Small Biogas Electrical Systems in rural Uganda

Factors for success, opportunities and barriers in an fragmented regime



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Executive Summary

This report aims at helping FACT Foundation—and its innovation partners— understand which are the success factors that are needed to overcome the barriers present in the adoption of small electrical biogas systems (SBES) for productive activities by rural entrepreneurs in Uganda. In order to do so, the report offers a multi-level perspective analysis of the innovation system of biogas technologies in Uganda. The report also analyses the different roles that the rural entrepreneurs, who will adopt the technology, need to play in order to successfully use this type of technology.

The multi-level analysis shows that the innovation system is characterized by the isolation of the different projects that are currently working with biogas in Uganda. Even in the case of the projects that are supported by FACT there is no exchange of experience between projects. The analysis also shows how currently in the rural areas of Uganda access to electricity is gained through different technologies and that there is not a single way—a dominant design—present. Since there is an increasing demand for electricity in Uganda, the fact that there is no dominant design in the way to access electricity can be seen as an advantage for the biodigesters FACT is trying to promote. However this also poses a major problem, since the instability of the innovation system creates more uncertainty towards new technologies and can increase the risk of adopting new technology. The low purchasing power of the majority of the population creates another barrier for the dissemination of SBES. Based on innovation science literature the present report proposes that a first step to overcome these barriers could be to promote the formation of networks between different actors and stakeholders of the innovation system.

As for the different roles of the entrepreneur the analysis shows that targeting big farmers who have access to feedstock and can use the electricity they produce in their own productivity activity could be a promising way to start promoting SBES. Another important characteristic that the entrepreneurs need to have is to be willing to adapt the SBES to its new environment. However this adaptation process cannot be the done only by the entrepreneurs, since it requires external support. This support could be given by both a local partner—situated in the field— and FACT Foundation.

Considering its novelty the SBES still needs to go through a long adaptation process to test not only its technical features but also its socio-economic ones, such as the business model that the rural entrepreneur will use. Because of this the report ends by questioning if Uganda—giving its economic constraints— is the best setting for the initial phase of the adaptation process or if another country with a more developed economy would be a better starting point.

Acknowledgements

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Contents

1. Introduction

This report aims at helping FACT Foundation, and its innovation partners, understand which are the success factors that are needed to overcome the barriers that are present in the adoption of small electrical biogas systems for productivity activities by rural entrepreneurs in Uganda.

In the past years in Uganda several projects have tried to promote the use of biogas technologies to help people in the rural areas improve their quality of life by giving them access to a clean source of energy. However, high investment costs for acquiring these biogas systems continues to be the main barrier that prevents their further dissemination (Kahubire, Byaruhanga, & Mohammed, 2010).

As a way to tackle this barrier FACT Foundation—a Dutch NGO that promotes sustainable biofuels and bioenergy for communities in developing countries—is trying to promote small biogas units that, instead of being used for cooking, will be connected to a electricity generator that runs on biogas. The rationale behind this idea is that the persons who buy the small biogas electrical systems (SBES) will be able to use the electricity to generate an extra income by improving their productivity activities and therefore will be able to overcome the financial barrier.

In this idea the role of small and medium rural entrepreneurs becomes critical, since they are the ones who are expected to adopt the new biogas system. Therefore, FACT Foundation wanted to understand what are the characteristics that an entrepreneur needs to have in order to adopt the new biogas systems for producing electricity and be successful. In order to be able to answer that question, it is equally important to understand the context in which this entrepreneur will be adopting the innovation; therefore studying the state of the innovation system for biogas will be the entry point for this research.

Based on their experience dealing with biogas systems FACT Foundation has developed an idea on the role that entrepreneurs will play in the innovation system. According to their initial view the role of the rural entrepreneur can be divided in three: first, the entrepreneur will have access to feedstock for the Small Biogas Electrical System (SBES) either because he/she produce the biomass by him/her self or by buying it from farmers. Then, the entrepreneur will own, operate and maintain a SBES to produce electricity with the feedstock. Finally the entrepreneur will sell the electricity either to households—by charging batteries—or small and medium enterprises—with a direct connection or by building a mini grid. There is also the possibility that the entrepreneur will use the electricity he/she produces for his/her own business. In their initial vision FACT Foundation also considers a fourth role for the entrepreneur in which he/she will use the slurry that the biodigester produces as fertilizer, which can be sold as a different product or use it to trade for feedstock for the SBES. All of the above can be summarized in Figure 1.

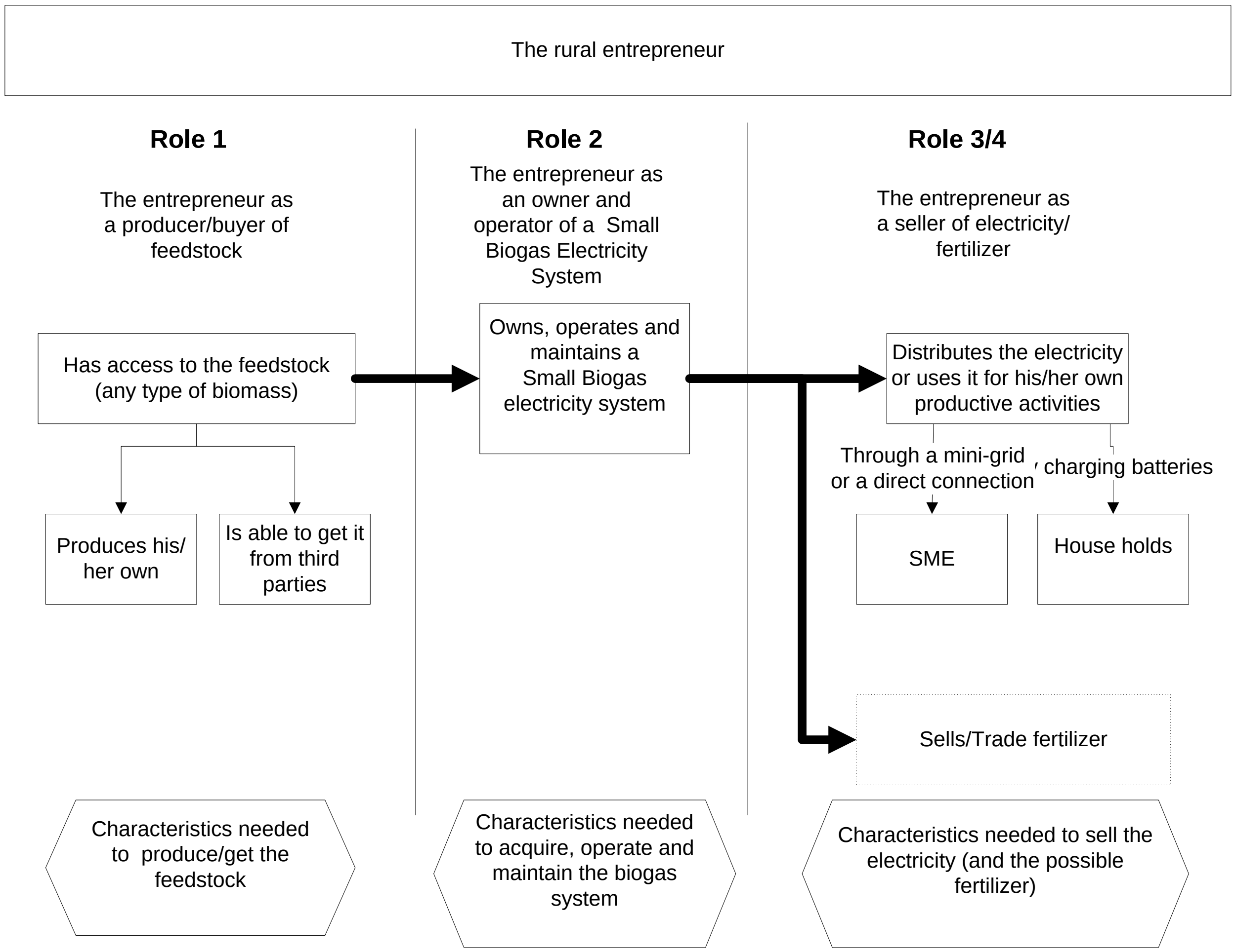

Figure 1 The different roles that the entrepreneur will have, according to the initial view of FACT Foundation

1.1. Research aim

Considering all this the aim of this research is to study the success factors that are needed so rural entrepreneurs are able to use the SBES in a sustainable and productive way.[1] Also this research aims to define the main elements of the innovation system that influence the adoption of small scale biogas electricity systems in rural Uganda, and to understand how these elements may prevent, or help, the entrepreneur fulfill his/her role.

[1] In that sense, I understand success factors as those that allow a rural entrepreneur to own, operate and maintain a small biogas electrical system and use it to generate an extra income that improves his/her quality of life.

1.2. Research question

Therefore the main question that this research aims at answering is the following:

How can innovation and learning theories, together with the expertise of FACT Foundation, be used to define success factors that entrepreneurs in rural Uganda need to have in order to use the biogas electrical system for productive activities.

As a way to answer this question, I divided it in several sub questions

1. How can the innovation system be characterized and what are its main elements? How do they affect the entrepreneur?
2. What are the success factors that the entrepreneur needs to have to fulfill his/her role as a producer/buyer of feedstock?
3. What are the success factors that the entrepreneur needs to have to fulfill his/her role as an owner/operator of a SMBE?
4. What are the success factors that the entrepreneur needs to have to fulfill his/her role as a seller of electricity and fertilizer?

2. Literature review

In this section I review two types of literature that will help me answer my research question. The first one, Strategic Niche Management, comes from innovation sciences and aims at giving a framework that explains how technological transitions happen. The second type of literature I review, The Learning Based Approach, comes from development studies and puts learning as central part of the innovation process. This literature also offers a framework to understand the phases which innovation goes through and offers advices on how to promote the shifting from one phase into the other.

2.1. Strategic Niche Management.

Romijn and Caniëls (2011, p. 619) (citing Hoogma, R., Kemp, R., Schot, J., Truffer, B., 2002) explain that Strategic Niche Management (SNM) claims that successful radical innovations with environmental sustainable characteristics—like biofuel technologies— emerge from socio-technical experiments in which different actors work together and exchange knowledge and experience—thus participate in a learning process—that facilities the incubation of new technologies. The protected space where this interaction occurs is called a niche. Schot and Geels (2008)—reviewing ten years of empirical findings in SNM—claim that there is a need for these protected spaces since new technologies cannot compete immediately in the market against already established technologies. The authors point out how for innovation with sustainability promise market niches and user demand are not readily available, due to the radical nature of the innovations, and therefore there is a need to create protected spaces that "nurtures a specific set of interactions between issues, but also between actors representing these issues" (Schot & Geels, 2008, p. 539).

In a recent paper Smith and Raven (2012) explore the concept of protected space and define three main functions of protection: shielding, nurturing and empowering. The authors define shielding as "those processes that hold at bay certain selection pressures from mainstream selection environments" (2012, p. 1027) and acknowledge that there might be two types of niche spaces, passive and active. In a passive space the selection pressures can be lower because of contingent reasons rather than strategic ones—for example geographical reasons that prevent the expansion of the electrical grid to certain areas. On the other hand, active protective spaces are the result of deliberate and strategic measures created by advocates of a specific innovation in order to shield it from selection pressures from the environment.

Regarding nurturing Smith and Raven define it as "as processes that support the development of the path-breaking innovation" (2012, p. 1027). Schot and Geels (2008, p. 540) —who are also cited in Smith and Raven (2012)—define three internal processes that occur inside the protected spaces and that can be considered as part of the nurturing process:

- The articulation of expectations: Crucial for providing direction to learning process, attract attention and legitimize the protection and nurturing. Expectations contribute to further the innovation when they are robust—shared by many actors—specific and of high quality—corroborated in the use of many projects.
- The building of social networks: A process that is important to create a constituency behind the new technology, a place that facilitates the interaction between the stakeholders and also provides the necessary resources: money, people and expertise. Networks contribute to the nurturing of the niche when they are broad—include plural perspectives—and deep—the members of the network are strongly committed.
- The learning process at multiple dimensions: Related, among others to learning about: the technological aspects and design specification, market and user preferences, cultural and symbolic meaning, infrastructure and maintenance networks. The authors also recognized the need to differentiate between first order learning—where the actors modified their actions according to the difference between expected and obtained outcomes— and second order learning—where the actors question the assumptions, values and policies that led to actions in the first place.

Schot and Geels (2008) also differentiate between two different levels of niches: local and global. Local niches, experiments or local projects, are carried out by a local network of actors who are interested in the innovation for local reasons and experiment with the technology in a specific context. At the beginning the cognitive rules—such as expectations— that guide these projects are diffuse, unstable and broad. As the projects go on and compare and aggregate their learning processes the cognitive rules become more stable, articulated and specific, creating a global niche. It is in this global niche level where an emergent technological trajectory can be seen. It is important to point out that in the SNM literature the term global does not refer necessarily to a worldwide level but rather to an emerging field around a particular sustainable technology. Figure 2 shows an example of local projects and a global niche.

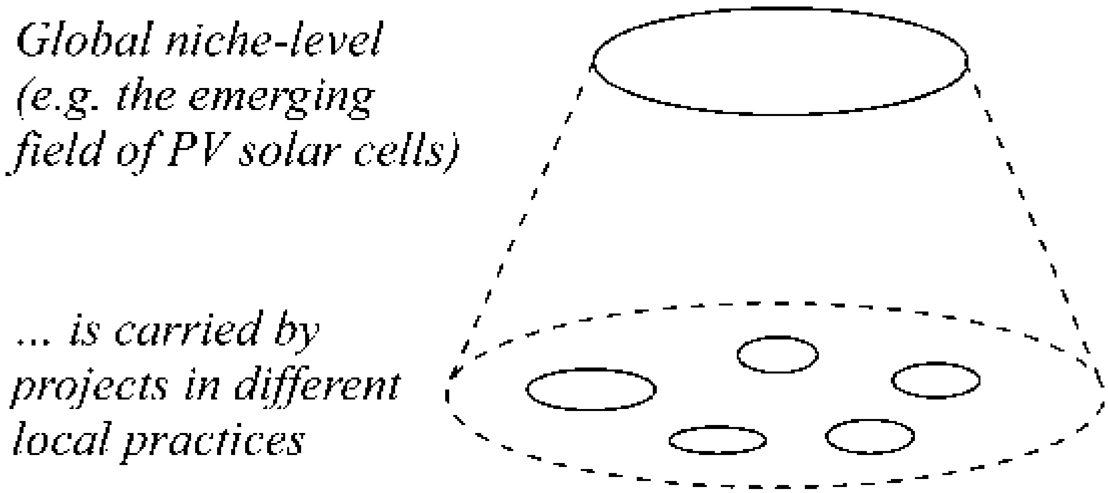

Figure 2 Local projects and global niche- Schot and Geels (2008, p. 543)

Finally Smith and Raven (2012, p. 1030) define the empowering function to be of two types: a fit and conform empowerment processes— that aims at making niche innovations competitive within an unchanged selection environment— and a stretch and transform empowerment processes— that aims at re-structuring mainstream selection environments in ways that are favorable to the niche.

2.1.1. Niches and the Multi Level Perspective

The technological niches that have been described are also situated in a broader context. As Schot and Geels (2008) show this context can be divided into three levels: a micro level, the level at which the niches are created and nurtured; a meso-level, which is also referred as socio-technical regime and can be defined as "the rule-set or grammar 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 them embedded in institutions and infrastructures" (Rip & Kemp, 1998, p. 338); and finally a macro-level or technological landscape, which can be described as the external context for all the actors, both in the niche and the regime, that is beyond their influence. Macro-economics, deep cultural patterns, macro-political developments or natural disasters can be considered as part of the technological landscape. Schot and Geels (2008, p. 545) show how the core notion of this Multi Level Perspective (MLP) is that transitions happen as a result of the interactions of different processes at different levels: first, the innovation in niches is nurtured until a point where it acquires momentum—there is a clear and stable technological trajectory forming at the niche level; at the same time changes at the landscape start creating pressure at the regime level; finally these pressures create a destabilization of the regime and provide 'a window of opportunity' for the innovations at the niche level. Figure 5 shows this process in a graphical way.

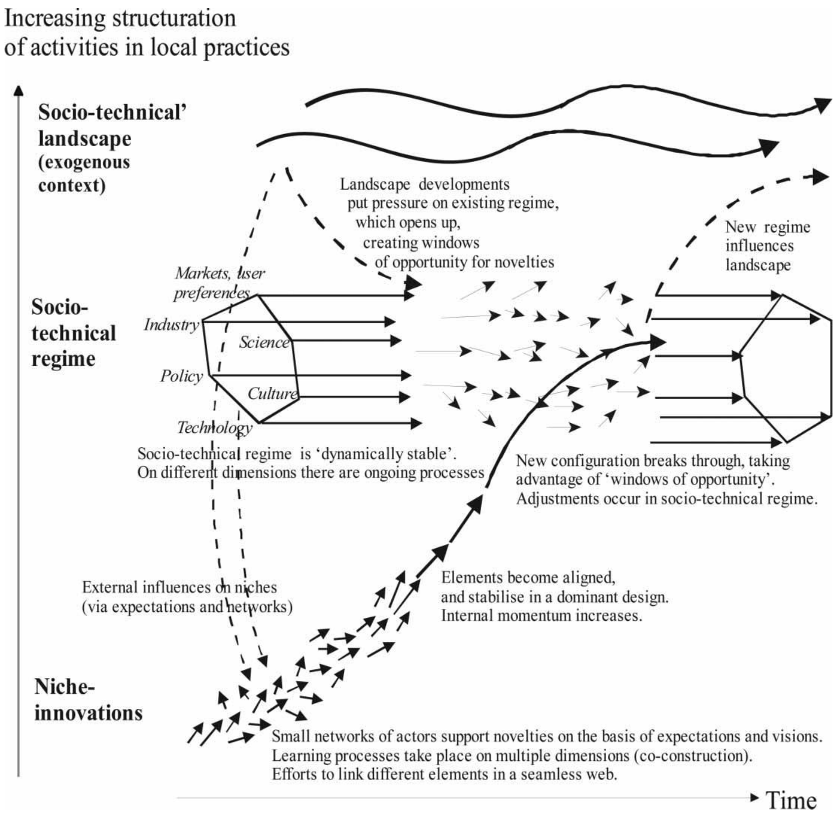

Figure 3 Multi-level perspective on transitions (Schot & Geels, 2008)

However, a very unstable regime might not necessarily create a window of opportunity for new, promising technologies. While analyzing the case of gasifiers in India Verbong, Christiaens, Raven and Balkema (2010) point out how too unstable and dynamic regimes might actually create more barriers for the development of niches. The authors propose that, a certain degree of stability is needed in the regime for a successful niche breakthrough. As the authors point out, this suggestion is based on the hypothesis of Raven (2005, p. 271) who claimed that too stable or unstable regimes will prevent a niche breakthrough.

In his book Raven (2005, p. 271) points out that a highly unstable regime can be characterized by not having a dominant design, actors that previously had a dominant role might be looking in other directions so there is not a share vision on the future of the regime and new actors have emerged with new strategies and supporting new technologies. Because of all this instability there are no longer clear markets or user preferences. In this situation, Raven points out, the niche breakthrough will be very difficult, since there is a high level of uncertainty about technological requirements and there is a scattered use of resources. Following Raven (2005, p. 271) and taking the case of the Indian gasifiers, as an example of unstable regimes, Verbong, Christiaens, Raven and Balkema (2010) propose that another promising niche development pathway would be that technological niches target market niches that are not currently served by the existing—and unstable— regime to create an alternative regime. In this way multiple regimes with similar functions in distinct locations could emerge and co-exist. However, the authors also stress that this idea still needs more research and refinement.

Romijn and Caniëls (2011) also point out that for radical innovations multiple regimes can also be present. However, in this case each regime would refer to a different sector in the economy. The reasons for these multiple regimes is that radical innovations often require the building of an entire new value chain across different sectors. In the biofuel case in Tanzania that the authors discuss they found that no less than four regimes were involved: (fossil) energy, agriculture, oil processing and land use and ownership customs and practices. It is also important to mention, as Jensen (2012) points out, that regimes are constructed in a context of specific representations— they do not exist independently of the concepts and vocabulary they represent. Therefore, different actors might frame a regime in a different way. Therefore, it is important to remember that "the regime notion should be seen more as an interpretative concept that invites an analysis of the patterns by which actors reproduce system elements and less as a concept that provides rigid guidelines for how to empirically identify and delineate regimes" (Geels, 2011, p.319 as cited by Jensen, 2012, p. 52)

2.2. The Learning Based Approach

In the next section I will focus on literature that comes from development studies and that focuses mainly on the learning process in the context of developing countries. For this research I am interested in this literature for two reasons: the first one is that I presume that one of the key characteristics of the rural entrepreneurs is their capacity to learn about new technologies and new opportunities. Understanding the details of the learning process could give a more detailed description of the characteristics needed by the entrepreneur and thus help answer questions two, three and four.

The second reason I am interested in this literature is that the framework presented earlier—Strategic Niche Management—has learning as one of their main processes. Therefore I consider that it is important to see in more detail how this learning process occurs in the context of a developing country. Since SNM was developed in a "Western" context I think that the combination of the literature of the learning process in developing countries and the literature from transitions management could be mutually beneficial. In order to combine them I follow (Romijn, Raven, & de Visser, 2010) who in their paper try to make the first bridges between Strategic Niche Management and the development literature on learning.

For describing the learning approach I will start by citing Romijn, Raven and de Visser (2010, p. 327) who defined learning-based approaches as those whose central focus is on learning and capacity building and that are based on experimentation, adaptation, participation and having a flexible managerial approach and gradual organic expansion. The authors explain that these approaches emphasize the importance of building-up problem-solving capacities and local institutions and that this can only be done when errors are embraced and seen as a necessary part of the learning process.

One of the authors that is constantly cited in the paper by Romijn, Raven and de Visser (2010) is Boru Douthwaite. Focusing on agricultural innovations in developing countries Douthwaite has developed a very interesting model for understanding and implementing participatory technological development that has learning at its base.

In their paper Douthwaite, Keatinge and Park (2002, p. 124) present a conceptual model of the innovation process. This model is shown in Figure 4. According to this model the innovation process starts with a bright idea that is developed during the first phase: the development phase. In this phase the R&D[2] team has the total control and the key stakeholders—that could be farmers or manufacturer—participate as consultants, if the participate at all. The development phase ends once the R&D team develops what they think is their "best bet"—a prototype that, the R&D team believes, will benefit the key stakeholders—and take the prototype to the field. Then, the start-up phase begins. In this phase the R&D team demonstrates the use of the machine, or lends it so people can actually try it. The main goal of the R&D team is to receive feedback from potential customers or manufacturers. Based on this feedback the R&D team modifies the"best-bet" to improve its performance. As this process continues, some key stakeholders are expected to become interested in the prototype and start believing that this "best bet" can be considered a "plausible promise" that would benefit them. Douthwaite, Keatinge and Park (2002) emphasize that the main difference between a "best bet" and a plausible promise is that the first one is defined by the R&D team while the second one is defined by the key stakeholders. Also the authors explain that, the "plausible promise" takes into account other sources of knowledge, like recommendations made by the stakeholders; in Figure 4 this is shown by the change of size in the gear-wheel and the change of the shading. The next phase, the adaptation phase, starts once there is a "plausible promise". In this phase the "plausible promise" profits from more sources of knowledge and evolves into a technology that fits the environment better and can be widely adoptable. During

[2] It is important to point out that Douthwaite, Keatinge and Park use the term "R&D team" in a very broad sense, referring to any institution that creates and/or supports an innovation. FACT Foundation is a good example of the "R&D team" the authors refer to. It is also worth mentioning that, in this context, innovation does not only refer to a technological artifact but also to new types of business models or organizational innovation.

this phase the participation of the R&D team and the key stakeholders is done on equal basis; although as the technology becomes more and more adopted, and adapted, the role of the R&D team decreases. This phase ends with the creation of what Douthwaite, Keatinge and Park (2002) call the "Widely Adoptable Technology". In the next and last phase the prototype evolves and gains even more sources of knowledge—represented by the increase of gear-wheels in the figure –as it is widely adopted by the population. In this phase the stakeholders are the ones who now control the machine, while the R&D team plays only a role of consultants.

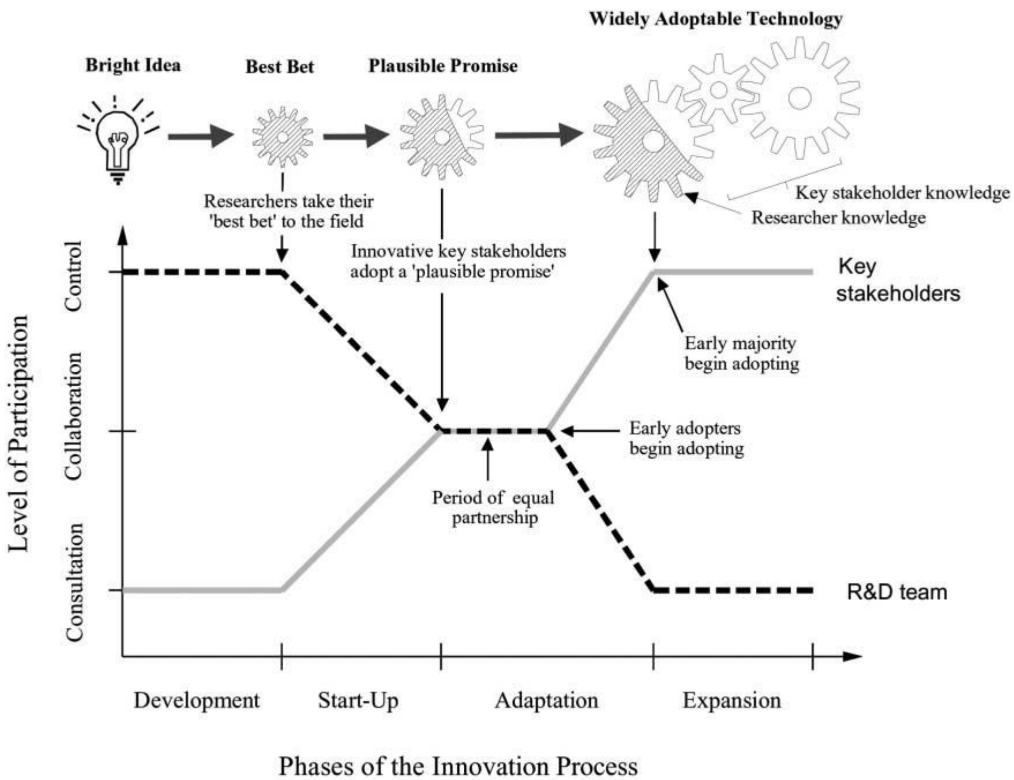

Figure 4 Evolution of knowledge during the innovation process and how stakeholder participation changes (Douthwaite, Keatinge, & Park, Learning selection: an evolutionary model for understanding, implementing and evaluating participatory technology development, 2002)

Towards the end of their paper Douthwaite, Keatinge and Park (2002) define seven prescriptive principles for setting up and managing a successful project. Here a successful project can be understood as a project that is able to promote the evolution of a certain technology to the point that it fits the people's needs and is able to be widely adopted on its own. The principles defined by the authors are:

1. Start with a plausible promise: a successful partnership between the stakeholder that posses the technical knowledge of the new technology and the people who

are going to build and use it. The key factor in this part is that the new technology makes a plausible promise to benefit the final users.

2. Keep the plausible promise simple: the new technology needs to be simple enough so its final users can understand it, flexible to allow revision and robust enough to work well even if it is not perfectly optimized yet.
3. Find a production champion: an individual—or a small group—who have sufficient interest and knowledge to nurture the innovation. This process means to promote the mechanisms that can shift the technology from a bright idea to a widely adoptable technology[3]. A production champion can also help to build a sense of common property around the technology.
4. Work in a site where there is a need for the technology: the more needed the technology is the greater the motivation the final users will have to work with it.
5. Work with innovative and motivated partners, since in the model the final user is the one who adapts the technology to its final needs, it is very important that he/she not only possess the ability to make improvements but is also willing to make them. It is also important that the final users feel that they will benefit from the adaptation of the new technology and that they are not taking all the risk on their own.
6. Do not release the innovation too widely too soon: although new technology can appear to be very promising very soon it is very important that the innovation goes through several learning process cycles before it is widely released, otherwise it might not be totally ready for the new environment.
7. Know when to let go: since the product champion will most likely become attached and emotionally involved with the project it is important that he/she realizes when is it time to let the technology go—either because it is clearly not going to succeed or on contrary because it has been able to attract enough users that it is ready to go "on its own".

[3] In their paper Douthwaite, Keatinge and Park (2002) define the "learning selection process" as the mechanism to shift the innovation through its different stages. The interested reader is referred to the already cited paper for more details.

3. Research Strategy and methodology

For doing this research I had seven weeks of field work in Uganda, between August and September of 2012. This fieldwork allowed me to gather most of the data I used for the analysis I present here. For gathering this information I conducted two types of interviews: in-depth interviews with different stakeholders of the biogas sectors and informal interviews with farmers, households and business owners in rural areas of Uganda. All the interviews I made were semi-structured with open-ended questions. The questions revolved around characteristics pointed up by the theories as discussed in chapter. All the interviews were recorded. While I was still in the field extensive summaries of the interviews were made, based on the records and notes. This allowed me to use the findings of my first interviews in the ones I made later. After my fieldwork was done, the extensive summaries were used for the data analysis, together with secondary sources that gave me a broader view of the context.

As part of my research strategy I split my research question into four different sub questions, as presented in chapter 1.2. This allowed me to focus on a specific part of my research during each interview; however I always tried to keep a holistic overview of the problem, trying to retrieve information for all the questions even if my main focus was in a particular sub question. In the next part, I go through all my research questions and explain in detail the type of interviews I made, the literature I used and what my secondary sources were.

3.1. The innovation system and Strategic Niche Management

For my first sub-question I used the SNM approach to understand what the main characteristics of the regime, niche and landscape are. Here I also explore the interaction between different projects that are currently promoting different types of biogas technologies.

For making this analysis I did 10 interviews—of around one hour each—with several actors that are involved in the biogas sector. Since my interviews touched upon sensitive topics I guarantee anonymity to all the persons I talked to. Therefore, all the claims they make are personal and do not necessarily represent the view of the institutions they work for. I also used the reports of the Uganda Domestic Biogas Program as a way of having an historical review of the biogas technology. Also, Energypedia was extensively used to understand the energy situation of the country.

3.2. The different roles of the entrepreneurs and the Learning Based approach

The next three questions deal with the different roles of the entrepreneur. To answer these questions, the research strategy was to interview farmers and rural entrepreneurs that might be interested in having access to electricity, operators of biogas systems and of battery charging stations— to have a better understanding of each role, and what barriers the entrepreneur will need to overcome. I did four field trips, three to Kassanda and the villages nearby—in the Central Region of Uganda— and one to Kalangala—in the Ssese islands (for a map of Uganda see Figure 5) In total I spent four days working in Kassanda and three days in Kalangala.

For the first role, the entrepreneur as producer/buyer of feedstock, I was mostly interested in farmers that have plenty of feedstock available and in entrepreneurs that do not have any feedstock and will need to buy it. I also had interviews with current users/operators of biogas systems and asked about their experience dealing with the acquisition of feedstock.

For the second role, the entrepreneur as an owner/operator of SBES, I focused on the current users of biogas to understand how they interact with the technology. Aside from interviewing key stakeholders I used the Learning Based approach presented earlier to understand in which phase of the innovation process the Small Biogas Electrical System is. Positioning the technology within a phase of the innovation process allows me, following Douthwaite, Keatinge and Park (2002), to define the roles that different stakeholders need to fulfill.

For the third role, the entrepreneur as a seller of electricity and fertilizer, I made two types of observations based on who would the entrepreneur sell the electricity to. In the case of households, I observed battery charging stations and interviewed both the users and the operators of them to understand the way they work and the barriers that biogas will have to deal with. For the case of SME I interviewed several small entrepreneurs in rural areas and trading centers, to see what their electricity needs are and also to understand the type of economic activity they were engaged in.

In total I made 40 informal interviews—of around 5 minutes each—with different stakeholders. In most of these interviews I needed an interpreter, since few people in the rural areas speak English.

An overview of the type of interviews that was made for each sub question and the research area where they were carried out can be seen in Table 1.

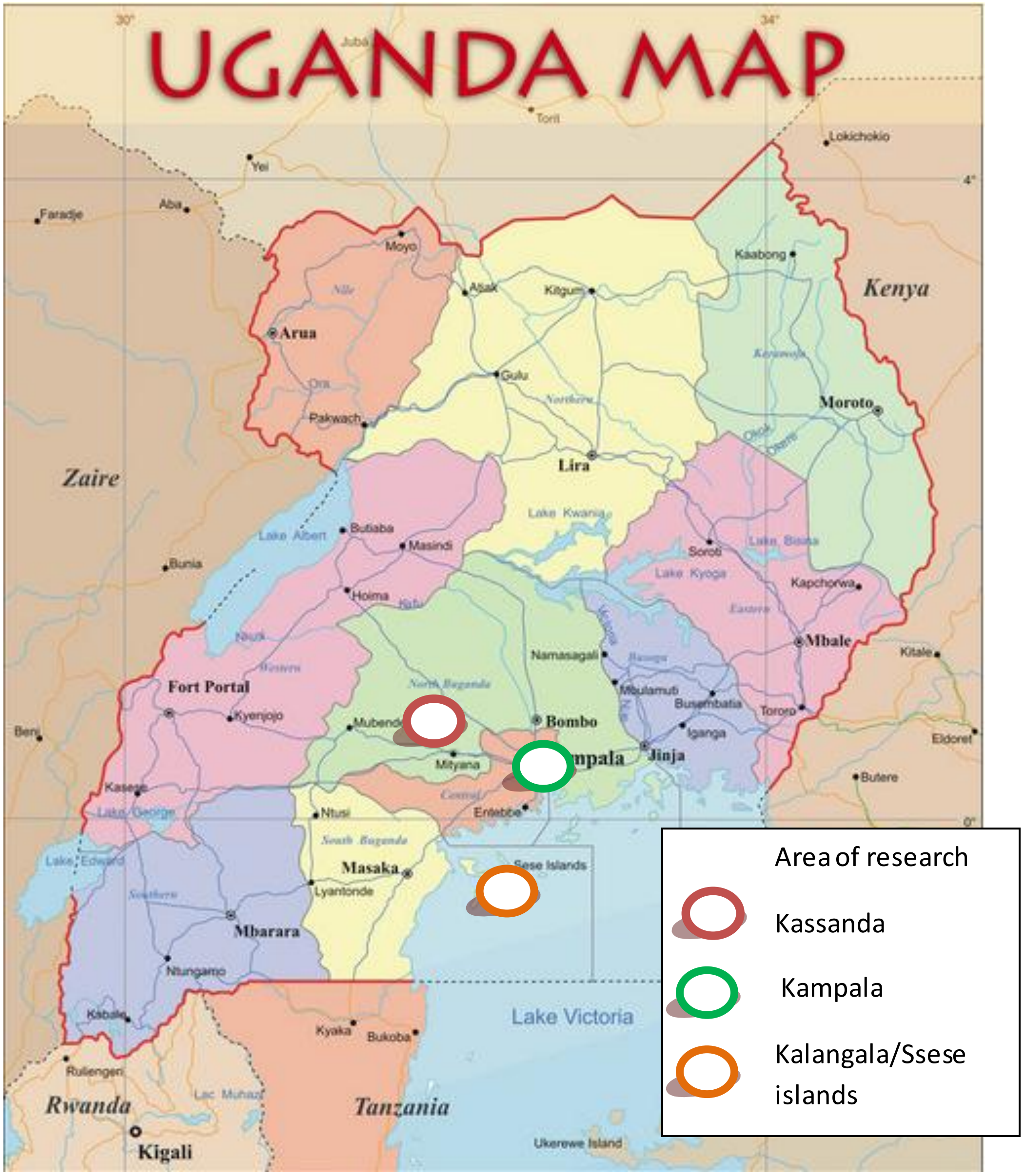

Figure 5 Areas where research was conducted

Sub question	Type of interview	Place
1. How can the innovation system be characterized and what are the main elements of it? How do they affect the entrepreneur?	In-depth interviews with people in: • SNV • Heifer • Solar Now • CREEC • Biogas construction company • Project Manager Kalangala • Project Manager Kassanda • Makerere Business School	Kampala,
2. What are the success factors that the entrepreneur needs to have to fulfill his/her role as a producer/buyer of feedstock?	• In-depth interviews with CREEC , Project Manager in Kalangala and Kassanda. • Informal interviews with: farmers, rural entrepreneurs and users of biogas systems	Kampala, Kalangala and Kassanda
3. What are the success factors that the entrepreneur needs to have to fulfill his/her role as an owner/operator of a SMBE?	• -In-depth interviews with: CREEC, Project Manager in Kalangala and Kassanda, a biogas constructor. • Informal interviews with users of biogas systems	Kampala, Kalangala and Kassanda
4. What are the success factors that the entrepreneur needs to have to fulfill his/her role as a seller of electricity and fertilizer?	• In-depth interviews with: CREEC , Project Manager in Kalangala and Kassanda, a teacher in Makerere Business School. • Informal interviews: Households in rural areas, rural entrepreneurs, battery charging stations and fertilizer traders	Kampala, Kalangala and Kassanda

Table 1 Overview of the research questions, the type of interviews and the area of research

3.3. Limitations

As I explained before the main sources of information for this report were the interviews I made during my field work. Given that interviews are always subjective I always tried to cross check the information I got. However this was not always possible. I also tried to use other sources of information, but unfortunately the information that is publically available regarding biogas in Uganda is little. The main documents that I could use were related to the Uganda Biogas Development Program.

Regarding the interviews, my original plan was to interview as many actors that would be related to the biogas sector. Nevertheless, most of my interviews were with actors that are involved to the UDPB, since the sector is still very limited and other actors were difficult to identify. However, considering that the UDBP was at that time the biggest program for biogas in Uganda, I think the results remain valid. As I already said asides from Kampala, I also did field work in two rural areas of Uganda, interviewing more than 40 different rural actors. My goal here was to understand the use of electricity in rural areas and to asses to possible introduction on biogas technologies there. I acknowledge that even if the number of interviews is considerable, visiting only two places does not allow me to have a general view of the situation of the country as a whole. This might be seen as one of the biggest shortcomings of this research.

Finally, this was my first research in Africa. My lack of experience doing research in African countries and the fact that I do not speak the local language could also have affected my research.

4. Uganda, a view of the landscape

Located in East-Central Africa, Uganda is a landlocked country that has borders with Kenya, Democratic Republic of Congo, South Sudan, Rwanda and Tanzania. With a population of more than 34 million people, a GDP per capita of 487 USD and 64% of its population living on less than 2 USD a day (The World Bank, 2012) Uganda is considered by the World Bank as a low income country. The same source points out that the country started a liberalization policy and embraced a pro-market policy in the late 1980's and by now has establish a prudent macro economic management. In the past years, and despite the global economic crisis, Uganda was able to have an economic growth above the average for sub-Saharan countries and for other low income countries (see Figure 6).

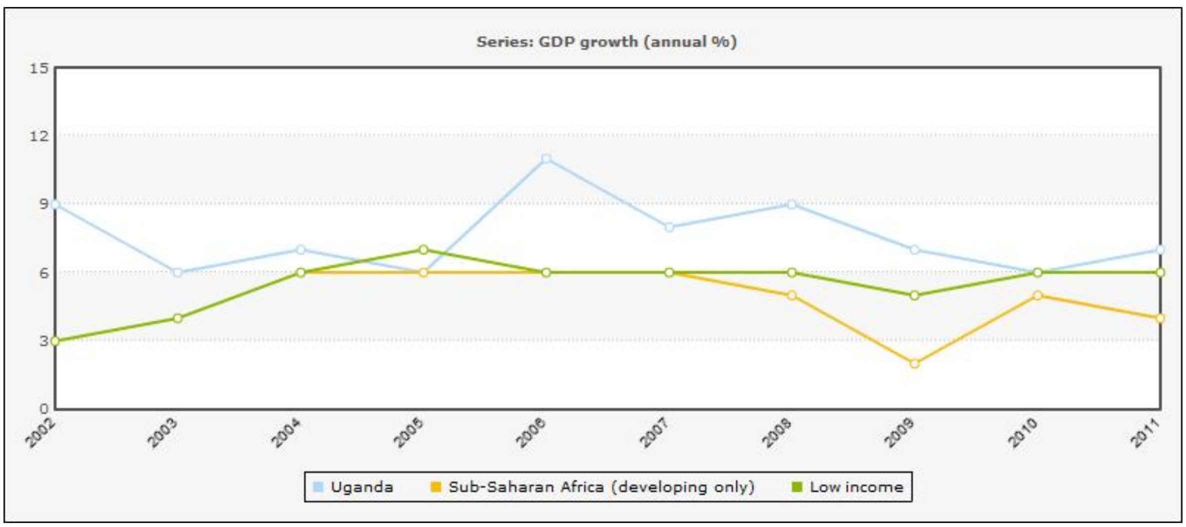

Figure 6 Annual GDP growth, (The World Bank, 2012)

In 2009 Uganda spent 3.2% of its GDP in education (CIA, 2012). The education expenditure in the country is low when compared with other countries of the region. In 2006 Kenya spent 7% of its GDP and Tanzania spent 6.8 in 2008 (CIA, 2012). As for the school enrollment, in 2010 the primary enrollment was a 90.9% of all the children on official school age (Index mundi, 2012). Uganda has made great accomplishment regarding primary enrollment since, according to the same source, in 1986 the primary school enrollment was only 56%. However, the primary enrollment of 2010 is slightly lower than the one of 2009—94,1, according to Index mundi (2012). The enrollments figures for secondary school are considerably lower; Index mundi (2012) shows that in 2004 only 15.5% of all the children in official school age were enrolled in secondary schools. This figure is also lower than the one in the previous year—in 2003 the secondary school enrollment was of 16%. Finally the same source shows that in 2009 the tertiary school enrollment—regardless of the age—was 4.2% of the total population. In 2008, according to the same source, this figure was of 3.8%.

Finally Index Mundi (2012) also shows that in 2010 the literacy rate—the percentage of people ages 15 and above who can read and write a short, simple statement — was of 73.2%. This figure is slightly higher than the one in Tanzania—72.9% according to the same source—but lower than the one in Kenya (87%).

Regarding the political stability, Uganda has now a multi-party democracy, although its current president, Yoweri Museveni, has been in power for 26 years. Museveni was last re-elected on February of 2011 with 68% of the votes for another five year period. According to the World Bank the current term of Musevendi has been characterized by protests led by the opposition pressure groups—mainly Activists for Change— who mainly protest against the high living costs, bad governance and high level of corruption. In April 2011, after the opposition leader was arrested, violent riots occurred in Kampala, the capital of Uganda, which ended with at least two dead people and hundreds of injured ones. Nevertheless since 2005, when the Lord Resistance Army –whose leader Joseph Kony was indicted for war crimes and crimes against humanity by the International Criminal Court in The Hague—was pushed out of the county, Uganda has not had any major security problems and the country lives in relative peace now.

4.1. Energy situation

Uganda has a total energy consumption of 11 million TOE (tons of oil equivalent). This energy consumption is mainly provided by biomass (90%), oil and its derivatives (8.9%) and electricity (1.1%) (Energypedia, 2012).

Regarding electricity demand, Energypedia (2012) shows that Uganda has an electrification rate of 12% at a national level, with only 5-6% in rural areas. Around 72% of the total energy supplied by the main the grid is consumed by 12% of the population, situated in the urban areas of Kampala, Entebbe and Jinja. Access to off-grid technologies by rural households is approximately 1%. The per capita electricity consumption, 70kWh/year, is one of the lowest of the world; far behind the world average (2,572 kWh/year) or even the African average (578 kWh/year). Energypedia (2012) points out that in Uganda the electricity demand has grown at an average of 10% each year, mainly driven by the high GDP growth of the past years. The same source shows that in 2011 household connections reached 450,000 almost double the number of connections in 2005. In his book chapter about the electrical situation in Uganda Gore (2009) points out that the effective demand—what consumers can and will pay for—has been growing at a pace of 30 MW per year. The previous shows that even if the electrification rate is very low in Uganda there is an ongoing demand for electricity. However, the low amount of people that have access to the grid makes it difficult to draw any conclusion regarding the consumption patterns of electricity. Energypedia (2012) points out that out of the total electricity demand 59.4% comes from the industrial sector, 25.7% from the residential and 14.9% from the commercial. The 2002 census reported that 7.7% of the households used electricity for lighting—37% in urban areas and 2.6% in rural ones. On contrary 74.8% of households—33.3% in urban areas and 88.2% in rural ones—were using a form of paraffin for lighting (Saundry, 2009). During my fieldwork in the rural areas of Uganda I could observe that—at the household level— electricity is mainly use for lighting, charging cell phones and powering small radios and—in a minority of cases—a TV. Asides from that several small businesses use it for their business; as cell phone charging stations, small hair dressers or by projecting movies and charging an entrance fee. In section 6.3 I give a more detailed explanation of this type of services.

As for the production of electricity, in Uganda hydro electrical plants are in charge of generating 80% of the installed capacity— 595 MW—the other 20% is generated by thermal and cogeneration plants (Energypedia, 2012). The ongoing rising demand for electricity has put a lot of pressure on the grid, in Uganda load shedding used to be a very common practice. During my interviews several persons mentioned that having power cuts every other day was normal in Uganda. In August of 2012 a new power plant—the Bujagali hydro power station— started to function with a capacity of 100 MW, and a planned capacity of 250 MW. The Bujagali power plant was long expected, since it was supposed to improve the energy situation and reduce the stress on the grid. My interviews show that the situation has indeed improved and power cuts have reduced, but most of the people I interviewed still consider the grid as very unreliable and weak. While I stayed in Uganda I experienced several power cuts.

Regarding the electricity sector, in 2004 the government dismantled the vertical integrated monopoly, Uganda Electricity Board, and make way for public-private partnerships. Since then private enterprises are in charge of the generation and distribution of electricity, while the transmission above 33kV remains public. When analyzing the energy sector in Uganda, Gore (2009, p. 414) concludes that in the short and medium term the privatization of the energy sector has not brought the benefits that were anticipated.

The cost of electricity has also increased dramatically in the last year, mainly because the government withdrew the subsidy to electricity. Before January 2012 the cost of producing electricity was estimated at 964 UGX/kWh(0.289 euro/kWh)—due to the high costs of running thermal plants to try to cope with the demand— while the user tariff was still fixed at 382 UGX/kWh (0,11 euro/kWh) (Energypedia, 2012) The difference between both tariffs was covered with a government subsidy . Given the huge size of the subsidy the Ugandan government was forced to withdraw it and allowed an increase of tariffs in electricity from January of 2012. The average increased was 55%. The current tariffs are:

Use	Example	Characteristics	Type of tariff	UGX	EURO
Domestic	Households, small shops, kiosks	Low voltage, single phase 240 V	Fixed monthly service charge	3360	1.008
			First 15 kWh	100	0.030
			Above 15kWh	524	0.157
Commercial	Maize mills, water pumps	Low voltage, three phase, a maximum of 100 amperes and 415 V	Fixed monthly service charge	3360	1.008
			Peak	550	0.165
			Shoulder	487.6	0.146
Commercial	Medium scale industries	Low voltage (415V) and a maximum demand of 500kVA	Fixed monthly service charge	3360	1.008
			Peak	518	0.155
			Shoulder	458	0.137

1 UGX=0.003 euros

Figure 7 Cost of electricity in Uganda, (UMEME, 2012)

Just to give a small comparison the price for domestic use per kWh in Kenya is 0.0731 Euros (8.1 Kenyan Shillings, where 1 Kshs=0.009 Euros) (Kenya Power, 2012); in France 0.1412 euro and in the UK 0.1419 euro (Europe's Energy Portal, 2012), making Uganda a country with very high electricity tariffs.

High tariffs are not the only problem to access electricity, connection costs are also very high. According to the company in charge of distributing energy in Uganda— Umeme Ltda— the connection costs are: 100,000 shillings for a security deposit and 98,000 shillings for a connection without a pole or 326,000 if they need to install a new pole (UMEME, 2012). This would make the total connection fee range between 198,000 and 426,000 shillings (between 59 and 127 Euros). This cost covers only the connection to the grid itself and does not consider the cost of making the internal wiring of the house. During one of my interviews a person mentioned that the real costs of connecting to the grid could even be higher, as it might include having more than one pole installed, ranged from 500,000 to 600,000 shillings (150-180 Euros) and the internal cost of wiring can go up to 800,000 shillings (240 Euros); this would make the total cost of installation range from 1.3 to 1.4 million shillings (between 390 to 420 Euros). The same source explained that in rural areas an average farmer can expect to earn 1 million shillings per harvesting season[4] and that usually one year will have 2 harvesting seasons. Thus, in a rural area the cost of connecting to the grid would require the entire income generated during a season. In all the interviews I made in rural areas that had access to the grid, the high cost of installation and monthly fees were always mentioned as the main barrier to get access to the grid.

To summarize, the situation of the grid in Uganda has major shortcomings. First, the grid has several problems to cope with the ongoing demand, even if the situation has improved in the last months there are still very frequent power cuts. Second, even with the demand scaling up at a 10% ratio, the number of people that are connected to the grid are still low. And third the prices, both for connection to the grid and using electricity, are so high as to create a great barrier for the expansion of the grid, especially to rural areas.

4.2. Renewable energy technologies in Uganda

4.2.1. Solar energy

As it has been stated before in Uganda off-grid technologies are responsible only for 1% of the energy production. Even if renewable energy remains a small part of the overall energy production, renewable energy technologies are present in Uganda. Excluding hydropower, the most important one is solar energy. Energypedia (2012) points out that, although a comprehensive study is lacking, the number of solar panels installed in the country is estimated over 20,000 units and the new photovoltaic capacity installed annually is estimated at 200 kWp. Also the solar panel sector—after almost 26 years of having been promoted by several NGO's— has managed to establish itself as commercially viable.

During my field work I observed that in both rural and urban areas there are plenty of private companies that sell solar panel systems[5], ranging from very small rural shops—which offer solar systems of low quality and price—to completely specialized firms—who can deliver solar panels of different types and sizes all around the country and offer a one year warranty.

[4] This can even be seen as a positive estimation considering that the GDP per capita is 487 USD or 1,254,025 UGX.

[5] This solar systems are standalone ones where the solar panels are connected to a battery that stores the electricity for its final use.

A small photovoltaic system, very common in the rural areas of Uganda.

In Uganda the prices of the solar systems vary a lot depending on the size and the quality of the system. The most common size I saw in the market was a 6 Watt solar panel, that will produce electricity for 2 lights bulbs and charging a phone. That type of panel, in a rural village of Uganda, had a cost of 200,000 UGX (almost 60 euros); the price does not include installation—which costs an additional 30,000 UGX (10 Euros)—and the product comes without any guarantee. The quality of this solar panels is dubious—in an interview with the person who sells them he told me that the solar panels he is selling are cheap, but do not last very long. In all the villages I visited during my field work I saw that many households had solar panels of this kind installed. I could interview some of them, and they complained that their solar systems were not producing as much electricity as they used to—mainly because there is a problem with the quality of the batteries.

In Uganda there are also specialized firms that are distributing high quality solar systems. I visited one of them in Kampala, called SolarNow. SolarNow sells Solar Home Systems in different sizes, ranging from 40 watt-peak (1 million UGX) to 400 watt-peak (10 Million UGX). The quality of the systems SolarNow sells is totally guaranteed and they also offer a pay plan for paying in installments. One of the managers of SolarNow explained me that during the last 10 years there have been plenty of programs that supported solar systems and created a lot of awareness about the benefits of this technology. He also told me that, due to the lobbying that GIZ (the German Cooperation Agency) did, in Uganda it is now possible to get a tax rebate when solar systems are imported. The increasing awareness of the technology, the fact that the prices have reduced considerably in the past years combined with the high need for electricity might be seen as key factors for making the solar sector a commercially viable one. However he also told me that the main barrier for the diffusion of the technology is the big investment that needs to be done upfront. Even if, in the long run, solar panels can be cheaper than other options—like buying kerosene or candles—people in the rural areas still find it very hard, or are just not able, to make the investment. Several households I interviewed that did not have access to electricity mentioned solar panels as the preferred option for lighting and electricity. However they also mention that they were not able to make the initial investment or were afraid that the system will not work and they would lose their money.

SolarNow also mentioned that financing mechanisms like micro-credit or normal bank loans are not working with solar panels, since solar panels are still seen as too risky by the banks. Some of the reasons mentioned were; lack of quality control and high interest rates for micro-credit. One of the interviewees mentioned it can go up to 20% of the amount of the loan[6]. Furthermore, the presence of these micro-finance institutions in rural areas is still very low. This, however, might be changing. While doing my field work I found a bank—Centenary Bank—who offered loans for up to 70% of the final cost of Solar Home Systems provided that the system was purchased from an specific list of providers.

4.2.2. Biogas systems

Biogas technologies have had a long history in Uganda. According to a report of the Uganda Domestic Biogas Program (UDBP, 2010, p. 14) biogas technology has been present in Uganda since 1950 and by 2008 the estimated number of systems was around 800—a great improvement over the 100 that were estimated to exist in 1990. The same source also point out that the failure rate can be estimated between 15-20%, and the main causes for failure are limited skills by the constructors of the systems and an inadequate operation and maintenance by the household. The report also points out that the main barriers for the diffusion of this technology have been a lack of technical capabilities and the comparatively high upfront cost.

In December 2008, with the support of the Dutch development cooperation, three NGO's—Hivos (fund manager), SNV (technical assistant) and Heiffer International (implementation partner)—started the Uganda Domestic Biogas Program (UDBP). The overall objective of the program, which is expected to finish in 2013, is: 'to disseminate domestic biogas in rural and peri-urban areas with the ultimate goal of establishing a sustainable and commercially viable biogas sector in Uganda.' (UDBP, 2010, p. 14). By the time I conducted my field work the UDBP was in the middle of its fourth year and was, by far, the most important program for promoting biogas in the country. However, the program was lagging behind in one of its main objectives since they had only installed

[6] However, it should be noted that, in 2011 the inflation rate was of 19%. Considering this, the real interest rate — the lending interest rate adjusted for inflation as measured by the GDP deflator —for 2011 is 16% (The World Bank, 2012)

close to 3,000 biogas units out of the 12,000 desired units. I interviewed two persons who work directly in the program and they both agree that the main problem for the program is that the price of the biogas units—even considering the subsidy of one third of the total cost—remained too high for the average farmer. They also mentioned that problems with the quality of the installations and with the way that farmers where using the digesters were other reasons for not achieving their goal. More details about these problems are given in section 5.2.2.

It is interesting to point out that even if there has been some important improvement in the dissemination of biodigester—since the UDBP started the amount of biogas units has grown almost four times—the main barrier for biogas technology continue to be the high initial costs and, to a lesser extent, the lack of technical capability concerning the construction and the use of the biodigester.

5. The innovation system of Biogas in Uganda

In this section I do an analysis using insights from Strategic Niche Management and the Multi-Level Perspective of the current situation of the innovation system of biogas in Uganda. My main aim is to provide the reader with a description of the context in which the small biogas systems for electricity production could be implemented. I do not intend to do a niche analysis of the small biogas systems for producing electricity—which would not be feasible given that by the time I did my fieldwork no experiments for this type of technology existed yet. Rather, in this report I use concepts from SNM and MLP to describe the innovation system and provide the context in which the rural entrepreneurs that buy these systems will be acting.

For achieving this aim I first do a quick historical review of the biogas sector in Uganda. Then, I turn my attention to analyze the Uganda Biogas Development Program, a project that started in December of 2008 and will end in 2013. This analysis, using insights from SNM, focuses on the main aspects of this project that could either help or hinder the introduction of the small biogas electrical systems (SBES) that FACT Foundation is trying to promote. Finally, I do an analysis of two starting projects that are currently being supported by FACT Foundation and that aim to test the technology for converting biogas into electricity. The section ends by giving an overall conclusion of the innovation system of biogas in Uganda. For a brief description of the three different types of biodigesters (fixed dome, floating drum and PVC bag) can be seen in the appendix (page 61).

5.1.A historical review (1959 to 2008) of the biogas sector

In Uganda biogas technologies are not new. According to a report by the UDBP (2010, p. 32)—the first biogas plant in Uganda was made in 1950 in Mbarara, by the Church Missionary Society. In the 1970's Makerere University started to do some research regarding biogas and different types of feedstock that could be used. However the research never left the laboratory. The already cited source points out that in the 1980' biogas for household use started being promoted by different NGO's, the Ministry of Energy and Mineral Development and even a cooperative of saving and credits— which loans money for the construction of the biodigesters. In 1992 Heifer International—one of the actual partners of the Uganda Domestic Biogas Program—started training masons in the construction of fixed domes digesters. The training was done by biogas engineers of the Centre for Agricultural Mechanization and Rural Technologies (CAMARTEC) in Arusha, Tanzania. According to the already cited UDBP report, by 2009 the trained masons had installed over 500 digesters all around the country, using the technology they learned at CAMARTEC, mainly for dairy farmers. Another benefit of the program led by Heifer was the installation of a fabrication plant for burners, stoves and lamps in Uganda. All these combined efforts led to an approximate number of 800 digester installed by 2008.

The UBPD report (2010, p. 32) also mentions that aside from the CAMARTEC design—the fixed dome type of digester implemented by the first project led by Heifer—the Integrated Rural Development Initiative (IRDI) disseminated near 400 tubular polyethylene digesters from 2000 to 2004. However, according to the report, the fragility of this type of digester hindered further development of the technology. In the feasibility study for the Uganda Domestic Biogas Program (Pandey, Subedi, Sengendo, & Monroe, 2007, p. 52) it is stated that IRDI only installed 45 digesters (and not 400) and that the cost of the digester was around 34,000 UGX (200 USD) each. The report also states that IRDI stopped promoting the digesters since they were less popular than expected. The main problem of the digesters was that the polyethylene bag was fragile—got punctured by sticks, stones or even cows— and lasted no more than 2 or 3 years. The report also points out that this type of digester was very easy to sabotage. Curiously, while I was doing the field work in Uganda, no one mentioned the IRDI project or the existence of tubular polyethylene digesters[7].

[7] While writing this report I tried to look for more information regarding the tubular digester and the IRDI program in Uganda. Unfortunately, the current website of the IRDI does not provide any more details.

5.2. The Uganda Domestic Biogas Program

5.2.1. Introduction

The Uganda Domestic Biogas Program (UDBP) is a joint program by SNV, HIVOS and Heifer International that aims at creating a commercially viable biogas sector in Uganda. By the time I did my field research in Uganda the program was the main actor in promoting the use of biogas in Uganda. By October 2012 the program had installed near 3,000 units and was still very far from its goal of having 12,000 units installed by the end of 2013. According to both my sources at SNV and Heifer, the biogas sector is not commercially viable yet, although there are some construction companies that offer their services for building biogas digesters outside the program.

It is important to point out that there are several differences between the biodigester that the UDBP is promoting and the small biogas electrical systems (SBES) concept. The most important one is that the biodigesters promoted by the UDBP are intended for a different use—cooking—and therefore face a different regime than the biodigesters for electricity production. The UDBP digester faces a cooking regime where the use of charcoal and firewood can be seen as the current rules. On the other hand the SEBS will be facing a completely different regime, an electrical power one. This, in my opinion, will make the (potential) niches develop in different directions. However, I still think that in the end both (potential) niches have a common ground—they both promote technologies that create biogas based on the anaerobic digestion of different types of feedstock—and they will (at least at an initial level) have an influence on each other. Another difference that is worth mentioning is the type of digester. While the UDBP is actively promoting a fixed dome type digester, FACT Foundation—the promoter of the SBES in Uganda— is interested in promoting a digester bag made out of reinforced PVC.

Considering all this, next I present an analysis of the UDBP using insights of SNM. In it I try to suggest ways in which the promoters of the SBES could, at least partially, avoid some problems that the UDBP has run into. Finally I discuss the reasons why the UDBP chose their current type of biodigester—the fixed dome type—and how that decision might affect the SBES.

5.2.2. An analysis of the UDBP using insights of SNM

The two persons I interviewed that worked for the UDBP[8], told me that the main barrier for the further dissemination of biogas is a financial one. Currently the program offers digesters that range from 6 m^3 (1.7 Million UGX, near 500 Euros) to 12 m^3 (2.6 million UGX, near 780 Euros) and that have a subsidy of 650,000 UGX (almost 200 Euros) According to the person I interviewed at Heifer the most popular digester in the program is the 6 m^3

[8] I interviewed one person who worked for the SNV and another who worked for Heifer.

partially because it is the cheapest one but also because it is the one that fits better the feedstock availability of the farmers.

The proud owner of a biogas system in Uganda.

My interviews also showed that farmers use their own resources to pay for the digesters since getting a loan for building a biogas plant is very difficult. One of the reasons for this is that finance institutions consider financing of low income farmers too risky; since the biogas plant is fixed in the farmer's land it cannot be removed in case the person fails to re pay the loan. Also finance institutes see the biodigester as a consumption good, therefore it implies a bigger risk—and thus they charge higher interests rates— than if it would be typified as a production good.

The second barrier that the UDBP is facing is technical one. Both my sources at SNV and Heifer mentioned that there has been a problem with the quality of the construction of the digesters. According to them, the problem is not that masons lack the capacity to build digesters but rather that they are trying to 'cut corners' and reduce the materials they use for building the digesters. Since the program gives the constructors a fixed amount of money for each digester they build, the masons have a big incentive to make the digesters as cheap as possible—even if that means to endanger the quality of the product. I interviewed one person at one of the construction companies that works for the program— and that was actually considered the best constructor company in 2010— and he acknowledged that the price that they receive from Heifer for constructing each digester is very low and that they had to diversify in to other activities—like building bigger digesters for schools or selling improved cook stoves —in order to be able to survive as a company.

One of the main accomplishments of the program is that it has trained several masons in the construction of biogas systems. Now there are several construction companies that are able to build biogas systems in Uganda. According to both my sources at SNV and Heifer currently 15 companies are working within the program. They all received training from Heifer on how to build biogas systems and also got business support and entrepreneurship training. Nevertheless most of these companies are still very dependent on the UDBP to survive since their only clients are the farmers served by the project. According to the person I interviewed at Heifer, it is because of this dependence on the program, that they expect that only three or four of them will be able to survive on their own once the program ends.

Another weak point I noticed is that there is no space where different companies can come together and share their knowledge, problems or expectations. Right now Heifer is the only common connection point they have, and once the program ends, the surviving companies could end up totally isolated from each other.

But it is not only the constructors who are lacking a network, I found that the same problem is present for the users of biogas. There is no place where a biogas user can go if he/she has a problem or a doubt. I found that some informal networks are being formed—users of biogas in the same village will try to solve their problems together—but the UDBP does not provide a space where users can come together and share their problems. Or, more important, there is no feedback mechanism that would allow the biogas constructors—or even the program itself—to know about user preferences or needs.

5.2.3. The UDBP and the fixed dome digester

As I stated at the beginning of this section the UDBP is using a different type of digester than the one FACT is planning to use for SBES. Currently the UDBP program is promoting a fix dome digester that is a modified version of the original CAMARTEC model (UDBP, 2010, p. 16). To understand the reasons behind this decision it is necessary to revert to a mission report of 2009 (Bos & Kombe, 2009) state that the final decision of which type of digester to use was made together with the constructors of the program during a workshop. In the report there are no more details about the rationale behind this decision, or what advantages the fixed dome might have against other types of digesters—like the floating drum or the tubular plastic. It is only mentioned that '(…)[the constructors] had already expressed their preference for a fixed dome model of bio-digester to be selected within the future national domestic biogas programme (…)Therefore we excluded other models like Indian floating drum and plastic tubular design which corresponded with the general feelings and opinions of the constructors present in the Workshop and our findings during the field visits.' (Bos & Kombe, 2009, p. 8). I cannot conclude what was the final reason to choose the CAMARTEC model against other models, but one of the reasons might have been that—as I have pointed out earlier—Heifer International had been promoting the CAMARTEC model for several years before the program started, and it is highly possible that most of the constructors that made the decision had experience with working with CAMARTEC digesters.

5.2.4. Conclusions

Following the Strategic Niche Management approach I can conclude that the lack of a network— that, if broad and deep enough, would create a constituency behind the new technology and allow the interaction between stakeholders—could be pointed out as one of the factors that is hindering the biogas sector from becoming commercially viable. One of the first measures that could be taken to overcome this barrier is to promote the creation of a network of constructors. This become particularly important for promoting the small biogas electricity systems, since I presume that the construction companies who manage to survive the end of the UDBP could be perfect partners—since they have the experience and technical skills— for promoting the small biogas electrical systems. Promoting the formation of a network could also be a crucial step to overcome the financial barrier that the UDBP is facing. As the SNM scholars show, broad and deep networks do not only help knowledge flow together, they are also able to mobilize resources. If a network of users and producers of biogas systems (regardless of whether the systems are used for cooking or for producing electricity) is formed it could lobby with finance institutions for getting access to credit. The example showed earlier on this report about Centenary Bank giving loans for Solar Panels—given that certified companies do the installation—can be seen as an example on how access to credit for renewable energies at household level is possible in Uganda, if there is an organized network of suppliers. Also, an organized network of suppliers for biogas could lobby for a tax exemption, just like GIZ did in the case of solar systems.

In this I section I also showed how the UDBP has been actively promoting a fixed dome type digester—the CAMARTEC model. Considering that the CAMARTEC model is the most promoted model in Uganda and that almost all the biodigesters that are present in the country are actually following this model, or a modified version of it, the idea of FACT of introducing another type of digester—the PVC bag—could lead to a lack of user acceptance. However the idea that the fixed dome is the best model for the biodigesters in Uganda can be questioned. The first, and probably main, reason for this questioning is that the fixed dome model is very expensive compared to other models. Even in the feasibility study for the UDBP it is stated that the CAMARTEC model is the most expensive one, compared to other fix dome models in Nepal and Cambodia. The price for a CAMARTEC digester of 8 m^3 is estimated at 1.7 Million UGX (1.000 USD) while the same type of digester in the Nepalese design will cost 1.3 Million UGX (770 USD) (Pandey, Subedi, Sengendo, & Monroe, 2007, p. 52). The second problem of this model of digester is that it requires skilled labor for its construction and that it is very difficult to repair once a crack in the digester appears. These two problems, high costs and problems with low quality constructions are exactly the two main reasons that are given to explain why the UDBP is failing to achieve its goals.

When I talked to the persons in SNV and Heifer they both acknowledged that trying another biodigester model might be beneficial for the program, but that they would need to be sure about its benefits first, in terms of price and performance. When I talked to the constructors of biogas they seemed very positive about the idea of replacing the fixed dome with PVC bag digesters but also mentioned that there is a need for testing the technology in the field.

Considering all this there is an opportunity for introducing new types of biodigesters in Uganda, given that they provide a similar performance to the fixed dome ones at a cheaper or at least equal price. Nevertheless is important to point out two aspects:

- In the past, there has already been an attempt to introduce a digester similar to the PVC bag and it failed, due to problems with the quality of the digester and the short life-span. The new biodigester model that FACT is trying to promote will have to proof that it is better than the one that IRDI tried to promote earlier.
- The fixed dome has been the dominant model for biogas in Uganda, therefore there could be some resistance from users and constructors towards the new model.

5.3. A SNM analysis of two experiments for biogas electrical systems

The project manager of Kalangala and his biodigester

Currently FACT Foundation is supporting two projects in Uganda that aim at producing electricity out of biogas. One of the projects is located in Kassanda, in the Mbudende District in the Central Region. The other project is located in the Kalangala District, in the Island of Bugala, part of the Ssese Islands in Lake Victoria. These projects will have big digesters (200 m^3) made of PVC bags that will be connected to biogas electrical generators that can produce up to 15 kW. In both cases the projects aim at getting the feedstock for the digesters partially by harvesting or growing it and partially from third parties. The project in Kassanda will use this electricity to power a maize mill and a battery charging station. The project in Kalangala will use the electricity for a battery charging station. Both projects are focusing on developing a business model for running a battery charging station that uses bio-electricity.

According to FACT, the SBES can be seen as a small scale version of the projects described above. Therefore these projects could be very important for the SBES as they could serve as pilot experiments for the technology—both the PVC bag and the bio gas electricity generator—but they could also be seen as the 'initiating experiments' around which a niche could be form. The use of biogas for producing electricity is very new in Uganda, and these two projects are—as far as I could find out—the only two that are trying this approach. Because of this, even if these projects are not working with SBES, I will do an SNM analysis of them.

My next analysis aims to show a picture of the current situation of the (potential) niche and give advice—by analyzing the internal niche processes—on how the (potential) niche could be developed further.

5.3.1. The niche level

By the time I did my fieldwork in Uganda only the project in Kalangala had a biodigester in place and was already producing small quantities of biogas, although it was not able yet to convert it into electricity. Since it was already operational the project in Kalangala can be seen as a starting experiment. The project in Kassanda, even if it already had started, was still dealing with all the preparations for the installation of the biogas plant. Because of this reason I would describe this project as a proto-experiment, in the sense that it is not an experiment yet—since there is no interaction with the technology—but it could soon become one.

In the following section I analyze the internal processes that are important for niche development –expectations, networks, learning process— for each one of the projects, followed by conclusions. [9]

Expectations

Both projects share the same vision that there would be a big demand for electricity produced out of biogas plants. This idea is also shared by other actors. For example researchers at CREEC (Center for Research in Energy and Energy Conservation) in Makerere University agree that the demand for electricity in Uganda is very high and that

[9] As I already showed in Section 2.1 (pag 9) the Strategic Niche Management literature points that niches develop as the expectations between the different actors become more robust and start being articulated, the social networks between experiments become deep and broad and there is a learning process that includes second order learning.

it can even grow exponentially in rural areas as soon as there is a reliable source—like biogas—nearby.

However there is no agreement yet on what the best size of digester is. One project manager thinks that the best option is to focus on big biogas systems that can provide big amounts of electricity (above 5 kW). One of the researchers at CREEC agrees with this idea, since he thinks that demand is not going to be a problem. On the other hand, the other project manager seems to think that scaling down the digesters to a household level is the best way to provide electricity in Uganda, since it could make the investment more affordable. The last vision is also shared by FACT Foundation and was also mentioned by the manager of SolarNow— one of the main solar energy companies in Uganda.

Regarding the way the biodigesters are made, both projects see PVC bags as a feasible solution. One of them even considers them as the best design for digesters at the household level. The same idea is shared by other actors. One of the researchers at CREEC also agrees that PVC can be the best option for small scale biogas plants. Also the persons I talked with at SNV and Heifer mentioned that PVC is worth trying.

It can be seen that although both experiments share some expectations, they disagree in other points. Also, some of the expectations although shared remain vague—for example the real size of electricity demand in rural areas of Uganda. SNM literature points out that, in order for a niche to develop, expectations need to be shared among actors and become more specific. The literature also points out that as expectations become more corroborated in several experiments, they increase in quality. In that sense, establishing a space where projects can share and corroborate their expectations, could be seen as the first step that is needed to develop these expectations further.

Networks

The two projects stand on opposites sides regarding this topic. Currently the project in Kalangala has a small and local network. This network is mainly form by farmers in the Kalangala islands and some local authorities. Asides from its local network, the project is also connect with FACT Foundation and received final support from Stichting StartLife, a Dutch foundation for the advancement of entrepreneurship in the domain of agriculture, food and the environment. I consider that the project is rather isolated in the biogas innovation system since none of the other stakeholders I interviewed mentioned it. Also, the project manager told me that so far no one has come to visit the project.

On the other hand the project in in Kassanda is building a big and diverse network. Currently the project has connections with: a research institute—the Center for Research on Energy and Energy Conservation (CREEC) and the African Energy Technology

Development Network-Uganda (EAETDN-U), an organization that currently promotes renewable energy technologies in Uganda. The project manager has also some good contacts inside both the SNV and Heifer, who are running the UDBP. The project manager also mentioned to me that currently he is working in expanding his network to other African countries, especially to Kenya.

During my fieldwork I realized that currently the projects are not sharing any type of information with one another, even when both project managers know each other and are both supported by FACT. One of the project managers mentioned that he feels that if he shares his experience and knowledge with other projects he will be losing a competitive advantage. In his vision, entrepreneurs need to protect their investments and cannot just share their experiences. As I showed in the literature review section, SNM scholars point out that niches develop when experiments start exchanging experiences. The fact that they remain unconnected can harm the development of the niche. If this exchange does not happen, the experiments will stay isolated and a niche would not be formed.

The literature of SNM has plenty of examples on how the sharing of experiences and knowledge can be highly beneficial for the development of the niche. Experiments that are connected and share information could strengthen the network and most importantly help the formation of a constituency behind the technology. This, in my opinion, is critical since a strong network could help with the development of a supply chain for biogas, a better access to finance mechanisms and even lobby for support from the government, in the form of tax exemption, for the technology. Sharing information can be sensitive for entrepreneurs; since they can see other projects as their competition and could be reluctant to exchange information that might also benefit others. However, based on the SNM literature, I think that in the current state of the niche, sharing knowledge could bring much more benefits than staying isolated. SNM scholars have shown how technological niches develop when different actors come together and form networks that are deep and broad. Without these networks, the development of the niche could be seriously hindered and the niche might not develop enough to make the transition from a technological niche to a market niche. In the end, competition is one of the main engines of a successful market development approach.

Learning process

By the time I did my fieldwork only the project in Kalangala had started operating the biogas system. Because of that there has been very limited interaction with the technology. Therefore an analysis of the learning process is not really feasible yet. However, during my fieldwork I observed that both projects were already learning from their own experiences, on a trial and error base. Also, I observed that most of the new knowledge remained tacit. Considering that learning by trial and error is often a slow and expensive process the role of social networks becomes bigger. The SNM literature shows that networks can promote learning and 'move' knowledge from one experiment to another. Also, the Learning Based Approach of Boru Douthwaite shows that networks of users play a vital role in the learning process; by giving feedback about the advantages — and limitations—of the new technology. Considering all this, one of the ways to promote the learning process could be to promote the social networks around the experiments.

5.3.2. Conclusion

Since the two experiments present in the field (October 2012) just started, there is no exchange of knowledge, experiences or rules between them yet. Also the other biogas initiatives are very much self-centered. Therefore it is not possible to talk about a niche yet. If anything, these two experiments can be considered to form the local phase of the niche level. A graphical representation of this idea can be seen in Figure 8.

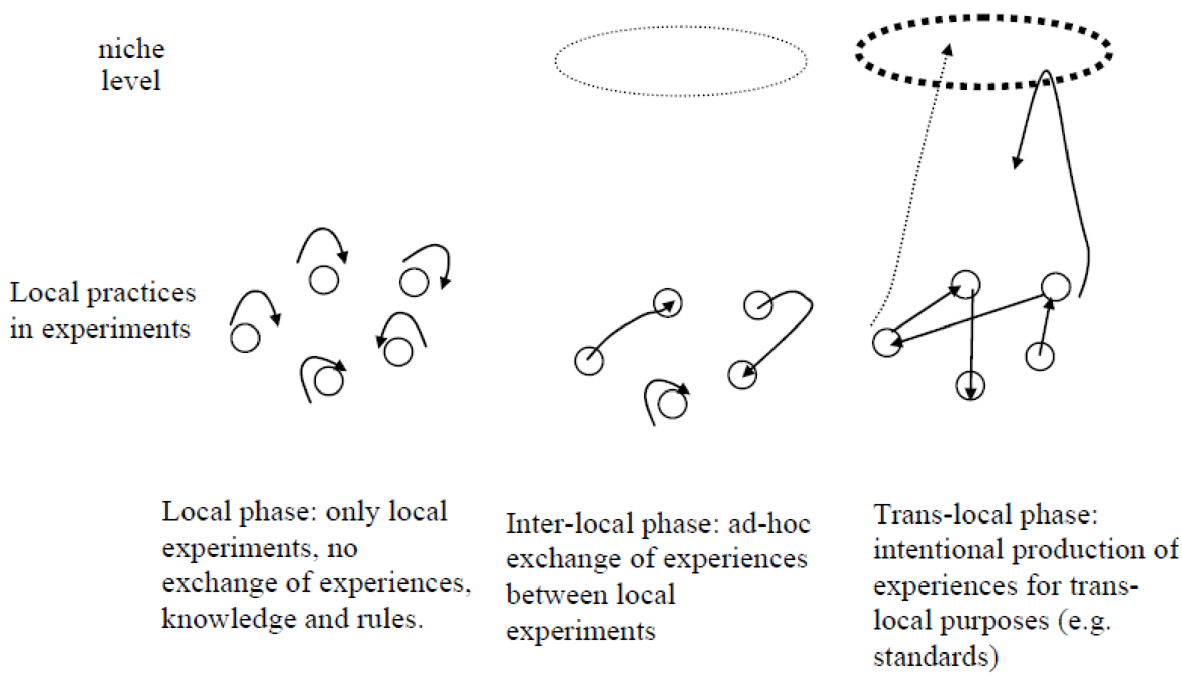

Figure 8 Different phases in niche construction (Adopted from (Raven, 2005, p. 47)

However, picturing these experiments as completely alone will not be totally accurate since they will also be affected by other biogas experiments, even if they do not use biogas for electricity. Examples of these experiments can be found in the biogas installations that are being carried out by different actors, like UNICEF, independent biogas construction companies or by the Uganda Domestic Biogas Program.

My analysis of the biogas system in Uganda shows that there are several potential biogas niches developing at, almost, the same time. One of them is made up of experiments that promote biogas systems for cooking, and since it is the oldest it might also be the most developed niche. The other, very new, is the potential niche for big biogas systems for producing electricity. As I showed before in this case the system is only in its local phase. Finally I could identify a third niche, which at the moment remains hypothetical. This hypothetical niche will develop around the first rural entrepreneurs who adopt the SBES. Considering that bigger projects, with more resources and experience, are having problems forming a niche, I expect that the experiments using SBES will also need some support to organize themselves. One way of providing this support would be to link the experiments that use the SBES with experiments that are currently using bigger biogas systems for producing electricity—like the one in Kalangala and Kassanda. Considering this I believe that the hypothetical niche for SBES would be very dependent—at least at the beginning— on the development of the niche for big biogas systems for producing electricity. Therefore both projects in Kalangala and Kassanda could play an important role in the development of the SBES niche. Furthermore, the project manager of Kassanda could already be seen as part of the social network of the SBES, since asides from working in his project he is also trying to become a supplier of PVC bags for the small digesters. The project manager also mentioned to me that he things that SBES have a great potential in the region. Finally, the project has several contacts with other actors of the innovation system that could be very beneficial for the niche. A graphical representation of the biogas sector in Uganda can be seen in Figure 9. The project in Kassanda is located in the intersection of the two circles because of the reasons explained above.

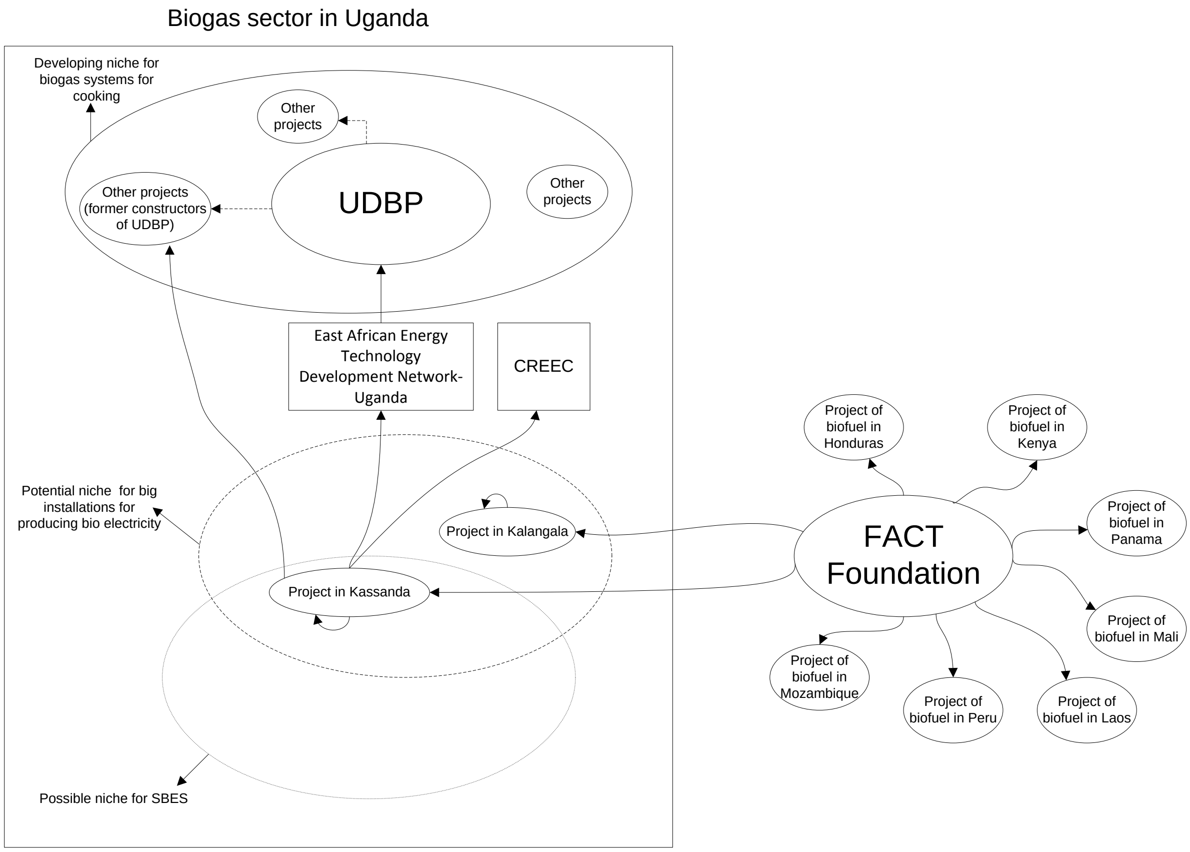

Figure 9 The current situation of the biogas sector in Uganda, following an SNM approach

5.3.3. The regime level

In the 'classical' SNM literature a niche needs to be nurtured in order to survive the regime pressures and acquire momentum while it waits for a 'window of opportunity'—an event that will destabilize the regime and allow the niche to break through. Therefore, an unstable regime is usually considered beneficial for niche development. However studies in emerging economies, see for example (Verbong, Christiaens, Raven, & Balkema, 2010), show that a too unstable regime can actually prevent the development of a niche. Raven (2005, p. 271) characterize an unstable regime as a regime that: does not have a dominant design, does not have a shared vision about the future of the regime, where new actors have emerged with new strategies and supporting new technologies and there are no clear markets or user preferences.

As I already pointed out the niches that use biogas for producing electricity will be facing a rural electricity regime. In a previous part of this report I showed that Uganda has a very low electrification rate and that, even if there has been an improvement in the grid, it is perceived as unreliable and weak. Even in the capital city, Kampala, power cuts are not unusual and many business and hotels have their own generators in case the grid fails—

which it does often. In the rural areas the situation is even worse, since there the grid is not only very unstable but also hardly present. Because of this getting access to electricity is seen as something each individual must seek on its own—there is a "do it yourself" attitude. The interviews I made during my fieldwork show that people in the rural areas do not expect to be connected to the grid soon, either because it is still too far from them or because they cannot afford the installation and monthly fees. Also several technologies (diesel generators, solar panels, car batteries and dry batteries) are used to gain this access to electricity. Therefore there is not a dominant design to access electricity and the dominant attitude—the guiding principle—is to try to get access to it in any possible way. Another characteristic that was constantly pointed out in my interviews is that, regarding the technology that is used, the price for getting electricity remains as the main decision factor. People seem to choose the way to access electricity based on their financial situation and not on a technical characteristic. Finally, the policy and regulations regarding rural electrification remain vague and unclear. Currently there is an energy policy that supports renewable energy technologies that could help improve the rural electrification rates in Uganda; however there is a gap between the policy and its implementation.

Based on this, and following Raven (2005, p. 271) and (Verbong, Christiaens, Raven, & Balkema, 2010), the rural electricity regime in Uganda could be seen as an unstable one. However I believe that in this particular case a particular type of instability is present. I think that the regime can be better described as a fragmented one, where several technologies are present. In this regime the fragments are hold together by the fact that people need to gain access electricity in any available way, using several technologies at the same time. Pressures from the landscape, for example a vague policy regarding rural electrification or the low purchasing power of the majority of the population, are also reasons for this fragmentation.

My analysis at the regime level also shows that there are, at least, two other regimes that are present in the biogas sector: the cooking regime and the developing aid regime. The first regime—the cooking one—affects mainly the niche for biogas systems for cooking. While the second one—the developing aid one—can affect both biogas niches: biogas for cooking and biogas for electricity production. It is out of the scope to do a detail analysis of these regimes, instead of that I will briefly point out the reasons why I think these two regimes can affect the potential niche for biogas systems that produce electricity. Since biogas has been historically used for cooking I believe that this regime—that can be characterized as a charcoal and firewood regime—will have an influence on any other type of biogas systems During my fieldwork in Uganda I could see a very strong perception that the only possible use of biogas is for cooking. Is because of this strong perception that I believe the cooking regime will influence the biogas systems for producing electricity.

Another regime that is present is the development aid regime. This regime affects all the development agencies that are involved in the biogas systems—either for cooking or for producing electricity. This regime can be broadly characterized by supporting biogas systems for cooking, using a fixed dome design and giving subsides to for the systems. Considering that the biogas systems that FACT wants to promote have the different characteristics—they are used for producing electricity, use a PVC bag as a digester and there is no subsidy involve—they will have to 'fight' the development aid regime. A graphical representation on how the regime is formed, and the pressures that it receives from the landscape can be seen in Figure 10.

In their paper dealing with unstable power regime in India, Verbong, Christianes, Raven and Balkema (2010) suggest that niches that need to deal with unstable regimes could focus on market niches that are currently not served by the existing regime to create an alternative regime that could co exist with the existing one. Given the fragmentation of the present regime, there are plenty of markets that are poorly served, or not served at all, and that could become the niche markets that biogas electrical systems should target at. However I consider the conditions in these niche markets still far from optimal. Interviews with nearly 40 micro and small enterprises in the Central region of Uganda showed me that even if there is an undeniable need for electricity the low purchasing power of the population creates a major barrier for the technology. Considering that the price of the electricity produced by a small biogas electrical system is currently 23% more expensive than the average domestic tariff of the grid[10], which is already considered very expensive, I foresee that only few people would be able to afford installing biogas electrical systems.

[10] the price is currently 685 UGX per kWh (personal communication with a member of Q-energy, October 2012)

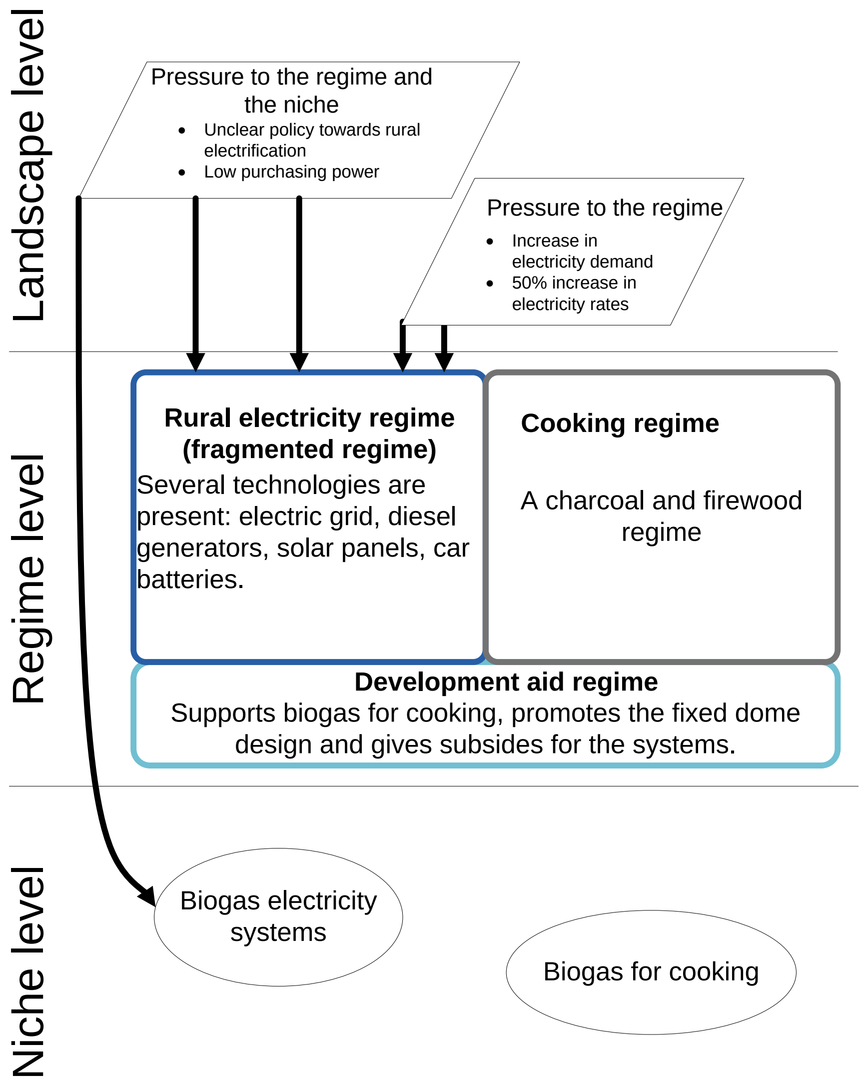

Figure 10 A multi level perspective on the innovation system for biogas in Uganda.

5.3.4. Conclusion

The fragmentation of the regime and the low purchasing power of the small entrepreneurs in the rural areas of Uganda seem to be the biggest barrier that the (potential) niche for small biogas electrical systems will face. Even if there appear to be several potential niche markets for the technology, the price of it still remains too high for the majority of the population. Also, the technology still needs to go through a maturation process, to fully adapt itself to the needs of the people and overcome the doubts that surround it (distrust in PVC bags, doubts about their capacity to produce biogas/electricity).

There is a need to build a constituency behind the new technology for biogas in order to overcome these barriers. I believe that small rural entrepreneurs—the target public for the SBES— might actually be too small to take on this task. I think that bigger projects, like the ones in Kassanda or Kalangala, are the actors who can perform this task in a better way. However, SNM literature has shown that these processes can only begin when different experiments come together and start forming a technological niche. Therefore, I believe that a way to help the introduction of SBES would be first to promote the formation of a technological niche for big biogas electrical systems (BBES).

As for how to start forming a technological niche for SBES, I believe that the best strategy could be to start with experiments that are close—in a geographical sense but also in the sense of having a close relationship—with the ongoing projects –the one in Kalangala or the one in Kassanda. As Douthwaite, Keatinge and Park (2002) show, the adoption and adaptation of a technology happen when there is a person or institution that takes the lead. I think that the current projects could take that role, therefore if the new experiments are close to them, it would make the process easier. Also, being close to the current projects might allow new experiments to also benefit from the networks and the lessons learned.

Targeting big farmers, who might have both the resources and the need for electricity, could be a promising way to start. In the next section—which deals with the characteristic of the entrepreneur—I will explore this idea further.

6. The different roles of the entrepreneur

In this section I focus on analyzing the three different roles that the rural entrepreneur will need to play. In each role I am interested in understanding what are the characteristics that the entrepreneur needs to have in order to successfully use the small electrical biogas system in a sustainable and productive way that will allow him/her to generate an extra income to improve his/her livelihood. The three roles that I defined, based on the expertise of FACT Foundation, are: the entrepreneur as a producer/buyer of feedstock, the entrepreneur as an owner and operator of the biogas system and finally the entrepreneur as a seller or user of electricity and fertilizer. For understanding the characteristics of each role I interviewed different actors in the biogas sector. More details about my research methodology can be found in chapter 3 of this report.

6.1. Role 1, the entrepreneur as a producer/buyer of feedstock

Having access to feedstock is the first condition that the entrepreneur needs to fulfill in order to be able to generate electricity using an SBES. In the original idea of the FACT Foundation the entrepreneur could acquire the feedstock needed for the biodigester either by producing it him/herself or by acquiring it from third parties.

The idea of acquiring feedstock from third parties is new and most of the people I interviewed were not sure if a setup like this would work. However, by the time I did my fieldwork, the project of Kalangala was acquiring all its feedstock—cow manure—from farmers who gave it in exchange for bio-slurry, in a 1:1 ratio. Therefore, I take this project as an example to analyze the characteristics needed to fulfill this role.

The cow manure was collected on regular basis from the farmers—who needed to gather it inside bins that were provided by the project—by two persons using a truck that was bought for that purpose. Once the bio gas plant starts producing bio-slurry, expected in November of 2012, the project will deliver to the farmers bio-slurry—that they will use as fertilizer—as they pick up new manure. The exact way in which the bio-slurry would be transported and delivered was not clear yet.

When I talked to the manager of the project he mentioned that he was very proud, and surprised, about how well the exchange of manure for bio slurry was working. When I asked about the reasons for success, he told me that the farmers feel that they are winning with the exchange, since they get a product with higher value—the bio-slurry—in exchange for their manure—which has no market value. Everyone I talked with in the biogas sector seems to agree that bio-slurry has a great potential as fertilizer, but no one knows exactly how to quantify this potential. This lack of knowledge makes it very hard to determine what the commercial and nutrient value of bio-slurry is, therefore an entrepreneur would not be able to know the opportunity cost for trading the bio-slurry for feedstock without first experimenting with it.

The manager of the project in Kalangala also told me that he does not feel completely safe knowing how dependent he is on third parties, and therefore he is also starting to collect his own feedstock—in this case water hyacinth—for running his biogas plant. As far as I know, the project in Kalangala is the only biogas project that —at least for a while—was fully dependent on third parties to get the feedstock. The other big electricity project I visited, located in Kassanda, was planning on growing its own feedstock first and then explore the option of trading banana peels, which would be used as feedstock, for bio-slurry. When I talked to the researchers at CREEC they mention that having the control over the access to feedstock was in their opinion one of the pre-requisites before starting any biogas project.

Considering all this, I think it is safe to conclude that one of the characteristics that the rural entrepreneur needs to have is control over its feedstock, either by growing it or by owning the animals that produce it. Although acquiring it from third parties seems possible, it involves a greater risk and additional costs in terms of labor and transportation. Besides, the real value of the bio-slurry still needs to be determined, which makes the business model of trading it for feedstock uncertain.

6.2. Role 2, the entrepreneur as an owner and operator of a small biogas electricity system

Assessing what characteristics are needed for an entrepreneur to acquire, operate and maintain a small biogas electricity system was a challenge given that, by the time I did my fieldwork, the technology only existed as an idea.

Previously in the report I showed that one of the main barriers for the adoption of the SBES is an economic one. Therefore, the first characteristic that the entrepreneur needs to have is the ability to overcome this barrier. Given that in the rural areas of Uganda having access to credit is difficult I believe that the only way for the entrepreneur to have access to the technology is because he/she has the money to pay for the investment upfront. Since the investment is relatively big and money is a scarce resource in the rural a areas of Uganda[11],I would presume that the entrepreneur will only take the risk if he/she has a secure market for the electricity the system will produce. During my fieldwork I found that the persons who best fit this description are relatively big farmers who have more than 20 cows or big cash crop plantations, that need the electricity to enhance their current economic activity—mill maize, peel coffee, store milk.

[11] In Uganda, 64% of the population live with less than 2 dollars a day (The World Bank, 2012)

Regarding the characteristics needed for the operation and maintenance of the system, my observation with similar biogas systems—big biogas systems for producing electricity and small biogas systems for cooking—showed me that the technology is not difficult to operate. The interviews with the owners of this technology reinforce this idea. All the owners of a biogas system told me that operating a biogas system did not require any advanced skills and was relatively easy. The only thing that is needed is time—approximately one hour a day—and feedstock. According to one researcher at CREEC one of the main parts of operating a biogas system is to feed the system regularly, therefore one of the main characteristics that the person needs to have is an ability to organize him/herself and be able to follow a schedule. Although this might sound trivial a recurring reason why biodigesters were not working was because farmers did not feed them according to regular schedule. In the case of electricity production, the technology becomes more difficult as it involves the operation and maintenance of a (bio)gas generator or an adapted gasoline generator. This requires some technical skills and the presence of a qualified mechanic in the proximity.

Even if the technology is rather easy, and simple, there are some risks involved in its operation. The main one is that the production of biogas takes a long time to start—the system has to be feed for three to four weeks to start biogas production. This means that the 'start up' time is very long, so re-starting production of biogas—that was stopped because of leakage for example—might take weeks. Therefore, another characteristic that the entrepreneur needs to have is an ability to deal with that risk, and maybe even reduce it by having several small digesters that can work at the same time. Having several digesters could also allowed the entrepreneur to be more flexible, since he could produce more or less electricity—and use more or less feedstock—depending of the demand.

As I showed in the literature review section 2.2, Boru Douthwaite developed a framework for understanding the different phases of an innovation process. This model defines different levels of participation—and therefore different characteristics — for the R&D team and the key user/stakeholder, depending on the stage of the innovation (for more details see page 14 in this report). Since currently the small electrical biogas system is only an idea that FACT Foundation—which can be seen as the R&D team—thinks could work on the field, I consider, following (Douthwaite, Keatinge, & Park, 2002), that the innovation is at the end of its R&D phase. Following the model of the cited authors the next step—the start-up phase— would be to take the 'best bet'—the prototype that the R&D team thinks could benefit the stakeholders—to the field. Douthwaite, Keatinge and Park (2002) propose that in this phase the objective is to make demonstrations, or even loan biogas systems, to get feedback from the users and adjust the fitness of the system to the new environment. According to the model, doing that will make some stakeholders—the first entrepreneurs or the innovators—interested in the technology, since they will start believing that the technology can actually solve their problems. Once the first entrepreneurs start adopting the system it stops being a 'best bet' and becomes a 'plausible promise' and will be ready to go into the adaptation phase.

Considering all this I believe that one important characteristic that the first entrepreneur needs to have, at least during the start-up phase, is a good relationship with the R&D team, either FACT Foundation or one of their partners in the field, since it is very likely that the technology will need to go through several phases of adaptation. It is also important for the entrepreneur to have some social skills, so the communication between him/her and the R&D team remains fluent, but also since the entrepreneur needs to be able and willing to interact with other entrepreneurs who are using—or are interested in using—the technology. Finally, I think the entrepreneur needs to have some degree of commitment to the technology, and understand that—as Douthwaite calls it—it is nothing more than plausible promise; it has the potential to deliver a solution to the entrepreneur's problem, but the potential is still only a promise that needs to be unleashed.

Considering all this, I can conclude that the characteristics needed to acquire, operate and maintain a biogas system are: having enough capital[12], have some experience with doing a repetitive task—such as feeding the digester daily, have or have access to technical skills, have social skills and be able to interact in a very fluent way with both the R&D team and other entrepreneurs and finally have a commitment with the further development of the technology, that will allow the entrepreneur to invest time and possibly money in the further adaptation of the SBES.

6.3. Role 3, the entrepreneur as an owner and operator of a small biogas electricity system

The final role of the entrepreneur is related to the characteristics he/she will need to sell the electricity and bio-slurry the SBES produces. In the original idea the entrepreneur had two options. He/she could sell the electricity to households through batteries that would be charged in small battery charging station or sell it to SME that would have a direct connection, or through a mini-grid.

[12] By the time I wrote this report, the price of a SBES was not fixed yet. However, the estimation is that a biogas system for producing 1 kWh would cost 8 million UGX (2,390 Euros) and a system that could produce 2 kWh would cost 11 million UGX (3,280 Euros)

A battery charging station in a rural town of Uganda

Regarding the first option, selling electricity to households using batteries, my research shows that batteries are still widely used in rural areas of Uganda. The battery charging stations are situated in places that have access to the grid, usually in rural towns. Being in a central place is very important for this business, since it makes it accessible to its customers. Therefore the SBES would need to be located either in a rural town or in one of the rural trading centers—a small version of a rural town. However, if located in a rural town or a trading center the access to feedstock could become very complicated; since is very difficult to find land available to grow feedstock or to have cattle near rural towns or trading centers. In a previous part I have shown that the entrepreneur needs to have control over the feedstock, either by growing it or by owning the animals that produce it. Therefore I consider that small battery charging station is not a feasible idea for a small electrical biogas system, since the access to the feedstock can become very expensive, due to transportation costs between the place where it is produced and the biogas system. A potential solution for this problem would be to divide the system in to two modules: one that creates the biogas and that would be located near the feedstock source; the other would create the electricity using the biogas and would be located in a rural town or trading center. However it is still unclear how feasible it is to transport the biogas from one place to another. Another option could be to install the biogas system and produce the electricity in a place that has direct access to feedstock, and then transport the electricity—using batteries—to the place where it be consumed, for example the trading center or a rural town. The main problem I see with this option is that storing electricity might be more complicated, and expensive, than storing and transporting biogas. However, just like in the other case, more research is needed to understand the advantages and constraints—both technical and economical—of splitting the biogas system in two.

A cell phone charging station, an example of a Micro and Small Enterprise in rural Uganda.

The other possibility is that the electricity is consumed by small and medium enterprises. A small and medium enterprise is a very broad definition. During my fieldwork I found that most of the businesses that are presented in the rural areas are so small that the term micro and small enterprises (MSE) is a better description of them. In this research I focused on businesses that have electricity as one of their key resources. In the field I found several of these businesses: cell phone charging stations, hair dressers, small shops that use fridges to sell cold sodas, places that show movies on a TV and charged an entrance fee. All these businesses have something in common: they only need relatively small amounts of electricity— below 1 kW— to work, therefore they could be perfect users for an SBES service. My research also shows that all these businesses charge very little for their services—charging a phone costs 500 UGX (0.14 Euros) a hair cut costs 1,000 UGX (0.28 Euros) –and have practically no access to finance mechanisms. Therefore the high initial investment of the SBES makes it unlikely for them to acquire the system themselves. A possible solution would be that an 'external' entrepreneur acquires the system and then sells the electricity to these MSE. However, I see two problems with this: the first one is that all these businesses are located either in trading centers or in rural towns. As I already discussed, the lack of direct access to feedstock in the trading centers or rural towns would create another barrier for the technology. The second problem is that this type of installation, a mini-grid, requires a more sophisticated technology—in order to control the loads, prevent an overcharging of the system and also to control the consumption of each user—and logistics to bill and collect the payments for the electricity. Although both problems can be solved, this would require an even bigger investment and can make the technology too complex for its adoption. And additional problem could be related to the need to have a license in order to be able to distribute energy. Given the small size of the entrepreneurs, getting the license might be a difficult process. Therefore I consider that, at least for the initial phase, selling electricity to MSE is not a feasible option for an entrepreneur.

Given that the minigrid is not an option—at least not yet—the only remaining one is to sell the electricity directly. One idea would be that the entrepreneur generates the electricity and then finds another person that needs it. However, given the problem of feedstock availability discussed before, the final user of electricity would have to be near the biodigester plant. This idea could work for big biogas plants—in fact the project in Kalangala is trying to work in this way—but I think that for a small biogas plant it would be unlikely to find a business that needs electricity and is willing to move near a source of feedstock—which most likely would be a near a farmer's plot. Therefore, the only available option is that it is the entrepreneur uses the electricity he/she produces.

Given this, the entrepreneur will need to have an economic activity that will require electricity. Considering that the technology needs already a lot of learning cycles to increase its fit and become a 'plausible promise', I suggest to look for an entrepreneur that would use the electricity he/she produces to improve an activity in which he/she is already involved—for example, a maize mill that is currently powered with a diesel generator—and thus where he/she already has some knowledge. This is to avoid overloading the entrepreneur with learning activities. Another solution is that the electricity is used to start a new activity that has a close relationship with the one the entrepreneur is already carrying out—for example, a farmer that sells coffee could use the electricity to power a coffee peeler machine. In this case, since the entrepreneur is already familiar with the activity, I expect the learning process to take less time. However, one of the main questions that still needs to be answer to assess the feasibility of this option is the final cost of electricity produced using a SBES and how can it be compared with other ways of producing electricity—mainly using diesel generators. Considering the low income in the rural areas I expect that the final decision on adopting or not an SBES will be highly influence by the cost of producing electricity. Therefore, a Cost-Benefit analysis of the use of SBES is highly recommended.

In the initial planning, the third role of the entrepreneur will also include selling the bio-slurry that the SBES produces. During my research I constantly asked about the fertilizer and its potential. All the actors I talked with agree that the bio-slurry has a great value—some even pointed out that it was greater than the biogas—but no one could explain in which way it could be sold—or if it could be sold at all. In my interviews the general view is that as the Uganda population grows there is an increasing perception of the need for fertilizer. However, currently its use is extremely low. According to the World Bank (2012) the average use of fertilizer per hectare of arable land in Uganda between 2007 and 2011 was 2.1 kg; the same source points out that for the same period Kenya used 32.4 kg/hectare and The Netherlands 238.3 kg/hectare. Given these very low numbers it is very difficult to assess the market opportunity of selling fertilizer. From the interviews with fertilizer traders it became clear that fertilizers are predominately used by farmers who work at industrial levels, producing tea or sugar cane. Given that the entrepreneur FACT is focusing on is of a different type I do not have enough information to derive any conclusion on what characteristics are needed to sell, or trade, fertilizer. My best guess is that the best option would be to use it for own consumption, when a farmer—who acts as an entrepreneur and produces electricity for his/her own use—also uses it on his/her own crops. The constant use of the fertilizer by the first innovators could help dissipate some of the doubts that currently surround the innovation. For example, if the first farmers start using the bio-slurry and register the (expected) increase in crop yields, the monetary value of using fertilizer could be determine—as the extra income that the farmer can get from using fertilizer. However, it is important to point that this process could take some time, since several harvesting seasons might be needed to see an increase in the yield of the crops. It is because of this long time that the learning process might need to be supported by the R&D team.

6.4. Conclusions, different roles, the same entrepreneur

In the previous part I tried to show the different roles that the entrepreneur will play during the adoption, and adaptation, of the SBES. Based on those roles, I defined some characteristics that the entrepreneur needs to have. These characteristics can be summarized in the following way. The entrepreneur needs to have: access, and control, over the feedstock; have an ongoing economic activity—or immediate plans to engage in one—that would directly benefit from gaining access to electricity. Finally the entrepreneur needs to have access to capital—most likely his/her own—to make the initial investment. On top of this, the entrepreneur needs to have a commitment towards the technology and its potential use. He/she needs to be willing to become an active actor in the process of increasing the fitness of the technology and needs to have the social skills to learn and teach about it.

As I showed before the learning process is vital in this early stage of the technology, so a very important characteristic is that the entrepreneur is able to invest time—and sometimes money—to go through it. However it will be a great challenge to find an entrepreneur who can and is willing to do all the work that is involved in the learning process on his/her own, especially in the beginning, when the technology is still 'the best bet' of the R&D team. As one entrepreneur told me: "nobody wants to be the first one to learn, at least not with their own money". In that sense, the final characteristic that the entrepreneur needs to have—at least the first ones who adopt the technology—is support of an institution while they go through the learning phases of the technology. This idea is not new, since Douthwaite, Keatinge and Park (2002) talk about the importance of having a *champion of the technology,* who is in charge of nurturing the learning process.

7. General conclusion

The overall objective of my research was to help FACT Foundation, and its implementing partners, to understand which success factors are needed by the entrepreneurs in rural areas of Uganda in order to overcome the barriers that are present in the adoption of small electrical biogas systems for productivity activities. I believe that the best way to see what these success factors are is to first understand the context in which the innovation will happen and where the entrepreneur will be working. Showing how this can be done, using insights from innovation sciences and development studies, was the research question of this report. In order to achieve my final goal, I posed a series of sub-questions. In the previous parts of this report I tried to give an answer to each of those questions (see the conclusions of sections 5 and 6). Therefore, in this overall conclusion I will try to answer my main question. To do so I first try to, very briefly, summarize all my findings regarding the barriers for the technology. Then I reflect about how the use of the insights from innovation sciences and the learning theories helped me to define these barriers and defined the success factors that are needed for the entrepreneur. I finalize this section, and the whole report, by giving some recommendations based on my conclusions.

The energy situation in Uganda has clear problems: electricity access remains very low, the grid is unstable and unreliable and the prices for electricity are surprisingly high—even comparable with European prices. In rural areas, where the grid is hardly present, the demand for electricity remains very high and people find several ways to fight the lack of access to electricity: solar panels, diesel or petrol engines, car batteries. This gives a clear opportunity for technologies that aim at producing electricity in sustainable ways. The small electrical biogas systems appear to be ideal for the rural areas of Uganda. They do not require a very complex process to be operated and access to feedstock and water seem to constitute the only requirement for this technology to work. Considering this SBES seems, at first glance, a very promising technology not only for providing access to electricity but also to enhance productive activities and help reduce poverty.

However, my analysis of both the innovation system (chapter 5) and of the different roles of the entrepreneur (chapter 6) showed that there are also many barriers that SBES, and its users will have to overcome. These barriers can be divided in to two types:

1. Barriers at the context level: barriers that become visible by doing a multi level analysis (niche, regime and landscape) of the innovation system
2. Barriers at the technology level: barriers that become visible because of the characteristics of the technology and its current stage of development.

The most important barrier at the context level is a combination between a very unstable electrical regime and the very low purchasing power of the population in Uganda. As I showed earlier the SNM literature points out that in unstable regimes the new technology might have a better chance of survival if it focuses on existing market niches that are not well served by the current regime. I argue that although this market niche indeed exists—and it is poorly served by the current electrical regime—the low purchasing capacity of the majority of the population make this niche very small. I believe that currently only very few people in the rural areas—mainly medium to big farmers—will be able to make the high investment the SBES requires. As I showed before both the Strategic Niche Management literature (see section 5.2.4, page 34) and the Learning Based Approach of Boru Douthwaite (see section 6.4 page 53) show that a way of making technology more affordable is to build a constituency behind it.

In the report I also showed how, given the current state of the innovation system of biogas in Uganda, the best way to promote the creation—and development—of socio-technical experiments that will eventually create a technological niche for the SBES is by supporting bigger experiments that are already present: the big biogas electrical systems (BBES). For promoting the development of a niche for the BBES, there is a need to promote a network between the existent projects (the one in Kalangala and the one in Kassanda) and other important actors in the biogas sector—like CREEC and the East African Energy Technology Development Network-Uganda (EAETDN-U). More details on how the networks can be promoted are given in section 7.1,

At the technology level I believe that the main barrier is formed by the high price of the technology and its novelty. In the report, using insights from (Douthwaite, Keatinge, & Park, 2002) I defined the SBES as a 'best bet' that needs to go through several learning cycles to adapt itself to the needs and conditions of the people in Uganda and become a 'plausible promise'. I also showed (page 53) how this process can only be undertaken with the active participation of the first entrepreneurs who adopt the technology and are willing to invest their (scarce) resources to adapt it. I also pointed that, as (Douthwaite, Keatinge, & Park, 2002) said, there is a very important role that needs to be played by the *champion of the technology*, a person or institution that nurtures the learning process that shifts the technology from a 'best bet', to a 'plausible promise ' to finally becoming a 'widely adoptable technology'. In this case I believe that the role of *Champion of the technology* is actually a double one that needs to be played by FACT Foundation and one of its implementation partners in the field. The role of FACT could be to create, collect and distribute knowledge about the SBES and the innovation system. FACT could also provide (partial) financial support for the local champion. Finally, FACT could be seen as the "international ambassador" for the SBES.

On the other hand the implementing partner could help the entrepreneurs overcome routinary problems and promote the adaptation of the technology to local conditions. The local partner could also encourage the development of a network, by organizing workshops for users, suppliers of the technology (for example local constructors) and engaging with local institutions (for example CREEC).

Defining the context in which the innovation happens proved to be very useful to understand the barriers that are likely to appear. Once the barriers are clear, it is easier to define the success factors that the entrepreneurs need to have to overcome those barriers. In that sense I consider that this reports shows how innovation studies—in particular SNM—can be very useful to define the context of the innovation. Defining niche(s), regime(s) and a landscape provides a 'roadmap' for the innovation and shows where the main barriers might appear. During this report I tried to show how the use of SNM can provide a 'helicopter view' on the innovation process. Although this macro view is very important, it is necessary to have a detailed view of the evolution of the technology and its possible adaptations to the new environment as well. The Learning Based model of Boru Douthwaite (Douthwaite, Keatinge, & Park, 2002) and the way he conceives the different phases of the innovation process allowed me to understand the current situation of the SBES and to be able to show what are the tasks that are needed to shift the technology from a 'best bet' to a 'widely adoptable one'.

I believe that small biogas electrical systems could be very beneficial in countries like Uganda, where there is a lack of electricity and technologies that help poverty reduction are an urgent need. However this technology is still a very new one and still needs to go through a long phase of adaptation before it is ready to be widely adopted. As I tried to show in this report both Innovation and learning theories propose that the best way to go through this adaptation phase is to support a small, yet very active, group of users that are willing to invest—both time and resources—in the technology. Considering that Uganda is—according to the World Bank—a low income country this adaptation phase needs to be heavily supported by some external source—for example a program similar to the UDBP—in order to succeed. Expecting that rural entrepreneurs in Uganda will take all the risk involved in adopting the technology on their own seems hard to believe. It could even be possible that Uganda is not the best setting for this first phase of the adaption process and that other countries could provide a better starting-point for the SBES technology. However, further research is needed to support this last claim.

7.1. Recommendations:

Based on my conclusions, I can recommend to FACT Foundation:

1) To encourage the creation of a network between the two projects (Kalangala and Kassanda) and other relevant actors of the biogas sector (CREEC, SNV, Heifer) that could help the development of a technological niche for big biogas electrical systems. In order to keep the network neutral and to benefit all the actors it could be built around a neutral actor–that is neither an entrepreneur nor a project. Currently there is an organization, the East African Energy Technology Development Network-Uganda (EAETDN-U) that could take on this role. Therefore, a partnership between FACT and the Energy Network is highly recommended. It is important to stress to both project managers that, at this stage of their projects, sharing information and creating a network is more beneficial than harmful to them. Considering that finding a neutral actor who could articulate the network is a process that requires some time, FACT could play this mediator role in the meantime.
2) To promote other projects to engage in big biogas electrical systems. In order to build a niche, there is a need to have more than two projects. In this case, the formation of the network between projects and other actors would be beneficial to attract new projects.
3) To field test and promote the use of bio-slurry as a fertilizer in order to be able to quantify the economic benefits of using it. Only by having this information, it would be possible to do a full cost-benefit analysis of the SBES. This requires research based learning and the involvement of a R&D institute that could support the entrepreneurs in this learning cycle?
4) To seek a *champion for the technology* who actively promotes the small biogas systems by:
    a) Promoting the development of a technological niche, both for small and big biogas electrical systems;
    b) Giving support to new users and encourage them to modify the current SBES so it can go from a 'best bet' to a 'plausible promise' and finally become a 'widely adoptable technology'.
5) To research the potential and performance of the innovation system of biogas in other developing countries that are classified as 'lower middle income' by the World Bank[13]. The purpose of this research would be to understand if more developed economies could provide a better starting point for the Small Biogas Electrical Systems.

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[13] To see how the World Bank makes this classifications, visit http://data.worldbank.org/about/country-classifications

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Appendix

Outline of the interviews

1. Who do you think are the principals actors involved in the innovation system
2. Can you see any link (asides from the obvious) between this actors (contacts between you and SNV, or other NGO's that are working with the same technology)
3. What do you think are we fighting against? What is the main barrier for developing the biogas system? And any possible 'help' that the technology might get (subsidies, tax reduction, government support, etc) Same thing with barriers (subsidies for kerosene/diesel/electricity)
4. What are your expectations towards the technology and your particular project, what were your motivations to begin with?
5. How do you feel about the technology? Do you think it fits the reality? Have you made some field test yet? Are you able to change things while you go?
6. While we are at it, how hard are these systems to operate? Any special skills you need? Do you see some farmers doing it by themselves? If you run into any trouble, how easy is to find spare pieces, or someone that can help you.
7. For your particular project, what are the main problems you are running into? And expect to run into? Do you see the grid as possible menace to your project?
8. In your knowledge, are you the first one to try this "new approach" towards biogas, if others can you mention them?
9. Regarding the feedstock, do you think is it possible for an entrepreneur to get it from farmers? Is there a cost for it? Or can it be seen as a way of helping farmers getting rid of something they don't want. Do you think a possible trade (feedstock for energy and/or fertilizer) would be interesting.
10. In your opinion, what would be the main barrier for the entrepreneurs? Technological one? Financial one? Cultural one?
11. Do you feel farmers/SME could be interested in these systems? Why?
12. Where do you think this is going? Do you see future in the SBES?

Technological characteristics of the biodigesters.

During this report three main types of biodigesters types have been discuss. The fixed dome type (which is being promoted by the UDBP); the PVC model—which can be broadly categorized as a Low-Cost Polyethylen Tube Digester—and is being promoted by FACT and the Floating drum type. The last one, although very popular in India, is hardly present in Uganda and it is only briefly discussed in the report, therefore I will not describe it here. The interested reader is referred to the source of this section for more details (see footnote). Therefore in the following section I do a brief description of the fixed dome digester and the PVC model, also known as low cost polyethylen tube digester[14]..

Fixed dome plants

Consist in a digester with a fixed, non-movable gas holder that is situated on top of it. Once the gas production begins the slurry is displaced out of the digester tank. The plant is constructed underground and thus is protected from any damage that animals or persons could cause. The expected life spam is of approximately 20 years. Constructing the fixed dome plant is labor-intensive and not an easy task. There is the need to have technical skills in order to be able to build a gas-tight digester.

In Uganda the CAMARTEC model, originally from Tanzania, is the most common type of fixed dome plant. Figure 11 shows a biodigester of this type.

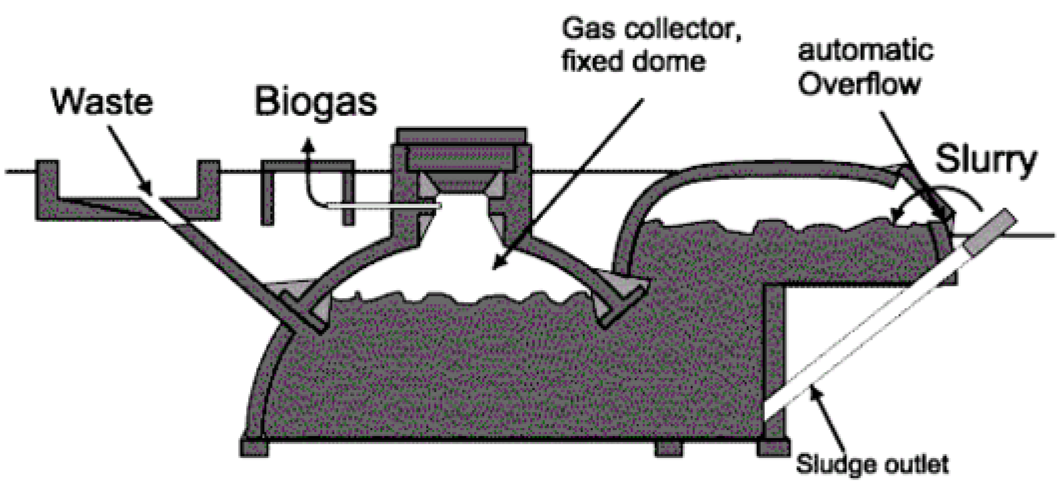

Figure 11 CAMARTEC design

[14] Unless indicated otherwise, the source for this section is always the following page of Energypedia https://energypedia.info/index.php/Types_of_Biogas_Digesters_and_Plants

The main advantages of the fixed dome design are: the absence of moving parts and of rusting steel parts; the long life spam of the digester, if built correctly; the fact that it saves space, since it is constructed underground, and that it is well isolated; and finally that the construction of the digesters provide opportunities for skilled local employment. The main disadvantage of this model is the need to have high technical skills to construct gas-tight digester, otherwise gas leaks can occur frequently. Energypedia recommends that this type of digesters should only be built in places where the construction can be supervised by an experienced biogas technician.

Low cost polyethylen tube digester

This type of digester is relatively new and is been applied successfully in Latin American countries such as Bolivia, Peru, Ecuador, Colombia and Mexico. In this case the digester is made by a PVC bag, made by two layers of PVC sheets cut in a rectangular shape, the two sheets are connected at the edges by hot air welding, creating a welded seam. Once the PVC bag is ready, two pipes—and inlet and outlet— are connected to the sides of the bag. In top of the bag another pipe—the biogas outlet—is installed. Since the digester is made of flexible materials it is necessary to construct a small ditch. The ditch will have two functions: it gives stability to the digester and it also offers some degree of protection to it.

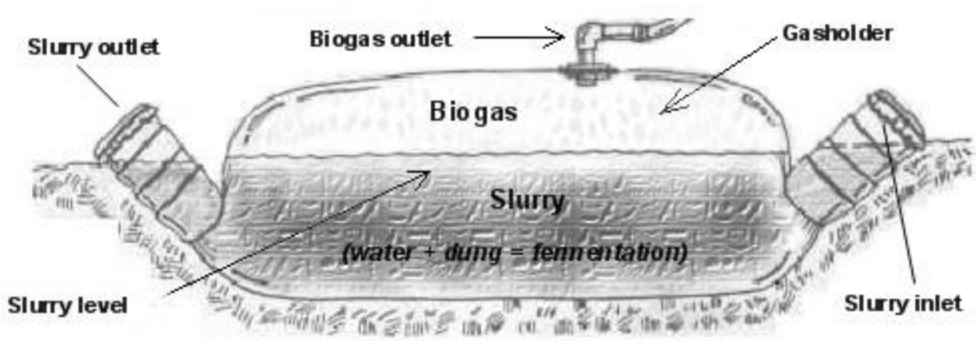

Figure 12 A low cost polyethylen tube digester.

The advantages of this type of digester are: the biodigester is not fixed and can be easily moved; its installation does not require advanced technical skills and it takes a short time; leaks are easy to fix; it is can be installed easily and in short time; all the materials, including the PVC bag, are produced in most countries, so it can have a low cost. The main disadvantage is that this type of digester has a lower gas pressure than the fixed dome or the floating drum; that it requires more space to be installed; and that the digester is more fragile, it can punctured by animals, sticks or rocks.