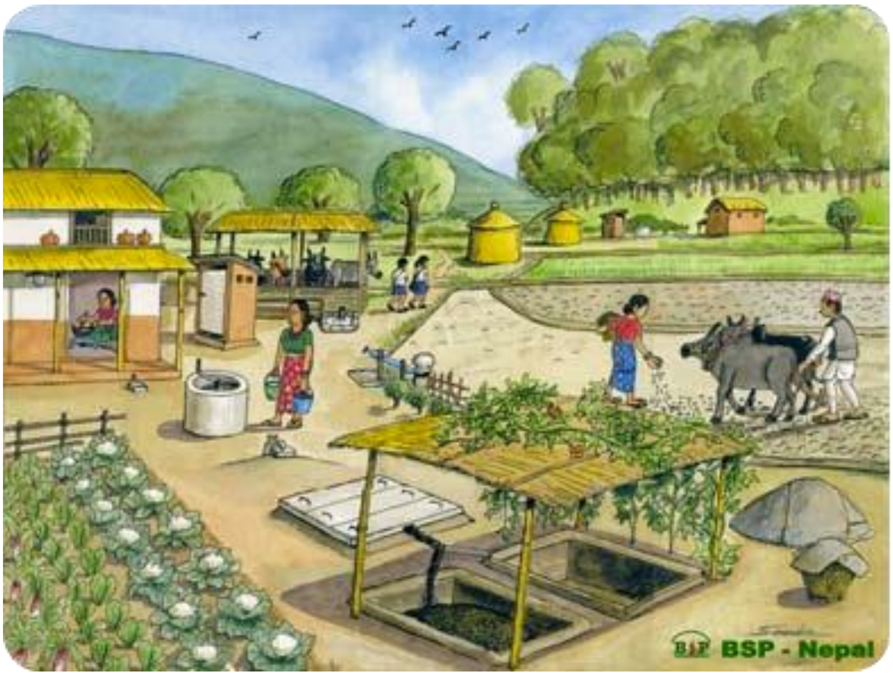
An Assessment of Small-Scale Biodigester Programmes in the Developing World: The SNV and Hivos Approach



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Abstract

Over the last decades, development organizations have been actively engaged in disseminating biogas technologies into the developing world. This study aims to evaluate the domestic biodigester approach of the Dutch NGOs SNV and Hivos, and identify key success factors and constraints behind its implementation in Africa and Asia. This paper contributes to the literature in a threefold manner. First, there is little known about the performance of small-scale biodigester programmes in developing countries and this study aims to fill this gap by providing an analysis of detailed project-specific data. Second, this study makes use of country-specific time-series data to establish outcomes of a set of indicators that allow a formal evaluation of the various biodigester programmes on several dimensions (scalability, affordability, energy capacity, productivity at the firm/worker level, cost efficiency and gender equality). Third, this paper simultaneously assesses the biodigester programmes at different scales: i.e. by looking at supporting factors and constraints on a *micro* level (firm/consumer level), a *meso* level (country energy regime, e.g. government level), as well as at the *macro* level (related to global landscape developments). Time and space data disaggregation from the individual biodigester programmes of SNV and Hivos allows this research to carry out a comparative analysis and identify cases of success and failure, in addition to detecting their underlying causes.

1.0 Introduction

Energy services are services that energy and energy appliances deliver and these services come in various forms (lighting, power for transport, heating for cooking, water pumping, and several other services that mechanical power, electricity and fuels make possible) (Pedrasa et al., 2010). Unfortunately, there is still a very large gap in energy service provision between developed and developing countries. Worldwide, approximately 2.5 billion people use traditional biomass fuels for cooking and nearly 1.5 billion people do not have access to electricity. Without scaling up the availability of sustainable energy services, another 1.4 billion people are at risk of being left without modern energy supplies by 2030 (Ghimire, 2013). Energy services are essential for both economic and social development. Poverty alleviation can be realized by increasing the availability of affordable and sustainable energy services. This is because energy services are associated with improvements in the fields of education, health, sanitation services, telecommunications, transportation, safe water and the productivity of income-generating activities in industry, agriculture and tertiary sectors (Modi et al., 2005). As such, universal access to electricity is important for the eradication of poverty and reduction of social inequality (Kaygusuz, 2011).

Provision of sustainable and affordable domestic energy is one of the key drivers behind enhancing the livelihoods of those living in poverty in Asia and Africa (Mwirigi et al., 2014). Biogas, a convenient fuel that is generated under anaerobic conditions from organic materials, has enormous potential to fulfill domestic energy demands in developing countries (Arthur et al., 2011). Over the last decades, development organizations have been actively engaged into disseminating biogas technologies in the developing world (Okello et al, 2013). The two private Dutch development agencies, the Netherlands Development Organisation (SNV) and the Humanist Institute for Co-operation with Developing Countries (Hivos) support renewable energy initiatives by initiating domestic biogas programmes in various Asian and African countries. These programmes can help enhance rural livelihoods by offering a clean alternative energy source, a potent organic fertiliser and economic benefits to the users (Ghimire, 2013).

The approach that is applied in the programmes is the multi-actor, market-based, sector development approach, where a biodigester sector is created with multiple actors participating at different stages of the value chain. Since 1992, SNV started to apply this approach in Nepal. Through this approach, a total of 579,306 biogas plants have been installed in Asia and Africa by the end of 2013, some in collaboration with Hivos (SNV, 2013). This study aims to evaluate the domestic biodigester approach of SNV and Hivos, and identify key success factors and constraints behind its implementation in Africa and Asia.

This leads to the following research question: *Is the approach used by SNV and Hivos to implement the use of biodigesters in Asian and African countries successful, and what are the key success factors for this approach?*

The number of countries participating in country programmes that implement biodigesters has increased over the years. SNV and Hivos have consequently had various programmes they have been involved with. This results in a unique data set on programme and sector development, which can be used for this thesis. This thesis makes use of this country-specific time-series data to establish a set of indicators that provide a formal evaluation of the different biodigester programmes on several dimensions (sector development, production, affordability, extension and gender). This thesis contributes to the existing literature since there is not much known about the performance of small-scale biodigester programmes in developing countries. This research aims to fill the gap by providing information regarding this performance with the use of detailed project-specific data. Furthermore, this thesis makes use of country-specific time-series data to establish a set of indicators. It simultaneously assesses the biodigester programmes at three different scales: i.e. by looking at supporting factors and constraints at a (1) *micro* level (firm/consumer level), at a (2) *meso* level (country energy regime, e.g. government level) as well as at a (3) *macro* level (related to global landscape developments). Time and space data disaggregation from the individual biodigester programmes of SNV and Hivos allow this paper to carry out a comparative analysis and identify cases of success and failure, as well as their underlying causes.

Before the data is evaluated, background information about biogas technologies is presented in chapter 2. In this chapter information on what biogas is and how it is produced will be given. In addition, the technology of domestic biodigesters and the numerous benefits of investing in digesters for households, society at large and even for the environment are given. In chapter 3, three different biogas programmes that operate in developing countries, which are not part of the SNV and Hivos programmes, are discussed. These programmes are evaluated through the use of the transition framework that is based on the Multilevel Perspective on System Innovation by Geels (2002, 2005). The importance of this is to establish what levels, namely *micro, meso* and *macro*, are relevant. In addition, not only the relevance is tested of these levels but also whether they have an impact on the success of biogas programmes. In chapter 4, the biodigester programmes applied by SNV and Hivos are discussed. Furthermore, detailed information about their specific approach is given. Chapter 5 consists of the evaluation of the different SNV and Hivos programmes where the approach is applied. Hereafter follows the discussion (chapter 6), in which an extensive evaluation of the programmes on three levels is described. Namely, on a *micro* level, *meso* level and *macro* level. This chapter also considers the assumptions and uncertainties associated with the programmes. The research question will be answered in chapter 7, in the conclusion.

2.0 Principles of Domestic biogas

This chapter provides an overview of what biogas is, how biogas technologies operate, as well as the benefits associated with the use of biogas technologies.

2.1 What is biogas?

Biogas is a mixture of gasses that is produced by anaerobic digestion of organic materials as agricultural wastes, animal dung and human excreta. The main compounds of biogas are methane (roughly 60%) and carbon dioxide (roughly 40%), along with other trace gasses (Frost and Gilkinson, 2011). Methane is a flammable gas that is produced by anaerobic fermentation of materials of organic matter by activities of micro-bacteria. If properly mixed with air, this gas burns with a blue flame and no smoke is produced (Laramee and Davis, 2013).
The most important factors that influence the biogas production are the temperature and the level of acidity of the organic materials. It is well known that biodigesters perform optimally with a temperature of around 35 degrees Celsius and a neutral pH, because a pH range between 6.7 and 7.5 allows the methanogens to grow optimally (Ward et al., 2008; Rajendran et al., 2012).

The primary end use application of domestically produced biogas is cooking; however, especially in remote rural areas where electrification does not exist, biogas is also used for illumination purposes. The residue of the biogas process, bio-slurry, can be collected relatively easy and can be used as organic fertilizer and soil improver (Ghimire, 2013). According to Bonten et al., (2014) nutrients in bio-slurry (mainly nitrogen (N)) are more readily available in comparison to undigested farmyard manure. This means that that bio-slurry can have a better fertilization effect in short term. However, the higher amount of N can also lead to greater risks for losses of this nutrient during storage, usage and application through and leaching volatilisation.

2.2 The technology of the domestic biogas plant

Domestic biodigesters are a simple construction that converts either human excrement or animal dung at household level into small but valuable quantities of biogas (Laramee and Davis, 2013). Throughout the world, various kinds of digesters are used. In developing countries, three major types of biogas reactors are used for the waste of livestock: the Indian floating drum digester, the Chinese fixed dome digester and balloon (or tube) digesters (Plöchl and Heiermann, 2006). All three types of digesters are usually sized to consume animal and human waste from one household. Generally, the energy that is generated flows directly back to the respective family. The volume of most biodigesters varies between 2 and 10 m^3 and produces about 0.5 m^3 biogas per m^3 biodigester volume. Nonetheless, this volume differs from country to country. In Vietnam and Pakistan, also larger biodigesters of up to 50 m^3 are used (Ghimire, 2013).

The principle of how a biodigester works is roughly the same, regardless of the different digester designs (figure 1). Generally the process is as follows. Feedstock enters the biodigester through the inlet pipe. This can be done either directly or after a mixing pit. Under anaerobic digestion the waste is fermented with the help of methanogenic bacteria, which in turn produces biogas (Heegde, 2010). After a substrate retention period of 20 to 100 days, the biogas is collected upon the slurry before it escapes through the outlet pipe (Ghimire, 2013).

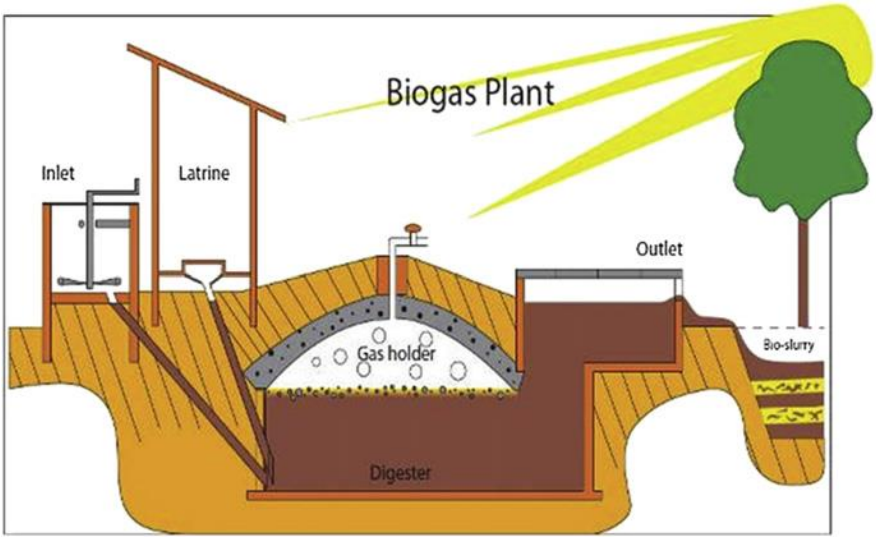

Figure 1. A typical design of a biogas plant (Ghimire, 2013).

Fixed dome digesters are the most popular design for rural households. The reason for this is their low maintenance requirement, reliability and ease to construct. In addition, it requires only locally and widely available materials for construction, such as stones, bricks, clay and cement. This type of biodigester only has fixed parts, which are not affected by erosion or rust, and is constructed underground to protect it from physical damage. Resulting in a lifespan of more than 20 years. Moreover, the underground construction helps to obtain a stable temperature regime to stimulate the bacteriological processes. Additionally, the underground construction saves space. Building the underground construction is labor intensive, which provides opportunities for local employment (Heegde, 2010).

2.3 What are the benefits of domestic biodigesters?

Winrock International has carried out a holistic cost-benefit analysis of biogas technology and considered the different benefits of a biodigester. The outcome of this study shows a high economic return (Renwick et al., 2008). Nevertheless, there are more benefits than economic ones. The most noteworthy benefits are listed below.

2.3.1 Socio-economic benefits

As mentioned above, anaerobic digestion can play an important role in the production of biogas (energy) as well as in the recycling of organic nutrients as fertilizer. One m^3 of purified biogas contains 6.5 kW[1] an amount of energy. This is equal to 1.7 L of bioethanol, 1.1 L of gasoline or 0.97 m^3 of natural gas (after Rajendran et al., 2012). In a conservative scenario, biogas digester of 6 m^3, with cattle manure as feedstock, produces around 1,7 m^3 biogas on a daily basis. Using the ratio above, a 6 m^3 biodigester provides 11.06 kWh thermal daily (White et al, 2010). Additionally, the bio-slurry that is produced by a domestic biodigester of 6 m^3 can easily fertilize 1-hectare of ground. Moreover, if enough organic waste is available, this number can even go up to 3.5 hectare when using larger digesters. Hence, the use of bio-slurry for agriculture purposes can results in increased yields.

The socio-economic benefits of biodigesters include the decreased use of conventional cooking fuels, allowing a reduction in the household's financial expenditures (i.e. reducing tradition fuel expenses). For example, according to Laramee and Davis (2013), who studied the adoption of the biodigester in 40 rural households in Tanzania, households with biodigesters spent on average $249 per year less on energy compared to household that had not adopted the technology. In this calculation, the value of the time that is saved by the household members is not included. The collection of biomass fuel (mainly firewood) requires time, so the switch from conventional cooking fuels to the biodigester technique results in a reduction in workload. Laramee and Davis (2013) state that households in Tanzania that adopted the biogas technology were found to spend, on average, 1.4 hours per person per day less on manure management activities and energy procurement compared to households that used conventional cooking fuels. Additionally, Laramee and Davis (2013) state that the benefits of domestic biodigesters accrue especially to women and children, considering that they are mostly responsible for cooking, fuel collection and agricultural activities. Different studies related to the use of biodigesters show a significant improvement of the livelihoods for women and children. This is due to the fact that the reduction workload enabled them to undertake more off-farm activities (Kes and Swaminathan, 2006). Moreover, once the biodigester operates, girls do not to have to assist with household tasks and this gives them the opportunity to continue with their school education. Furthermore, biogas supported

[1] The content of methane in biogas can vary due to various factors for instance the animal diet. For this research it is assumed that biogas consists of 60% methane, with an energy content of 23.4 MJ/m^3 (White et al., 2010).

illumination enables children to spend, for example, longer hours on reading (Ghimire, 2013).

2.3.2 Health benefits

Since most households in developing countries are completely dependent on biomass from firewood for their energy needs (in Africa this number is close to 70%), deaths from acute respiratory infections as a result of indoor air pollution are extremely high (Mwirigi et al., 2014). According to the World Health Organization (WHO), 4.2 million people die annually from indoor air pollution caused by this way of cooking. Especially women and children are affected, as their exposure to indoor air pollution is higher. Usage of domestic biogas reduces indoor air pollution. Therefore, averting respiratory diseases, caused by the smoke inherent to traditional cooking (Gwavuya et al., 2012).

Furthermore, biogas modernizes the farm, since cooking is no longer done on the ground and sanitation conditions improve. The cattle dung is no longer saved in the yard of the farm, but is directly fed into the biogas plant. This improves sanitation through the reduction of flies, smell and organic pollution. Hygiene can be enhanced even further if the toilet is directly attached to the biogas plant (Gautam et al., 2009).

2.3.3 Environmental benefits

To fulfill greenhouse emission reductions, biogas can be a solution. While combustion of biogas produces carbon dioxide, the carbon in biogas comes from plant matter that fixed this carbon from atmospheric CO^2. Thus, biogas is a carbon-neutral energy source. Moreover, using biogas for cooking instead of wood or charcoal decreases the demand for firewood. As a result, deforestation will be reduced and precious forests, which are carbon sinks, will be saved. In addition, further emission reduction can be achieved through the management of manure. The methane emanating from the manure is captured in the digester. Once captured this gas is used for cooking purposes. In this manner the methane is transformed to CO^2, which global warming impact is as much as 25 times lower than methane. Typically, the above-mentioned advantages can result in emission reductions of 2.5 tCO^2 annually per family sized biodigester. Therefore, the biodigester provides not only benefits for the investor, but it provides global benefits in terms of climate stability (Bhattacharya and Salam, 2002).

Due to the multidimensional nature of these various benefits, the biogas technology has great potential to make simultaneous progress on the Millennium Development Goals, since it meaningfully improves the living standards for poor African households

(Mwirigi et al., 2014). There are eight Millennium Development goals and domestic biogas has a strong direct link with four of them: MDG 1, MDG 3, MDG 6 and MDG 7 (figure 1) (Amigun and Blottnitz, 2010). This suggests that the benefits not solely profit the investor, but also generate benefits for the community (Heegde et al., 2007).

Table 1. Examples how domestic biogas contribute to reaching the Millennium Development Goal (TDBP, 2014).

Millennium Development Goal	Examples
MDG 1: Eradicate extreme poverty and hunger	-Construction and installation of biogas creates employment for landless rural people -Less use of traditional cooking fuels and therefore more availability of these fuels for the (very) poor -Pollution control and waste management benefit all members of the community
MDG 3: Promote gender equality and empower women	-Biogas can provide light that helps women and girls with their study -Domestic biogas reduces the workload of women -Biogas can improve the health of women (and children) who are most exposed to the dangers of wood smoke.
MDG 6: Combat HIV/AIDS, malaria and other diseases	-Indoor air pollution and poor sanitary conditions annually cause millions of premature deaths
MDG 7: Ensure environmental sustainability	- Reducing (GHG) emissions - Application of bio-slurry increases soil structure - Fertility reduces the need for application of chemical fertilizer

3.0 Biogas programs in developing countries

The absence of access to modern energy sources aggravates poverty, especially in rural areas where opportunities are scarce (Kaygusuz, 2011). The biogas technology is an established, proven technology and is capable of solving parts of the environmental and energy problems of both poor rural communities, as well as the industrial urban populations (Mwirigi et al., 2014).

Currently, biogas programmes have been launched in more than 50 different countries. These programmes have been developed as a way of advancing agricultural productivity, renewable energy use and waste management. Furthermore, as mentioned in the previous chapter, these projects claim that they guarantee a variety of benefits at socioeconomic level, environmental level, and health benefits for households. However, the achieved levels of success of many biogas programmes have been low, and there is a perception that biogas dissemination programmes are largely a failure (Bhat et al., 2001; Buysman and Mol, 2013). In this chapter, three different biogas programmes that operate in developing countries are discussed: (1) failure of the biogas programme in Ethiopia, (2) success story of the National Programme on Biogas Development (NPBD) in India and (3) the Biogas Programme in China that has to adapt to external factors. It needs to be noted that these three programmes are not part of the SNV and Hivos programmes. The information regarding the three programmes is derived from academic references. The evaluation relates primarily to how the programmes performed as a business model. In this chapter, their success is evaluated and the main barriers they faced are identified. These success and failure stories could provide lessons to promote successful biogas programmes in other areas. By identifying sides, this thesis tries to pinpoint the drivers behind the success and failure. Hereafter, a comparison between their relevance in the context of the SNV and Hivos approach is given. The most important programme selection criterion was age of the programme. The programmes had to be implemented at least 20 years ago, as recently implemented programmes cannot be assessed sufficiently in terms of failure or success. More specifically, the first programme analyzed, Ethiopia, shows what can go wrong with programmes and why. The second story, namely of India, shows the potential of biodigester programmes and its successes. The third analysis shows the success of the programme in China. However, this success might be threatened by changing factors. In conclusion, different analyses are made to establish what drivers of success and failure are.

3.1 Failure story of the Ethiopia

In 1979, Ambo Agricultural College constructed the first batch type digester in Ethiopia. The Ethiopian Rural Energy Development and Promotion Centre introduced a new renewable energy programme to reduce the negative effects of the energy crisis of the 1970s. The main focus of the programme was the introduction of anaerobic technologies and demonstration pilots. The biodigester technology has not spread widely in Ethiopia; the EEA reported in 1991 that only 103 biogas units had been installed. Over the last two and a half decades around one thousand biogas plants were built. The government built most of the biogas units mainly for demonstration purposes. The government did not consider follow-up, variations in design and the existence of standardized biogas technology. Consequently, the usage of biogas technology did not scale up as estimated (Eshete et al., 2006). Nowadays, around 40% of the biogas units are not operational as a result of weak and ineffective management, poor follow-up, technical complications, less interest, reduction in animal holdings and evacuation of ownership. For the afore-mentioned reasons, the reputation of domestic biodigesters in Ethiopia is not good (NBP, 2008).

3.2 Success story of the National Programme on Biogas Development (NPBD) in India

The Ministry of Non-Conventional Energy Sources in India launched the National Programme on Biogas Development (NPBD) in 1982, with the objective to provide quality fuel in the form of biogas in a sustainable way and to promote the use of bio-slurry. In this period, it was seen that the majority of rural households could meet their energy requirements for cooking through the use of biogas technology (Bhattacharya and Jana, 2009). This required dissemination of biogas plants (c. 2 to 4 m^3 gas per day) by using dung as the major feedstock. In south India, in the Sirsi block of Uttara Kannada (UK) district of the Karnataka state, the success rate of the dissemination of the biogas technology was extremely high. Specifically, 100% of the digesters that were built functioned satisfactorily. Furthermore, 85% of the households that use the biogas technology met their energy needs for cooking with this biogas. This very high level of success, despite being a high-rainfall region, can mainly be explained by the following factors (Bhat et al., 2001):

- High awareness among rural household for the need for high-quality fuel, especially among women.
- The households used cattle dung efficiently, and this led to gas sufficiency, even when there was less than 5 kg per capita of dung available per day.
- In the agricultural activities, the stake for quality manure was high.
- The dissemination network involved multiple agencies with sufficient interest in the project like promoters, private enterprises and users' interest groups.
- Several entrepreneurs were dependent on the construction of biogas plants for their living. As a result, there was competition among builders and this encouraged high quality construction of the biogas plants.

The main message for national programmes on biogas development that can be derived from this example is to: launch a promotion programme, train a large number of entrepreneurs, procure subsidies, guarantee performance and free servicing/maintenance. In conclusion, the presence of multiple agencies and stakeholders in the network is of great importance (Bhat et al., 2001).

3.3 China's Biogas Programme has to adapt

China's Biogas Programme plays the leading role in the worldwide dissemination of household-based biogas technology. A decade of heavy investments by the government of the People's Republic of China resulted in around 41.68 million households using the biogas technology by the end of 2011. When including centralized biogas supply, around 160 million people in rural China were benefitting from biogas by the end of 2011 (Cheng et al., 2013). Additionally, according to data from the Ministry of Agriculture, biogas units in China produce 410 million tonnes of organic fertilizer annually and moderate CO_2 emissions by 61 million tonnes.

Nonetheless, China is changing, and different challenges with respect to the programme have surfaced. Problems include migration from villages to cities. The urbanization that occurred rapid has increased the cost of rural labor since the labor supply shrinks, and this increased cost. Resulting in higher cost for biogas constructions. Furthermore, the amount of manure is decreasing, since traditional animal husbandry is declining in rural areas. This new socioeconomic landscape in China could put pressure on biogas as a sustainable energy source for many rural households. Therefore, it is necessary for China to review its biogas programme and biogas sector. In order to secure the success of the biodigester programmes four important steps have to be taken. First, an objective analysis of the biogas sector has to be made. Second, service and maintenance of biodigesters has to be improved. Third, subsidies have to become more cost-effective. Lastly, alternative forms of subsidy have to be explored. Once the above steps are taken into consideration and actions to improve them are made the success of the programme can be assured (Zuzhang and Wilson, 2014).

3.4 What can be learned from the programmes?

The reason that biogas programmes sometimes fail and sometimes succeed can be explained by the transition framework, which is based on the Multilevel Perspective on System Innovation by Geels (2002, 2005). This is a three-level model that includes a *micro*-, *meso*- and *macro*-level (figure 2).

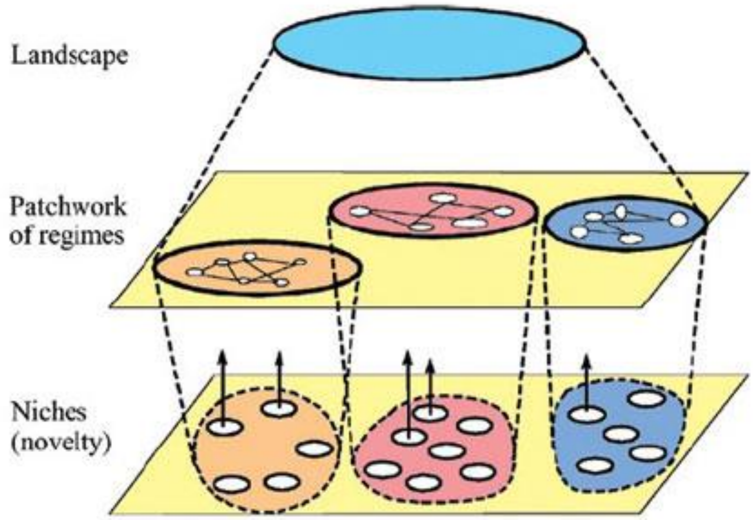

Figure 2. Transition framework that is based on the Multilevel Perspective on System Innovation elaborated by Geels.

The *micro-level* is characterized as being composed of *niches*, within which innovations emerge as 'experiments' in relatively protected contexts, such as the introduction of the biogas technology. Niches play an important role in enabling learning and as space to build social networks in support of innovations. Examples of sustainable energy niche-innovations are PV systems in rural areas and the idea of Consumers as energy producers.

The *meso*-level regimes refer to the '…the rules set…embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artifacts and persons, ways of defining problems. All of these are embedded in institutions and infrastructures' (Rip and Kemp, 1998). So the *meso-level,* also so-called a *socio-technical regime*, describes complex relationships of three interlinked dimensions: (1) network of social groups and actors, (2) rules (formal, normative and cognitive) that guide the actions of actors and (3) material and technical elements (Geels, 2005). Examples of the energy regime are fossil fuel infrastructure with their respective technologies and actor-configuration with large- scale, powerful energy companies.

The *macro-level* is called the socio-technological landscape in this model and describes the formation of a wide range of interconnected and aligned elements, including the material and virtual infrastructure, macro-economic systems, political framework and value systems. Socio-technological landscapes stay relatively stable over time, because of the linkages that exit between these different elements and as such create a context in which different regimes are established (Kemp and Rotmans, 2001). Examples of the energy landscape are: climate change discourse, population growth, depletion of fossil fuels, increasing oil prices and the financial crisis.

This three-level model stresses the interaction between dynamics at these three different levels. Although the landscapes are relatively stable they can and do change over time, for instance under the influence of exogenous factors. Such exogenous factors are, for example, an aging population, warfare, or change in oil prices. These changes in the socio-technological landscape put pressure on one or more regimes. Consequently, they destabilize a regime by the disturbance of its coherence. When regimes are instable they are open for change and this creates opportunities for alternative solutions to be obtained by system actors. Innovations that occur in technological niches may break through into an incumbent regime. As a result, new technological practices and platforms can be developed. Alternatively, innovations that arise in niche markets seldom lead to changes in the incumbent regime since these adjustments will be relatively local and have no implications for the structure of the system (Geels, 2005).

When applying this transition framework to the biogas sector in developing countries, it can be observed that all three levels are relevant towards the understanding of the effectiveness and efficiency of biogas programmes. Doing so helps to find the answer to *why* in some cases the technology did lead to widespread dissemination and in other cases it did not. For example, the barriers can be related to technological areas: the technology may be costly, there may be resistance to use it and so on. Other barriers could originate from both the incumbent regimes (for example, unfavorable legislation or opposition to change due to vested interest), and landscape changes (e.g. population growth and urbanization). Since barriers are caused and removed by multiple actors, it should also be possible to identify those actors primarily responsible for each of the barriers and opportunities.

In the case of Ethiopia, the biogas technology is seen as a niche that form alternative ways of energy provision for traditional biomass-based energy systems. The biogas technology was introduced free of charge through a demonstration project or a pilot. These projects were generally implemented by the government, which believed that a demonstration on ‘how to construct a biogas plant’ would ensure the automatic adoption of the biogas technology. However, this approach seems not to be successful since it did not lead to market development and dissemination of the technology on a large scale (Mwirigi et al., 2014). In short, the alternative niches did not break through to the regime. For widespread dissemination, one needs to arrive at a critical production rate in the market. A pilot – as the word says – is an experiment, often heavily controlled and subsidized, in a slight segment of the market[2]. Hence, a successful biogas dissemination programme in the context of Ethiopia needs participation and commitment of a number of different stakeholders, whose interests and perspectives are aligned. Therefore, a clear design and institutional arrangement of the programme is required with well-defined responsibilities for all stakeholders (Eshete et al., 2006). This was the case in India, where multiple agencies were present in the network, and consequently the programme was successful. For the case in China, the social technical landscape is changing (e.g. rapid urbanization) and this puts pressures on the regime were biogas is the sustainable energy source (Zuzhang and Wilson, 2014).

Table 2. The three levels of the Multilevel Perspective on System Innovation elaborated by Geels. and the three case studies discussed.

Case study	Niche	Regime	Landscape
Ethiopia *No successful transition to biogas*	Biogas as niche innovation is available and is sufficiently developed	Regime still stable and not open for change. Lack of agencies and stakeholders in the network interested in the dissemination of the biogas technology.	There is sufficient pressure from the landscape (population growth and need for more energy)
India *Successful transition to biogas*	Biogas as niche innovation is available and is sufficiently developed	A regime change due to the presence of multiple agencies and stakeholders in the network that have interest in the dissemination of the biogas technology. Also, high awareness of the technology among rural households plays an important role.	There is sufficient pressure from the landscape (population growth and need for energy)
China *Is becoming less successful*	The costs of digesters are increasing	Pressures on the regime where biogas is the sustainable energy source	Pressure by urbanization

In conclusion, it is important to know for biogas programmes that energy services for poverty alleviation are not just about the technology. Therefore, energy projects need to be integrated in a holistic manner, together with other improvement efforts relating to job creation, education, agriculture and health, to ensure that the new technology breaks through to incumbent regime.

For this reason, the focus should not only lie on biogas programmes. More specifically, it should be based on the biogas sector as a whole. For the development of the biogas sector, it is necessary that there is close cooperation amongst all relevant stakeholders (non- government, government, and private sector) and in the sector at all levels (*micro, meso, macro*). Programmes, projects and policies do not have to start with promoting a particular technology, but must rather start to make an assessment of the user's needs.

[2] Personal communication with Wim van Nes, Strategy Officer Renewable Energy at SNV (2 Juni 2014).

Different rural communities also have different needs. Finding suitable technologies and successful implementation strategies varies from case to case (Kaygusuz, 2011). In order to ensure that biogas programmes succeed, they need to move away from a product-based project approach that is implemented by just a single actor. Preferable is the market-oriented programme approach, were different actors participate on the basis of institutional arrangements (Mwirigi et al., 2014).

4.0 Description of SNV and Hivos programme/approach

As mentioned in chapter 3, several small-scale biogas projects report temporary successes. However, many large-scale projects have failed and in the long run chances of failure increase as well. The participation of different actors is an important success factor, which is shown in the India case study. Furthermore, according to Buysman and Mol (2013), the challenge to develop a successful biogas programme is to find a right mode of implementation and design of biogas installations. It is important that they ensure ownership, participation and responsibility of the end users of these biodigesters and offer sustainable long-term financing mechanisms. Presently, SNV and Hivos have long-term experience in market-based dissemination of domestic biodigesters in both Asian and African countries. The support of SNV has resulted in the installation of almost 580,000 biodigesters by the end of 2013, of which over 41,000 were built in Africa, partially in collaboration with Hivos (data SVN, 2014). This chapter first provides background information about the two organizations. Thereafter, the different biogas programmes of SNV and Hivos are presented, followed by a clear explanation of the approach that SNV and Hivos apply.

4.1 SNV and Hivos

4.1.1 Netherlands Development Organisation - SNV

SNV is an international non-profit development organization that operates in 38 countries and was founded in the Netherlands in 1965. A team of both local and international advisors collaborates with local partners to equip businesses, communities and organizations in the developing world with the knowledge, connections and tools needed to increase their income to subsequently break the cycle of poverty. By sharing specialist knowledge in renewable energy, agriculture, sanitation, hygiene and water, this organization helps to solve some of the main problems that the world is facing today. SNV has more than 25 years of experience in the management, design and support of dissemination programmes for domestic biogas in different countries. Specifically, SNV has been active as an NGO in Asia since 1989, in Africa since 2006 and in Latin America since 2012 (ABPP, 2013).

4.1.2 Humanist Institute for Co-operation with Developing Countries - Hivos

Hivos was founded in 1968 and is a Dutch development NGO. Hivos operates in 32 countries across East and South Africa, South and South East Asia, and Latin America. It has six regional offices and employs around 300 employees. Their key work areas are: support smallholder organizations' access to markets, sustainable agriculture, business development and finance, carbon finance and sustainable energy. The Dutch NGO pays attention to agricultural biodiversity, soil fertility, green knowledge and climate change mitigation to improve the living conditions for farmers and gender inclusiveness (ABPP, 2013).

4.2 Biogas programmes implemented by SNV and Hivos

SNV first started the support of biogas activities in Nepal. Here, sector development has started in a systemic manner in 1992 under The Biogas Support Programme (BSP). Under this biogas programme, more than 290,000 biogas units had been installed throughout Nepal by the end of 2013. This success in Nepal encouraged SNV to start the support of another national biogas programme, namely in Vietnam in 2003. Afterwards, comparable programmes were launched in other Asian countries: Cambodia, Bangladesh, Laos, Pakistan and Indonesia (Surendra et al., 2014).

In Africa, the first actions to prepare national biogas programmes were started in 2005 by SNV, the Netherlands Directorate General for International Cooperation (DGIS) and several African partners. In the run up to the programme launch, a preparatory conference took place in Amsterdam in 2006, followed by an African domestic biogas conference, which took place in Nairobi in 2007. In 2008 the programme preparations were completed. This resulted in the Africa Biogas Partnership Programme (ABPP) being officially launched in 2009. SNV and Hivos have together implemented ABPP, which is co-funded by DGIS. Hivos is responsible as fund manager for the programme and SNV provides technical assistance (table 3). The programme operates in six African countries: Ethiopia, Kenya, Burkina Faso, Uganda, Tanzania and Senegal[3]. The general

[3] In 2011, the programme in Senegal was terminated due to its poor results caused by a number of factors including the performance of the selected partner.

objective of this programme is to contribute to the achievement of the Millennium Development Goals (MDG), as mentioned in chapter 2.3. This objective is accomplished through the constant construction of domestic biogas units as a sustainable local energy source. The programme sets up national biodigester programmes under the multi-actor biodigester sector development and market approach and is further explained in section 4.3 (Castro, 2011).

Table 3. Capability statement of SNV and Hivos around the ABPP (Africa biogas partnership programme, 2013).

SNV	Hivos
Implementation of large-scale biogas dissemination programs requires local presence. SNV has a local presence in more than 30 countries.	Experience and track record on fund mobilization and management for larger (3rd party) programs. Local presence in 10 countries.
A well developed and fine-tuned domestic biogas sector development approach.	Institutionalized inclusive approach, combining fund management with capacity building on operational management, finance, administration and M&E.
Multi-region and multi-country experience in domestic biogas programme implementation.	Well regulated systems (ISO 2000) allowing for accountability and combining TA and programme funding.
Technical expertise on domestic biogas and ODID / value chain facilitation for sector and market development, PSD, credit and bioslurry.	Experience in mainstreaming gender in renewable energy sector.
A knowledge network allowing programmes to capture and share experiences and innovation both on programme implementation and programme management.	Experience in developing carbon revenue components to biogas programs.
Institutionalized infrastructure and track record for (long term) and close (local presence) capacity building.	Institutionalized infrastructure and track record for financial services and loan product development.

SNV and Hivos expanded the domestic biogas activities to other countries in Africa that show sufficient potential to increase the biogas adoption rate (Benin and Cameroon). Furthermore, Hivos implemented the National Domestic Biogas Programme in Indonesia (BIRU), joined the Nicaragua Biogas Programme and developed the carbon credits system for the National Biodigester Programme in Cambodia. The countries were SNV and Hivos implemented the domestic biogas programmes are presented in table 4.

The number of biodigesters across both Asia and Africa is increasing, mostly due to national domestic biogas programmes, such the ABPP. Table 4 also provides an overview of the cumulative production numbers of biogas units installed through the support of SNS and/or Hivos by the end of 2013. In addition, this table reveals that thousands of biogas units have been built in the participating countries. In some countries one sees the accomplishment of tens of thousands or even hundreds of thousands biogas units. For example, since 2009, Kenya has constructed 11,579 biodigesters through this initiative. The rate of installation in Asia compared to the installation rate in Africa is even higher. Vietnam constructed 173,905 units since 2003 and Nepal achieved the highest number of biodigesters: 292,979 biogas plants since 1992. The Indonesia Domestic Biogas Programme supported by Hivos achieved a milestone of 11,331 biogas plants installations by the end of 2013 (data Hivos, 2013).

Table 4. Number of biodigesters that have been built in Asia and Africa where Hivos and/or SNV operate up to 2013 (data SNV, 2014).

	Starting date	**Cumulative number of digesters built under the programmes by the end of 2013**
Nepal	1992	292.927
Viet Nam	2003	173905
Cambodia	2006	20288
Lao PDR	2007	2888
Indonesia	2009	11331
Pakistan	2009	3344
Bangladesh	2006	31886
Burkina Faso	2010	4014
Ethiopia	2009	8161
Kenya	2009	11579
Rwanda	2007	3517
Tanzania	2009	8799
Uganda	2009	5168
Bhutan	2011	839
Cameroon	2009	198
Benin	2010	72
Senegal	2010	334
Nicaragua	2012	4

4.3 Market-oriented programme approach

The programmes of SNV and Hivos are based on a multi-actor biodigester sector and market development approach. The programmes are helping countries in both Asia and Africa to develop a commercially viable, market-oriented biogas sector, which promotes the usage of domestic biodigesters as a sustainable and local energy source and source for soil fertilization (SNV, 2009).

Central to the domestic biogas sector development programmes are masons or biogas companies (also called biogas construction enterprises) that built and sell the biogas plants to the farmer's household. Preferably, at the start of any national biogas programme, SNV and Hivos like to mobilise existing companies in the sector, train and coach them on the ground to become biogas companies. However, in many countries such companies do not exist. Hence, SNV and Hivos have to start to train individuals (masons) to become biogas companies. The households, who are the end users, are informed of the benefits of the biogas technology through promotional activities. In addition, they receive training about the operation and maintenance of the digester. Likewise, information regarding the use of slurry in agriculture is provided. Bio-slurry application trainings are provided by third party agricultural organizations. Furthermore, quality controls over the construction and installation are carrying out. Besides, quality assurance and warrantee systems are put in place. Meaning that one or two year warrantee against any construction errors or other malfunctions is given. Carbon credits are developed and provide finance that is plowed back into the programmes. Households can make use of micro credits to finance the relatively high investment costs required for the construction and installation of a biogas unit. Because it is complicated to finance large-scale domestic biogas programmes it is required that national governments contribute to these costs (Ghimire, 2013). Development and research activities are done to create more efficient biogas digesters to achieve further improvements for the biodigester technologies, for example by the use other materials in the construction of biogas digester like Fiber-reinforced plastic and modified plastic (Cheng et al., 2014). The biodigester programmes rely on digesters that: have relatively low construction cost (achieved through the use of locally available materials), utilize little space because they are constructed underground, have a high lifespan (around 20 years) and are constructed on-site. Depending on different factors like the needs of the families, availability of space, cost and the number of animals on the farm, different plant size can be purchased. If everything is organized well, it takes between 10 and 20 days to complete the construction of a biodigester.

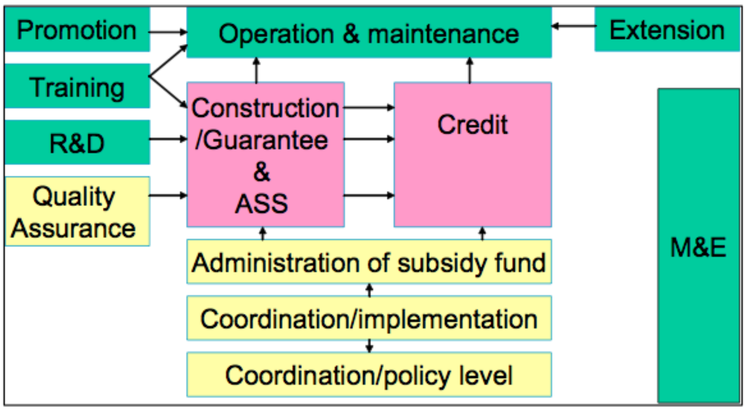

Figure 3. Programme functions, this are the required functions for a National Biogas Programme to develop a biogas sector with multiple stakeholders (SNV, 2009).

As mentioned above, SNV and Hivos aim to involve institutional and organizational capabilities that are already present in the country as much as possible and strengthen these capacities by organizations of local capacity building. So, SNV and Hivos do not directly implement activities and therefore limiting the deployment of people to just a small number of advisers per programme (Ghimire, 2013). In every country, an existing organization is selected to coordinate the programme among all different stakeholders in the country. SNV and Hivos provide technical management support to these coordinating organizations. In addition, SNV and Hivis are involved in planning, monitoring and evaluation of the programmes (figure 3). When the programme evolves, these functions of the programme team may be decentralized to a certain extent to implementing partners. The ultimate goal for the market-based sector development approach would be that biodigester constructors or contractors sell biodigesters to households and that they provide the necessary services to these households to sustain further market development (SNV, 2009).

It is important to notice that a national biogas programme should fit in a country-specific environment. This is because countries are different in their economic, technical, cultural, social, political and environmental make-up. Therefore, programmes differ significantly between countries. For example, the private sector is the main driver of the biogas programme in Nepal, whereas the provincial governments manage the programme in Vietnam. The search for the best suitable programme is expressed in the feasibility nexus (figure 4). This is the central point of the steps that have to be taken in the preparatory process. In the feasibility study the social, economic and environmental aspects are evaluated in detail. This feasibility study results in the provision of information on the commercial possibility of the programme and gives an indication of high-potential areas in the selected country (Nes and Heegde, 2008).

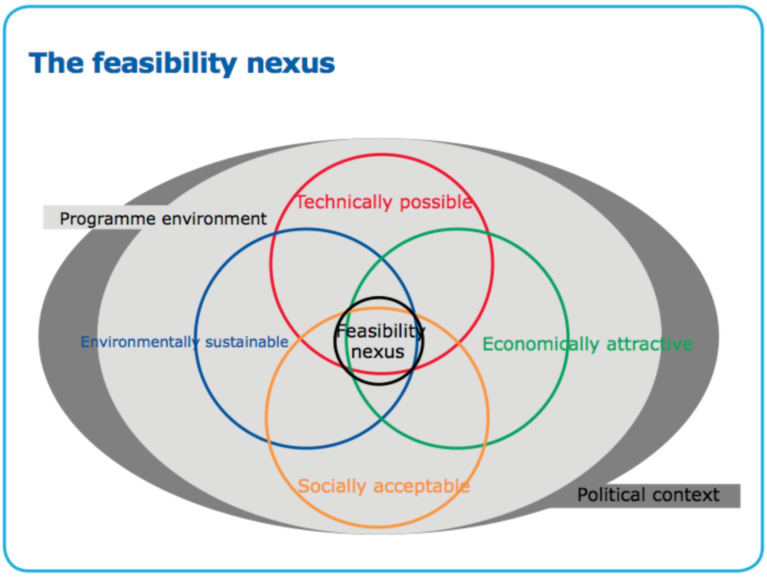

Figure 4. The feasibility nexus, the quest for the best fit is expressed in this nexus (SNV, 2009).

5.0 Evaluation of programs

In table 4, the number of biodigesters that have been installed so far by the programmes is presented. The number of biodigesters has increased in the selected African and Asian countries, which shows that there is an increased interest in them. However, the success of a biogas programme cannot only be measured in terms of the numbers of biogas plants that have been built. Additionally, important indicators to measure success include whether and to what extent biogas technology contributes to a sustainable increase of quality of life of people (Ghimire, 2013). In this chapter, five indicators that track the success of the biogas programmes are discussed; sector development, production, affordability, extension and gender (figure 5). The indicators used to evaluate success are similar to those in the ABPP dashboard that was developed in 2010. The aim of the ABPP dashboard was to present a tool for the management of programmes to see if there was "development of a commercially viable biogas sector " along a selected set of key indicators. (Dashboard Report, 2012). Furthermore, at the end of this chapter an explanation of the different outcomes of the Asian and African biogas programmes is given.

5.1 Data evaluation

Participation in country programmes has increased over time, resulting in a unique data set on programme and sector development, which this chapter aims to document. The data that is used for this chapter is made available by SNV and Hivos[4]

For the data from the African countries and Indonesia, the local programme officers were asked to fill out a quarterly questionnaire (Appendix 1) and results were, together with basic monthly data, processed in an excel spreadsheet (http://sites.google.com/site/biogas4all/). The data of 2012 and 2013 was produced with the same questionnaires and therefore entirely comparable. In contrast, the data of 2011 was generated with different surveys (in 2012 and 2013 the indicators were reduced in measurement frequency and more simplified questionnaire were asked quarterly instead of monthly). Therefore, most graphs regarding the African countries are on a quarterly basis and from the following period: beginning of 2012 till the end of 2013. The data from the Asian countries is not as comprehensive as the data from Africa. Furthermore, it is important to notice that the data used for this research is data till the end of 2013 (Dashboard Report, 2012).

[4] Data have been kindly provided by Mr Harrie Openoorth (HIVOS) and Wim van Nes (SNV).

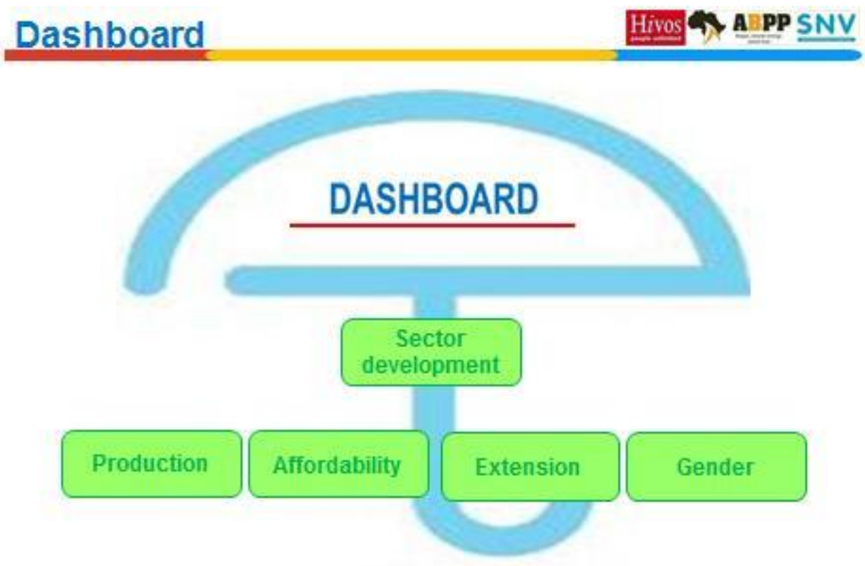

Figure 5. The five indicators that track the biogas program that are used for this study are; sector development, production, affordability, extension and gender.

5.1.1 Sector development

One central objective of all biogas programmes of the SNV and Hivos is the development of a market-oriented biogas sector, i.e. a sector that can be sustained by capable stakeholders and be financed without Official Development Assistance (ODA). Sector development in this context means that all the relevant stakeholders (government, non-government and the private sector) are involved in the biogas programme. All the different sector levels will be involved, from *micro*, to *meso* and *macro*. The building capacity of the different stakeholders should be in-line with the demands of a successful biogas programme. In the selected Asian and African countries, the biogas sector was either not present or weakly developed at the beginning of the programme implementation. However, this sector is currently developing. Sector development is a complex and difficult task. In order to create a sustainable biogas sector, a long-term effort is needed, anywhere between seven and twenty years (SNV, 2009). SNV and Hivos play an active role in mobilizing the necessary resources for subsequent phases of programmes. An example in which the biogas sector is developed properly is in Nepal. The key-reason for this success is the joint effort and collaboration of different stakeholders (Gautam et al., 2009).

In order to determine whether a sector has developed sufficiently over the years, one can look at different indicators, for instance:

<u>- The number of active masons</u>. When the sector attracted more masons the average production of installations increased and the sector developed further. The amount of active masons, trained by national and also by regional implementing partners to construct biodigesters, gave an indication how the sector developed over time (SNV, 2009).

In figure 6, the number of active biogas masons for 7 consecutive quarters, from Q1-2012 to Q3-2013 is presented for the following countries: Ethiopia, Kenya, Rwanda, Tanzania, Uganda and Burkina Faso. In all these African countries the number of active biogas masons has clearly increased during the 7-quarter period. The specific, percentage increase between Q1-2012 and Q3-2013 are as follows: Ethiopia by 920% (from 45 to 459 active masons), Kenya by 812% (from 73 to 666 active masons), Rwanda by 658% (from 33 to 250 active masons) Tanzania by 845% (from 66 to 624 active masons) Uganda by 2364% (from 28 to 690 active masons) and Burkina Faso by 2494% (17 to 441 active masons). In total, the number of active biogas masons has increased from 262 in Q1-2012 to 3130 active biogas masons in the Q3-2013 (1095 %).

Unfortunately, there is no data available about the number of active masons before 2012. Nor is there for other countries.

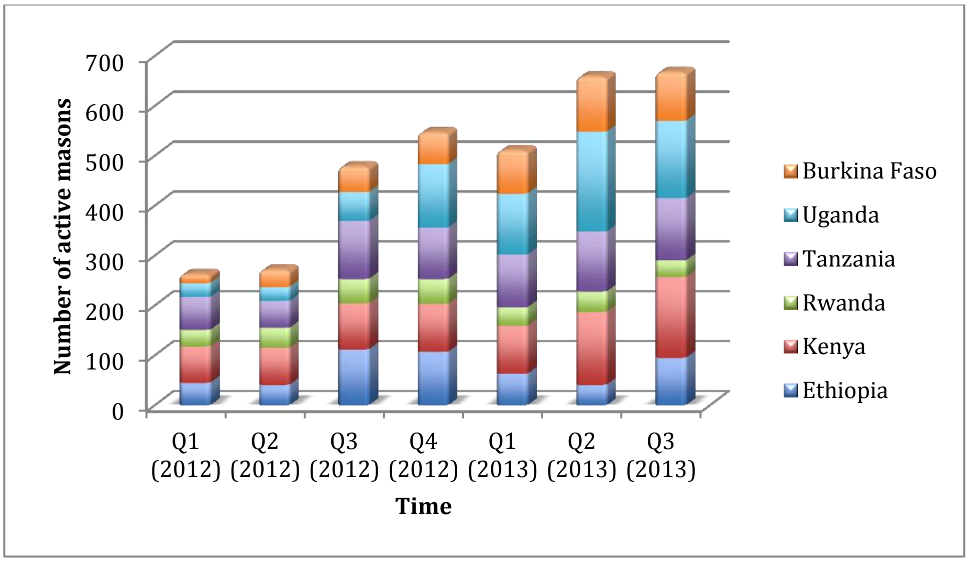

Figure 6. Number of active biogas masons in Ethiopia, Kenya, Rwanda, Tanzania, Uganda and Burkina Faso per quarter from Q1-2012 to Q3-2013.

<u>- The number of Biodigester construction Enterprises (BCEs).</u> Besides the skill training required for building biodigesters, the masons can also apply for business development training that is offered by the programme. An increasing number of masons seize this opportunity and attempt to become entrepreneurs. If this has success, they can form

Biodigester Construction Enterprises (BCEs) or masons are asked to join cooperatives. In this way, the private sector is gradually becoming more important in the biogas sector in the selected countries where the SNV and Hivos approach is applied. For example, figure 7 shows that in 2012 the numbers of active biogas companies continuously increased in several African countries. In total, the number of BCEs has increased from 51 in Q1-2012 to 688 in the Q3-2013 (1249 %). Mainly in Tanzania, which shows an increase from 6 in Q1-2012 to 213 BCEs in Q3-2013 (3450%), and in Kenya where an increase from 23 BCE's in Q1-2012 to 169 BCEs in Q3-2013 (635%) is observed. Smaller increases are seen in Ethiopia, from 4 BCE's to 45 BCEs (however in percentage increase with 1025%) and Burkina Faso from 2 BCE's to 15 BCEs (650%) over the same period.

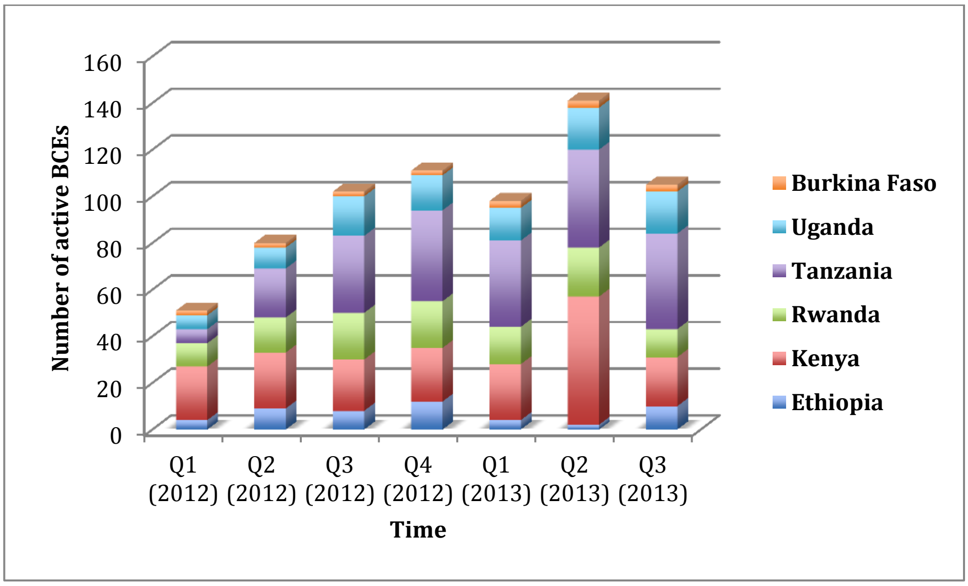

Figure 7. Number of active BCEs in Ethiopia, Kenya, Rwanda, Tanzania, Uganda and Burkina Faso per quarter: from Q1-2013 to Q3-2013.

Not only in the African countries the number of Biodigester Construction Enterprises increased over the years. For example, as shown in figure 8, in Indonesia this number grew from 4 in 2009 to 58 BCEs in 2013 (increase during this 4 years period by 1350%).

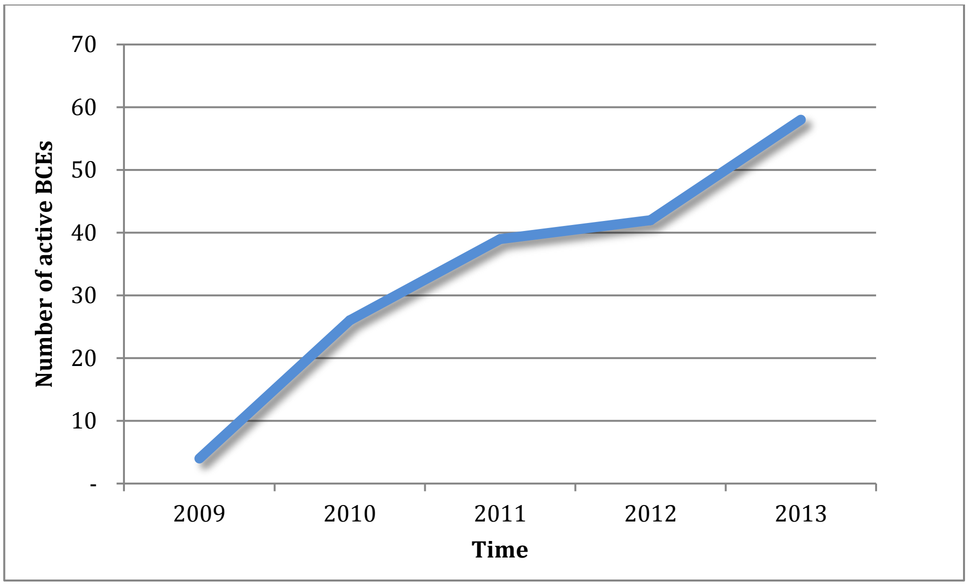

Figure 8. Number of active Biodigester Construction Enterprises for the Indonesia biogas programme (2009-2013).

In general, all countries in which SNV and/or Hivos operate show continuous improvement and sector development. This can be concluded since the number of active masons and the number Biodigester Construction Enterprises increased over the years. However, the extent of sector development varies from country to country.

5.1.2 Production

SNV started supporting biogas activities in Asia, beginning in Nepal in 1992 under the Biogas Support Programme (BSP). Due to this programme, the biogas sector has developed significantly over the years (Gautam et al., 2009). As shown in figure 9, around 293,000 households had adopted the biogas technology by the end of 2013 (data SNV, 2014). The approach of SNV that is applied in the programme leads to this success. In addition, the unique conditions in Nepal have contributed to this success: the biodigester fits well into the integrated farming system where the production of crops and animal husbandry are combined. Furthermore, most rural households have cattle dung and the handling of dung is not a taboo in the Hindu culture. Lastly, in Nepal it is becoming more difficult to obtain timber that can be used as fuel, this is a strong incentive to switch to alternative cooking fuels like biogas (Mendis and Nes, 1999). Figure 9 also shows the cumulative number of biogas units installed in Vietnam between 2005 and 2013. In that period, 173,905 domestic biogas plants were installed in Vietnam.

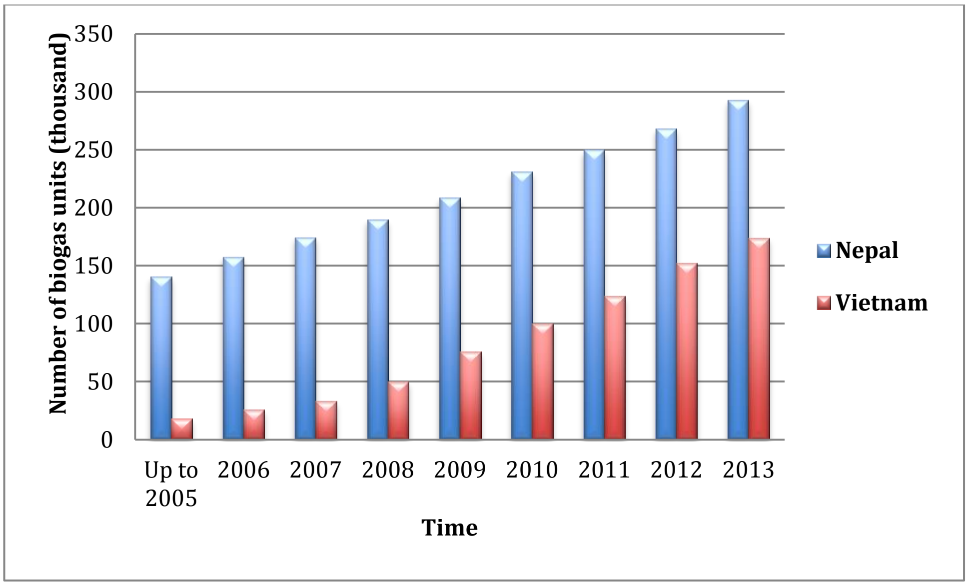

Figure 9. The cumulative number of biogas units installed in Nepal and Vietnam between 2005 and 2013.

With the support of SNV, market-based national programmes have started in eight Asian countries. In Asia, 537,460 biogas plants had been installed by the end of 2013. Data regarding the installation of biodigesters in the six other Asian countries in the period from 2005 till 2013 are presented in figure 10 (cumulative number), figure 11 (number installations per year per country) and figure 12 (number of installations divided by total population in 2013).

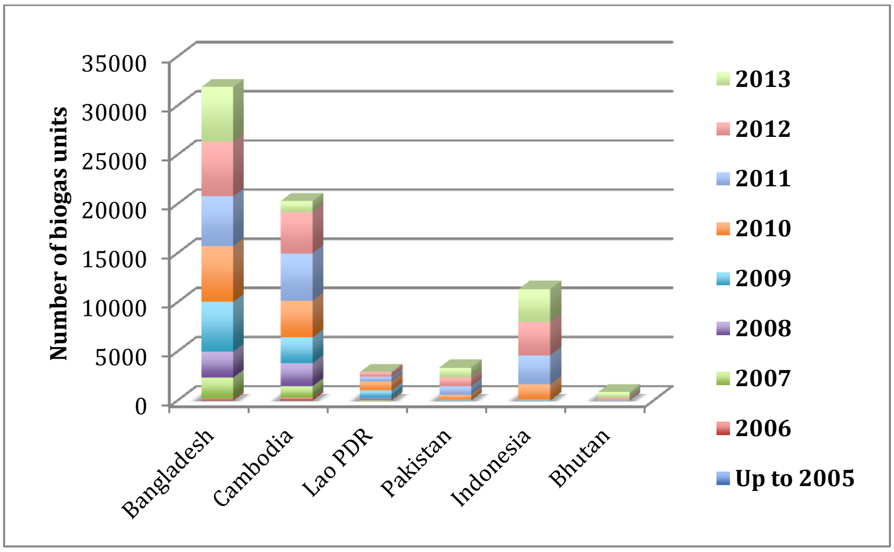

Figure 10. Cumulative number of domestic biogas plants installed per country and year in Bangladesh, Cambodia, Lao PDR, Pakistan, Indonesia and Bhutan up to 2013.

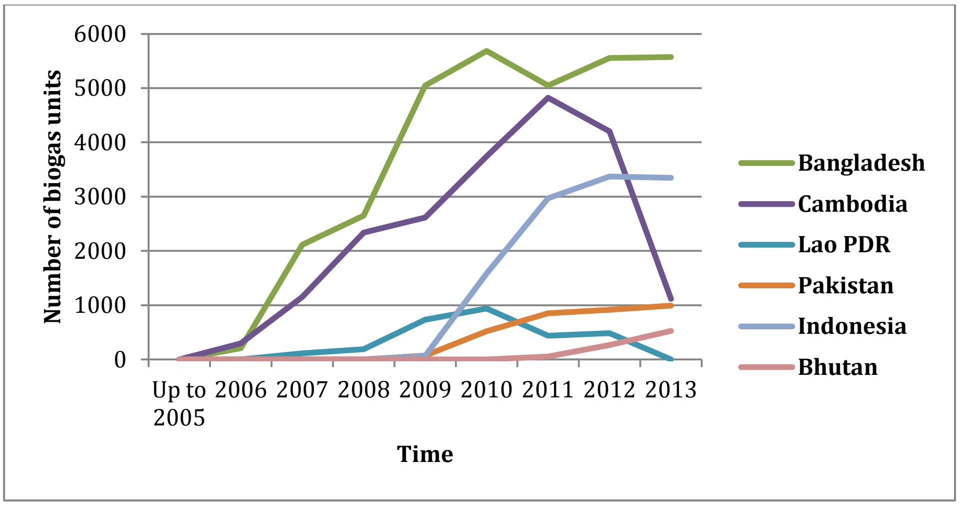

Figure 11. Number of domestic biogas plants installed by country and year in Bangladesh, Cambodia, Lao PDR[5], Pakistan, Indonesia and Bhutan up to 2013.

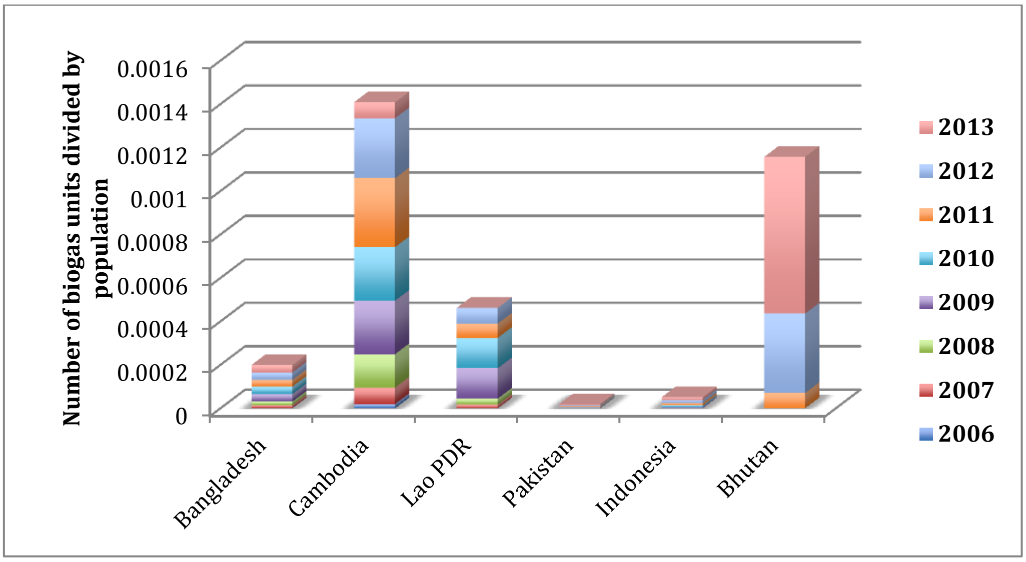

Figure 12. The total number of installations between 2006-2013 standardised by the country population (in 2013). Data available for Bangladesh, Cambodia, Lao PDR, Pakistan, Indonesia and Bhutan.

As shown in the figures above, in all Asian countries the number of biodigesters has increased between 2006 (total number of biogas digesters was 183,870), and 2013 (total number of biogas digesters was 537,460, accomplishing a 192% increase). After Nepal and Vietnam, the programmes in Bangladesh and Cambodia realized the largest numbers of biodigesters, respectively, 31,886 biogas installations and 20,288 biogas installations up to 2013. The Indonesia Domestic Biogas Program, managed by Hivos, reached a milestone of 11,250 biodigesters built between 2009-2013.

5 Note that the number of biogas installations in Cambodia and Lao PDR declined after 2011. This is because there are only small programmes left in these countries that do no promote anymore on a scale as before. Also there is more production outside the programme, because there are no subsidies available anymore.

In comparison to the Asian countries, the uptake of biogas technology occurred at a slower rate in African countries. For the six ABPP countries, the programme aimed to install a total of 70,550 biogas digesters in 4 years. This target was scaled down at a larger stage to 54,000 digesters in 5.5 years. The reason for this was that the realization of a biogas sector appeared to be more difficult than in Asia (explained in chapter 5.2). The six ABPP countries did not reach its numerical target at the end of 2013. However, most programmes did come close to its targets. Exceptions are Uganda that did not perform well. In addition, Ethiopia and Burkina Faso are still slightly lagging behind. However, as shown in figure 13, the production rates in Uganda have been improving during the last year. Furthermore, Burkina Faso and Ethiopia show a positive development of production in recent years as well. The Senegal programme was closed in July 2011. The main reason for this was that the organizational structures in the country were too limited to providing support by SNV and Hivos (SNV, 2014). Hence, the production of the biogas installation did not increase after this period.

Although the uptake of the biogas technology has not gone as fast as in Asia, in all participating countries in Africa the biogas has gained significant acceptance and recognition. Programmes have been able to reach unprecedented numerical and development results compared with all past experiences in Africa, like the Ethiopian case in chapter 3.2. Resulting that by the end of 2013 41,842 biogas digesters were built in Africa under the SNV and Hivos approach.

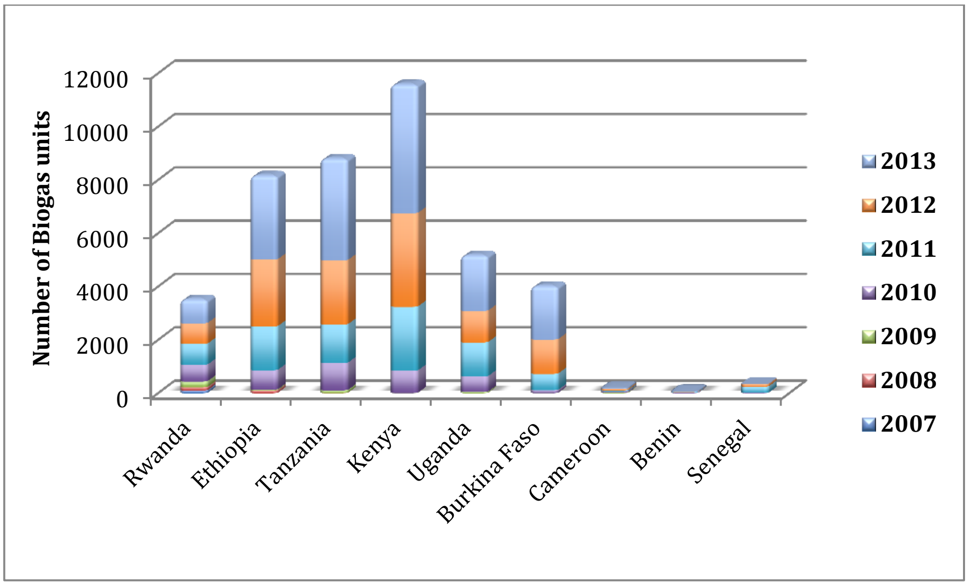

Figure 13. Cumulative number of domestic biogas plants installed by African country (Rwanda, Ethiopia, Tanzania, Kenya, Uganda, Burkina Faso, Cameroon, Benin and Senegal) and year up to 2013.

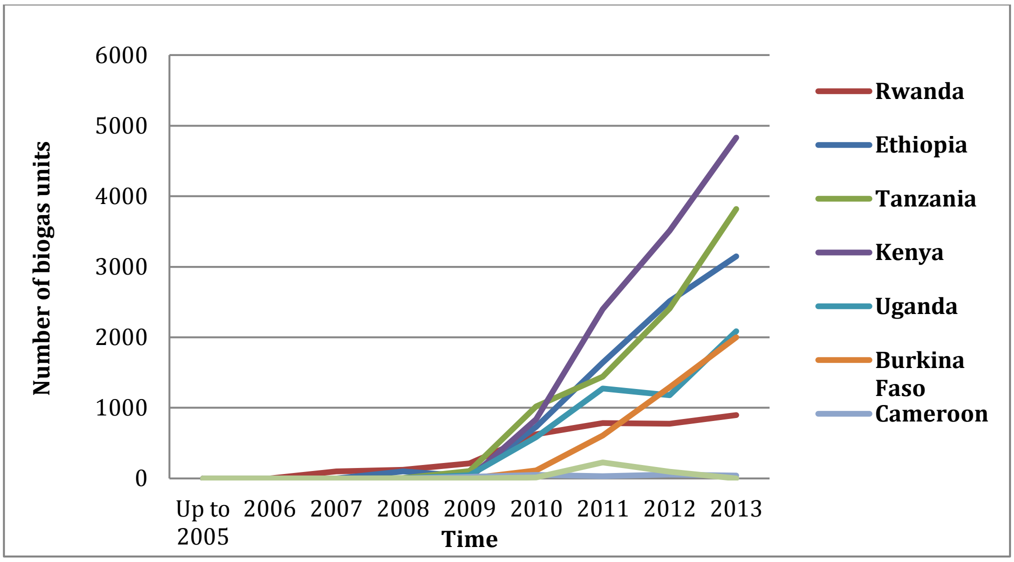

Figure 14. Number of domestic biogas plants installed by African country (Rwanda, Ethiopia, Tanzania, Kenya, Uganda, Burkina Faso, Cameroon, Benin and Senegal) and year up to 2013.

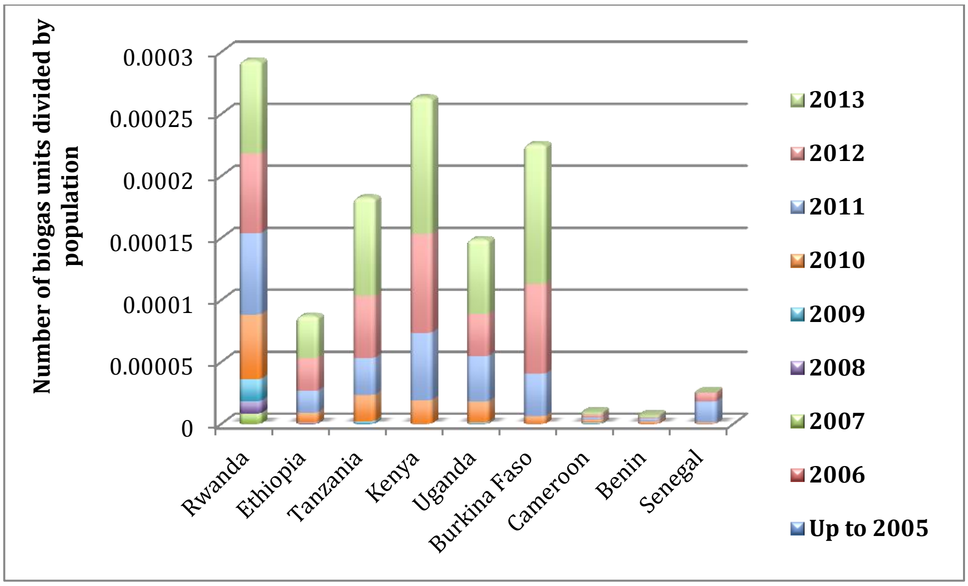

Figure 15. The total number of installations divided by total population in 2013, in Rwanda, Ethiopia, Tanzania, Kenya, Uganda, Burkina Faso, Cameroon, Benin and Senegal up to 2013.

In conclusion, in almost all of the Asian and African countries, the level of production has been growing steadily over the last decade. Logically, this growth was strongly correlated with the level of the sector development. If the sector is well developed, there is a strong institutional infrastructure, and therefore, organizations are more effective. Hence, the sector performs. Visa versa, if the sector is poorly developed, the institutional infrastructure is not strong and/or organizations are less effective and the sector cannot perform well (ABPP Phase II, 2013).

5.1.3 Affordability

In the biodigester programmes of SNV and Hivos the costs of installing a biogas digester vary a lot. The cost of the investment varies between 300 and 600 euros in Asian countries and 500 Euro to 1000 in African countries. This depends on the size of the plant, labour-wages, availability of construction materials, location of construction, and end- use applications (Ghimire, 2013). Biogas units continue to be more expensive in Africa than in Asia. This can partly be explained by the business environment (high prices of fittings and cement, high artisan wages) and partly results from the relatively low penetration rate in Africa. Although the biogas units are more expensive in Africa, prices are coming down (figure 16). For example, the average cost declined in Rwanda from 963 euros in Q1-2012 to 673 euro in Q3-2013 (decline of 30%) and in Uganda the cost declined from 588 to 535 euros (decline of 9 %) over the same period. This is a result of the biogas programmes, in the means of steady improvement of the local technical expertise, and because the development of R&D to use locally obtainable materials for the construction of biodigester. Note that in Tanzania the investment costs have gone up during this period. This is the result of the large share of SSD installations.

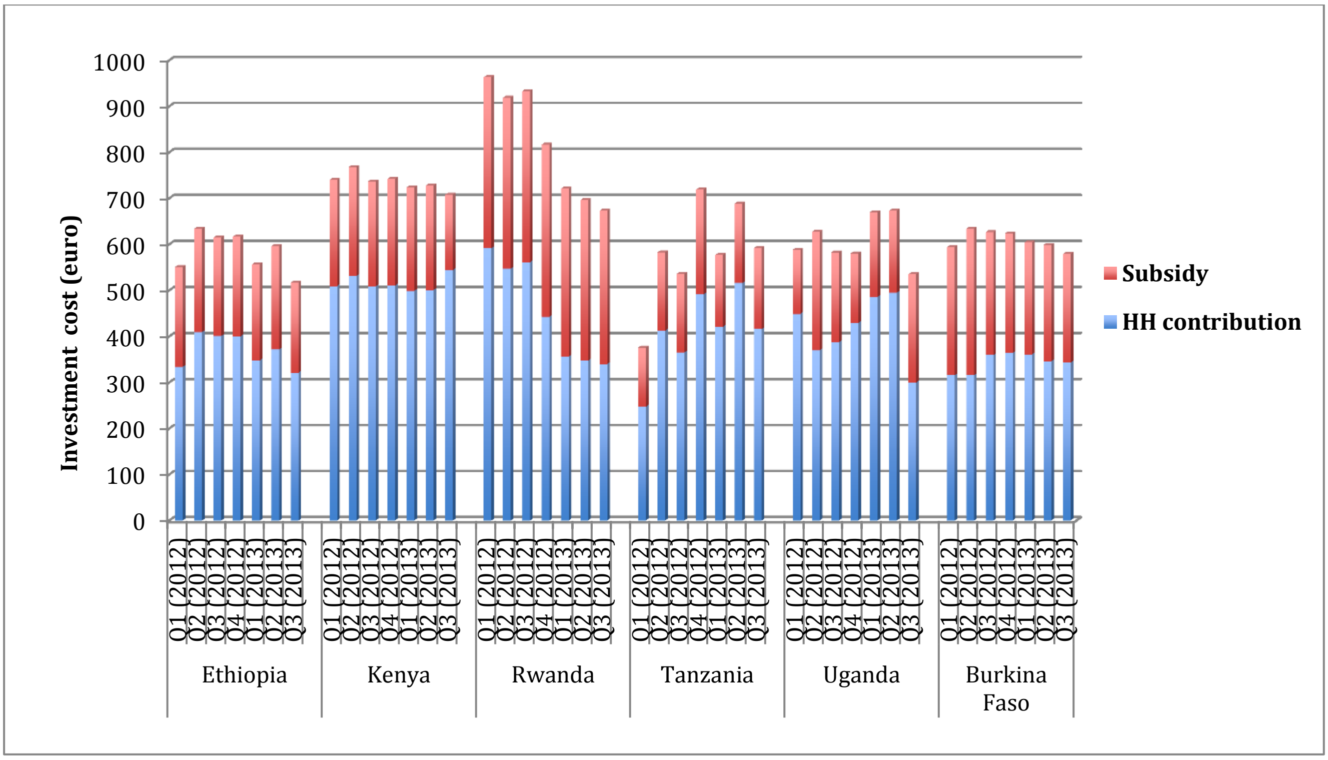

Figure 16. Investment costs (euro) with subsidy and house hold contribution in Ethiopia, Kenya, Rwanda, Tanzania, Uganda and Burkina Faso, in 7 quarters: Q2012) to Q3-2013.

In figure 17, the investment as share of GDP per capita in the period from 2010 to Q3-2013 in Ethiopia, Kenya, Rwanda[6], Tanzania, Uganda and Burkina Faso are presented. In addition, this graph shows a reduction in investment cost as share of GDP per capita for that period. Figure 18, where the total costs in euro/m^3 digester volume are presented over a period of 7 quarters, shows a steady decrease.

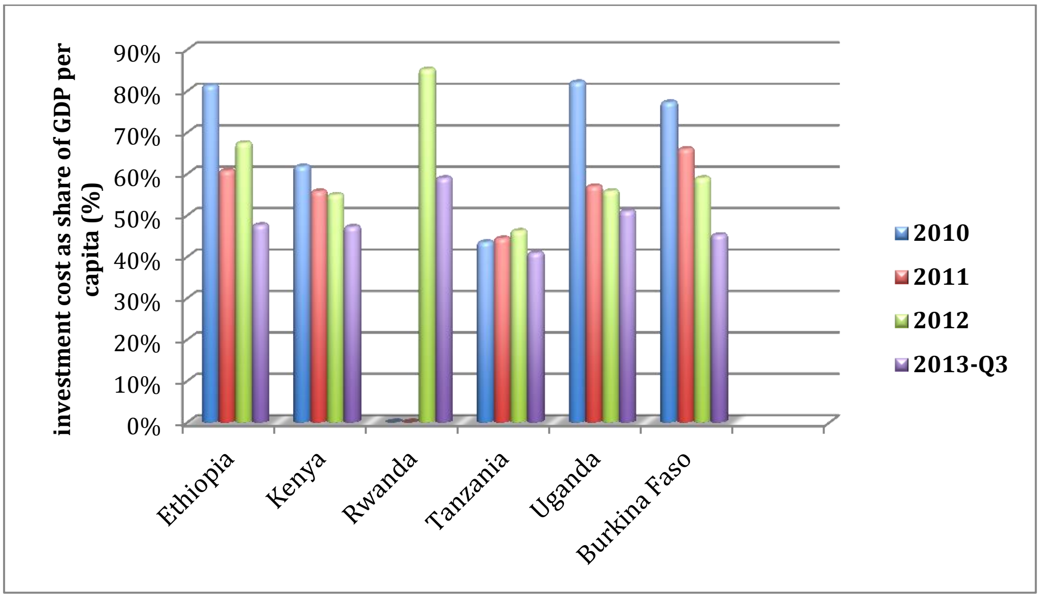

Figure 17. Investment as share of GDP per capita over the years (2010-2013-Q3) in Ethiopia, Kenya, Rwanda, Tanzania, Uganda and Burkina Faso.

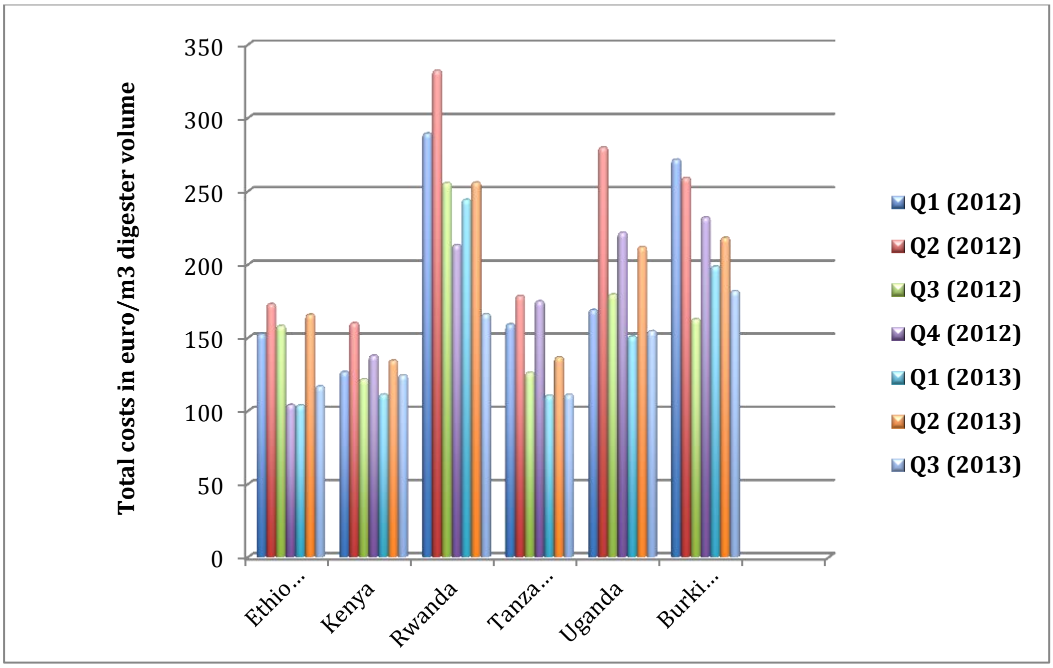

Figure 18. Total costs in euro/m^3 of digester volume in Ethiopia, Kenya, Rwanda, Tanzania, Uganda and Burkina Faso in 7 quarters: Q2012) to Q3-2013.

[6] *Data Rwanda is missing for two years (2010 and 2011) because there is no data.*

In most African countries, the cost per digester are still high but are coming down. However, not at a rapid rate; the average cost in the six African countries declined from 637 euro in Q1-2012 to 601 euro in Q3-2013 (decline of 5.8%). Therefore, the financial accessibility for many poor people is still a constraint for supporting a continuous growth pattern. This is in particular the case if an effective credit system is not available. Nevertheless, it is expected that a further reduction of biogas unit prices can be achieved by 25% to 30% on average, when using local materials. The only exception to this reduction is Burkina Faso, because here similar cost reductions have already been achieved due to the national biogas programmes of SVN and Hivos. It is important to note that such cost reduction would compensate for subsidies (Mshandete and Parawira, 2009). In the ideal case, the cost per plant are low and subsidies are no longer required.

As mentioned before, the average cost of a digester is lower in Asian countries compared to African countries. However, as demonstrated in figure 19, the average costs have increased between 2008-2012 in Bangladesh, Cambodia, Indonesia, Nepal end Vietnam on an average by 24% (€ 352 to € 435). This high cost explained by higher prices for construction materials (especially cement) and that the average size of the biogas plants in Bangladesh and Vietnam has increased over the years. Inflation and exchange rate between local currencies and the euro has also influenced the increased cost. In addition, the investment cost as share of GDP per capita has declined over the years (figure 20).

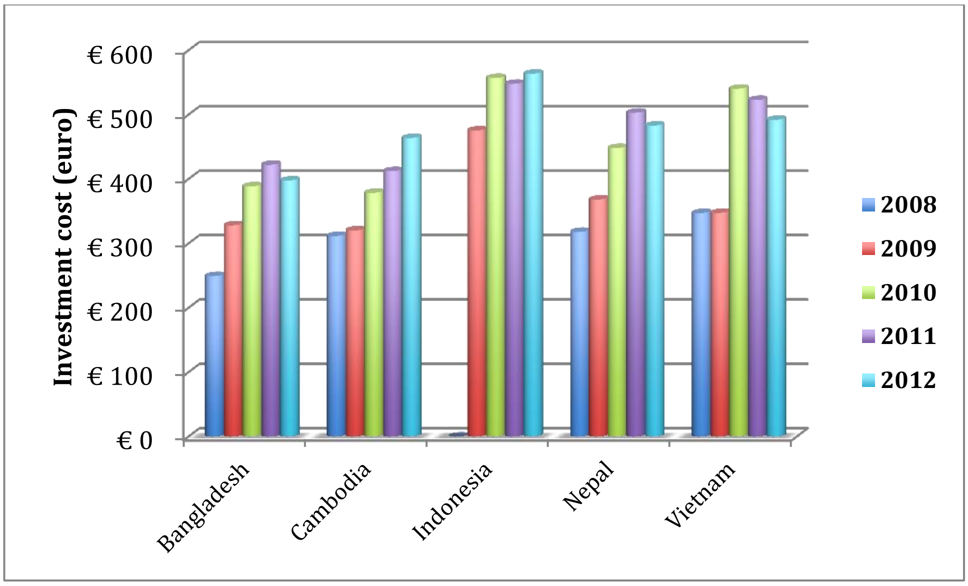

Figure 19. Average cost of an average-sized digester over the years (2008-2012) in Bangladesh, Cambodia, Indonesia, Nepal and Vietnam (euro).

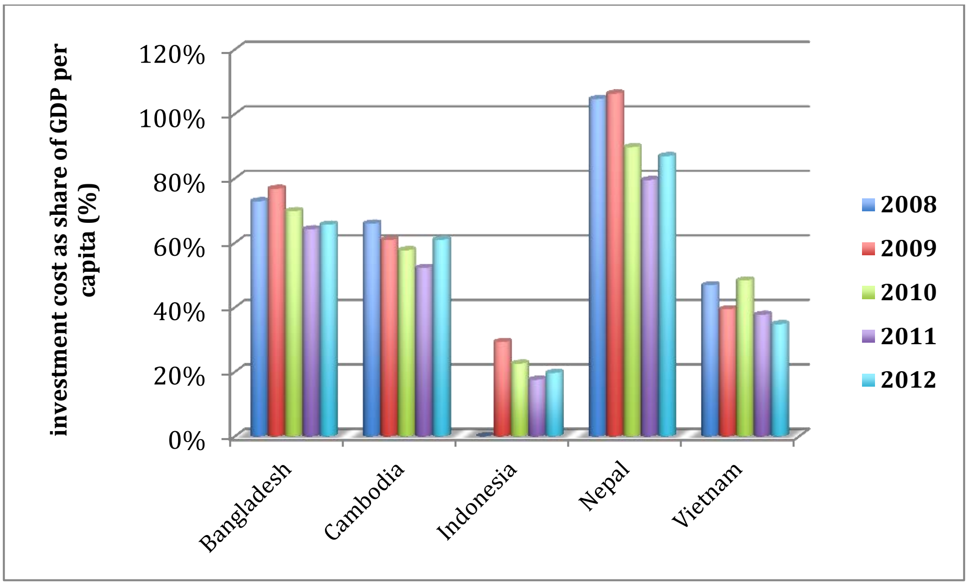

Figure 20. Investment cost as share of GDP per capita over the years (2008-2012) in Bangladesh, Cambodia, Indonesia, Nepal and Vietnam.

The availability of credit also affects the rate of adoption of biodigester. According to Mwirigi et al. (2014), several Asian countries and Ethiopia show that when credit is available, 50% to 60% of the households will finance their biodigester with the help of credit. Therefore, the growth will increase by 25% to 30%. For example, in Ethiopia, the biogas programme showed poor performances in 2009 and 2010. However, an exponential increase in biodigester units can be noted after regional government support for credit was launched. Through credit availability, dissemination is being accelerated and the poorer segments of the population are reached (Mwirigi et al., 2014).

The biogas programmes of SNV and/or HIVOS are increasingly prioritizing the availability of credit for households and much effort is actively put into achieving this objective. As a result, more micro credits specifically for biogas installations have become available for end-users. For example, increased interest into credits provided by the Rabobank Foundation can be noticed. Similar interests can be noted by national banks in several countries, for example by CBA in Tanzania. At present, for the Asian countries, the usages of loans are higher than in African countries. For example, 86% of all biogas units are financed through credit in Bangladesh, in Indonesia this number is 84% and in Cambodia 54% of the biogas plants are financed through credits (Mwirigi et al., 2014). For six African countries, the share of micro-credit used for the financing of biodigesters is presented in figure 21. The initial high loan share is, in particular, noticeable in Ethiopia and Rwanda. The provision of credit for biogas installations is steadily developing in Kenya. Nonetheless, credit availability is still a concern in Uganda, Tanzania and Burkina Faso. This is due to the fact that in these countries the microcredit sector is still underdeveloped. The underdevelopment in these countries is one of the main reasons why the number of biodigesters has not increased as much, in comparison with other countries where the biogas programmes are implemented by SNV and Hivos (Mwirigi et al., 2014).

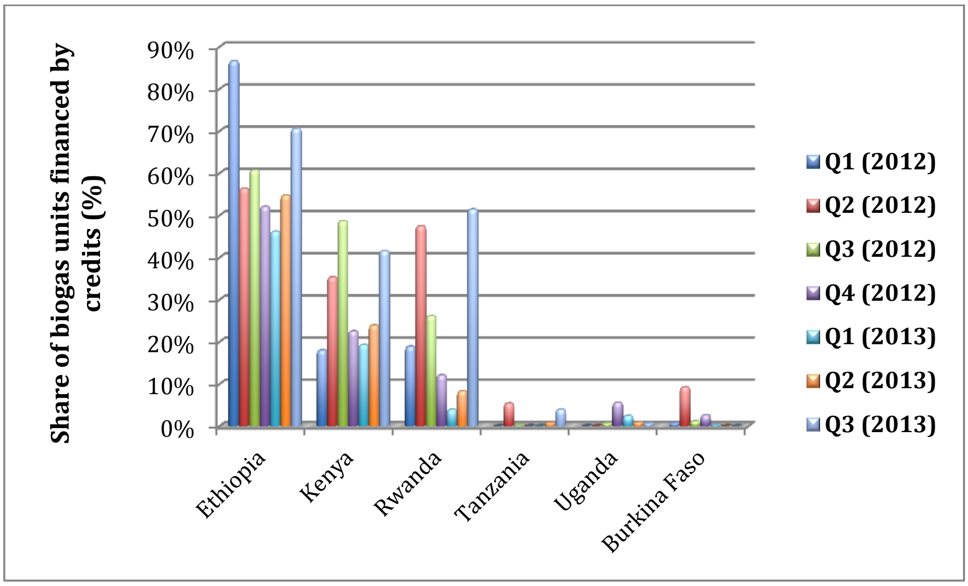

Figure 21. Share of digesters financed by credits in Ethiopia, Kenya, Rwanda, Tanzania, Uganda and Burkina Faso per quarter: Q1-2013 to Q3-2013.

In general, domestic biogas digesters are relatively expensive. Therefore, it is important to establish whether the benefits of a digester outweigh the investment cost for a small farmers household. Table 5 depicts the potential benefits that a household can achieve, on average, when they invest in a domestic biodigester. It is important to mention that the information in this table is not applicable for all households since not all households make use of chemical fertilizers. Nevertheless, this table reveals data that is coherent with many programmes. The table indicates that digesters can be paid back from cost savings or additional income in a rather short period of time, namely in two to three years. For this reason, the installation of a biodigester is an attractive proposition. Especially, since not all benefits are not mentioned in this table (data ABPP Hivos, 2013).

Table 5. Average cost and benefits of the biogas digester (data ABPP Hivos, 2013).

Digester size	6 m³	8 m³	10 m³	12 m³
Actual Investment costs (US$)	700	800	900	1000
Annual Maintenance costs	30	40	50	60

Annual Fuel cost reduction	120	150	180	210
Annual Fertiliser cost reduction	40	50	70	100
Annual Food cost reduction	60	80	110	150
Annual Additional revenue from increased agricultural production	120	150	200	250
Balance of annual costs and benefits to the rural household	310	390	510	650
Simple payback (years)	2.3	2.1	1.8	1.5

5.2.4 Bio- slurry Extension

The residue of the production of domestic biogas is 'bio-slurry.' This slurry can simply be collected and used as organic fertilizer. However, as mention in chapter 2.1, the value of this fertilizer depends on the nutrient losses (leaching of nitrogen and potassium and volatilisation of ammonia) that occur during storage, handling and/or application. In the biogas programmes of SNV and Hivos research is done on the comparative value of the slurry as fertilizer and soil improver (Bonten et al., 2014).

At the same time, the most biogas programmes supported by SNV and Hivos in both Asia and Africa has included a bio-slurry extension component to realize the benefits of the use of bio-slurry. This component aims to maximize the revenues for farmers on their investments by making optimal use of the bio-slurry compost as organic fertilizer to improve agricultural productivity. The national biogas programmes have bio-slurry officers that are working with several institutions who deliver extension services. The extension is carried out in numerous ways: directly thought by the bio-slurry officers, visits to neighbors (promoter and model farmers), through government and private training institutions, in short courses, through rural development NGOs, longer trainings, presentations, etcetera. (SNV, 2009). The companies that construct the biogas digesters are increasingly encouraged to provide bio-slurry extension in their installations, like compost pits[7]. A study conducted in Nepal shows that compost pits have become a fundamental requirement of biogas units to collect the biogas-slurry. The availability of compost pits in the installation not only provides protection of bio-slurry from surface flow, but also enhances the process of decomposition. The size and number of the pit are normally determined by the biogas plant size and the availability of space (Country Report on the Use of Bio-slurry in Nepal, 2006).

In this research the similar measurement for extension is used as the dashboard 2013 interim report: "the extent to which farmers made special provisions aiming at proper bio-slurry application (compost pits)". In figure 22, the extension in Ethiopia, Kenya,

[7] A slurry pit is a hole in the ground where the slurry flows into when the gas pressure in the dome builds up. The slurry is store temporarily in this pit before it is applied to the field. When there is organic waste on the farm, this waste can compost together with the slurry to improve the fertilizing quality. This is done in another hole or two holes, called the compost pits.

Rwanda, Tanzania, Uganda and Burkina Faso over 7 quarter (Q1-2012 to Q3-2013) is presented. It is important to note that extension is only captured in a limited way. The farmers apply the bio-slurry to the crops and fields. Experts explained the exact dosage and usage to them. Once the farmers applied the slurry optimally they are able to achieve much higher production. This additional benefit is not captured in the measurement for extension. Furthermore, only data dating back 2 years is available. Nonetheless, figure 22 clearly shows that the installations in Burkina Faso and Rwanda remain being delivered with a compost pit. Being at a low rate, Tanzania displays steady improvement in 2012 compared to 2011. Unfortunately, the usage of compost pits in Uganda has worsened in 2013.

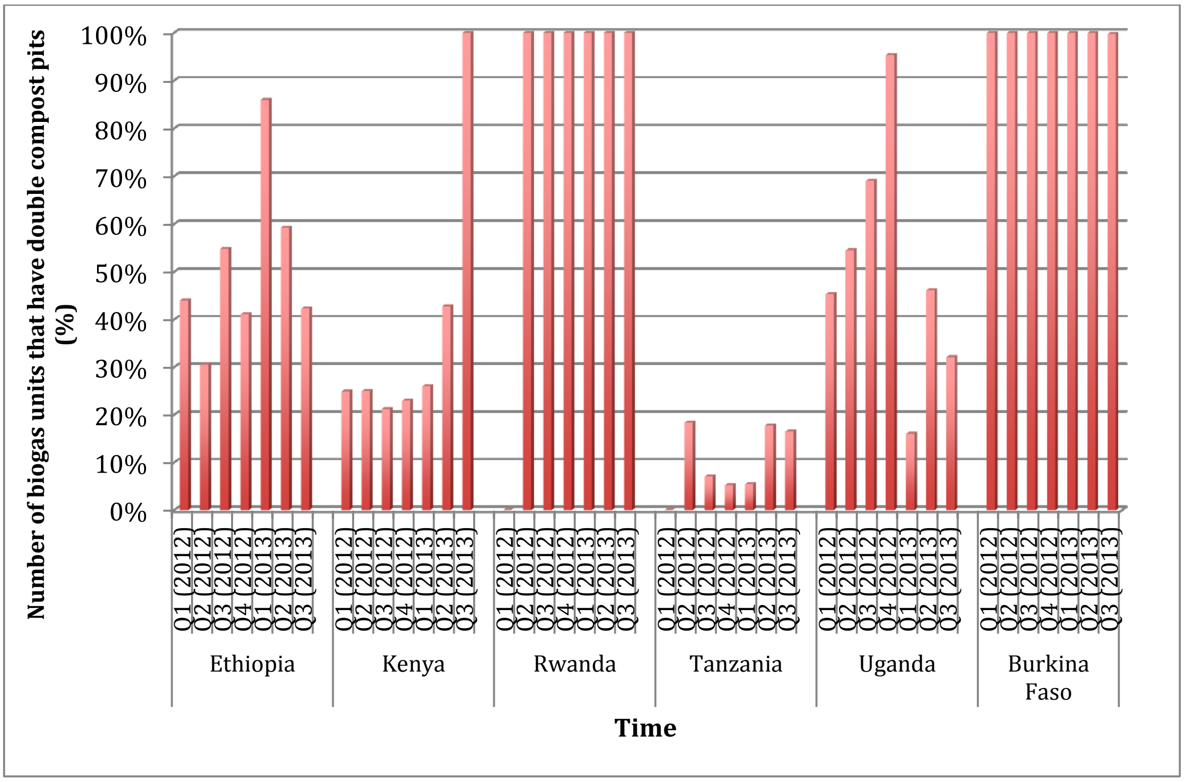

Figure 22. The share of compost pits attached to installations in Ethiopia, Kenya, Rwanda, Tanzania, Uganda and Burkina Faso over 7 quarter (Q1-2012 to Q3- 2013).

The task of the national programmes is to increase the number of extension services (mainly with farmers' organizations) and it is expected that this increase will take place in the years to follow. [8]

[8] Personal communication with Mr Harrie Oppenoorth, Senior Adviser in Renewable Energy, Hivos (3 juni 2014).

5.2.5 Gender

Women are primarily responsible for biogas related activities such as, the collection of cooking fuel, organization of cattle dung, cooking, cleaning of cooking pots and the collection of water. Hence, the installation of a biodigester benefits women the most (Ghimire, 2013). Therefore, it is essential for the biogas programmes to have a particular focus on women (Kaygusuz, 2011).

The SNV and Hivos programmes aim that the role of women in society will become more on the foreground. They do so by empowering them as masons, plant owners, and also by creating useful economic time that was previously wasted in search of fuel.

A study conducted in Nepal, researched the effect of biogas as a "new technology" on the workload of women from a gender perspective (NDBMP, 2008). The research demonstrated that the female users perceived this technology as workload reducing in two ways. Firstly, in a quantitatively manner – the collection of fuel wood for cooking was reduced by a factor of 5. Secondly, in a qualitatively manner - washing pots to remove stains created by the fire was no longer needed, cooking became easier, one does not have to blow the coals to keep the fire burning, indoor smoke is not developed and mainly not needing to go to the jungle was felt as an improvement. Whereas the above benefits are usually expressed in most studies, a biogas study in Bangladesh (reference) states that the workload of several women did not decrease (UDBP, 2013). The explanation for this is that the women spent the time that had been saved on other household chores. Just a small percentage of women (4%) stated that their workload had increased because of maintenance and management of the biogas plant, livestock caring, slurry management and other biogas plant operation laborious.

The participation of woman in the biogas technology varies by country as shown in figure 23. For example, the share of loans extended to women in three selected African countries is presented in figure 23. In particular in Kenya it is shown that women got most loans for biodigesters (80-90%). In Ethiopia, mainly men received the majority of loans, because here the decision-making power lies with the male heads that control resources and its allocation (Mwirigi et al., 2014).

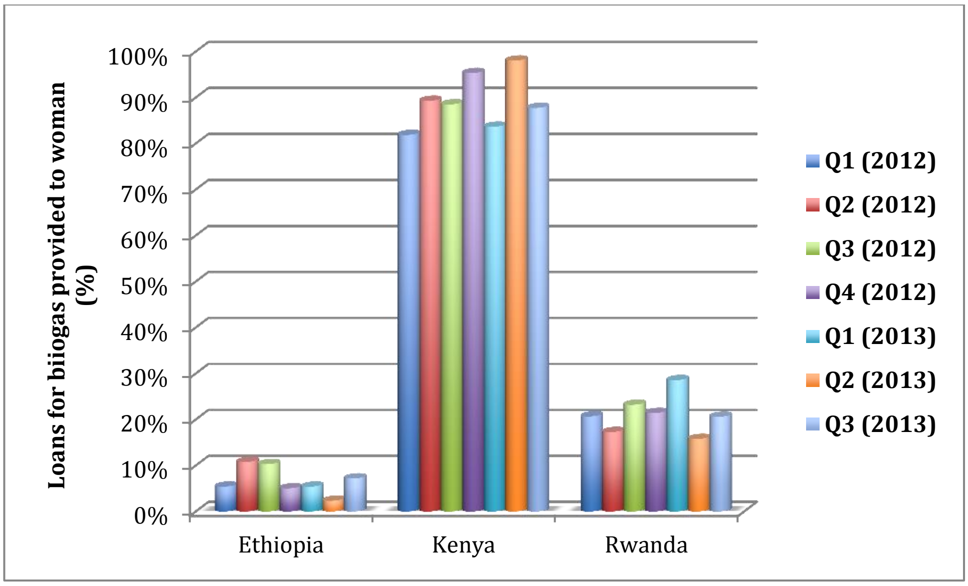

Figure 23. Percentage of loans for biogas provided to women for Ethiopia, Kenya and Rwanda.

The participation of women in the operation of the installation and training on how to use it is crucial for the successful operation, since they are the main operators of the biogas installation. A proper understanding of the system is thus vital, knowing how to feed the system, as well as the functioning of the valves, how to tweak the stove, etcetera lead to a successful operation. (ABPP, 2013). Figure 24 shows that average female participation in the Operation and Maintenance (O&M) training in six African countries increased from 35% in Q1-2013 to 52% in Q3-2013. Since the percentage of women participation is still not high, biogas programmes have to pay additional attention to the participation of woman in this training.

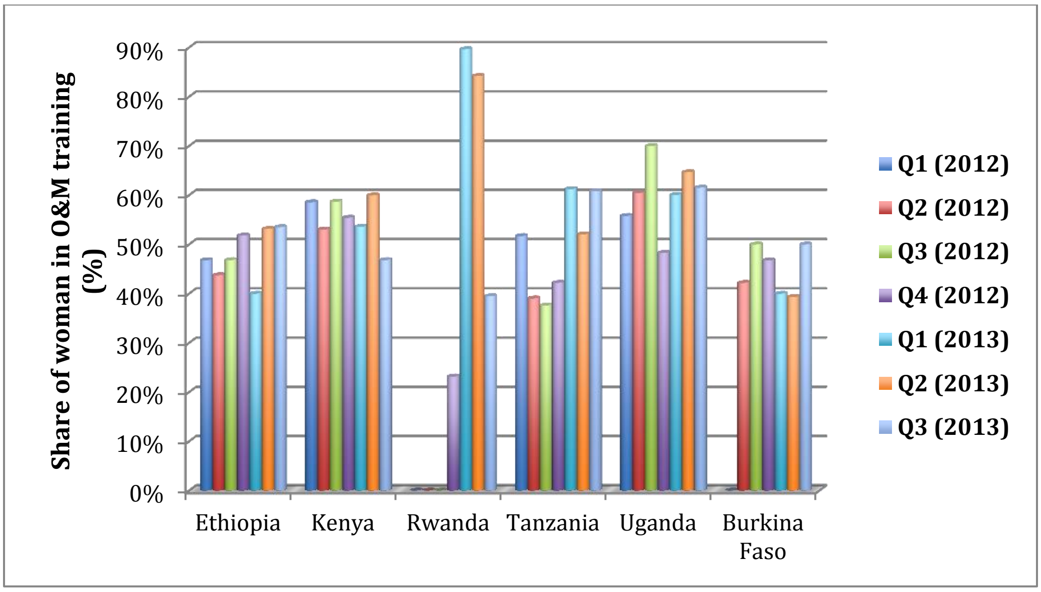

Figure 24. Share of women in O&M training (%) in Ethiopia, Kenya, Rwanda, Tanzania, Uganda and Burkina Faso, in 7 quarters: Q1-2012 to Q3-2013.

Likewise, participation of women in training on how to use bio-slurry (figure 24) is important. Also in here, the average female participation increased from Q1-2012 to Q3-2012, but is still too low (in Q1-2012 a percentage of 36% of woman and in Q3-2013 a percentage of 47% of woman participated the bio-slurry training).

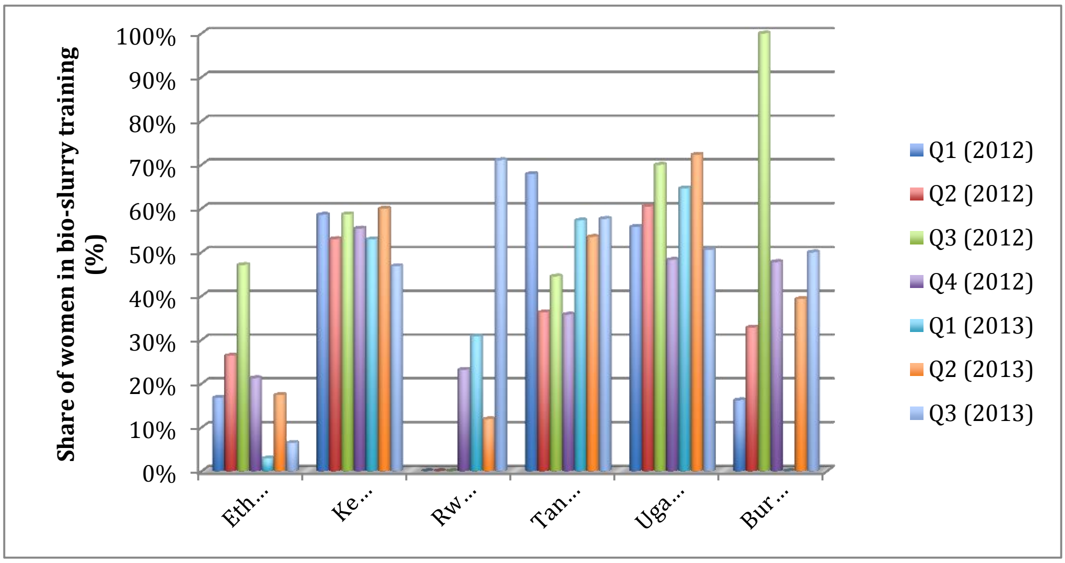

Figure 24. Share of women in bio-slurry training (%) in Ethiopia, Kenya, Rwanda, Tanzania, Uganda and Burkina Faso, in 7 quarters: Q1-2012 to Q3-2013.[9]

The awareness of gender differences in the national programmes is increasing. However, up to this point women are not predominantly attracted to the biogas construction. This can be concluded because both in employment and in training, women play to small of a role. Nevertheless, the participation of women in the training has increased from Q1-2012 to Q3-2013, and thus a modest improvement is visible.

5.2 Programmes in Africa and Asia

For the African countries, the number of biogas units that are already installed may seem high as demonstrated in section 5.1.2. This growth may seem rapid, however, less than 1% of the technical potential has been tapped into in each of the six African countries. For this report, "technical potential" is defined as the number of households that fulfills the following two basic requirements to run a biogas installation: 1) sufficient obtainability of dung and 2) access to water (Heegde and Sonder, 2007). The estimation of the potential for domestic biogas in Africa is high; the technical potential

9 Data for Q1-2013 in Burkina Faso is missing, since this data was not collected in that period.

market in Africa for biogas installations is estimated at 18.5 million households (Nes and Nhete, 2007).

Despite the huge potential of biogas, the dissemination of the biogas technology in Africa has not been that successful relative to Asia. This is caused by the failure of national governments to support biogas technology by the means of a clear energy policy. Moreover, the following barriers were faced in the dissemination of the biogas technology: poor dissemination strategies, poor design of biogas plants, lack of maintenance and monitoring, poor ownership responsibility by users, ethnical barriers, lack of awareness raising activities, fewer animals are available for manure production in comparison to Asia. The two main problems for rural farmers are: (1) the investment cost of biogas plants is often far too high for the rural farmer. This high cost is the result of the fact that labour and prices of construction materials are higher in Africa compared to Asia. (2) The credit facilities are not as widely spread in Africa (Arthur et al., 2011).

6.0 Discussion

The results of the evaluation of the SNV and/or Hivos biogas programmes show that the approach has been successful especially in Asia; most programmes have resulted in the construction of a considerable number of biodigesters, many BCE's were involved and created, new models of biodigester are entering the market, the investment cost are declining (already low in Asia) and financial institutions offer microcredits (more in Asia).

This success can be explained by the transition framework that is based on the Multilevel Perspective on System Innovation elaborated by Geels (see chapter 3.4). The biogas programmes of SNV and Hivos are not only introducing the biogas technology through a demonstration project or a pilot. In the case of Ethiopia, where dissemination of the technology did not take place on a large scale, it was seen that solely a demonstration project or pilot did not contribute to widespread dissemination of biodigesters (chapter 3.2). In the biogas programmes where the approach of SNV and Hivos is applied, a holistic perspective is taken. Meaning that the whole biogas sector and the relationship between the *micro, meso* and *macro* levels are taken into account. These three levels all play an important role in the dissemination of the biogas technology and they are being approached differently (Arthur et al., 2011). For example, at the *micro* level, intensive promotion, sales and campaign programmes are developed. At the *meso* level different functions, which are fulfilled by different actors are analyzed. At the *macro* level (which receives less attention in their analysis) they find that the biodigester market is rather stable and minimally affected by landscape changes (Mwirigi et al., 2014).

Furthermore, according to Romijn et al. (2010), active inter-stakeholder interaction in the niche network and the formation of expectations concerning the innovation among and within several social groups are likely to be very important for successful outcomes. The relevance of this is in particularly seen in the up-scaling of technologies. This is also showed in the Indian case (chapter 3.3), multiple agencies were present in the network, and consequently the programme was successful. These two processes are also highlighted in the market based multi-actor sector development approach of SNV and Hivos.

However, despite the significant achievements of the national biogas programmes where the multi-stakeholders sector development approach is applied, the sector and the market are still facing several challenges to achieve up-scaling targets and to deal with capacity constraints. The programmes key conditions and proposed activities are:

- The dissemination of the biogas technology on a wide scale is difficult in countries where a policy on renewable energy is largely absent. Therefore, renewable energy should be part of the government's policy agenda (Ghimire, 2013). The Government is supposed to provide the policy, but will not act as an implementing agency. An independent implementation agency with a full mandate to implement the biogas programme is essential.
- A national policy has to be developed in such a manner that the participation of private companies in the biogas sector is stimulated. The reason for this is that the private sector plays a key role in the promotion of renewable energy, making the biogas sector market-oriented and commercially sustainable. Furthermore, the financial viability of the private sector needs to be strengthened to guarantee sufficient supply of biogas producers (Ghimire, 2013).
- Lowering of the existing costs of installation without affecting the quality and performance is required and access to microcredit to make the biogas digester more affordable are crucial to ensure the supply to those at the lowest layers in the socio-economic pyramid. The carbon fund can be a sustainable source of money to continue the programme. Therefore, attention should be given to this fund from the start. Subsidies can be a temporary solution, but to make the sector sustainable the final goal is to face out subsidies.

- Institutional capabilities of the multiple stakeholders need to be supported. Furthermore, collaboration between the stakeholders, even if their interests are different and sometimes conflicting, can improve the chances of success (Ghimire, 2013). The ultimate goal is to decrease the programme support and increase privatized coordination.
- The growth of slurry extension can improve production and increase income. Consequently, the capacity to repay loans is enhanced. This can be achieved since the slurry decreases traditional fertilizer expenses.
- Create awareness and encourage potential farmers to make use of the biogas technology. Specifically, if they have had previous negative experiences with the technology.
- Also, programmes can be faced with political instability in a country and/or extreme weather conditions such as floods, earthquakes and droughts. This could hinder the progress of the programme. Hence, risk management should be performed and integrated within the programmes.

With the proposed activities, it is expected that countries were the approach is applied will succeed to achieve a sustainable private sector led market development where the sector develops its own dynamics. In the long run, the sector will be able to continue without the programme support that was initially needed.

7.0 Conclusion

In this research, the domestic biodigester approach of the Dutch NGOs SNV and Hivos is evaluated. Furthermore, the key success factors and constraints behind its implementation in both Africa and Asia are identified.

The findings of this report show that the use of the biogas technology offers many socio-economic, environmental and health benefits. In addition, if enhanced and continued, these benefits can contribute to the Millennium Development Goals. However, often the literature reports short-term successes of biogas programmes and failure of the programmes in the long run. These failures can be explained because biogas programmes do not focus on the biogas sector as a whole. A holistic approach is in most cases necessary for success. For the development of a biogas sector, it is essential that there is close cooperation between all relevant stakeholders (non-government, government, and private sector) and in the sector at all levels (*micro, meso* and *macro*). In that sense, the multi-stakeholders sector development approach of SNV and Hivos that is based on the creation of a market for domestic biodigesters, has been a success:

- Sector development is showing continuous improvements. In Ethiopia, Kenya, Rwanda, Tanzania, Uganda and Burkina Faso the total number of active biogas masons has increased from 262 in Q1-2012 to 3130 active biogas masons in the Q3-2013 (increase of 1095%). Likewise, the number of Biodigester Construction Enterprises (BCEs) has increased in these countries; the total number has increased from 51 in Q1-2012 to 688 in the Q3-2013 (increase 1249 %). Not only in the African countries the number of BCEs increased over the years, but it also did in Asia. For example, in Indonesia this number grew from 4 in 2009 to 58 BCEs in 2013 (increase of 1350%).
- The programs have built a significant amount of biodigesters. The total number of biogas installations that have been installed with the SNV and Hivos approach until 2013 are: 537,460 in the selected Asian countries and 41,842 in the selected African countries.
- In most African countries the cost per digester remain relatively high. Nevertheless prices are coming down. The average cost in the six African countries declined from 637 euros in Q1-2012 to 601 euro in Q3-2013 (decline of 5.8%).
- The number of extension service (mainly with farmers' organizations) is expected to increase in the years to follow.
- A biodigester is a financially interesting investment that gives high economic returns. Additionally, the usage of the biogas resulted in timesaving, mainly for the women who are most involved in household chores.

Despite the success of the national biogas programmes, the high cost of installation and absence of credit for farmers hindered the widespread adoption in the African countries. In general, the findings from this study show the multi-actor market and sector development approach is effective in both Africa and Asia. However, more research is needed to identify if the approach continues to be successful after 2013. In addition, more data from the Asian biogas programmes is required for a more comprehensive evaluation.

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Appendix 1, Dashboard 2012 questionnaire

	Quarterly entry sheet for:													
	Country:	KENYA												
	Programme:	KENDBIP												
Explanations	**Production**	unit	2012-Q1			2012-Q2			2012-Q3			2012-Q4		
			<8 m³	8-10 m³	>10 m³	<8 m³	8-10 m³	>10 m³	<8 m³	8-10 m³	>10 m³	<8 m³	8-10 m³	>10 m³
Construction divided over 3 size categories	Plants per size	[# of plants]	185	425	220	193	411	244	236	445	198	225	494	234
	Affordability	unit	2012-Q1			2012-Q2			2012-Q3			2012-Q4		
Investement of houshehold + subsidy	Average total investment	[KSH/plant]	81,216			81,216			81,216			81,216		
	Average investment subsidy	[KSH/plant]	25,319			25,000			25,136			25,340		
Costs of activities, overheads and NIA/IP costs	Programme support costs ex subsidy	[KSH]	35,220,101			38,298,224			29,815,444			48,877,645		
			female	male		female	male		female	male		female	male	
Loans extended by formal institutions (banks, saccos)	Plants financed by registered loan	[# of loans]	122	27		267	32		378	49		204	10	
	Sector development	unit	2012-Q1			2012-Q2			2012-Q3			2012-Q4		
			female	male		female	male		female	male		female	male	
BMs trained in this quarter	New biogas masons trained	[# of new BM]												
BMs buidling 3 biogas plants or more per quarter	Active biogas masons	[# of act BM]	5	68		6	68		12	80		16	80	
Total # of plants constructed by active masons this quarter	Plants constructed by active masons	[# of plants]	376			357			599			617		
BCEs buidling 9 biogas plants or more per quarter	Active BCEs	[# of BCEs]	23			24			22			23		
Total # of plants constructed by active BCEs this quarter	Plants constructed under active BCEs	[# of plants]	312			304			280			216		
	IPs under contract	[# of IPs]	2			2			3			3		
	Plants constructed under Ips	[# of plants]	274			304			419			673		
	Extension	unit	2012-Q1			2012-Q2			2012-Q3			2012-Q4		
			female	male		female	male		female	male		female	male	
Users trained in this quarter (formal trg setting)	Users trained on O&M	[# of users]	639	452		813	720		873	615		469	377	
Users trained in this quarter (formal trg setting)	Users trained on bio-slurry application	[# of users]	639	452		813	720		873	615		469	377	
	Biogas plants with slurry pit	[# of plants]	647			678			729			848		
	Biogas plants with double compost pits	[# of plants]	207			212			187			219		
	Biogas plants with toilet attached	[# of plants]	0			0			0			0		