	167,044	180,289	178,697	227,163	106,717	46,885	69,540
Criollo											
LFUs	404,153	114,169	57,143	40,263	46,729	51,158	37,582	35,670	14,582	4,833	2,024
Head	1,193,052	246,887	130,950	100,387	124,185	159,222	134,875	147,656	71,000	28,980	48,909
Mixed breed											
LFUs	38,585	10,809	4,324	2,336	3,252	3,550	3,915	4,984	3,181	1,559	675
Head	297,695	38,462	16,604	10,660	35,542	18,443	39,622	73,714	28,526	16,730	19,392
Pura-bred											
LFUs	1,344	383	153	38	68	126	155	225	77	72	49
Head	36,368	4,602	1,467	759	7,316	2,623	4,201	5,792	7,192	1,176	1,239
Source: RRCNC, 2016											



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CONTINENTAL ECUADOR – MAP OF LOCATION OF MILK COLLECTION CENTRES ESTABLISHED BY THE SUBSECRETARIAT FOR LIVESTOCK