DOMESTIC BIOGAS DIFFUSION IN RWANDA – KEY LEARNINGS FOR SCALE UP

MARCH 2016

Feedback from VSF-B / IMBARAGA domestic biogas diffusion in Southern Rwanda
and key learnings to accelerate biogas diffusion at national level

Executive Summary

The NGO Vétérinaires Sans Frontières Belgium (VSF-B) supports local populations to improve livestock keeping and other related aspects such as natural resources management and micro-loans. In 2013, ENEA conducted a study to assess the opportunity for VSF-B to include domestic biogas energy within its scope of activities in Rwanda. In 2014, VSF-B launched the EVE project to install 100 biodigesters and provide capacity building to smallholder farmers in Southern Rwanda within 3 years. The project is strongly integrated to the local context, partnering with a local federation of farmers, IMBARAGA, to implement the project, and leveraging the Rwandan National Domestic Biogas Program (NDBP). In mid 2015, ENEA conducted a new study to provide VSF-B with an intermediate evaluation of the project, a preliminary assessment of its impacts as well as recommendations to scale-up.

VSF-B / IMBARAGA's activity on biogas within the EVE project is successful thanks to an efficient approach combining sensitisation and financial and technical support.

By September 2015, half of the target of the pilot phase had been reached – 50 biogas systems were installed or under construction – and the remaining half was likely to be reached by the end of the project. This is the result of an efficient approach for domestic biogas distribution set up by VSF-B / IMBARAGA. Intensive work of sensitisation of farmers combined with an adapted financial support scheme (additional subsidies and guarantee funds for credit) and with technical support and monitoring of farmers are the three pillars on which VSF-B / IMBARAGA's success is based.

End-users are highly satisfied of biogas systems and use, thanks to the robustness of the technology and the various outcomes delivered. Although the initial levers for biogas adoption by farmers were fuel savings and convenience to cook, other outcomes appears to be as meaningful to them once they start using the system: increased convenience to boil water or milk, increased hygiene of the kitchen, increased hygiene of toilets, reduced time to collect wood and use of bioslurry as fertiliser agent.

Impacts of the project on climate change and on livelihoods already materialise and most of them will be measurable at the end of the project.

Biogas is used to cook and boil water but former cooking fuels (i.e. wood and charcoal) are still used for time consuming meals such as beans for which biogas production is insufficient. However, savings on wood, and in limited cases on charcoal, are significant even though their measurement at the pilot survey stage includes uncertainties. Significant improvements on hygiene and sanitation thanks to biogas use were proven on a qualitative basis for smoke exposure in the kitchen and for toilets hygiene in particular.

The use of a baseline measurement is key to enable for proper impact assessment at the end of the project. Surveys should be conducted in the same period of the year and at the house of the farmer with the most knowledgeable person as respondent for each topic. While most of indicators tested by ENEA in the pilot survey for impact evaluation are suited and measurable, those involving the measurement of daily quantities should however be measured by biogas users directly during evaluation campaigns (cow dung fed into the digester, cooking fuels savings, daily use time of cooking and lighting devices).

Although domestic biogas is suited to a limited fraction of farmers in Rwanda, the potential to scale up the project is significant if subsidies from public authorities are maintained.

Adopting biogas requires holding at least 2 adult cows and subscribing to a credit which is suited to the wealthiest and most progressive part of farmers in a rural village. This automatically restricts the number of farmers who could adopt biogas. However, a target of 450 to 900 new end-users is estimated to be realistic for a scale up phase in the 3 districts currently covered and for a 5 years period (2017-2021), if subsidies from public authorities are maintained.

VSF-B / IMBARAGA have achieved a considerable work in the pilot phase by implementing biogas in villages where the technology was completely unknown. The power of sensitisation by current users of the technology in these villages should now be leveraged in a scale up phase.

Finding sufficient funding from investors to finance such a scale up and securing public subsidies remains the main challenges for VSF-B to leverage the success of the pilot phase and multiply its impact on farmers and climate change in Rwanda.

Content

1 Introduction

1.1 Domestic biogas presentation

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

- **Energy access:** energy access plays a key role in poverty alleviation (time gain, energy expenses reduction, health benefits, increased productivity...), but for instance it is estimated that in Africa 68% of the population live without access to clean cooking facilities and 70% do not have access to electricity[1] [2].
- **Resources depletion:** the wide use of firewood or charcoal for cooking contributes to local forests depletion, which in turn makes firewood collection and charcoal making harder in deforested areas, thus contributing to energy poverty of local populations.
- **Climate change mitigation:** agriculture (*i.e.* the production of crop and livestock products) accounts for 13.5% of global Green House Gases (GHG) emissions [3] and extensive systems are sometimes blamed for having a larger contribution to climate change per kg of product than intensive systems.

In this context, **domestic biogas production** can help rural communities benefit from a cleaner and more sustainable source of energy while reducing their need for traditional biomass and alleviating current pressures on the environment.

Biogas can be produced through the natural degradation of dung in the absence of air, through a process called anaerobic digestion or methanisation. This process occurs in a biodigester which mainly consists of an air tight vessel. Different types of biodigesters are characterised by their shapes, sizes and construction materials (see ENEA's publication [4] for more details on biodigesters). The flammable gas produced from this process is mainly composed of methane (CH_4); it burns cleanly and can be used as a fuel for cooking or lighting, in substitution to solid biomass or fossil fuels.

Besides biogas, the methanisation process produces bio-slurry, a solid effluent resulting from the digestion of organic materials. It mainly consists in a mix of digested matter and water, with a high concentration of mineral substances and nutrients such as nitrogen (N), phosphorous (P), potassium (K) and magnesium (Mg). As a consequence, bio-slurry has valuable fertilising properties and is particularly interesting in a predominantly agricultural context.

1.2 Context in Rwanda: the National Domestic Biogas Program

The National Domestic Biogas Program (NDBP) in Rwanda aims at promoting the diffusion of the biogas technology at domestic levels for farmers and in public infrastructures such as prisons and schools. The program is managed by the REG (Rwandan Energy Group) under the authority of the Ministry of Infrastructure (MININFRA). It has been created in 2007, initially partly financed by the Dutch government through GIZ until 2011, and currently fully financed by the Rwandan government. In 2007, biogas was a completely new technology in Rwanda. A significant effort of capacity building and skill transfer has been made since then, in particular with the support of SNV and feedback from the Tanzanian experience. In Rwanda, more than 500 masons were trained to biogas technology (i.e. construction techniques and maintenance services), out of which around 200 were particularly active and created a total of approximately 40 biogas companies officially authorized by the NDBP. [5]

The upfront costs of a biogas system are particularly high compared to rural household incomes and represent the main barrier for the adoption of the technology at household level. To help overcome this barrier, the NDBP provides a subsidy for each system installed, the farmer being expected to finance the rest of the upfront costs, with a possible credit to a bank or a SACCO (Saving and Credit Cooperative). A simplified diagram of the NDBP subsidy mechanism is given in Figure 1. The subsidy approval scheme has evolved since the inception of the NDBP. In the initial form of the NDBP, authorized biogas companies applied for subsidies to local authorities for final approval by the REG. The subsidy was transferred to the biogas company in three instalments, according to a schedule involving a quality control process by a local technician of the REG (1 to 2 REG technicians per district were entitled to conduct the quality controls). In mid-2015, the NDBP in its initial form was closing but was under transfer to the biogas unit of EDCL (Energy Development Corporation Ltd), a branch of the REG under the MININFRA. In this new version, the process for subsidy approval and quality control is decentralized from the REG (EDCL) to district authorities. Each district is now responsible for the relationship with biogas companies, subsidy approval and field visits to check the supervision and quality control for biogas systems construction. Despite this evolution of the program, subsidies should be maintained in the future years according to EDCL [6].

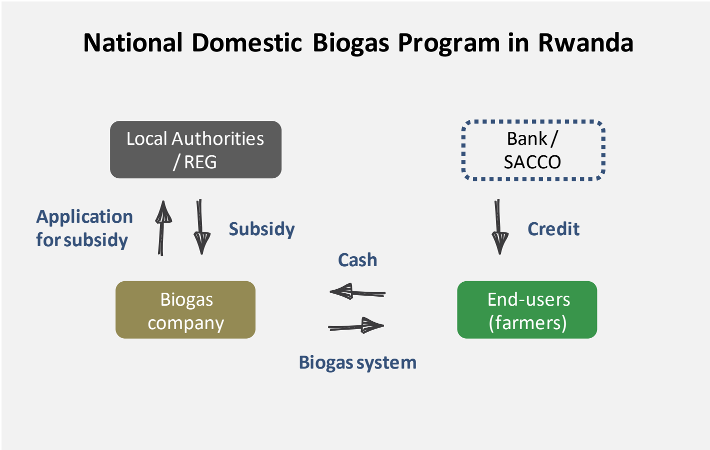

Figure 1 – Simplified process diagram of the NDBP

The NDBP provides a similar amount of subsidy regardless of the size or type of biodigester. In the example of a RW1[1] type of biodigester (Table 1), the subsidy can represent 37 to 54% of the total cost of the system depending on its size. In addition to subsidies for the construction of the biogas system, the NDBP provides, for each constructed biodigester, a lighting equipment for the household (i.e. a biogas lamp or a solar lamp).

Biodigester type and size (m^3)	Total cost of biogas system (RWF)	NDBP subsidy (RWF)	Share of NDBP subsidy on total cost (%)	Remaining upfront cost for end-user
RW1 4m^3	555,000	300,000	54%	225,000
RW1 6m^3	624,000	300,000	48%	324,000
RW1 8m^3	712,000	300,000	42%	412,000
RW1 10m^3	818,000	300,000	37%	518,000

Table 1 – Share of NDBP subsidy on the total cost of RW1 biogas systems

The NDBP aimed at launching the domestic biogas sector in Rwanda with the installation of 12,500 subsidised biogas systems between 2007 and 2017, and the goal of increasing the awareness of the population and the capacity and experience of biogas companies. Thanks to this program, the government initially also expected a more massive and unsubsidized development of the domestic biogas sector in Rwanda with a total target of 100,000 systems installed at the national level by 2017.

By mid-2015, 6,000 subsidised biogas systems had been installed under the NDBP and no particular development of unsubsidised activity had yet been observed in the country [6]. According to EDCL, the annual budget available to subsidise domestic biogas systems allows the installation of 3,500 systems per year, which is higher than the current rate of deployment [6]. The development of biogas systems is thus not jeopardised by a lack of subsidies and if the number of installed biogas systems exceeds 3,500 systems per year, the budget for subsidies could even be increased [6]. According to SNV's evaluation of the NDBP performed in 2013, the robustness of the technology (i.e. fixed dome biodigesters) and its positive outcomes (ex: fuel savings) are identified as strength of domestic biogas systems

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[1]RW1, RW2 and RW3 are different types of biodigesters, all of them being variants of fixed dome models built in Rwanda. The RW1 (Rwanda 1) is fully made of burnt bricks and cement while RW2 and RW3 also include concrete and stones. The RW1 model is the most used type of biodigesters in areas of activity of the EVE project. Plastic canvas (plastic tube biodigesters) are an alternative to fixed dome models but have not been the preferred option in Rwanda.

implemented at household level so far [7]. However, the high upfront cost of the system for a household was identified as the main cause for slow diffusion of the technology, despite subsidies provided by the NDBP [7].

Finally the NDBP enabled the launch the domestic biogas sector in Rwanda with the transfer of know-how on the technology, the creation of companies able to ensure the construction of biogas systems and a durable frame for subsidies to increase the affordability of the technology to end-users. Nevertheless, the diffusion of the technology is much slower than expected, possibly due to a remaining high upfront cost of biogas systems or other barriers. The project and impact evaluation performed by ENEA for VSF-B / IMBARAGA also addressed the question of barriers and levers for biogas diffusion at national level, with key findings and recommendations shared in this open source report.

1.3 Context of ENEA’s intervention

The NGO Vétérinaires Sans Frontière Belgium (VSF-B) supports local populations in developing countries to improve livestock keeping and many other related aspects. These include micro-loans and natural resources management but also training, emergency aid and peace negotiations.

In early 2013, ENEA conducted a pro-bono support mission for VSF-B, the scope of which was the identification and analysis of opportunities for the implementation of biogas systems in rural areas of Rwanda [4]. The main recommendations of this mission – include local partners from the formulation of the project onwards, include an activity on decentralized awareness-raising on biogas and work on a financing scheme with local microfinance institutions (SACCOs) so that farmers have access to loans – helped VSF-B and its local partner IMBARAGA, define and implement the biogas pillar of EVE (Energie Verte et Elevage) project. IMBARAGA, one of the main farmer federations in Rwanda, plays the role of operating agent for the EVE project and provides expertise of the Rwandan agricultural sector while capitalizing the knowledge and best practices acquired with VSF-B’s project.

The EVE project implementation spans the years 2014-2016, and its biogas pillar has the overall objectives of installing 100 biodigesters in 3 districts of Rwanda Southern Province: Huye, Nyanza and Nyamagabe. It also acts as a pilot phase for VSF-B / IMBARAGA to prepare a potential scale-up of their biogas activity.

Following the previous collaboration with ENEA on the project formulation in 2013, VSF-B applied to ENEA Access 2015 Call for Projects to get an intermediate evaluation of the biogas pillar of EVE project and its impacts, and was selected as a winner for pro-bono consulting support from ENEA. VSF-B / IMBARAGA fields of expertise focus on farming and animals breeding, and their knowledge of biogas has significantly improved since ENEA’s first mission. However, since this field of action is recent to VSF-B / IMABARAGA, the ability of ENEA to provide an external and independent point of view on the project – with a background expertise in energy and projects scale-ups and evaluations – was perceived as complementary to VSF-B / IMBARAGA knowledge and of potential high added-value to the project.

ENEA’s objectives in this consulting mission were to:

- Conduct an intermediate review and evaluation of the biogas pillar of EVE project (further referred to as “EVE biogas project”)
- Conduct a pilot survey and strengthen VSF-B/IMABARAGA impact-oriented and customer satisfaction evaluation methodology
- Elaborate user-friendly solutions to facilitate future evaluations
- Provide recommendations for the scale-up of EVE biogas project

1.4 Content and objectives of this document

This document is derived from ENEA’s mission conducted in 2015 for VSF-B on biogas activities. It aims at sharing feedback, learnings and good practices developed by VSF-B / IMBARAGA on biogas diffusion in the Rwandan context.

This document also provides ENEA’s vision and recommendations to public authorities, private founders and project developers on the role domestic biogas could play in the energy access and smallholding agriculture landscape and on the possible levers to accelerate its diffusion.

2 Biogas diffusion and adoption: feedback from the EVE project

2.1 Process for biogas systems implementation

2.1.1 Description of the EVE process for biogas systems implementation

The EVE process for biogas systems implementation is based on the NDBP frame and provides additional financial and technical support to end-users. The process is composed of two main phases: first the identification and selection of end-users (described in Figure 2 and Figure 3), second the construction and use of the biogas system (described in Figure 4 and Figure 6).

VSF-B / IMBARAGA play a critical role in both phases with a combined role of coordination of the several actors implied, identification and training of end-users and financial support to the construction of the biogas system. The financial support is provided with two complementary tools that both aim at facilitating financial access to the biogas system to end users. On one side, VSF-B / IMBARAGA provide cement and sand for the construction of the biogas system in order to reduce the final cost for the end-user (i.e. the amount of the credit to the SACCO). On the other side, VSF-B / IMBARAGA provide SACCOs with a guarantee fund in cash on behalf of end-users. Table 2 gives the breakdown of the financial contribution for the construction of a biogas system in the case of a RW1[2] biodigester. With such a financial arrangement, the amount of the credit represents monthly reimbursements of around 10,000 to 5,000 RWF (USD 14 to 7) depending on the duration of the payback period (1 or 2 years).

Source of funding	Type of funding	Amount (RWF)	Share on the total cost of the system
REG	NDBP subsidy	300,000	54%
VSF-B / IMBARAGA	Cement & sand	105,000	19%
End-user	Workforce and gravel	15,000	3%
End-user (through SACCO)	Credit	135,000	24%
Total	-	555,000	100%

Table 2 – Breakdown of the funding sources of a 4m^3 RW1 biogas system in the EVE project

Farmers groups: a pillar of VSF-B / IMBARAGA's approach

Farmers groups gather, at the level of an administrative cell[3], the members of a regional or national farming cooperative such as IMBARAGA. In the districts covered by the EVE project, about 60% of farmers are affiliated to such a cooperative. Farmers groups are an interesting instrument to identify farmers suited to adopt biogas because it provides an easy access to groups of educated farmers in a given administrative cell (being affiliated to a cooperative translates into a certain level of education and material conditions). Moreover, farmers groups are used to try innovative farming solutions and regularly meet to share information and best practices. Therefore, VSF-B / IMBARAGA first targets farmers groups in the process of sensitisation and selection of potential end-users.

[2] The 4 m^3 RW1 biodigester is the smallest and most used type of biodigester in EVE project so far.
[3] The Republic of Rwanda is divided into different levels of administrative units: Provinces, Districts, Sectors, Cells and Villages. A cell comprises several villages accounting for several hundreds to few thousands of inhabitants.

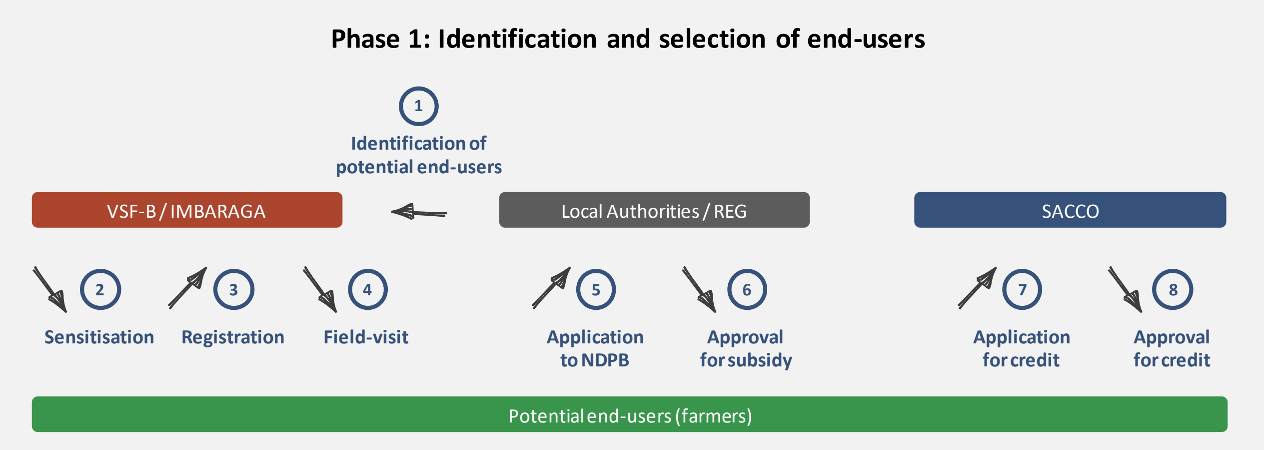


Figure 2 – Detailed process diagram of the EVE project phase of identification and selection of biogas end-users

1 Identification of potential end-users

Local authorities at sector level support VSF-B / IMBARAGA in identifying farmers groups and the number of farmers likely to hold at least 2 cows in the different administrative cells of the sector. VSF-B / IMBARAGA then selects the most promising areas (cells/villages) where to organise sensitisation sessions. Local authorities also facilitate the organisation of sensitisation sessions with cells representatives.

2 Sensitisation sessions

VSF / IMBARAGA organize sensitisation sessions with farmers groups identified in the target area or at village level in collaboration with the cell and village representatives. Several sensitisation sessions can be organized within an administrative cell (with several farmers groups and/or in several villages).

Sensitisation sessions with farmers groups generally involve 15 to 30 farmers most of whom have at least one adult cow. When organized at village level, these sessions can gather a larger audience than with farmers groups (typically 50 to 100 households in village sessions) but with a reduced number holding at least one adult cow. . Therefore, the farmers groups are preferred target for sensitization sessions.

These sessions aim at communicating on biogas systems, their operation mode and benefits. Conditions for eligibility and process steps to acquire a biogas system with the support of VSF-B / IMBARAGA are also described to farmers or households at this stage. The session is conducted by the biogas activity manager of VSF-B / IMBARAGA with the possible contribution of the local representative of IMBARAGA in the cell, the local REG agent for biogas activities and the biogas representative of local authorities at the sector level. The sensitisation session is mainly conducted through oral communication and posters.

3 Registration

At the end of a sensitisation session, potential end-users interested in the acquisition of a biogas system with the support of VSF-B / IMBARAGA register in a prospect list.

4 **Field-visit**

VSF-B / IMBARAGA conduct a field-visit to all potential end-users registered in the prospect list in order to check the eligibility and confirm the interest of the farmers for biogas. The visit is conducted by the biogas activity manager of VSF-B / IMBARAGA with the possible attendance of the local representative of IMBARAGA and the biogas representative of local authorities at the sector level.

To be eligible to the use of a biogas system several conditions are checked:

- The farmer must hold 2 adult cows to properly feed the biodigester,
- The dwelling must have access to sufficient water to properly feed the biodigester,
- The dwelling must be located in the official settlement zone of a village (*Imudugudu*),
- Sufficient land must be available close to the dwelling to install a biogas system.

Once the eligibility conditions are confirmed, the farmer and visitors discuss various aspects of the use of a biogas system and of the procedure to acquire one, including the need for a credit to a SACCO in particular.

5 **Application to NDBP**

If the farmer is eligible and interested in the acquisition of a biogas system, he/she fills in an application form for subsidies of the NDBP, with the technical support of VSF-B / IMBARAGA. The application form is then submitted by VSF-B / IMBARAGA for approval first to the cell office, then to the sector office.

6 **Approval for subsidy**

Once the form is approved at cell and sector level, it is transferred to the national office of the REG for final approval. The REG then selects a biogas company authorized under the NDBP to be in charge of the construction of the biogas system.

Given the current decentralisation of the NDPB program, it is likely that in the future the district office will be responsible for the final approval of the form and selection of the biogas company.

7 **Application for credit**

The farmer applies for a credit to the local SACCO according to a conventional procedure:

- The farmer must have or create an account in the SACCO and should not have an ongoing credit
- The account must have been active for 3 months and have at least 5,000 RWF of deposit before an application for credit can be made.
- The credit application requires to define a project and the need for financing (135,000 RWF in the case of a RW1 biodigester)
- In discussion with the SACCO, the farmer chooses the reimbursement modalities (monthly or quarterly reimbursements during 1 or 2 years).
- In a conventional procedure, the farmer must provide a guarantee with lands of a value equal to the credit, but with VSF-B / IMBARAGA providing half of the guarantee in cash, the farmer has to provide a guarantee with lands of a value of half of the credit (65,000 RWF in the case of a RW1 biodigester).
- A SACCO agent conducts a field-visit to the farmer in order to assess its wealth and reimbursement capacity.

Previous discussions between VSF-B / IMBARAGA and SACCOs improved the awareness of SACCO agents on the biogas technology and allowed them to properly assess the eligibility of potential end-users to such a credit. The application of a preferred rate of 14%, instead of the usual 24%, has been negotiated by VSF-B / IMBARAGA with the partnering SACCOs for all credits for biogas systems.

8 **Approval for credit**

The application for credit is analysed by the SACCO agent and is eventually approved in the SACCO committee for credit (generally held twice a month). A letter of approval is then sent to VSF-B / IMBARAGA that communicate the information to the farmer and ask for the farmer to confirm his/her interest in the acquisition of a biogas system.

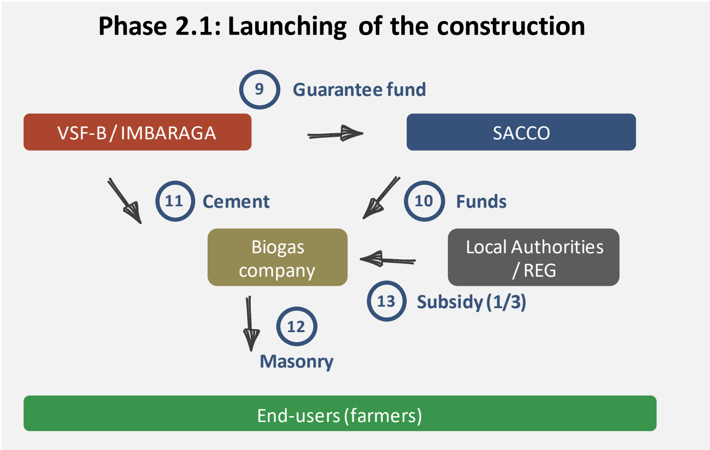


Figure 3 – Detailed process diagram of the EVE project phase of the launching of the construction of the biogas system

9 **Guarantee funds**

After the approval of NDBP subsidies and SACCO credit and final confirmation of potential end-users will to acquire a biogas system, VSF-B / IMBARAGA transfer the guarantee funds in cash to the SACCO (65,000 RWF in the case of a RW1 biodigester).

10 **Credit funds**

The biogas company conducts a field-visit to the construction site to design the system, in agreement with the end-user to start the building work. Once the building work officially started, the funds from the SACCO credit are directly transferred from the SACCO to the biogas company (135,000 RWF in the case of a RW1 biodigester).

11 **Cement**

VSF-B / IMBARAGA provides the biogas company with cement and sand for the masonry (equivalent value of 105,000 RWF for a RW1 biodigester).

12 **Masonry**

The end-user is responsible for digging the hole before the biogas company provides bricks and the masonry work.

13 **Subsidy (1/3)**

The local REG agent for biogas activities visits the construction site and controls the progress and quality of the work after completion of the masonry work. If the status is satisfactory, the REG agent transfers the 1st instalment of NDBP subsidies (150,000 RWF in the case of a RW1 biodigester).

Given the current decentralisation of the NDPB program, it is likely that in the future, the district office will be responsible for progress and quality control and payment of the subsidy.

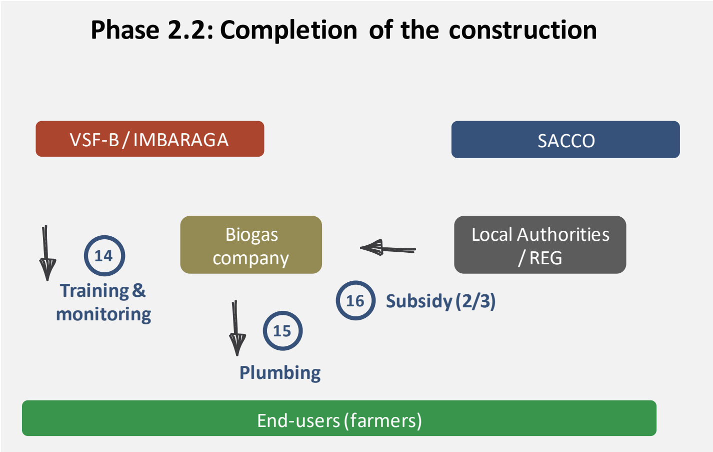


Figure 4 – Detailed process diagram of the EVE project phase of completion of the biogas system construction

14 Training & monitoring on biodigester feeding

The biodigester must be fed with cow dung and water several months before it starts producing gas. The second part of the biogas system (plumbing) is not provided by the biogas company until the biodigester starts producing biogas.

VSF-B / IMBARAGA train the end-user to properly feed the biodigester and monitor the quality and steadiness of the feeding phase.

15 Plumbing

When the biodigester reaches a steady regime of biogas production (bioslurry starts to be pushed out of the biodigester), the biogas company installs the plumbing (pipes and devices to connect the biodigester to the biogas stove and pressure measurement).

16 Subsidy (2/3)

The REG agent performs a second progress and quality control on the plumbing part of the construction before transferring the second instalment of the NDBP to the biogas company (130,000 RWF).

Given the current decentralisation of the NDPB program, it is likely that in the future, the district office will be responsible for progress and quality control and payment of the subsidy.

Figure 5 – Adult cows of a future biogas user (ENEA Consulting)

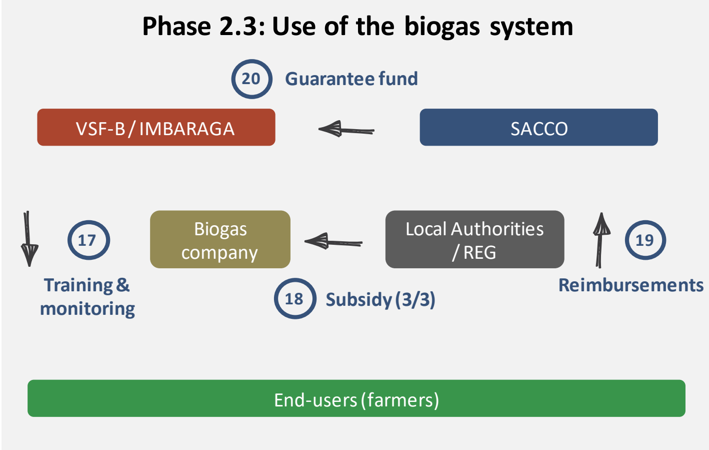


Figure 6 – Detailed process diagram of the EVE project phase of use of the biogas system

17 Training & monitoring

VSF-B / IMBARAGA train the end-user to the use of biogas and monitor the operation of the system. If any failure is observed in the biogas system, the end-user benefits from a guarantee of one year provided by the biogas company.

18 Subsidy

After one year of operation, the REG agent performs a third and last visit for quality control and transfers the remaining instalment of the NDBP subsidy (20,000 RWF).

19 Reimbursements

The end-user pays back the SACCO with periodic reimbursements according to the conditions of the credit agreement negotiated with the SACCO (monthly or quarterly reimbursements during 1 to 2 years). The reimbursement period starts from the credit funds transfer from the SACCO to the biogas company (step 10).

20 Guarantee fund

When the credit is fully reimbursed (after 1 or 2 years), the SACCO transfers back the guarantee fund to VSF-B / IMBARAGA, who can use it for another credit.

2.1.2 Evaluation of the process efficiency and identification of levers for improvement

VSF-B / IMBARAGA dedicate intense human resources into the identification and selection process, with sensitisation sessions and field-visits to potential end-users in particular. The analysis of the efficiency of the process allows for the identification of possible inefficiencies and levers for improvements.

Given the geographical approach of VSF-B / IMBARAGA (application of the process on a specific village or cell), the efficiency of the process can be analysed based on the conversion rate on potential end-users (i.e. the final number of end-users compared to the initial number of potential end-users targeted). By August 2015, a total of 512 potential end-users (farmers) had been attending sensitisation sessions on biogas by VSF-B / IMBARAGA since the beginning of the EVE project. However, only 51 farmers were in the construction phase or already using the biogas system while almost all of the other potential end-users had exited the process. This leads to a final conversion rate of the process of 10%. Considering all the possible barriers for farmers to be willing to adopt and finance a biogas system (see §0), this result can be considered as satisfactory even though it might be improved.

Losses in the conversion of potential end-users to effective end-users are found in the first phase of the process only (i.e. Identification and selection of end-users). Once the credit has been approved by the SACCO, the construction of the biogas system is systematically achieved. Figure 7 gives a detailed analysis of the evolution of the conversion rate between identification and credit approval. More than 80% of losses are found in only two steps: sensitisation sessions (66%) and application procedure for credit (17%).

Only one-third of farmers attending sensitisation sessions register to go further in the process with VSF-B / IMBARAGA. The most likely cause for such a defection rate is the number of adult cows owned by these farmers. Indeed, most of farmers in villages do not own two adult cows. Another likely cause is the persistent apprehension of farmers for biogas despite information given during the sensitisation session. Indeed, biogas is a completely new technology for farmers and some of them do not trust it before successful track records are observed in their village. Finally, farmers could also be reluctant to go further in the process due to their fear or lack of knowledge on credit (see §0).

Significant losses are also observed at the step of application for a credit to a SACCO: out of the 143 farmers approved for subsidies (step 6), 87 have exited the process (70 did not apply for credit and 17 quit even though their credit was approved by the SACCO). This represents a loss of 60% of the panel at this step of the process as no farmer was able to self finance the upfront cost of the biogas system. The lack of knowledge on credit and the reluctance to subscribe to a credit are the two main causes for such a high rate of losses.

Field-visits show a high rate of success which means that farmers registered at the end of the sensitisation session were aware of the eligibility conditions. No losses are observed on the process steps for subsidy application and approval by the REG, probably in part thanks to the efforts and support of VSF-B / IMBARAGA in following this process. A large share of farmers that eventually applied to a credit had their credit approved. Only 5 applications out of 73 have been rejected by SACCOs.

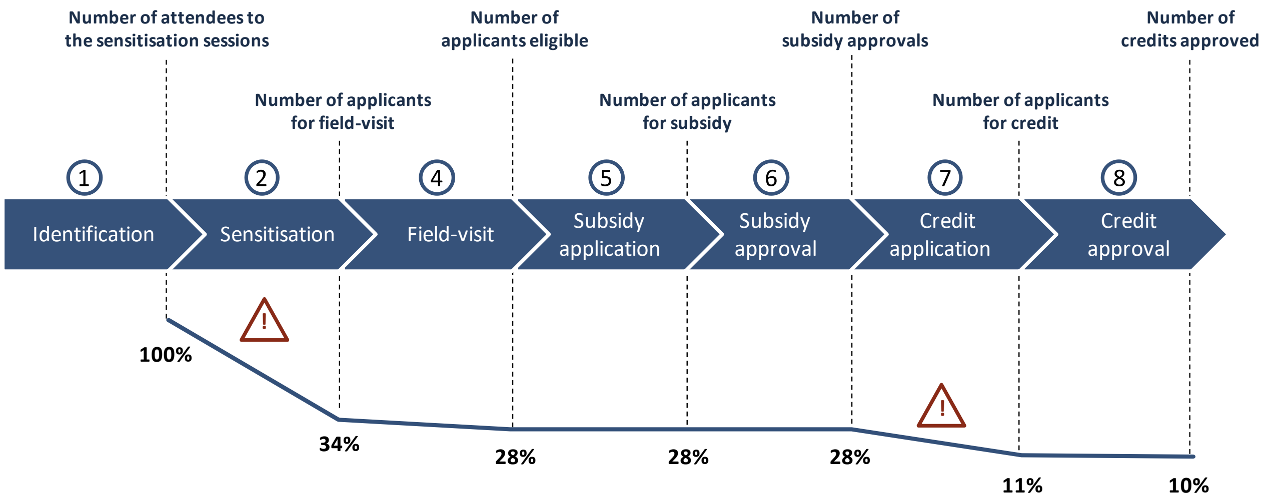


Figure 7 – Evolution of the conversion rate on potential end-users along the first phase of the process

A complementary indicator to assess the efficiency of the process is the calendar time required. Indeed, an excessively long process is generally a source of inefficiencies and is also likely to be unattractive for potential end-users (i.e. have a negative impact on the conversion rate). According to feedback on the first 50 biogas systems implemented by VSF-B / IMBARAGA the full process from step 1 to step 17 can take 5 months in the best cases and up to 12 months in the worst cases (excluding the period of credit reimbursement). Figure 7 displays the time required for the main segments of the process in the best and worst cases. Three main causes of delay are identified.

First, some SACCOs can be slow in the procedure of analysis and approval of the credit application (up to 2 months instead of 2 weeks in the best case). The most efficient option to reduce delays would be to partner with the most efficient SACCOs only but this is not possible given the lack of competition (currently there is only one SACCO establishment per sector). Therefore, levers for planning improvements at this stage are limited.

Second, biogas companies can create significant delays in the launching phase of the construction. In the worst cases, the masonry work is started up to 2 months after the funds transfer from the SACCO to the biogas company and the agreement with the farmer to start the work. According to VSF-B / IMBARAGA feedback, this delay occurred repeatedly with the same companies while other biogas companies systematically started the work quickly after the funds transfer. A preferred partnership with the most responsive biogas companies could thus improve the planning of the process, but has to be built with the authorities in charge of selecting the biogas company for each system.

Third, farmers can take a long time to properly feed the biodigester and to start producing gas, which is a condition for the biogas company to complete the construction. In some cases observed by VSF-B / IMBARAGA, this step of the process took more than 3 months while it should normally take less than 2 months. In addition to the delay produced, inappropriate[4] feeding of the biodigester creates dissatisfaction on farmer side and negative image of biogas at village level (i.e. the farmer can feel cheated when noticing that the digester does not produce gas). Although VSF-B / IMBARAGA already put significant efforts and time into training and monitoring farmers in the biodigester feeding phase, a particular attention should be devoted to this step in order to control the risk for delays and negative externalities (i.e. dissatisfaction and negative image).

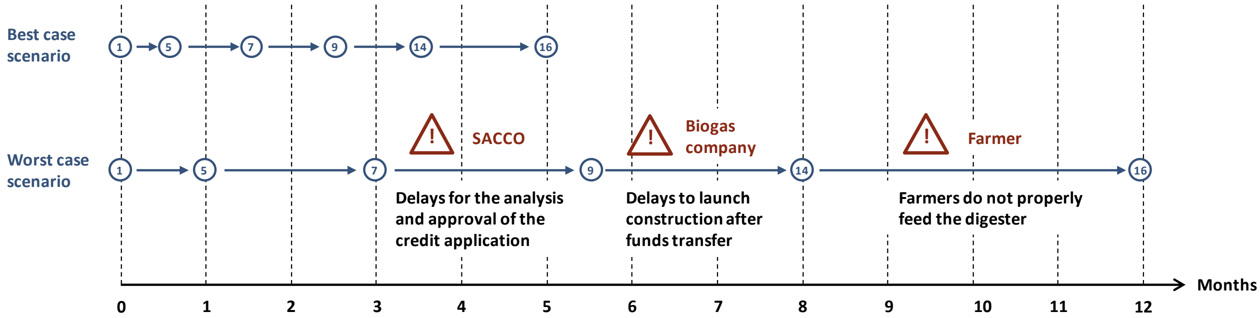


Figure 8 – Planning performance of the EVE process for domestic biogas implementation

Finally, the process designed and used by VSF-B / IMBARAGA is found to be efficient despite numerous actors and steps involved. The current conversion rate of 10% is satisfactory given the initial lack of knowledge of farmers on biogas technology and the need for farmers to hold 2 cows to be eligible. It could however be increased with improved communication and sensitisation on biogas and specifically on credits and SACCOs (see recommendations in §2.4). In best conditions, the process can take a reduced calendar time (i.e. 5 months) but some critical delays can significantly affect this performance (i.e. up to 12 months). The selection of the most efficient biogas companies and significant efforts dedicated to farmers training and monitoring to feed the biodigester can enable the reduction of this risk.

Figure 9 – SACCO of Karama sector, Huye district (ENEA Consulting)

[4] Inappropriate feeding of the biodigester can be caused by irregular feeding or wrong proportions in the dung and water mixture.

2.2 End-users satisfaction: challenges and opportunities

The end-users satisfaction was assessed based on a field survey conducted by ENEA on current end-users of the EVE project with questionnaires jointly administrated with the impact evaluation.

Figure 10 displays the level of satisfaction of end-users regarding their experience with biogas and with VSF-B / IMBARAGA along the project process. End-users declare to be very satisfied with their overall experience of biogas and VSF-B / IMBARAGA support and with the two trainings provided on biodigester feeding and biogas use in particular. According to feedback collected in focus groups (see §0), the main reasons for this high satisfaction rate are the ease of operation of the biogas system and its positive outcomes and close and reactive training and support provided by VSF-B / IMBARAGA to end-users. The seldom cases of dissatisfaction are due to technical problems not solved yet at the time of the survey.

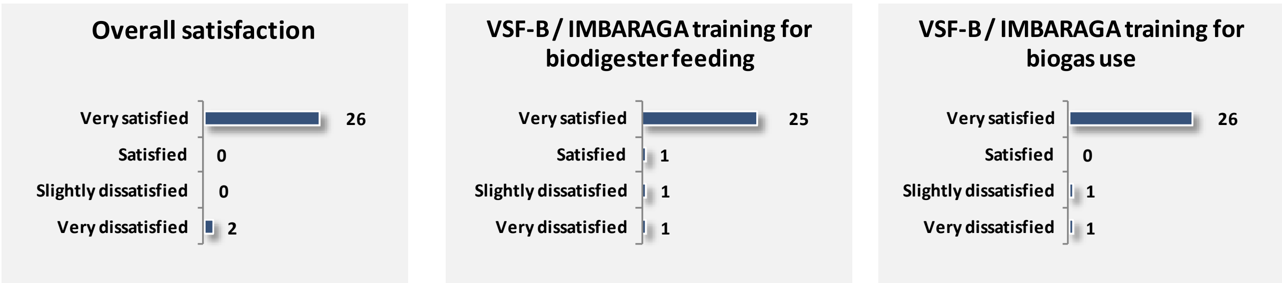


Figure 10 – Satisfaction of end-users regarding their experience with biogas and with VSF-B / IMBARAGA along the project process

Figure 11 gives information on the technical problems encountered by end-users with their biogas system. Among the 28 end-users interviewed, only 6 encountered a technical problem, all during the period of guarantee (i.e. first year after the construction of the system). Thus the biogas company which manufactured the system provided the necessary repairs without additional costs for end-users. The technical problems encountered were due to a manufacturing default on the biodigester (masonry), on the piping or fittings (plumbing) or on the feeding system (handle to mix the cow dung with water). Among the biogas companies involved in the EVE project so far, some of them are responsible for most of technical problems as well as delays in the construction phase.

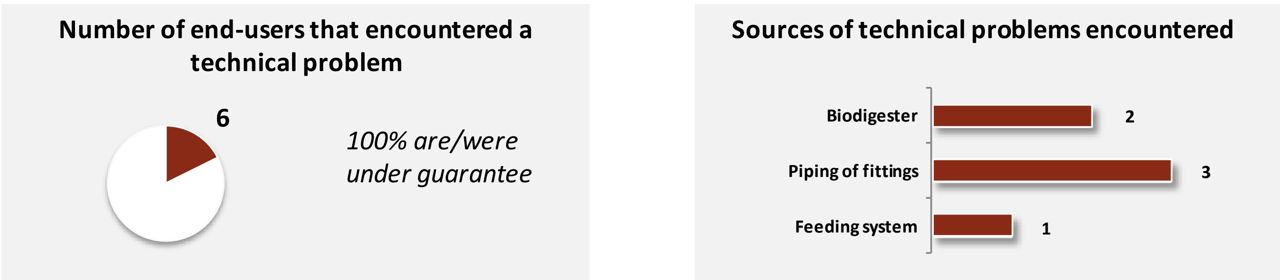


Figure 11 – Statistics on the technical problems encountered by end-users with their biogas system

Even though end-users satisfaction is already high, VSF-B / IMBARAGA could easily improve it by working with the most satisfactory biogas companies. Moreover, the high satisfaction of end-users is a strength that VSF-B / IMBARAGA could leverage to communicate and sensitise new potential end-users on biogas.

2.3 Adopting biogas: levers and barriers

Adoption of biogas by farmers relies on a series of levers to mobilise (attractiveness) and barriers to overcome (reluctance). An analysis of such levers and barriers is proposed, based on the field survey conducted by ENEA on current end-users[5], former potential end-users[6] who exited the process, sector representatives for biogas, SACCO managers and workshops and discussions with the staff of VSF-B / IMBARAGA.

According to end-users, their interest in biogas before they actually use it was mainly in the reduction of expenses for cooking or lighting fuels and the use of a more convenient cooking solution. However, various additional benefits can be expected from the use of biogas. Among them, the most often mentioned in the literature (and observed by VSF-B / IMBARAGA) are: the reduction of smoke exposure, the production and use of a fertilizer (bioslurry), the reduction of time to collect fuel, possible increase of hygiene with toilets (if toilets are connected to the biodigester) and the improvement of the social status of the end-user in the village thanks to the use of an innovative technology.

Figure 12 gives the average ranking of actual benefits of biogas use by end-users among a series of 8 options proposed in the survey[7]. A significant balance in the final ranking is observed between all proposals with the first 4 being at a similar level and no proposal being with an extremely low score. Biogas thus produces various benefits whose importance varies significantly from an end-user to another. Plus, the initial sources of interest for end-users are not systematically the most important benefit observed once they start using the biogas system. Therefore awareness of potential end-users should be raised on all of these benefits in order to maximise the chances to leverage their interest in biogas (during sensitisation sessions for instance).

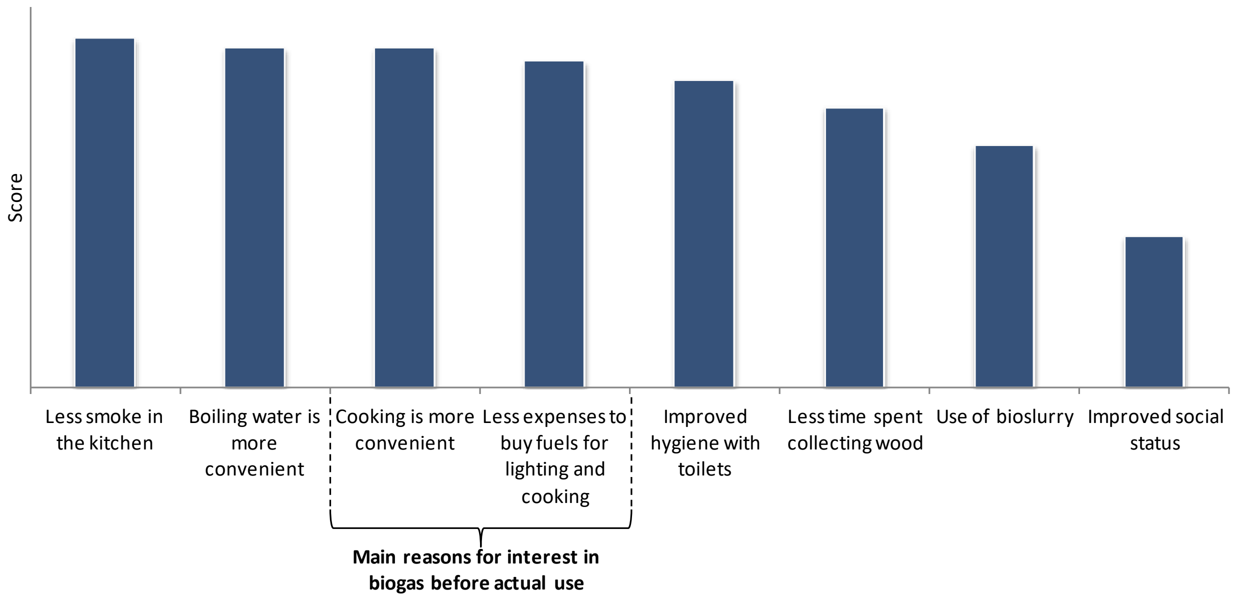


Figure 12 – Initial and actual benefits of biogas use ranked by end-users

Figure 13 represents the barriers to be overcome by a farmer to adopt biogas, according to the feedback from the EVE project stakeholders[8]. Each barrier is positioned along the process and classified according to three categories.

The first category (red area) contains barriers that are inherent to the situation of a farmer and that cannot be overcome within the frame of the EVE project. Technical eligibility to biogas and financial eligibility to credit for

[5] In addition to the individual questionnaires jointly administrated with the impact evaluation, ENEA conducted meetings with end-users in groups to gather collective feedback and discussions. Three discussion groups have been conducted with 32 end-users: Huye (8), Nyanza (9) and Nyamagabe (15).
[6] A sample of 15 former potential end-users has been interviewed individually.
[7] Each end-user interviewed with the individual questionnaire has been asked to rank the 8 proposals by decreasing order of relevance according to its actual experience with biogas. Each rank was given a score (from 8 points for rank 1 to 1 point for rank 8) and the final score of a proposal is the sum of the scores for each end-user.
[8] Potential end-users, actual end-users, SACCO managers, sector representatives, VSF-B / IMBARAGA staff.

farmers are the two inherent barriers for biogas adoption on which VSF-B / IMBARAGA cannot have an impact. The need for a famer to hold two cows is notably responsible for a drastic reduction of the number of potential end-users. Even though financial conditions of a farmer are inherent to his/her situation independently from the EVE project, VSF-B / IMBARAGA still contribute to overcome this barrier for a part of potential end-users thanks to additional subsidies (i.e. cement) to reduce the amount of the credit and thanks to the guarantee fund provided to SACCOs. This barrier can therefore be positioned astride the first and second category.

The second category (blue area) contains barriers that VSF-B / IMBARAGA contribute to overcome for a part of potential end-users: the lack of knowledge of farmers on biogas, SACCOs and credits and their reluctance to credit. The sensitisation sessions and the field visit to potential end-users are two critical steps in the process where VSF-B / IMBARAGA remove these barriers for a certain number of farmers, thanks to intensive communication and discussion. According to the feedbacks gathered from project stakeholders, a significant share of farmers living in villages where VSF-B / IMBARAGA operate would be technically eligible to biogas but are not yet willing to adopt it, due to one or several of these barriers. Therefore, there is a likely margin of improvement on the removal of these barriers thanks to increased sensitisation of potential farmers on biogas, SACCOs and credit.

The third category (green area) contains the remaining barriers faced by end-users and that VSF-B / IMBARAGA systematically contribute to overcome. It consists in a series of possible fears or doubts on biogas mentioned by current end-users such as the fear of handling a flammable gas, doubts on the real outcomes of using biogas, the uncertainty on the reimbursement capacity of the household. Some of these fears and rumours are linked to past experiences of earlier non-working biogas systems build in the villages under other programs. Thanks to the initial field visit and close support to potential end-users afterwards in the process, VSF-B / IMBARAGA greatly contributes to inhibit these fears. Nevertheless, adopting biogas in a rural village in Rwanda still remains an innovative act that requires a progressive protagonist.

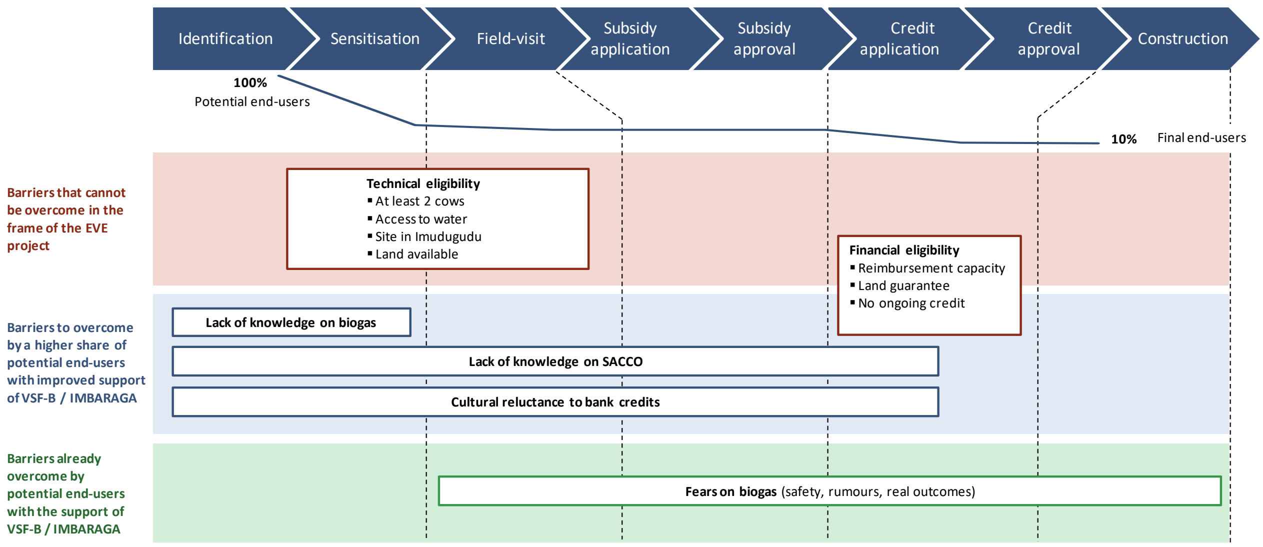


Figure 13 – Barriers to overcome by farmers for biogas adoption

2.4 Recommendations to accelerate biogas diffusion and scale up the project

In the 6 administrative sectors currently covered by the EVE project, it is estimated that rural villages account for a total of 1,500 to 3,000 potential biogas end-users (i.e. households holding at least 2 adult cows). This represents a large resource of future biogas end-users even covering only the current geographical area of the EVE project. At the national level, Rwanda accounts for close to 400 administrative sectors and tens of thousands of rural households currently eligible to domestic biogas. There is thus a large potential for the diffusion of the technology at local and national scale.

The analysis performed on the project process and on levers and barriers for biogas adoption shows that domestic biogas diffusion with VSF-B's approach is successful and replicable. Nevertheless, margins of improvements are identified and recommendations can be drawn up to improve the efficiency of this approach and accelerate the biogas diffusion in the perspective of scaling up activities and replication through other local organisations active in Rwanda.

It is recommended to keep the average process duration as short as possible, with a reachable target of 6 months from step 1 (identification of potential end-users) to step 17 (actual use of biogas). With reduced process duration, VSF-B / IMBARAGA will likely increase the efficiency of its human resources allocated to biogas activities and increase end-users satisfaction. A better control of the process duration is also a valuable strength for a possible future scale-up of activities. To do so, two simple recommendations should be implemented: **avoid working with unsatisfactory biogas companies and dedicate particular attention to the training and monitoring of farmers on the phase of biodigester feeding.** Feedback from the first half of the project shows that a limited number of biogas companies are responsible for most of the delays and manufacturing defaults. Working with the most efficient companies will reduce the occurrence of delays in the construction phase. In the specific context of the NDBP this would require setting up an agreement with district authorities which are in charge of selecting a biogas company for each system to install. The phase of initial feeding of the biodigester can be a source of significant delays in the process, even though VSF-B / IMBARAGA already provide intensive support to farmers at this step. In the first week following the training, it seems necessary that VSF-B / IMBARAGA pay specific attention to check that the farmer properly feed the digester. In order to avoid excessive allocation of resources in this phase in the following weeks, the monitoring of farmers during the feeding phase could then be transferred to reliable end-users already using biogas in the village.

The presence of biogas technology in a village is a very efficient tool for sensitisation of farmers. The implementation of the first biogas units in a village is in fact the hardest part of the sensitisation work. Once the technology is in the village, farmers are curious and biogas end-users can play an active and efficient role of sensitisation (i.e. trust in the technology is stronger when information comes from a satisfied user). **VSF-B / IMBARAGA have thus achieved a considerable work in the pilot phase by implementing biogas in villages where the technology was completely unknown. The power of sensitisation by current users of the technology in these villages should now be leveraged in a scale up phase**. **In these villages, it is thus recommended to set up a "biogas representative" who will ensure the identification and preliminary sensitisation of new potential end-users**. Moreover, the biogas representatives might also play a positive role for the sensitisation of farmers on credits and relationships with SACCOs.

It is recommended that a biogas representative is selected on a voluntary basis, in agreement with the panel of biogas users of the village. This mode will favour motivation and legitimacy of the selected farmers as biogas representatives. Key functions of a biogas representative would be to:

- Sensitise other farmers of the village on biogas with possible demonstrations of the biogas system operated by the biogas representative,
- Identify farmers interested in biogas and technically eligible in order to set up a field-visit with VSF-B / IMBARAGA,
- Identify if a new sensitisation session should be organised in the village.

With such a representative in villages, VSF-B / IMBARAGA will be able to increase the number of end-users in villages with reduced efforts of prospection and higher availability of the staff to conduct sensitisation sessions in new villages. According to the feedback of current end-users, each village currently accounts for a potential of 10 to 15 farmers technically eligible to adopt biogas. The diffusion effect of biogas thanks to biogas representatives could thus significantly increase the conversion rate of the approach in a mid-term perspective (i.e. several years after first biogas systems implementation in a given village).

Finally, the conversion rate could be increased with improved sensitisation sessions. The process and barriers analysis for biogas adoption shows that more farmers could be reached during sensitisation sessions. Sensitisation sessions could be improved thanks to several possible and complementary options:

- **General communication on biogas benefits should be more comprehensive and leverage the positive impacts observed on end-users of the pilot phase:**
  - All the benefits declared as meaningful by actual end-users should be mentioned with specific attention during sensitisation sessions (see §0)
  - Argumentation on biogas benefits should use examples and feedback[9] from the project feedback.
- **The positive and practical testimony of current end-users should be leveraged to sensitise farmers**. In this purpose, an end-user of another village (possibly the biogas representative) could participate to sensitisation sessions (see §0).
- **A short movie of typically 5 to 10 minutes, produced by VSF-B / IMBARAGA could be used during sensitisation sessions in order to provide a practical description of biogas and its benefits.** The movie should focus on biogas only, and not on the project or the process to adopt biogas. This movie could be used as an alternative or a complementary tool to the testimony of end-users during sensitisation sessions. In a lower extent, posters could be used to describe biogas systems, their benefits and the project process.
- **The sensitisation session should also focus on the description of SACCOs and credits and generate discussions with the audience on the possible fears and reluctance of farmers with credit.** This could be achieved with the support of a SACCO agent or with the support of an end-user already familiar with SACCOs and credit. Practical examples and feedback from end-users should be used to illustrate the eligibility conditions for credit and most of all, to explicit the eventual satisfaction of end-users on credit despite his/her initial reluctance.

[9] For instance, ENEA's survey shows that for a significant share of end-users, savings on fuels thanks to biogas equals or exceed the reimbursements of the SACCO credit. This feedback is a robust argument to sensitise farmers on their actual capacity to reimburse a credit subscribed for biogas.

3 Social and environmental impacts: feedback from the EVE project

3.1 Scope

ENEA conducted a pilot survey with VSF-B / IMBARAGA's team on biogas end-users of the project in order to prepare impact evaluation to be handled at the end of the project and to assess impacts that already materialized at mid-project. The pilot survey was designed to cover the 3 districts of Rwanda in which VSF-B / IMBARAGA operates: Huye, Nyamagabe and Nyanza. In each district, three types of end-users were interviewed (Table 3): current end-users owning a biodigester that already produces biogas, current end-users owning a biodigester in construction or feeding phase, and farmers that were identified as potential end-users by VSF-B / IMBARAGA.

Questions regarding the baseline (status before having biogas) were asked to all types of respondents, while questions on the status after having biogas were asked only to current end-users with biodigesters already producing biogas. It has to be noted that baseline questions for current users of biogas were not asked initially before the commissioning of their biodigester. Building a baseline *ex-post* requires to rely strongly on the memory of respondents, which provides high uncertainties on data. Also, while the pilot survey enables the production of a first set of indicators at the project mid-term, another survey at the end of the project (endline) would enable to better understand the impacts, and capitalize on lessons learned from the pilot survey.

The survey questionnaire included both impact-related questions and customer satisfaction oriented questions. Results related to customer satisfaction are presented in section 2.2. The impact evaluation results obtained from the pilot survey on 28 end-users and presented in §3.4 will have to be confirmed by VSF-B/IMABARAGA in future monitoring and evaluations.

	Total		Huye		Nyamagabe		Nyanza	
	to date	surveyed	to date	surveyed	to date	surveyed	to date	surveyed
With biogas (baseline + endline)	**39**	28*	**8**	8	**19**	10	**12**	10
Feeding/construction (baseline)	**9**	7	**2**	2	**7**	5	**0**	0
Potential (baseline)	**23**	15	**11**	5	**6**	5	**6**	5
Total	**71**	50	**21**	15	**32**	20	**18**	15

* 2 of which did not use gas at the time of the interview (dysfunction)

Table 3 – Number of EVE project end-users to date and pilot survey sample (August 2015).

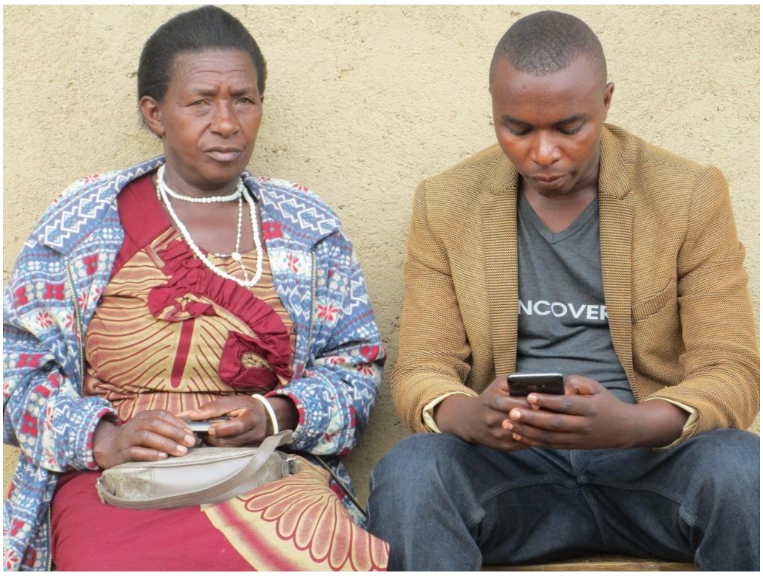


Figure 14 – IMBARAGA surveyor and EVE project end-user (ENEA Consulting)

3.2 Expected impacts: theory of change

Evaluating the impacts of an activity consists in evaluating changes that can be attributed to this activity. Changes can be evaluated at different levels: direct outputs of the project, direct changes on target population (outcomes or results) and longer-term changes on the target population (impacts).The first step in building an evaluation is thus to describe the "theory of change", i.e. the causal chain of the activity, from inputs to expected impacts, and identify items to evaluate at each step of the chain. Indeed, external factors might also lead to the same final changes, and causality is key to attribute the observed impacts to the activity. A theory of change of EVE biogas project is proposed in Figure 16: the project is expected to contribute to environmental sustainability, improvement of livelihoods and Rwanda's economy[10]. **The final impacts on environmental sustainability and livelihoods depend on three outcomes of the project: use of biogas for cooking, use of biogas for lighting[11] and use of bioslurry.** These outcomes must thus constitute the first level of impact evaluation: they are key to attribute the other levels of impact, and can also be more robustly monitored, proved, and attributed to the project than further level indicators. However, some further level indicators on decreased consumption of alternative fuels, improved sanitation, exposure to indoor air pollution, lighting time, freed time and savings on energy expenses were tested in the pilot survey. Impact indicators chosen for each category are described in §3.3.

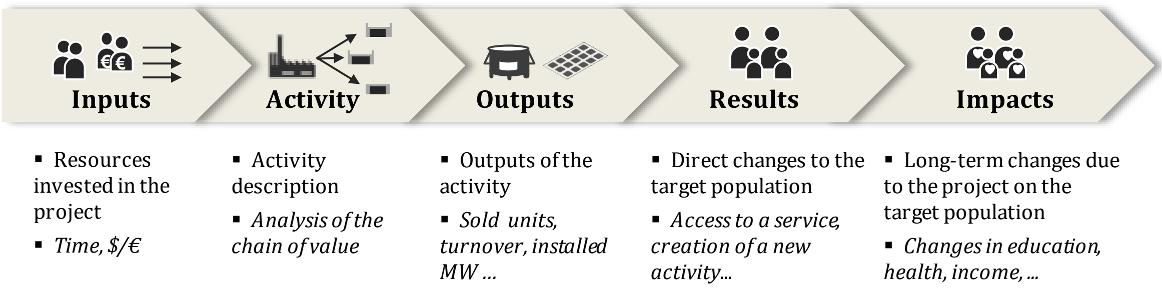


Figure 15 – Causal chain of an activity, from resources to impacts

[10] Contribution to Rwanda's economy is out of the scope of this study and pilot survey.
[11] In the frame of the NDBP, end-users were proposed to use biogas lamps and are now provided with solar lamps in addition to biogas systems.

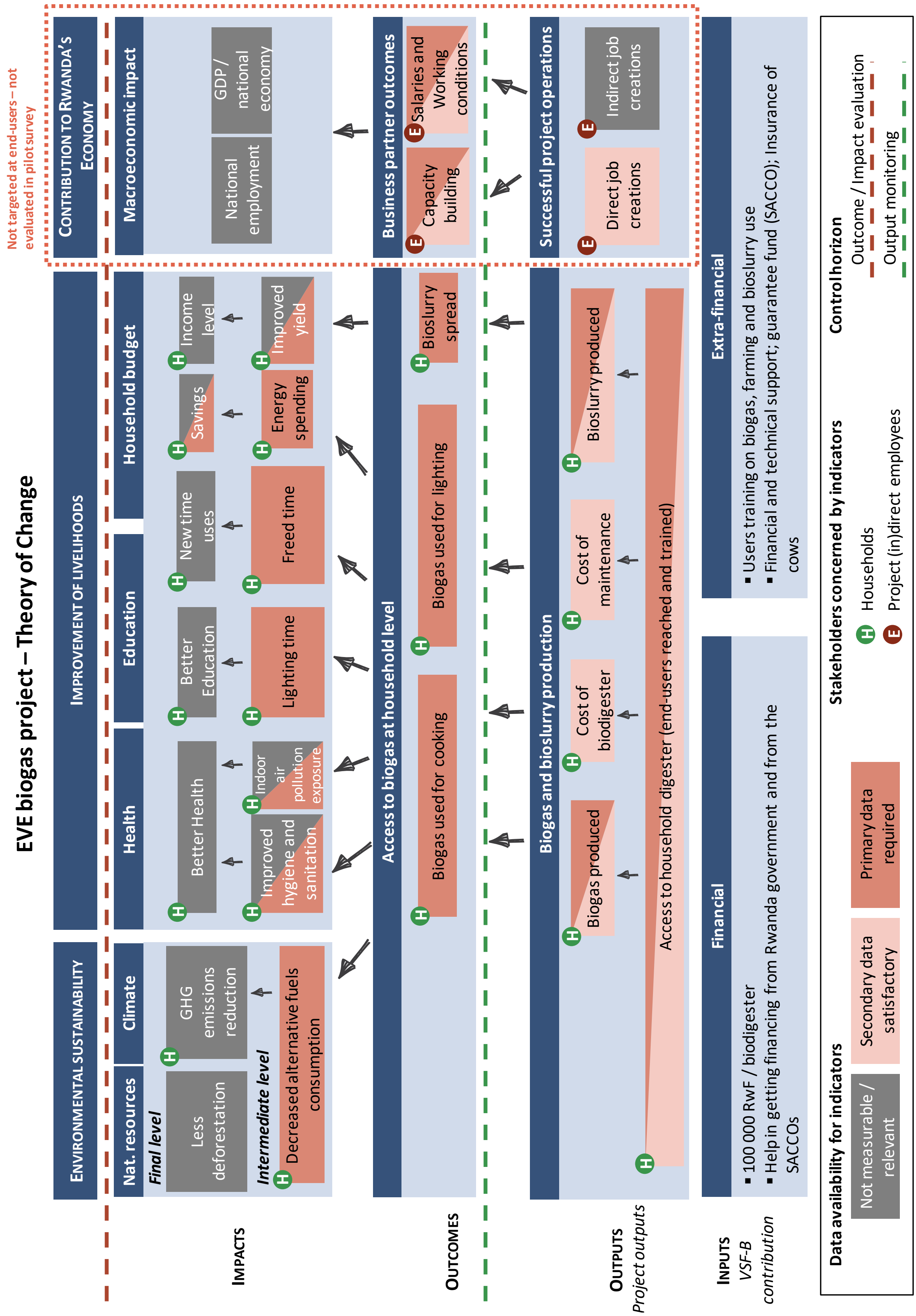


Figure 16 – Theory of change of EVE biogas project

3.3 Impact Indicators

The causal chain and indicators that would be relevant to evaluated for each impact category (Natural Resources, Climate Change, Health, Education and Household budget) are presented below. It has to be noted that some impacts are more difficult to evaluate and attribute, and that the choice of indicators, level of expectancy on precision and robustness of results of evaluation has to be calibrated with the resources and efforts that can be dedicated to the evaluation. In this pilot survey, the data for some indicators mentioned below have proved difficult to gather or unreliable to use. Results and recommendations for future evaluations are provided in §3.4 and §3.5.

3.3.1 Environmental sustainability

The use of biogas is expected to reduce the pressure on natural resources and contribution to climate change, through a reduced consumption of alternative fuels used in the baseline (mainly wood and charcoal).

Natural Resources: Reducing the consumption of baseline fuels (mainly wood and charcoal for cooking) contributes to reducing the stress on forest resources, and thus to less deforestation. However deforestation at a national level is linked to many more factors than the effects of one project, especially when of a small size, and measuring the impact of the project at the final level is thus not feasible. **In the pilot survey, the decrease in baseline fuels consumption was chosen as an intermediate-level indicator to approach the pressure on natural resources.** This decrease was approached in terms of expenses, for lack of reliable data on masses.

Climate Change: Reducing the consumption of baseline fuels also contribute to fighting Climate Change, especially in contexts were wood resources are non renewable[12]. However, proving a reduced consumption of baseline fuels is not sufficient for the overall net effect of a biogas project towards climate change to be positive. Indeed, the net contribution to climate change depends on the renewability of alternative fuels and on fugitive emissions of greenhouse gases in production processes. Methane having a GWP (Global Warming Potential) of 28[13] [8], and being the main component of biogas, the net GHG emissions of a biogas project can be greatly affected by fugitive emissions from biodigesters. Uncertainties on those fugitive emissions are very important: values reported in the literature are commonly of 1% to 1.8% at the biodigester level [9][10], and can vary from "non-detectable" for the best industrial-scale available technologies in good operating conditions [11] up to more than 10% in some dysfunctional cases [12]. The IPCC recommends, without further information, to consider a value of 5% [12]. For the evaluation of EVE project, the high level of uncertainties on the amount of biomass saved, on the amount of biogas produced and on biogas fugitive emissions at the biodigester level lead to the choice of not evaluating the final net impact on Climate Change. **In the pilot survey, the decrease in baseline fuels consumption was used as an intermediate-level indicator to approach the impact on climate change.**

[12] The fraction of non renewable biomass (fNRB) in Rwanda is 98% [17].
[13] This means that 1kg of methane emitted to the atmosphere contributes 28 times more to global warming than 1kg of CO_2 emitted to the atmosphere. The GWP_{100} of methane was updated to 28 by the IPCC in its last report (formerly 25).

Figure 17 – Collect of fuel wood for cooking in Nyamagabe district (ENEA Consulting)

3.3.2 Improvement of livelihoods

Switching from solid fuels to biogas can lead to improvements in the livelihoods of end-users, and produce direct or indirect impacts on Health, Education and Household budget.

Health: using biogas systems rather than solid fuels is linked to the improvement of end-users health through two causal chains: reduction of exposure to indoor air pollution[14] and improved hygiene and sanitation.

- Reduction of exposure to indoor air pollution is due to the switch from solid fuels, which emit high level of fine particle matter (PM2.5) while burning, to a clean fuel such as biogas which emits very low amounts of particle matter while burning (at least 1 to 2 orders of magnitude lower than the combustion of solid fuels [13]). Evaluating the final effects on the health of end-users requires heavy means (materials, method, time) and is not suitable to yield conclusive results at a small scale. Many factors could indeed explain changes in health conditions of end-users (better access to health centres, to clean water…) and would have to be controlled to ensure the attribution of results to the project. Moreover, relying on information from health centres would provide data of unknown quality, as some end-users may not consult the health centre, for instance as a result of chronic health conditions, distance from health centre or cost. **In the pilot survey, it was thus decided to use the reduction of time spent cooking as a proxy for the reduction of time spent in the kitchen (and of exposure to cooking smoke) and to ask the perception of users on the evolution of the amount of smoke in the kitchen since using the biodigester.** It has to be noted that exposure is linked to time spent exposed to PM2.5, but also to the concentration of PM2.5 in the kitchen air, which could not be approximated. While very low amounts of PM2.5 are emitted by biogas while burning, some PM2.5 are still emitted in the kitchen of end-users since they keep using partially wood or charcoal, although for a reduced daily time.
- Improved hygiene and sanitation are linked to the cleanliness of biogas use in the kitchen, to the ability to quickly boil water for sterilizing utensils and to the possibility of connecting toilets to the biodigester. **In the pilot survey, end-users were asked whether they had connected toilets to the biodigester and their perception on the overall improvement of hygiene and sanitation since using the biodigester.**

Education: EVE biogas project could also lead indirectly to improvements in education levels, through the distribution of a biogas or solar lamp with the biogas system[15]. However, factors leading to better education levels are multiple,

[14] The WHO estimated in 2012 about 4.2 million premature deaths worldwide due to the lack of access to clean or modern energy services for cooking [18].

and the impact of EVE project at the final level was not estimated to be measurable. **In the pilot survey, it was thus decided to approach education impacts by asking the perception of users on the difference made by the lamp provided by EVE project on the time spent studying at home after sunset.**

Household budget: the impacts of EVE biogas project on the household budget are derived from several aspects: reduction of energy spending for cooking, lighting or fertilizers, and improvement of yields thanks to the use of bioslurry[16] – thus potentially enabling or increasing the ability to sell part of the harvest to generate income. **In the pilot evaluation, measures of the evolution of budgets for cooking, lighting and fertilizers were attempted.** The evaluability of budgets for cooking was better than budgets for lighting or fertilizers, although with high uncertainties (see §3.4). The lower evaluability of budgets for lighting was due to the occurrence of more external factors and influences since the baseline (wider variety of lighting sources, purchase of other solar lamps, connection to the grid, increase of lighting points in the household…). Savings on fertilizers were not evaluable because of seasonal variations in fertilizer uses and in farming activities (type of crops and surface of lands cultivated).

Indirect impacts on livelihoods can also be due to time saved thanks to the switch from solid fuels to biogas. In the pilot survey, the importance of time saved was evaluated qualitatively through the ranking by users of the main benefits of biogas, and from the reduction of time spent cooking.

Figure 18 – EVE project end-user biogas stoves in Huye district (ENEA Consulting)

[15] This lamp is provided through the Rwandan National Domestic Biogas Program (NDBP), which also specifies the model of lamp to be distributed.

[16] Anaerobic digestion indeed converts nutrients into forms that are more readily available for uptake by plants [19], and can lead to increased yields.

3.4 Results of the pilot survey

3.4.1 Profile of end-users

The surface of land and number of cows owned shows that the end-users of EVE biogas project can be considered as relatively wealthy in their community.

Although the project initially targeted small farmers, 70% of potential and current end-users own 1 hectare or more (22 out of the 28 end-users currently producing biogas). Although 13 end-users own less than 1 hectare, it appears that very few potential new end-users are in this range. Several factors can explain this: smaller farmers may not own the required 2 cows to feed the biodigester – and are thus not eligible for the project or the NDBP, and they may also face a higher adoption barrier regarding microcredit (see 0).

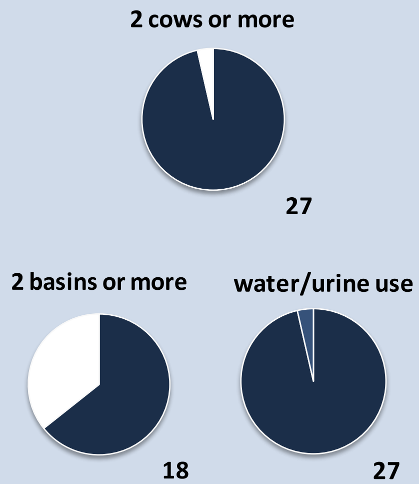
Numbers provided out of the
28 end-users currently producing biogas

Regarding cattle, a larger proportion of end-users own more cows in the 'after situation' than at the time they bought the biogas system. This can be explained by births and/or new acquisitions of cows, and depicts the fact that end-users of biogas systems are among the wealthiest in their community.

3.4.2 Biodigester feeding

To work properly, a 4 m^3 biodigester requires to be daily fed with 2 basins (40 kg) of cow dung and 2 jerricans (40 L) of water or urine (feeding urine provides a larger quantity of gas). Most farmers feed the biodigester with water rather than urine, the latter being harder to collect, and urine collection systems being costly to install.

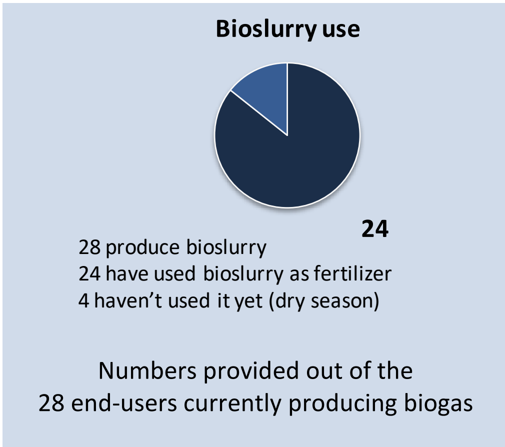
Regarding cow dung, the amount of cow dung needed requires a minimum of 2 adult cows. Although almost all of the 28 end-users currently producing biogas also declare owning 2 cows or more, about one third of biodigesters are fed with less than the required minimum of 2 basins a day. This apparent discrepancy between livestock owned and biodigester feeding can be due to farmers not having enough cow dung, either because less dung is produced in the dry season or because adult cows and others were counted indifferently farmers, while young cows produce less dung. Being clearer in differentiating adult cows and young cows in future surveys would enable a better understanding of the biodigester feeding dynamics. It would also be interesting to conduct a similar evaluation during the rainy season to understand if the cow dung production issue is solved during this season.



Numbers provided out of the
28 end-users currently producing biogas

Figure 19 – Biodigester inlet, jerrican and basin – or 'cut jerrican' (ENEA consulting)

3.4.3 Bioslurry uses



The 24 end-users currently producing biogas and that already produced bioslurry during the last cultural season declare using bioslurry as a fertilizer. The 4 end-users that started producing biogas and bioslurry only during the ongoing dry season plan to use bioslurry as a fertilizer during the next cultural season.

Information gathered on the fertilizers used before and after the biodigester commissioning show that in both cases end-users use a combination of different fertilizers (Figure 20). While all end-users that produced bioslurry during the last cultural season use it as a fertilizer, mostly instead of cow dung[17], they also keep using other fertilizers in complement. In the 'after' situation, some households use the cow dung produced in excess directly, the number of households using other animal dung (pigs, goats, sheep…) increased, and chemical fertilizers are still used – although by fewer households. The use of different types of fertilizers can be due to several factors, which were not studied in this pilot survey: fertilizers have different agronomic values (N,P,K), can be complementary and have to be adapted to the needs of the plant; the agronomic value of bioslurry can vary depending on handling practices[18]; the amount of bioslurry produced might not be sufficient to fertilize all the cultures owned; the number of animals owned may have changed; the households budget might not have allowed to buy more chemical fertilizers.

One end-user mentioned that she noticed a better yield since using bioslurry instead of cow dung. This end-user also sells part of the bioslurry production to neighbour farmers (5000 RWF for an estimated amount of bioslurry of 250 L per week, i.e. at a price of about 20 RWF per L).

[17] Cow dung is used to feed the biodigester in the 'after' situation.

[18] While nutrients in bioslurry (especially nitrogen) are more readily available than in cow dung, some nutrient losses can occur during storage (up to 50% losses of NH4 in one month, that can be reduces 10 times by coverage), handling and application through volatilization and leaching (especially in the case of storage with no bottom liner) [19].

The end-users interviewed use bioslurry on most of the culture types cultivated (see Figure 21). Results show that beans & peas, vegetables, bananas, potatoes and wheat are cultures on which bioslurry is spread preferentially for half of them or more. None of the end-users interviewed spread bioslurry on rice, tea or coffee, but this information has to be interpreted with caution because of the very low number of end-users interviewed cultivating those crops.

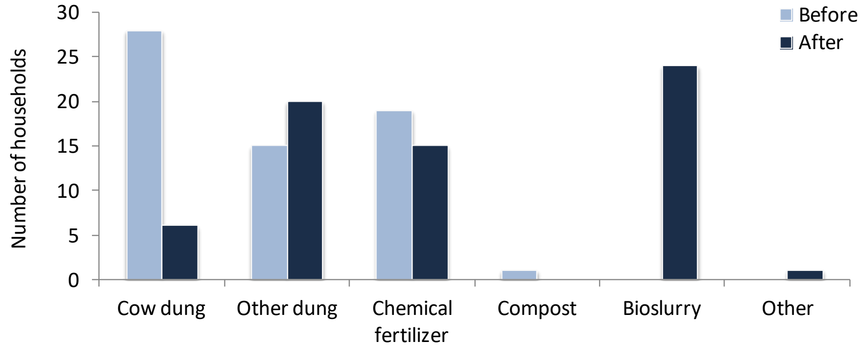


Figure 20 - Fertilizer used by end-users before and after the biodigester commissioning

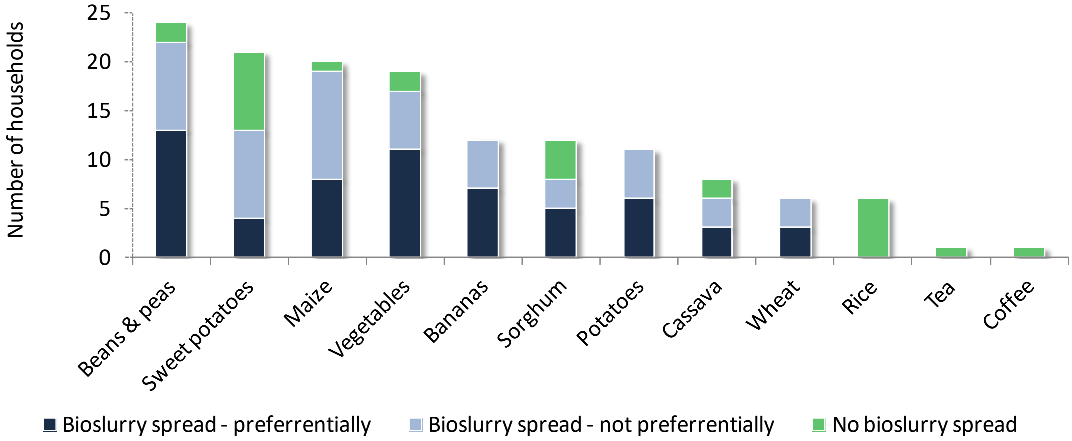


Figure 21 - Practices regarding preferential spread of bioslurry on different culture types

Savings on fertilizers

The method used in the pilot survey was not appropriate to enable the evaluation of savings on fertilizers, mainly because external factors such as seasonal variations in fertilizer uses. No consistent pattern could be found in the data.

In order to get an insight on the value for the end-user of producing and using bioslurry rather than cow dung, a possibility would be to evaluate the difference between the financial valorisation of cow dung fed to the biodigester (amount fed in kg x value in RWF/kg) and the financial valorisation of bioslurry produced (amount produced[19] x value in RWF/kg). While this method would not provide results on savings on fertilizers, it could be used as an argument to convince potential new end-users of the value of bioslurry.

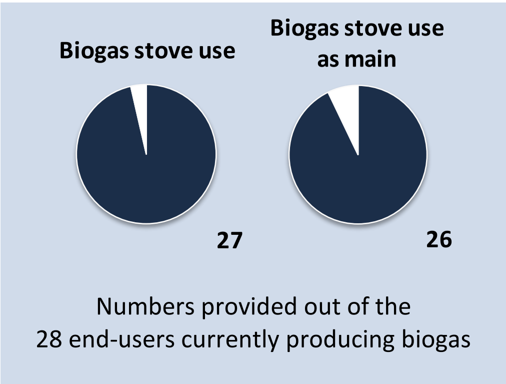
[19] The mass of bioslurry produced is estimated to be about 90% of the entrant mass [20].

Figure 22 – Bioslurry pit at a end-user's farm in Huye district (ENEA Consulting)

3.4.4 Cooking uses

Stove use and cooking habits

Almost all of the end-users currently producing biogas use their biogas stove, and most of them as their main stove[20]. It has to be noted that wood and charcoal are also still used by end-users, although some households have stopped using one or the other (see Figure 23).



The fuel types used after are linked to the suitability of fuels to fit the cooking habits. For instance, beans and maize are a daily meal in Rwanda, and they have to simmer for hours to be fully cooked; the biogas production of a $4m^3$ biodigester is not sufficient to cover this cooking need, and end-users thus never cook them on biogas stove (see Figure 24) but keep using wood or charcoal stoves instead. Thus in the 'after' situation, complementary uses of the different stove types lead to using biogas and wood or charcoal stoves on a daily basis.

Figure 23 shows that the biogas stove is used by almost all the end-users interviewed to cook daily meals other than beans: solid vegetables (tubers) and cereals, vegetables and sauces, and other liquids such as milk and gruel. More than 2/3 of end-users also use it to boil water, either to make it suitable for drinking or to boil it for sanitary purposes (sterilizing utensils or washing utensils or people). About half of them also use the biogas stove to cook other types of solid meals (including meat or fish).

[20] 2 end-users did not use the stove at the time of the survey, due to temporary dysfunctions in the biogas system.

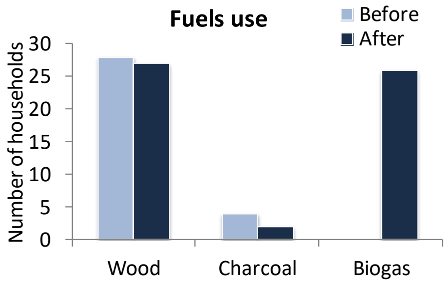


Figure 23 - Fuels used for cooking by end-users before and after the biodigester commissioning

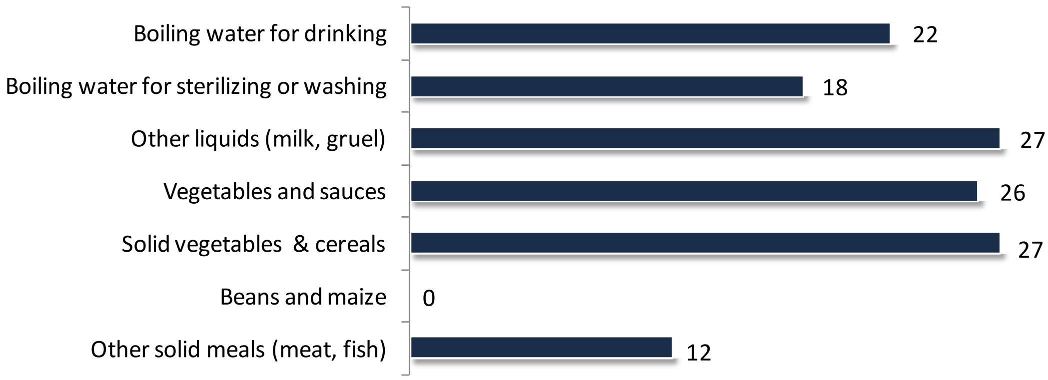


Figure 24 – Types of dishes cooked with biogas by current end-users

Budget and savings on cooking fuel

All of the interviewed end-users use wood as a baseline fuel, and only 4 out of 28 also used charcoal in addition to wood in the 'before' situation. The use of biogas lead to a partial switch, all of the end-users still using wood or charcoal in the 'after' situation, and 2 of them having abandoned charcoal as a complementary fuel.

In terms of budget spent on cooking fuels, the quality of data gathered during the pilot survey was not fully satisfactory, probably due to memory-effects and respondent not always being the one in charge of buying fuels. Results show large variations between end-users[21], with expenses 'before' ranging from about 700 RWF/week to more than 17 500 RWF/week, and expenses after ranging from 200 RWF/week to 3 800 RWF/week.

Savings on cooking fuels (RwF/week)

Mean: 2,968
Min: 0
Max: 16,500
Median: 1,500

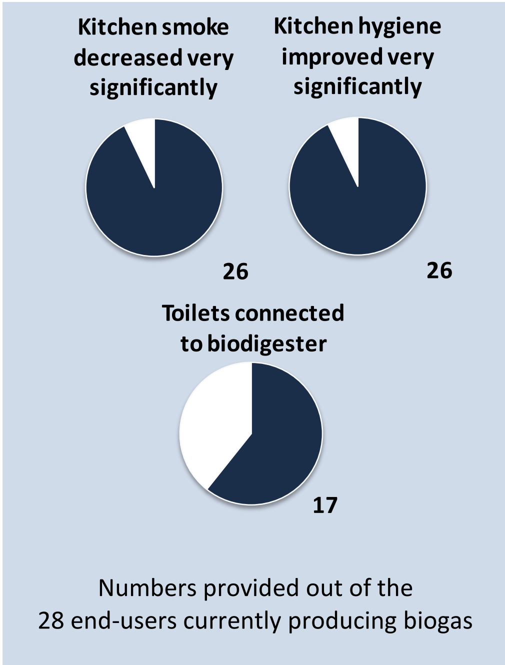
Numbers provided out of the 28 end-users currently producing biogas

Overall, it can be said with a relatively high level of certainty that about 2/3 of households save more than 1 000 RWF/week from their cooking fuel budget, and that part or all of the monthly credit (5 000 to 10 000 RWF) can thus be covered thanks to cooking fuels savings.

[21] These variations can be due to memory effects in answers from the ends users, to variations in family sizes, and to cooking habits.

Changes linked to health and sanitation

The use of a biodigester leads to changes linked to health and sanitation in several ways: reduction of exposure to indoor air pollution, improved hygiene in the kitchen and improved sanitation.



The pilot survey shows that about 2/3 of end-users have connected their toilets to the biodigester, which results in both additional feeding to the biodigester[22] (although marginal compared to cow dung), improved toilet sanitation, and removes the need for digging new holes and building regularly new toilets[23].

Other changes linked to health are due to the cleanliness of burning gas compared to burning solid fuels, and to the possibility to boil water more quickly and use it for drinking or for washing and sterilizing utensils. All of the 26 end-users that currently use the biogas stove as their main stove declare that smoke in the kitchen decreased very significantly and that hygiene in the kitchen also improved very significantly. End-users also all mention improvements either in eyes and respiratory comfort or disorders (see Figure 25).

Time of exposure to smoke was evaluated through the proxy of time spent in the kitchen; end-users interviewed declared spending on average 4 hours in the kitchen before using biogas and about 1h50 on average since using biogas (i.e. a reduction by more than 50 % of time spent in the kitchen). They also declare using the biogas stove on average for 2h50 per day, which shows that they are not in the kitchen the whole time the biogas stove is on but rather go in and out. It has to be noted that wide variations were observed between respondents in terms of time spent cooking, resulting in a standard deviation of about half the calculated average – the average values provided thus have to be considered with caution and will have to be confirmed by future surveys. This can be explained by several factors, including the fact that end-users do not have a habit and/or the tools to measure time precisely, resulting in the evaluation of time spent cooking being a very rough estimate of the reality. In addition to this, memory effects can lead to biases in time evaluation by the respondent, and other biases are due to the respondent not being systematically the person cooking at home. It is therefore possible to improve the method and conduct a more robust evaluation of time gained, first by conducting the interview at home and asking the most knowledgeable person and, depending on resources and evaluation method chosen, by asking end-users to record for a few weeks the time spent cooking both in the 'before' (for instance during the period of biodigester building) and 'after' situations (in the first months following the installation of the biodigester).

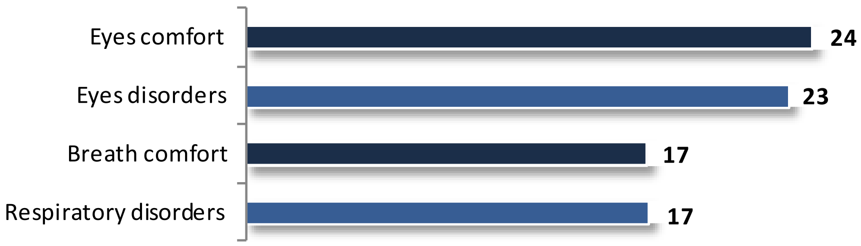


Figure 25 – Health improvements mentioned by current end-users

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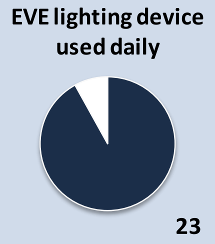
[22] The biodigester can also be fed with chamber pots (or "Marie-Chantal') in use in the rural districts of Rwanda.
[23] Toilets in rural Rwanda consist mostly of holes dug on purpose, with new holes being dug when the previous ones are full.

3.4.5 Lighting uses

Lighting devices used

Devices distributed by EVE biogas project under the NDBP vary between households (see Figure 26), depending on house characteristics and on the date they became end-users of the EVE project.

At the beginning of EVE project, the devices distributed were biogas lamps, while more recent end-users received a solar lamp. 2 end-users had received another device (additional biogas stove) because their house was already connected to the grid and they preferred receiving an additional stove than a lamp. 1 end-user had not yet received his device, the attribution of which was underway.



Numbers provided out of the 25 end-users having received a lighting device

Both lamp models distributed by EVE project are those specified by the NDBP. However, several end-users complained that the quality of the solar lamp was not good (low quality, dysfunctions and not enough powerful). However, the EVE project raised awareness of end-users on the benefits of solar lamps, and some of them also had bought other lighting devices (torches, solar lamps) since owning the biodigester. While the lighting devices distributed by EVE project were still used on a daily basis, in terms of access to lighting the impacts of this particular lighting device are not possible to isolate from the others sources of lighting.

Despite the critics made to the lighting device distributed under the NDBP, the number of households using wood, candles, kerosene or torches as lighting devices decreased between the 'before' and 'after' situation, and a switch can be observed to biogas lamps and solar lamps (distributed by EVE project or bought by end-users) (see Figure 27). End-users connected to the grid and that received a lighting device also use it as a complement to grid lighting, probably because there are no operational expenses linked to the use (while grid electricity cost is 198 RWF/kWh).

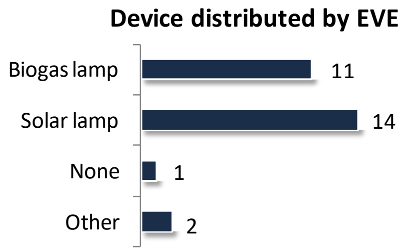


Figure 26 – Devices distributed by EVE project, under the NBDP program

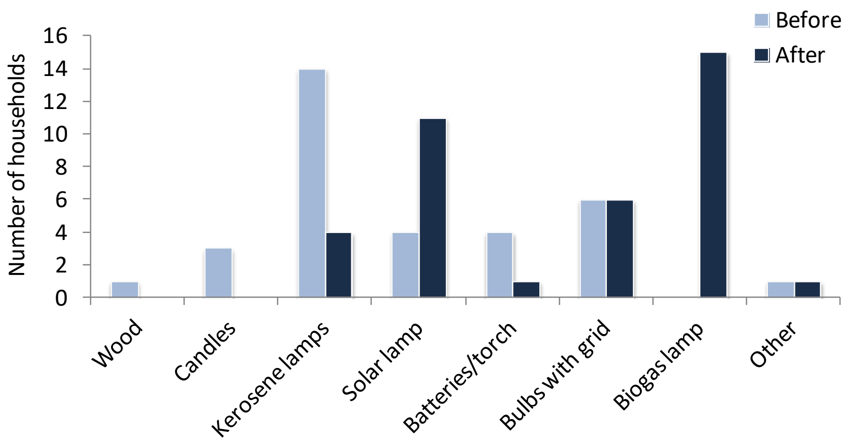
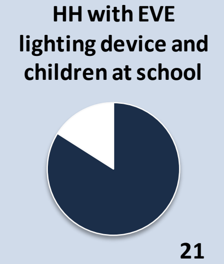


Figure 27 – Lighting devices used before and after the biodigester commissioning

Causal link between lighting and education

Although the causal link between the lighting device distributed by EVE project and the different uses of lighting at the household level is weak, questions were asked to identify whether the device was used for education purposes at home.

21 of the households having received a lighting device also have children at school. For about 2/3 of them, the end-users declare that the lighting device made a difference in the time spent studying at night: for 10 of them it is the only lighting system available at night, and for 3 of them other systems are also available (see Figure 28). The other respondents were not sure about changes made in time studying at nigh thanks to the device.



Numbers provided out of the 25 end-users having received a lighting device

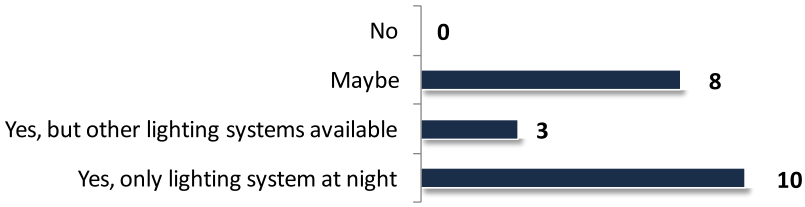


Figure 28 – Difference in time spent studying at night by EVE lighting device

Savings on lighting fuels

The large variations in lighting devices owned, some new buys made by end-users, and the variety of lighting uses did not enable to calculate savings on lighting fuels. Indeed switch to the EVE lighting device is partial or complementary to existing lighting devices, and new devices were bought in some cases. Since lighting is not the primary goal of EVE project, the impacts on savings for lighting fuels are expected to be limited. Moreover, the household budget for lighting is much lower than the household budget for cooking. The important efforts that would be required to quantify the impacts of lighting are thus not commensurate with the possibility to attribute a share of the impacts to the project, and we do not recommend to further try to quantify those impacts.

3.5 Recommendations for impact evaluation of domestic biogas

Conducting the pilot survey at a small scale, in a very short period of time and the same day as focus groups enabled to test the evaluability of some indicators, but also contained some intrinsic limitations linked to the logistics of the survey (and more specifically to the fact that the interviews of end-users were conducted out of their houses) and to the fact that both 'before' and 'after' data were collected at the same time with important memory biases regarding the 'before' situation.

Some recommendations to improve surveys are provided hereafter, both in terms of survey methodology and in terms of survey planning.

3.5.1 Survey methodology

First, to ensure a high quality of results, it is important to conduct surveys at the end-users' house rather than having end-users all come to a same place. Although more time-consuming for the surveyors, this is key to the quality of data collected. When conducting the survey at end-users house, surveyors will be enabled to and should:

- Choose the most knowledgeable person as respondent for each topic (might vary depending on topic, e.g. wife for cooking related questions and husband for farming related questions);
- Observe/control data whenever possible, rather than relying on declarations from end-users (ensures better data quality and evaluation robustness). This might require some training of surveyors on elements to observe, way to challenge the data provided by the end-user compared to the observation, etc.
- If some measurements are made by surveyors, they should be trained to the measurement method in order to ensure replicability and homogeneity of the method between different surveyors.

Depending on topics, the evaluation method can also be improved by having some measurements made directly by users to avoid memory-effect biases, improve the accuracy of the data, and minimize seasonality or short-term memory effects in answers. End-users could be involved in measuring the following data:

- Masses of cow dung and water/urine fed to biodigester, mass of bioslurry removed from the pit, mass of cow dung remaining (not fed to the biodigester);
- Masses and costs of wood and charcoal used;
- Masses and costs of cow dung and bioslurry sold;
- Time spent cooking, time spent exposed to solid fuels smoke, time spent studying at night with EVE device (in each case: time spent x number of people).

These measurements by end-users can be included from the beginning of the project, training them together values for the baseline situation and relying on them to gather values when the biodigester starts producing biogas.

It is also important to ensure that surveyors are trained to the survey methodology and survey materials (e.g. mobile device tools, procedure to have users rank the benefits of biogas). It is thus recommended to train a team of surveyors and have the same team conduct the baseline surveys and the surveys after the beginning of biogas production.

3.5.2 Planning of surveys

Including surveys in the planning of the project from its inception will also enable to improve the quality of data collected, and avoid memory effect biases.

It is particularly important to conduct baseline surveys systematically **before** the biodigester starts producing biogas. Ideally the baseline survey is conducted just before the biodigester is built, after the end-users have obtained the credit approval from the SACCO. The period has to be decided to be coherent with the season of future evaluations. Some attention thus has to be put into the choice of dates for baseline evaluations so that the data gathered prove useful for the comparison with endline surveys.

More generally, the surveys should be conducted at the same period of year to avoid seasonality biases. Ideally, one survey could be conducted during the dry season and another one during the rainy season to evaluate seasonality variations, avoid memory effect biases and improve evaluation of yearly impacts.

3.5.3 Evaluability of indicators from the pilot survey

Conclusions from the pilot survey in terms of evaluability and recommendations for future evaluations are summarized in Table 4 and Table 5.

Indicator	Evaluability	Recommendations for future surveys
Overall satisfaction	✓	N/A
Satisfaction on training for biodigester feeding	✓	N/A
Satisfaction on training for biodigester operation	✓	N/A
Technical problem encountered	✓	N/A
Sources of technical problems encountered	✓	N/A
Actual benefits of biogas (ranking by end-users)	✓	N/A

Table 4 – Evaluability of customer satisfaction indicators and recommendations for future surveys

Indicator	Evaluability	Recommendations for future surveys
Surface of land owned	✓	Target respondent with knowledge of surface owned.
Livestock owned	✓	Focus on adult animals only, or differentiate between young animals and adult ones.
Biodigester feeding	To be improved	To be measured by users rather than relying on memory. Need to rely on a secondary unit of measure (basin or jerrican) and have someone from EVE project measure once the mass or volume of basin or jerrican, for each household if types vary.
Types of fertilizers used	✓	N/A
Spread of fertilizers on culture types	✓	N/A
Savings on fertilizers	✗	Measurement methodology used was not appropriate (variations on fertilizer use). Financial valorisation of cow dung and bioslurry could be used for marketing/raising awareness.
Biogas stove used as main stove	✓	N/A
Average daily use time of biogas stove	To be improved	Target respondent with best knowledge of cooking time (cook). To avoid memory biases, may be measured directly by the user for a few weeks before and after the commissioning of the biodigester.
Dishes cooked with biogas	✓	N/A
Types of cooking fuels used	✓	N/A
Evolution of consumption of baseline fuels	To be improved	To avoid memory biases, rely on end-users recording their weekly expenses and mass of each type of fuel, and have external surveyor measure cost and mass of typical unit (bag of charcoal, bundle of wood …) at the time of the evaluation.
Evolution of time spent cooking with solid fuels	To be improved	Rely on end-users recording time spent cooking for a few weeks 'before' and 'after' the commissioning of the biodigester.
Savings on cooking fuels	✓	To avoid memory biases, rely on end-users recording their weekly expenses for each type of fuel.
Perception of smoke amount in kitchen (air quality)	✓	N/A
Perception of improvement in eyes comfort or disorders	✓	N/A
Perception of improvement in respiratory comfort or disorders	✓	N/A
Perception of evolution of hygiene in kitchen	✓	N/A
Connection of toilets to biodigester	✓	N/A
Lighting device distributed	✓	Can be replaced by device other than lighting if end-user connected to the grid.
Daily time use of lighting device provided by EVE biogas project	To be improved	Not a priority compared to measuring cooking time and savings. Target respondent with best knowledge of use of lighting device. To avoid memory biases, may be measured directly by user a few weeks before and after the beginning of biogas production.
Types of lighting devices used before	✓	N/A
Perception that EVE lighting device made difference in night study	✓	N/A
Savings on lighting fuels	✗	Low evaluability, further evaluation not recommended.

Table 5 - Evaluability of output, outcome and impact indicators and recommendations for future surveys

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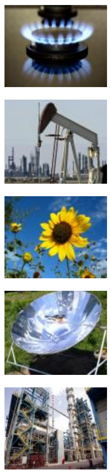
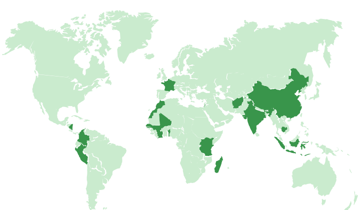
- Expertise & training

TECHNICAL EXPERTISE



- Energy efficiency
- Waste recovery
- Bioenergies & biofuels
- New energies
- Energy storage
- CO_2 Capture & storage
- Hydrogen & Fuel cells
- Industrial ecology
- Social acceptability

Our commitment



Contribute to the access to energy for all :

- **1500 days of volunteer work,** as part of **45 missions**
- **25 partners**, missions in **18 countries**
- **15** freely distributed **study reports**
- An **R&D program** on impact measurement

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