EVALUATION OF PROGRAM DECENTRALIZATION OF THE SMALL SCALE ENERGY SYSTEMS CONSTRUCTION AND MAINTENANCE MANAGEMENT IN RWANDA A CASE STUDY OF THE RWANDA DOMESTIC BIOGAS PROGRAM

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Evaluation of Program Decentralization of the Small-Scale Energy Systems Construction and Maintenance Management in Rwanda: A Case Study of the Rwanda Domestic Biogas Program

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

Signed ……………………………….Date………………………………..

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This thesis has been submitted for examination with our approval as the university supervisors

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DEDICATION

To my beloved wife Munezero Santiana, son Sacha and Michel's family for their warm daily support.

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I would like to express my gratitude to Prof Diang'a and Dr Gwaya for their guidance and leadership in the course of my research. To my colleagues and classmates who encouraged me and kept my energy vivid.

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ACRONYMS AND ABBREVIATIONS

BORDA	Bremen Overseas Research & Development Association
BSP	Biogas Sector Partnership Nepal
CAMARTEC	Centre for Agricultural Mechanization and Rural Technology
EDCL	Rwanda Energy Development Corporation Limited
EDPRS	Economic Development and Poverty Reduction strategy
EICV	Integrated Household Living Condition Survey
EWSA	Energy Water and Sanitation Authority
FAO	The Food and Agriculture Organization of the United Nations
FGD	Focus Group Discussion
GHG	Green House Gases
KII	Key informants' interview
IPCC	Intergovernmental Panel on Climate Change
MININFRA	Ministry of Infrastructure
MINALOC	Ministry of Local Government
NDBP	National Domestic Biogas Program
NISR	Rwanda National Institute of Statistics
GOV	Government
REG	Rwanda Energy Group
SACCO	Savings and Credit Cooperatives (At administrative sector level)
SNV	Netherlands Development Organisation
RWF	Rwandese Franc
UNDP	United Nations Development Program

ABSTRACT

Decentralization of the domestic biogas plants construction and maintenance has been ongoing in Rwanda since 2014. However, the performance of the decentralization endeavor has not been thoroughly evaluated. Such evaluation is necessary for the decentralization policy endorsement or refinement. In Rwanda, the government implements the domestic biogas program through REG (Rwanda Energy Group), which provides subsidies for biogas constructions. Those subsidies are channeled through the districts and get to private construction companies. From 2006 to 2013, the biogas was centralized and managed essentially from REG, Kigali office. However, since the beginning of 2014, the biogas program decentralization has been initiated by REG and a partner NGO, SNV (The Netherlands Development Organization). Prior to the decentralization, the rural people were still underserved and some of the installed biogas digesters constructed were non-operational. Therefore, this research study aimed at determining whether the biogas program decentralization from central level to Districts had contributed to more biogas constructions and better maintenance services thus increased access to energy by rural people. The study was carried out in Bugesera and Kirehe Districts, Eastern province of Rwanda, whereby 93 respondents participated in the study and were selected through random and purposive sampling. Data were collected from biogas households grouped into two categories: those who owned a biogas plant before decentralization and those who owned a biogas plant after decentralization. Additionally, other actors directly involved in the implementation of the program - biogas company owners, District and REG staff- were also interviewed. In this study, it is concluded that the domestic biogas program development in Rwanda has been improved significantly, by adopting the decentralization policy. A greater number of biogas plants, higher level of biogas user satisfaction and higher quality of the construction and maintenance services are evident benefits. From these conclusions, the study recommends further capacity building for District level actors and continued program decentralization to lower spheres of the public administration, at least to sector level. Additionally, there is the need for further strengthening of local construction companies, construction cooperatives and local masons to provide better services and reach out to more people, to achieve the government aspirations. This remains an unfulfilled dream.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Rwanda's rural household condition surveys, underline their reliance on bio-mass to meet energy needs. The target set by the Government of Rwanda for the biomass energy subsector is to reduce the percentage of households that use inefficient firewood technologies for cooking to 42% by 2024.

Between 2014 and 2017, the use of firewood as the main source of energy for cooking only reduced from 83.3 % of households to 79.9%, according to the National Institute of Statistics (MININFRA 2019). The effort Rwanda is making to develop the biogas sector and undertake other initiatives may be characterized as an attempt to diversify energy sources, reduce reliance on firewood consumption and at the same time help preserve forests/the environment. Rwanda had plans to promote the use of bio-digesters within households and government institutions with a target to deliver 100,000 bio-digesters by 2018 (Ministry of Infrastructure, 2013). Again, the Rwanda biomass strategy (2018-2030), re-emphasized the commitment of the government to promote biogas, as a viable solution to replacing the 3-stones firewood (Ministry of Infrastructure, 2019). In fact, Biogas has a large number of potential benefits. It is part of a closed ecological cycle, which makes it a sustainable and renewable source of energy.

By replacing traditional energy sources and by digesting dung in a closed environment, it yields a significant reduction in the emission of greenhouse gasses (Hynek Roubik, 2020). In most cases (more than 95 % of all households) it replaces firewood and agricultural waste as the principal source of energy for cooking. This saves women time from collecting firewood, cooking and cleaning cooking utensils. Cooking with biogas instead of firewood or coal reduces the amount of smoke and health damaging particles.

This has a beneficial effect on the health status of the persons concerned, especially women and children. On top of that, if properly stored, treated and applied to the fields, biogas plant effluent has a far higher fertilizer value than ordinary farmyard manure (Karki, 2005).

Majority of households in Rwanda own two or more cattle, used for milk, meat and dung production and for financial security. In 2012, 32% of household possessed cattle, meaning 771,200 households (There was 2.41 million private households in Rwanda) and that this corresponded to 764,600 cows of local/Cross/exotic breed (National Institute of Statistics, 2012). Legislation is in place that prohibits the free roaming of cattle. Almost all cattle are kept in stables overnight, while a growing number of cattle are kept on zero grazing. At farms where stabling is practiced, farmers have access to water.

Most farmers till plots to satisfy the family's needs for vegetables and staple foods like banana, sorghum and beans. The quality of the arable land is mostly poor due to the high cultivation intensity. Due to the consequent need for fertilizers, the composting of dung is commonly practised to maintain or improve the soil fertility. The climatic conditions in Rwanda are favourable to operate biogas plants all year round.

To this end, a biogas intervention has a number of synergies with other development sectors like health, women's development, agriculture, forestry and livestock management. In addition to cooking fuel, biogas can be viewed as a wood saving and forest conservation technique. It can also be promoted to improve the quality of life for women by reducing the drudgery of fuel wood collection and cooking in a smoke-filled kitchen. Biogas can also be used to produce good-quality organic fertilizer at low cost, complementing agriculture-related programmes. The synergies can be utilized effectively if biogas is functionally integrated with other programmes. Integration essentially means identifying these synergies and incorporating them in the process of implementation. There could be numbers of motivational factors for the potential farmers to install bio digesters. It could be improvement on the quality of life of the families, especially that of women. The second motivation could be the use of slurry bi-product as organic fertilizer. There are also rooms to integrate biogas programme with wood saving and forest conservation programmes.

As described earlier, more than 700,000 Rwandan families have the technical potential (collect at least 20 kg of dung on a daily basis) for biogas plant installation and use, a number that is expected to rise with the continuing enforcement of zero grazing legislation, as well as other favourable policies such as the one cow per family (Girinka) Program. When access to credit is made available to farmers on reasonable terms, a substantial portion of these households is able and willing to invest in the technology.

The Rwanda National Domestic Biogas Programme (NDBP) is implemented by the recently created Rwanda Energy Group Ltd. – REG (former EWSA)- A public entity and aims at the large-scale dissemination of domestic bio-digester plant constructions of 6 – 10 m3 to be used by farmers able to feed at least 20kg dung per day into the digester (Dekelver,2006).

The National Domestic Biogas Programme has adopted models which fulfil the following criteria:

- reliable, durable and user-friendly: the digesters should have an estimated lifetime of over 20 years with a minimum of maintenance;
- Replicable: with local available material and local skilled manpower, the digesters must be able to be constructed nationwide;
- Adapted to local conditions (climatic and soil conditions, water levels, quality and quantity of feeding material, etc.);

- The cost of the digesters should be as low as possible without affecting the durability.

Importantly, there is the need to develop and establish linkages between potential stakeholders for programme integration at the policy level as well. By December 2013, prior to decentralisation NDBP had installed around 3,500 digesters (2007-2013), of which 3,400 were fixed dome masonry plants and 100 fiber glass plants (NDBP). However, the rural population was still largely underserved as the government target 25,000 digesters (Government retreat 2012- recommendations) were far from being achieved. Despite a favorable policy environment and appropriate climatic conditions to support gas production, the programme has fallen short of its targets. By the end of November 2012, the programme had achieved about 15 percent of its originally intended target (Arjun, 2013). As mentioned above, the Ministry of Infrastructure later on set even more ambitious targets of 100,000 bio-digesters by 2018 (Ministry of Infrastructure, 2013). Furthermore, in the period 2007-2013, the NDBP was managed from national/Central level by REG. This means that all activities were planned and implemented from the Kigali Offices. The activities in the field were followed by the 15 field technicians that were posted in district towns. The main duty of the field staff was quality control and monitoring digesters constructed by private contractors. The field technicians were also assisting in promotional activities, training of the contractors and masons, they also supported clients accessing biogas loans in SACCO (Saving and Credit Cooperatives). It is clear that the field activities country-wide could not be delegated to these 15 technicians only.

In addition, all financial transactions were managed by the NDBP office in Kigali. A number of steps are required to ensure that the correct payments (especially for the government subsidy) are carried out and this involves the verification of the required documentation and invoices by the field manager (with help of the data base officer), administrative officer, project coordinator and also the REG director general (who is ultimately responsible for the project implementation and therefore the payments).The number of contract, as well as, payment transactions per month was gradually growing as the number of new digesters planned (and completed) was increasing rapidly. While by the end of 2012, the monthly number of completed digesters was around 30 – 40/month, in the course of 2013, the program recorded over 80 per month (NDBP). It was expected that the number of digesters would keep increasing every month thereafter and would reach 250 – 400 /month in the period 2014-2017(NDBP).

Therefore, the increasing number of transactions was one of the reasons to look for alternative arrangements by accelerating the biogas program decentralization. Prior to that, the districts had been limitedly involved.

Again, in a drive to further promote biogas, it was recommended that local governments needed to put more emphasis on District biogas targets during District Performance Contract (Imihigo) formulation and implementation to include biogas dissemination (District IMIHIGO Evaluation Report, 2012-2013). Even though later on, the districts started including domestic biogas in their annual performance plans, districts did not really own biogas activities and were waiting from central level initiatives (REG) to lead implementation.

On the other side, recommendations had been provided, to this regard: ‘Districts should take full ownership and management of bio-gas projects if they are to realize their objectives and benefit Rwandans, James Musoni, the Minster for Infrastructure, had said’ (Newtimes, 2014-11-25). Again, there were also claims that the some of the installed biogas digesters were underperforming or non-operational. The former Minister James Musoni had warned to blacklist inefficient contractors involved in bio-gas projects for failure to deliver on time or compromise on quality (Newtimes, 2014-11-25). Through decentralization, the proximity of District staff to rural people, could contribute to enforcing measures that would see those biogas constructions well maintained.

The onus for promoting, delivering and coordinating energy decentralization is likely to fall on local government. Because they tend to be smaller, decisions can be taken quickly and their structure can adapt more quickly to new situations, as compared to larger and more bureaucratic national governments (Puppim de Oliveira, 2002).

Since 2014, decentralization of the biogas program has been initiated by REG and SNV (The Netherlands Development Organization). This drive aimed at bringing effectiveness for an increased number of biogas plants constructed, and also better maintenance services. The program activities started being decentralized, whereby the 30 administrative Districts of Rwanda took the lead in its implementation. In addition, in a drive to bring proximity services to the beneficiaries District biogas youth-led cooperatives were established, with young [masons from all the 416 administrative sectors of Rwanda; this was done in a drive to complement existing biogas companies or bring biogas construction and maintenance services in some Districts, with no private companies operating in this specific sector.

1.2 Statement of the Problem

Decentralization of domestic biogas plants construction and maintenance has been ongoing in Rwanda, since 2014; this policy was instituted in order to boost production in this sector, in order to meet the national targets of 100,000 bio-digesters (Rwanda Energy Sector Strategic Plan, 2017-2018), which had been so far, an elusive dream. However, the suitability of the program decentralization model has not yet been established. Questions are to which extent the decentralization model has aided to achieve the objective of increased production of biogas plants and better maintenance of the existing stock of biogas plants.

Biogas technology had been identified by the government of Rwanda as one of possible solutions to energy supply especially for domestic cooking and lighting. Prior to the Rwanda Domestic Biogas Programme decentralization, the programme was significantly lagging behind its output targets numbers. One of the main challenges to achieving the targets was the delay in gearing the Rwanda Domestic Biogas Programme towards a truly localized and dissemination-focused organization (Rwanda Domestic Biogas Programme Mid-term Review, 2009). Originally, especially before decentralization, there were lengthy procedures, as most of the works were handled by REG in Kigali. There was also lack of capacity for local biogas construction companies to build with quality and maintain existing biogas plants, as some of the already built biogas plants were underperforming or non-operational. In fact, 10% of the completed digesters were not producing gas at all, while 25% of digesters owners were not satisfied with the volume of produced biogas (Arjun, 2013). Furthermore, lack of Districts ownership was also leading to low investment into mobilization, thus to low numbers of new constructions, while supervision of construction companies for quality constructions was very limited. These are the issues which motivated the decentralization of the program and implementation of related policy.

Ineffectiveness of the centralized biogas program model and unsuitability of the biogas plants construction production or maintenance management techniques imply that the potential beneficiaries of the biogas intervention are not yet reaped in the country. Accordingly, the number of biogas plants remains low and the maintenance culture of the existing stock of biogas plants remains poor. Consequently, the benefits of social welfare promotion, including increased energy access, environmental conservation, and agriculture productivity (bio-fertilizer) enhancement, remains a mirage. If the decentralization model is tested and found unsuitable, or otherwise, ineffective, then it would be necessary to explore other models. Thus the need for this study.

1.3. Objectives of the Study

1.3.1 General Objective

The general objective of the study is to evaluate the program decentralization of the small-scale energy systems construction and maintenance management in Rwanda, for the purpose of informing policy formulation and reform in the sector.

1.3.2 Specific Objectives

1) To determine the contribution of decentralization of the domestic biogas program to increase in small scale biogas systems construction and thus energy production.
2) To find out the contribution of decentralization of the domestic biogas program towards improving maintenance services for the constructed small-scale biogas systems.
3) To determine the suitability of program decentralization as a model for the small-scale energy systems construction and maintenance.

1.4. Research Questions

1) What was the effect of the domestic biogas program decentralization towards increasing the number of constructed small scale biogas systems and thus energy production?

2) What were the effects of the domestic biogas program decentralization on improved maintenance services for already constructed small scale biogas systems?

3) Is program decentralization a suitable model for small scale energy systems construction and maintenance?

1.5. Justification of the Study

The study should be able to demonstrate whether the decentralization of the Rwanda domestic biogas program has led to closing ineffectiveness gaps compared to the previous centralized system. On the other side, the study should demonstrate if the decentralization model has led to an increased number of domestic biogas constructions and better maintenance services for existing biogas constructions. The study would then be able to provide recommendations that would be applied in order to further improve the domestic biogas program, while also confirming if this model could be replicated for other Small Scale Energy systems. Last, if the decentralization model is tested and found ineffective, then it would be necessary to explore other models. Thus, the need for this study.

1.6. Significance of the Study

The researcher is conducting this study in order guide policy reform. The study will benefit government entities involved with biogas and energy programs, Districts and other stakeholders. Ultimately, the study will contribute to improving rural people's livelihoods through recommendations towards more effective small-Scale energy systems.

1.7. Scope and Limitations

The study assessed the effects of the Domestic Biogas Program Decentralization, directly linking the specific objectives of the study to some of the relevant functions of the Domestic Biogas Program, these being Coordination at implementation level, Promotion & extension services at community and household level, quality biogas plants construction and maintenance services. To this regard, the study was carried out in Bugesera and Kirehe Districts, Eastern province of Rwanda, whereby 93 respondents participated in this study and were selected through random and purposive sampling.

Data was collected from biogas households grouped into two categories, those who owned a biogas plant before decentralization and those who owned a biogas plant after decentralization, but also other actors directly involved into the implementation of the program, and these includes biogas companies' owners, District and REG staff were interviewed.

1.8 Outline of the Study

The Thesis is composed of five main chapters in order to tackle all the main elements for this important research. Chapter One discusses the importance of access to small scale energy systems, in this case domestic biogas and the challenges faced during implementation, especially in terms of reaching the set targets and maintenance services for the already installed biogas plants. It also outlines the research problem, the objectives of the study, research question, limitations and scope, as well as the study justification. Chapter Two brings in theories on biogas technology, the biogas program itself, as well as decentralization concepts and related status in Rwanda. To this regard, the necessary theories guiding the study are well reviewed. Chapter Three informs on the methodology used to conduct the study, including the target population, sample design, research instruments, data collection methods and data analysis. Chapter four presents the results obtained from the analysis. Chapter Five provides the conclusions and recommendations of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The chapter aims at introducing the country context and further elaborates on the energy thematic areas and challenges in general. The chapter also explains why biogas is part of the solutions and gives insights on the biogas technology itself. The chapter further informs on the domestic biogas program implementing and wider dissemination of domestic biogas plants. Finally, the chapter elaborates on decentralization processes in Rwanda and how the biogas program went into the same drive.

2.2 Country Context

Rwanda is a land-locked country located in central Africa with capital Kigali. Rwanda is bordered by Uganda to the north, Tanzania to the east, Burundi to the south and the Democratic Republic of Congo to the west. Rwanda's total area is estimated to be 26,338 KM^2. According to Rwanda's National Institute of Statistics (NISR), in 2015, the population density in Rwanda was estimated to be 445 people per km^2 and the total population is approximately 11,809,295 according to 2017 NISR projection

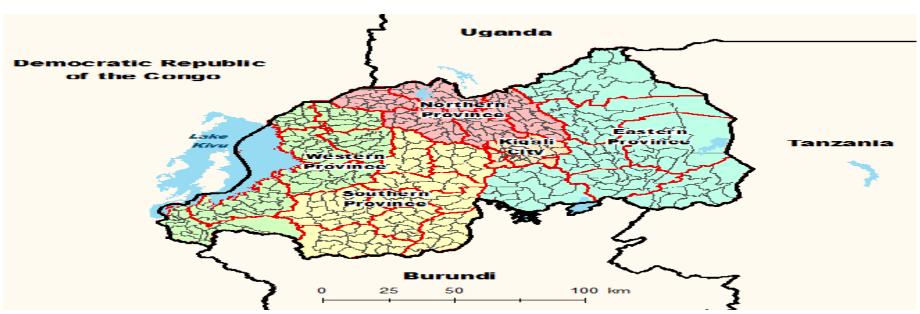


Figure 2.1: Rwanda Provinces, Districts and Sectors (MINALOC)

Rwanda is subdivided in 5 provinces, 30 districts and administrative 416 sectors (See figure 1). The five provinces of Rwanda are divided into 30 districts (Kinyarwanda: *uturere*, sing.*akarere*). Each district is in turn divided into sectors (Kinyarwanda: *imirenge*, sing, *umurenge*), which are in turn divided into *cells* (Kinyarwanda: *utugari*, sing. *akagari*), which are in turn divided into *villages* (Kinyarwanda: *imidugudu*, sing. *umudugudu*).

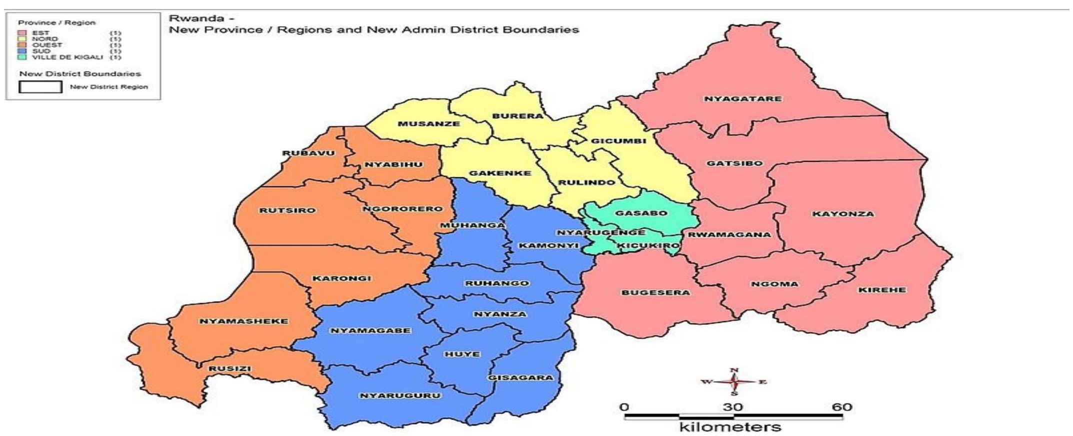


Figure 2.2: Rwanda District map (MINALOC)

According to the World Bank, Rwanda met most of the Millennium Development Goals (MDGs) by the end of 2015. Strong economic growth was accompanied by substantial improvements in living standards, evidenced by a two-thirds drop in child mortality and the attainment of near-universal primary school enrolment. A strong focus on homegrown policies and initiatives contributed to a significant improvement in access to services and in human development indicators. The poverty declined from 77% in 2001 to 55% in 2017, while life expectancy at birth improved from 29 in the mid-1990s to 69 in 2019 (The World Bank). Agriculture is also crucial for Rwanda's growth and reduction of poverty, as the backbone of the economy, it accounts for 39 percent of gross domestic product (GDP), 80 percent of employment, 63 percent of foreign exchange earnings, and 90 percent of food needs.

2.3 Energy Access and Small-Scale Energy Systems

Access to energy is as a critical element for human development. Institutions such as the EU, UN, World Bank believe that energy is essential to promote or improve a range of basic services, such as lighting, drinking water, health centers, schools and communications. There is also a common understanding that most of the Millennium Development Goals can be met only if appropriate access to such services can be reached first. Therefore, the challenge to provide modern energy services to the majority of the poor in the world is huge. According to the World Energy Outlook 2016, 2,742 billion people in the world rely on traditional use of biomass for cooking in 2014, including 0.792 from sub-Saharan Africa, representing 81% of the population (World Energy Outlook 2016). In addition, the rural electrification rate in sub-Saharan Africa was 19% (World Energy Outlook 2016).

Rwanda's energy consumption is dominated by biomass that accounts for about 85% of primary energy use while petroleum accounts for 11% and electricity for the remaining 4% (World Energy Outlook, 2016). Biomass is used in the form of firewood, charcoal or agricultural residues mainly for cooking purposes in Rwandan households, and also in some industries (MININFRA 2012). In the rural areas, biomass meets up to 94 per cent of national needs; with the balance being met by other options such as kerosene, diesel, dry cells, grid and non-grid electricity, biogas, solar, wind and other renewable energies. Biomass is already in short supply with the country facing a biomass deficit of over 4 million m^3 per year.

In Rwanda, combined, firewood and charcoal represent more than 95% of urban cooking energy consumption and close to 100% for the rural population. Wood fuels (firewood and charcoal) remain the dominant energy for households as well as for public and private institutions. Charcoal, which is the main urban fuel, in particular in Kigali city (65%), seems to obtain an increasing share also in rural areas.

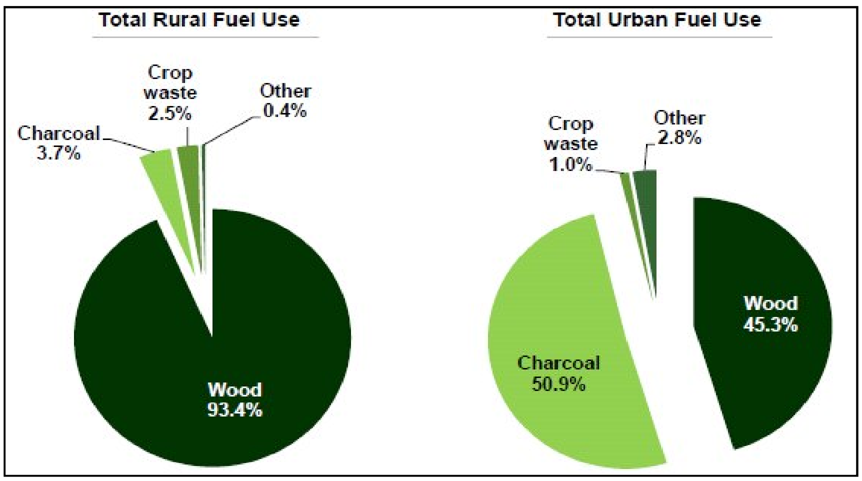


Figure 2.3: Fuel sources for cooking in percentage.

In rural areas, households have limited alternatives to firewood and charcoal for cooking, in addition, the existing alternatives are comparatively expensive, while firewood may be collected free of charge. As previously highlighted, it is becoming particularly challenging for rural dwellers to satisfy their daily requirements of firewood as new legislation has restricted access to forests and the use of firewood in an attempt to protect natural forests (Ndayambaje, 2011). Collection of traditional fuels takes a lot of time, in particular for women and children, which could have been spent otherwise at school or used for productive activities. By burning these fuels, particularly women and small children are exposed to smoke and prone to respiratory illnesses and eye ailments. At many places, the collection of traditional fuels damages the environment on which the people so heavily rely. Throughout the rural areas, the main sources of lighting energy (households use more than one source of lighting, here are only indicated the primary sources) are lanterns (36.6%), batteries/torch (32.2%), firewood (10%) and oil lamp (9.4%). The figures are relatively different in the urban settings. Although fuel wood consumption is expected to increase in the short-term, the long-term strategy of the EDPRS (Economic Development and Poverty Reduction strategy) is to reduce fuel wood consumption from 94 to 50 per cent by the end of 2020. Measures to address this include a plan to increase the area under forest from 20 to 23.5 per cent by 2012. This will be accompanied by a concurrent decrease in wood consumption from 8.9 to 6.2 million m^3.

The Government of Rwanda (GoR) has set objectives and targets for the energy sector to be fulfilled under the Economic Development and Poverty Reduction Strategy (EDPRS 2) including: (i) 100% of the population to be connected through on-grid and off-grid solutions; (ii) it also aims at achieving rapid economic growth, rural development, productivity and youth employment, and accountable governance. Ensuring access to affordable and modern sources of energy is essential if these objectives are to be achieved. Again, the Rwanda biomass strategy (2018-2030), re-emphasized the commitment of the government to promote biogas, as a viable solution to replacing the 3-stones firewood (Ministry of Infrastructure, 2019)

On the other side, Small-scale energy systems can be developed either through small hydropower plants or through other sources mainly biogas and solar energy contributing to the Rwanda off-grid-solutions targets. You will find, Hereunder, a list of reasons perceived to be possible effects of the deployment of small-scale renewable systems (Clarke, 1999):

i. Reduction in energy dependence, move towards self-reliance with diversification of sources.

ii. Promotion of specialized services in Engineering and consulting in the use of renewable energies at local level.

iii. Development of research and development in companies and local education centres.

iv. Increased level of services to the local community.

v. Employment creation – research, design, equipment production, installation, maintenance and exploitation.

vi. As we move into the 21st century, the supply of fuel has become more problematic – becoming more concentrated in the Middle East.

vii. The cost of fossil fuel is likely to rise as a result of regional concentration, environmental taxes (climate change levy) and dwindling resource.

viii. The environmental impacts of fuel choice are widely understood.

ix. Renewable, clean energy systems are unlikely to present themselves as a large-scale alternative largely due to their intermittent nature or the difficulties associated with related fuel transportation.

x. Elimination of fuel poverty where areas that are rich in renewable resource are penalized for not being in an area of high population density. The potential is there to actually complete the task in areas rich in renewable resource.

2.4. Biogas as a Solution

2.4.1. Introduction

This chapter introduces the biogas technology and its benefits. It also provides information on biogas constructions, maintenance and operation.

2.4.2. History of Biogas in Rwanda

The first record of the construction of domestic biogas plants dates back to 1982. On the invitation of the FAO, a biogas consultant from Nepal constructed 4 plants ranging in size from 8 to 20 m^3 at the '*Projet Développement du Petit Elevage*' at Kabuye. At the same time a biogas training course was organised for technicians. Following this course and with support from SNV Rwanda, plants were constructed in Rwesero near Lac Muhazi and at the cultural development project project in Murambi.

According to an international biogas survey published by BORDA in Bremen, thereafter, some hundred domestic biogas plants of the fixed dome model had been constructed, at the end of 1990, in schools and barracks by the Ministry of Public Works and Energy and by the International Association for Rural Development. Some others have been constructed for religious organizations and rich families. At present, there are no ongoing programmes aimed at the large-scale dissemination of domestic biogas plants in Rwanda. The following organisations with ongoing activities in the biogas sector were identified and contacted:

a) ***Centre for Innovations and Technology Transfer (CITT):*** the CITT is part of the Kigali Institute of Science and Technology (KIST), established in 1997 as Rwanda's first technological institute for higher education and supported by the Ministry of Education, UNDP Rwanda, GTZ and the Governments of Japan and The Netherlands. CITT is a centre for applied research leading to environmentally friendly technological innovations and the subsequent transfer of these technologies to rural areas. The centre has installed a number of large institutional biogas systems at prisons and schools in collaboration with the Ministry of Energy, Water and Natural Resources (MINERENA). These systems, the CAMARTEC model, range in size from 75 to 1000 m^3 and are primarily meant for waste treatment. Also, a smaller 35 m^3 plant has been constructed at the dairy demonstration and training farm of Send a Cow, a local NGO;

b) ***Technological and Scientific Research Institution (IRST*)**: the IRST is a research centre allied to the National University of Rwanda in Butare. The centre has research departments relevant to biogas, being fertiliser production with locally available raw materials; local construction materials and renewable energy. At the institute's compound the renewable energy department is conducting experiments with solar drying, water heating and solar stills, improved wood stoves, small biogas plants and gasification through pyrolysis. Furthermore, it is conducting studies on the use of methane gas from the Kivu Lake, rural electrification through Solar Home Systems and micro-hydro plants. At the 10 m^3 fixed dome plant installed at the institute's site, experiments have been conducted with different feeding materials and the use of slurry as fertiliser. A small number of plants have been installed at schools as an energy source for the school kitchen. The aim of the institute is to spread the use of plants at schools and the institute works together with the Ministry of Education to achieve this goal. A concrete programme has not yet been developed though.

c) ***Ministry of Infrastructure (MININFRA):*** the Minister of State is heading the departments of communication and energy within the MININFRA. Biomass is a section of the energy department. Within the framework of a technical cooperation agreement between Rwanda and China, two technical training courses were conducted in 2004 in Kigali. Each course was attended by 17 participants and lasted for 5 weeks. As part of the training, two domestic biogas plants were constructed at dairy farms in the vicinity of Kigali. The participants invited for the courses were civil servants, engineers and technicians, working for schools, hospitals, prisons and army camps in the provinces. The idea behind this selection procedure was that the participants would gain the technical know-how and become motivated to introduce biogas technology in their working environment. Besides the two domestic plants, one 100 m^3 decentralised wastewater treatment system (DEWATS) was installed during the trainings at the Kigali Institute of Education. The biogas produced by this system is used for lighting 8 lamps and fuelling one stove. No further biogas collaboration with the Chinese is currently planned. The Minister of State for Communication and Energy though that it was time to start with the mass dissemination of the technology among the rural population.

2.4.3. Biogas Technology

Biogas originates from bacteria in the process of biodegradation of organic material under anaerobic (without air) conditions. The natural generation of biogas is an important part of the biochemical carbon cycle. Methanogens (bacteria producing methane) are the last link in a chain of micro-organisms, which degrade organic compounds and return metabolites to the biosphere cycle (Amrit, 2005). In this process biogas, a source of renewable energy is generated

Biogas is a mixture of gasses, composed chiefly of:

a) methane (CH_4) 50-70 vol.%

b) carbon dioxide (CO_2) 30-50 vol.%

c) others, including

- hydrogen (H_2) 0-1vol.%
- hydrogen sulfide (H_2S) 0-3 vol.%

The characteristic properties of biogas depend on the pressure and the temperature that prevail during its generation. They are also affected by the moisture content of the substrate to be digested.

The calorific value of biogas is about 6 KWh/m3. This corresponds to about 5.5 kg of firewood. The net calorific value depends mainly on the percentage of methane and efficiency of the burner or other appliances. Methane is the valuable component under the aspect of using biogas as a fuel (Prakash Ghimire, 2006).2.4.3 Types of biogas plants

The biogas types are classified, as below (Lam, 2010):

The fixed dome also known as Chinese model biogas plant was developed and built in China as early as 1936. It consists of an underground brick masonry compartment (fermentation chamber) with a dome on the top for gas storage. In this design, the fermentation chamber and gas holder are combined as one unit. This design eliminates the use of costlier mild steel gas holder which is susceptible to corrosion. The life of fixed dome type plant is longer (over 20 years) compared to the floating drum design.

1: digester part

2: gas holding part

3: inlet

4: manhole

5: gas pipe

6: outlet chamber also called compensation chamber

The original Chinese model is usually complete made out of concrete and constructed with the help of moulds.

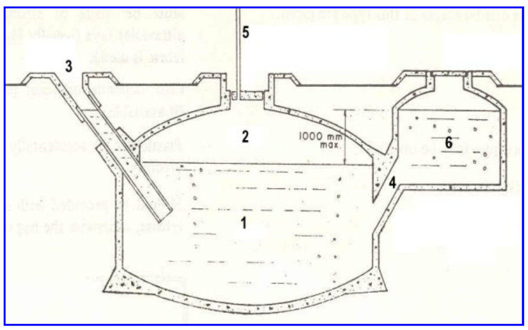


Figure 2.4: – Drawing of a fixed dome plant

a) ***GGC 2047 Nepal design*** Based on the principles of fixed dome model from China many different designs have been made. In Nepal a very successful design has been developed and constructed on a large scale since the last 20 years. The concrete dome is the main characteristic of the Nepal design.

The digester's round wall and the outlet can be made out of bricks or stones. Therefore this model can be constructed throughout the country, also in the hilly areas where bricks are not commonly available. A noticeable change to the original Chinese design is the manhole. This has been moved from the top of the dome to the connection between digester and outlet.

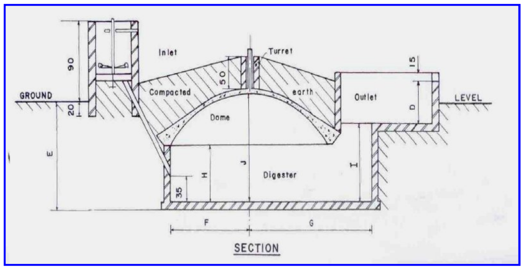
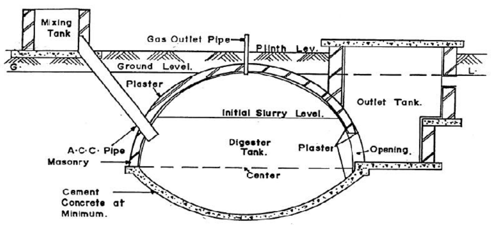


Figure 2.5: GGC 2047 Nepal design

b) Deenbandhu Model

In an effort to further bring down the investment cost, the Deenbandhu model was put forth in 1984 by the Action for Food Production (AFPRO), New Delhi, India. This model proved to be some percent cheaper than other fixed dome designs used at that time in India. It also proved to be about 45 percent cheaper than a floating drum plant of comparable size. Deenbandhu plants are made entirely of brick masonry work with a spherical shaped gas holder at the top and a concave bottom. A typical design of Deenbandhu plant is shown in Figure 1.3 (Singh. Myles and Dhussa, 1987). The Deenbandhu model is now the most commonly used plant in India with more than 3 million plants constructed.



FIGURE–1·3 DEENBANDHU BIOGAS PLANT($3m^3$ gas production per day)

Figure 2.6: Deenbandhu Model

c) Low-cost Digesters

The above two designs are developed particularly for household use in developing countries and with durability as an important criterion. In many countries models have been promoted which have low cost as the most important norm.

The most commonly used low-cost plant is the Plastic Bag Digester

The plastic bag digester consists of a trench (trench length has to be considerably greater than the width and depth) lined with a plastic tube.

Because of the low investment cost this type of digester has been popular in south-east Asia, notably the south of Vietnam. The great weakness of this plant is its vulnerability, it is easily damaged by cattle and playing children. Also, the UV rays in sunlight make the plastic to get brittle. Another disadvantage is the large ground surface, which is needed for the plant which, unlike for the dome design, cannot be used for other purposes after the construction.

An advantage is that this type of plant is easy to construct in areas with high water tables.

1: Digester part

2: Gas holding part

3: Dung inlet

4: Slurry outlet

5: Gas outlet pipe

On the drawing below, drawing stones have been put on top of the bag to increase the gas pressure.

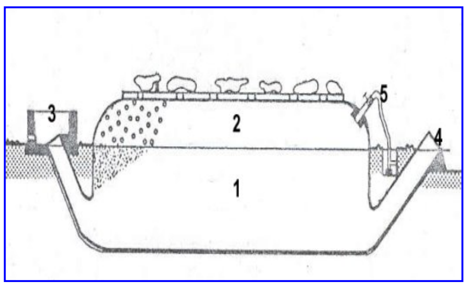


Figure 2.7: Plastic Bag Digester

2.4.4 Biogas Plant Operation

The biogas digester operates as follows. When dung is collected, it is mixed with an equal amount of water in the inlet of the digester. Foreign particles, such as grasses, should be removed before the mixture can be released into the digester via the feeder inlet. Once the biogas digester is completely filled, biogas will be produced within two weeks, but optimum biogas production occurs after 50 days of retention time in the digester. In order to continuously sustain biogas production, the feeding process should be daily repeated after the initial feeding. In addition, dung and water could be mixed with urine, which facilitates the production of slurry with a higher 'fertilizing capacity' for the farm. The produced biogas is harvested through pipes and directed to a cooker or a gas lamp. In addition, the digestion process generates a bio-slurry, which is a potent organic fertilizer. This slurry can be directly applied to the farm and thereby increases agricultural productivity. An additional option is that a latrine is directly connected to the plant and human manure can also be digested. (SNV, 2010)

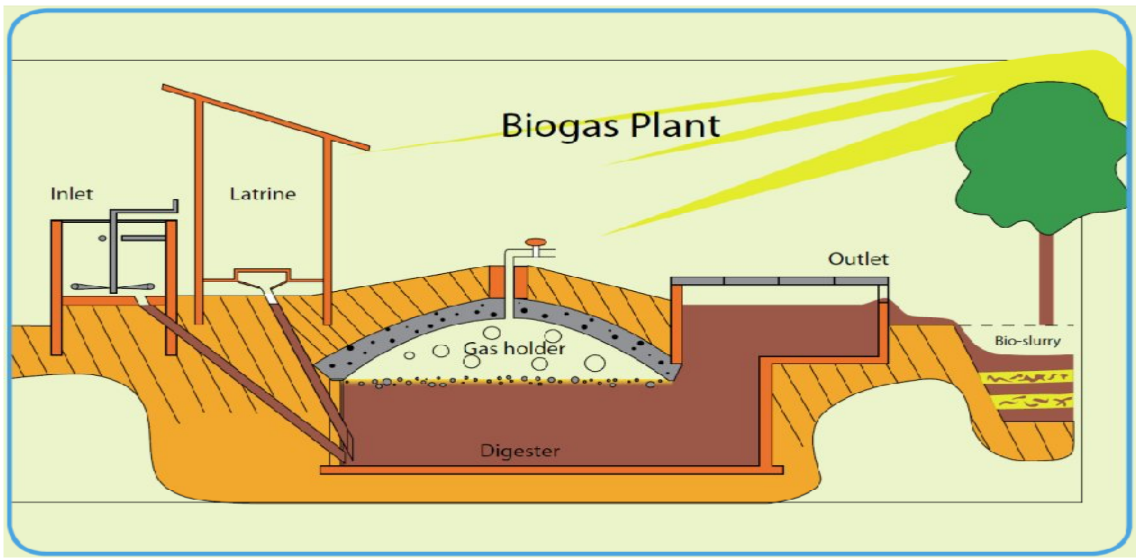


Figure 2.8: Illustration of a Biogas Plant (Van Nes, 2009)

Different sizes of digester volume require a different amount of feeding. For example, in order to operate a 6m3 digester (initially the most common size used in Rwanda), an amount of at least 2-3 cattle is required, corresponding to a minimum of 40 kg dung per day. This can lead to a biogas production sufficient for 3 hours of cooking or 9 hours light on daily basis. (Amrit, 2005)

2.4.5. Biogas Plants Benefits

Specific advantages of fixed dome biogas digesters are that they are easy to operate and have a relatively cheap maintenance. The lifetime of such a plant is 15 years. However, since 2014 cheaper plastic digester types have been introduced. (SNV, Rwanda Domestic Biogas Program).

The implementation of domestic biogas technology has several benefits compared to the use of traditional cooking stoves, both on household as on macro scale level. (Dekelver, 2007)

a) *Savings of conventional fuel sources, mainly firewood.* The limited availability of fuel wood makes biogas technology a suitable alternative energy supply. Firewood is saved when biogas is produced from dung and used for cooking. In addition, biogas lamps can provide lighting in the evening and can save costs on expensive kerosene.

b) *Reduction of the workload and time required for cooking*, especially for women and children. Less time is spent to collect the wood and cooking on gas requires less time than cooking on stoves. Biogas thereby enables children to go to school instead of looking for firewood. It also contributes to gender equality since women spend less time to cook.

c) *Improvements in family health and sanitation.* Health problems of the family are reduced since the smoke causing respiratory problems is no longer emitted and indoor air pollution is reduced. When a latrine is attached to the biogas plant, the sanitation and hygiene of the household is also improved.

d) *Increased agricultural production by utilization of remaining slurry.* The slurry produced in the biogas digester is a very good fertilizer, which can be directly added on the farm and can thereby increase the agricultural productivity.

e) *Generation of employment.* Economic (macro scale) benefits of domestic biogas are the possible creation of a biogas market sector and leading to higher employment, ESPECIALY FOR MASONS. A well-established energy market will contribute to an effective growth of the national economy and thereby to an improved standard of living for the entire nation. It provides energy security and is a way of import substitution.

f) *Reduction in greenhouse gas emissions.* Environmental benefits of the use of biogas are that firewood is saved, less deforestation occurs, and greenhouse gas (GHG) emissions might be reduced. Since less wood is burnt, less CO2 is emitted to the air. Due to slower deforestation rates, higher carbon dioxide storage in trees is obtained. In addition, since methane, a strong greenhouse gas, is burnt and no longer released from dung, this might also lead to a net reduction in GHG emissions.

On the other side, an essential part of any marketing strategy for biogas digesters is and will remain the quality of the product and the services. As the investment for a biogas digester is high, low-quality plants with a short lifespan cannot be accepted. Furthermore, a well-functioning plant is the best possible promotion and the satisfied user the best possible promoter for biogas digester technology. Therefore, control of quality regarding plant sizing, construction, user training on operation and maintenance and after-sales services will be of utmost importance.

In addition, the following benefits are expected:

a) improvement of hygienic conditions, especially of women and children, by eliminating indoor air pollution and by stimulating better management of dung (the stable is cleaned, and the dung fed into the digester on a daily basis) and night soil (latrine attachments);

b) reduction of the daily workload for women (wood collection, cooking, cleaning cooking utensils) since operation and maintenance activities hardly require extra labour. Biogas does not require constant attention or blowing on the coals, so the user can put a pot on the burner and do other activities while the food is cooked. Introduction of biogas does not necessarily change traditional patterns in the division of labour. Strategic gender needs are thus not specifically addressed by biogas. However, in many cases the reduction of workload can be considered as a pre-condition to make opportunities available for women to organise and attend meetings, increase skills and awareness through training courses, etc.

c) natural resources protection:

   i. combat soil depletion: the organic materials that are fed into the plant are used without being destroyed. The nutrients and organic matter (apart from some carbon and hydrogen) will still be available in the effluent of the biogas plant and can be returned to the soil.

   ii. reduce deforestation by reducing the consumption of fuelwood and charcoal.

   iii. reduce erosion: biogas slurry contributes to sustain the amount of organic matter in the soil, improving infiltration rates and water holding capacity on its turn having a positive effect on reducing run-off and limiting soil erosion.

iv. reduce harmful emissions (at local and global level): burning biogas is much cleaner than burning biomass and coal. Apart from being smokeless, it submits only CO_2 and H_2O to the atmosphere whereas a wood or coal fire gives much more pollution. Burning biogas does not contribute to global warming, because the fodder used to feed the animals uses an equal amount of CO_2 in the ecological cycle. The reduction on the emission of CO_2 will amount to 53 865 tons of CO_2 per year on account of the imbalance in fuelwood consumption and production, assuming an emission coefficient of 1.4 tons CO_2 per ton firewood (M. Keeman, Avebury studies in Green Research, Brookfield, USA). Furthermore, biogas is not released in the atmosphere in the natural dung digesting process. This burning of the CH_4 component in the biogas leads to an additional CO_2 equivalent emission reduction.

d) micro-economical benefits:

i. energy and fertiliser substitution, e.g. eliminating the need to buy expensive fuelwood and chemical fertilisers;

ii. additional income sources, since time saved can be used in more directly economically productive ways;

iii. increasing yields in animal husbandry and agriculture by using the full potential of digester effluent as organic fertiliser. If properly stored, treated and applied to the fields, biogas slurry has a higher fertiliser value than ordinary farmyard manure;

e) macro-economical benefits:

i. import substitution (fossil fuels and fertilizers);

ii. job creation: the programme is expected to generate a fair amount of employment in the regions where it is active, through the staff of biogas companies, by the labour required for the production of appliances and building materials and through the unskilled labour used during the construction of the plants.

2.4.6. Biogas Plant Construction and Maintenance

Construction work starts with the process of layout works. The layout is carried out to mark the dimensions of the plant in the ground to start the digging work. When the construction works of the round wall, is completed then the spherical (dome-shaped) gas holder has to be constructed. Gas-tightness of the gasholder is very important for the effective functioning of any bio digester. If the gas stored in the gas-holder escapes through the minute pores, the users will not be able to get gas at the point of application. Usually, the inlet tank is constructed after the completion of the construction of the outlet tank; however, it can be constructed simultaneously. If the feeding material is cattle dung, then an inlet tank is constructed. The biogas produced in the digester and stored in the gas holder is conveyed through a pipeline. If the laying and joining of pipes is not done properly, the produced gas cannot be conveyed effectively to the point of application. Compost pits are an integral part of the bio digester; no plant is complete without them. A minimum of two composting pits should be constructed near the outlet overflow in such a manner that the slurry can flow easily into the pit.

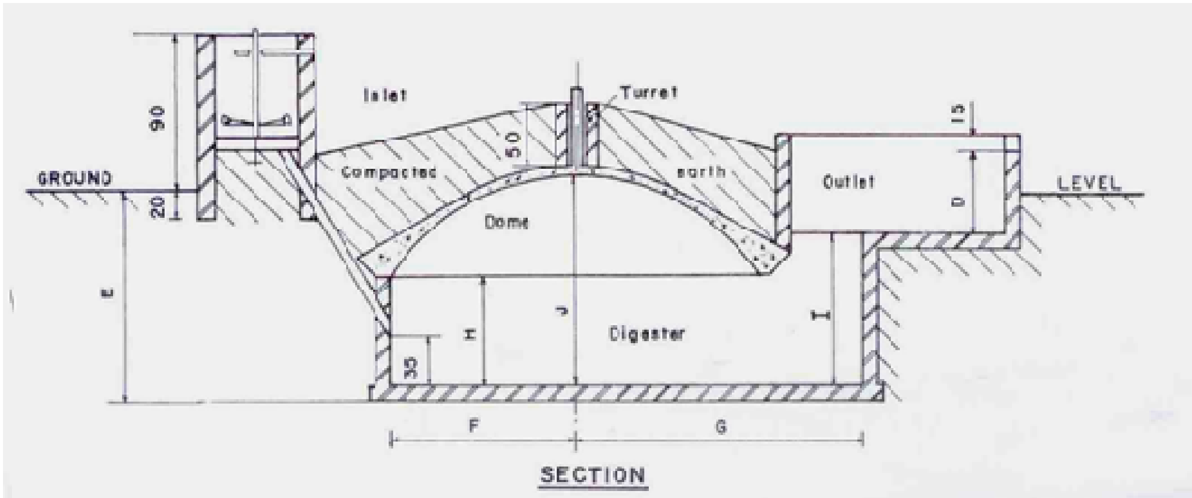


Figure 2.9: Drawing of a Biogas Plant (BSP, 2006)

Hereunder, Basic design quality standards (Amrit, 2005):

a) Cement has to be high quality Portland cement from a brand with a good reputation. It must be fresh, without lumps and stored in a dry place. Bags of cement should never be stacked directly on the floor or against the walls, but wooden planks should be placed on the floor to protect cement from dampness;

b) sand must be clean. Dirty sand has a very negative effect on the strength of the structure. If the sand contains 3 % or more impurities, it must be washed. The quantity of impurities especially the mud in the sand can be determined by a simple 'bottle test'. For this test, small quantity of sand is put in a bottle. After this, water is poured in and the bottle is stirred vigorously. The bottle is than left stationary to allow the sand to settle down. The particles of sand are heavier than that of mud, so it settles down quickly. After 20-25 minutes, the layer of mud verses sand inside the bottle is measured. Course and granular sand can be used for concreting work, but fine sand will be better for plastering work;

c) gravel should not be too big or very small. It should not be bigger than 25 % of the thickness of the concrete product where it is used in. As the slabs and the top of the dome are not more than 3" thick, gravel should not be larger than 0.75" (2 cm) in size. Furthermore, the gravel must be clean. If it is dirty, it should be washed with clean water. When stones are used for plant construction, the remains of shaping the stones can be used as gravel.

d) water is mainly used for preparing the mortar for masonry work, concreting work and plastering. It is also used to soak bricks. Besides these, water is used for washing sand and aggregates. Water must be clean since dirty water adversely affects the strength of the structure.

e) bricks must be of the best quality locally available. When hitting two bricks, the sound must be clear. They must be well baked and regular in shape. Before use, bricks must be soaked for a few minutes in clean water, not to soak moisture from the mortar afterwards.

f) stones used for masonry work have to be clean, strong and of good quality. Stones have to be shaped before use (to avoid having to use too much cement) and should be washed if dirty.

g) the gas pipe conveying the gas from the plant to the user point is vulnerable for damages, therefore it should be of light, quality iron pipe which must be, were possible, buried 1 foot below ground level. Pipeline fittings must be kept to a necessary minimum and sealed with zinc putty, Teflon tape or jute and paint.

h) for proper insulation and as counterweight against the gas pressure inside, a minimum top filling of 40 cm compacted earth is required on the dome.

Additional detailed technical specifications can be found under APPENDIX VII(Quality standards for the installation of modified GGC model of bio digesters (Lam, 2010).

On the other side, with a view to enhance knowledge of users on proper bio-digester operation and minor repair & maintenance works to ensure that the installed bio digesters function without any trouble, different training programmes are proposed by the programme. One day operation and maintenance trainings for the users will be organized immediately after the installation of bio digesters. Likewise, follow-up/refresher user's training will also be conducted based upon the demand of the users. In the program centralized setting, Technicians from the biogas programme and private companies will frequently visit the bio digester to assess its performance (APPENDIX VII: Quality Standards for the Installation of Modified GGC Model of Bio digester), and solve minor problems, if any. The users can lodge requests/complaints in the biogas programme for required technical assistances.

For the actual construction of bio digesters and after-sales service, the establishment of local biogas enterprises/Builder cooperatives is encouraged.

Companies wishing to become biogas construction companies and willing to cooperate with the programme seek recognition from the National Domestic Biogas Programme.

Such recognition is be subjected to a series of strict conditions and responsibilities to adhere (APPENDIX VIII:Companie's conditions and responsibilities to become biogas companies(Lam, 2010).On the other hand, biogas constructors (Companies or cooperatives) are the main service providers to the client. These are monitored by NDBP and with its technical assistance, biogas constructors improve their professionalism on delivering quality services and marketing business services as per the demand.

Appliances used in biogas plants are locally produced: water drain, gas stoves, gas tap, main gas valve and gas pipe. Appliance's manufacturing workshops have been established and pre-qualified by the NDBP, based on their technical capability, human resources, workshop facilities and equipments. For the sustainability of these manufacturers and production of quality appliances, these are closely monitored, and their products will be checked regularly.

2.5. The Biogas Program

The effort Rwanda is making to develop the biogas sector and undertaking other initiatives may be characterized as an attempt to diversify energy sources, reduce reliance on firewood consumption and at the same time help preserve forests/the environment. With regard to biogas in particular, access to the technology and the use of biogas has a relatively long history in the country and has been available since the end of the 1990s. Initially, the use of biogas was promoted at large institutional entities, especially prisons, not only for reducing firewood but also to enhance hygiene and sanitation. Indeed, the government's biogas program for prisons has drawn international attention and recognition. In 2000, a number of other institutions such as schools and hospitals also built biogas plants and in 2006 the government launched the National Domestic Biogas Programme (Dekelver, 2006).

In order to launch a large-scale domestic biogas programme based on a commercially viable, market-oriented basis, a number of pre-conditions have to be met.

a) Technical Conditions

Daily ambient temperature above 20^{o}C throughout the year; the biological process in a digester is temperature dependent. The optimum temperature is 35^{o}C, below 15^{o}C the process comes practically to a stand-still and availability of at least 20 kg cattle and/or pig dung per day at a large number of farms. Cattle should be at least kept in a stable during the night. 10 kg of dung yields enough gas to operate a normal sized kitchen stove for 1 hour, to make an investment remunerative a minimum of 2 stove hours per day are required. Also, availability of water. Cattle dung fed into a plant needs to be mixed with water on a 1:1 ratio.

b) Economic conditions

The use of organic fertiliser is traditionally practised and integrated farming systems are common. Often it is not the saved firewood but increased crop production from the use of bio-slurry that generates additional income. In addition, traditional cooking fuels like firewood and charcoal are difficult (time consuming) to gather or expensive. If firewood is cheap and easy to come by, it will be difficult to motivate farmers to make the necessary investment. On the other side, farmers should have access to (micro) credit on reasonable terms, and have the possibility to invest, e.g. by having the title deeds of their farms as collateral. Even with the use of subsidies, farmers still have to make a considerable investment.

c) Social Conditions

The role of women in domestic decision making: Women are the main direct beneficiaries of the biogas plant, they spend less time on fuel collection, cooking and cleaning of cooking utensils. Furthermore, as there is far less indoor air pollution, they will suffer less from eye and respiratory ailments. Therefore, women should be accessible for extension services and have a say in the decision-making process at household level. In addition, the role of women in livestock keeping and dung handling. As women will be the users of the gas, they will be most motivated to keep the plant in good operational order. There should be no cultural barriers for them to operate the plant or to participate in local training programmes.

d) Institutional Conditions

The political will from the Government to support a national biogas programme: Preferably a Governmental institution should act as a national coordinating body for the programme and governmental extension services should be involved in promotion and on farm training. But also, the existence of farmer unions, like dairy cooperatives, is not essential but will be very helpful.

By 2013, close to 3,365 biogas digesters had been disseminated to households by about 41 local companies. The installations costs are borne by the consumers (on their own revenues or credit from lenders) and the government (subsidy) on a 50/50 cost sharing principle. The subsidy is disbursed through the districts which have signed MoUs with local Credit giving institutions (SACCOS) to extend credit to the biogas project owners on request.

However, by 2013 again it is clear that the programme had achieved only about 15 percent of its originally intended target. In addition to the less than expected uptake, it was found that about 10 percent of the completed digesters were not producing gas at all while 25 percent of digester owners were not satisfied with the volume of production (IOB Evaluation of the impact of Rwanda's National Domestic Biogas Programme, 2013).

2.6. National Domestic Biogas Program Decentralization

2.6.1. Introduction

Prior to the Rwanda Domestic Biogas Programme decentralization, the programme was significantly lagging behind its output targets numbers. One of the main challenges to achieving the targets was the delay in gearing the programme towards a truly localized and dissemination-focused organization (Rwanda Domestic Biogas Programme mid-term Review, 2009). In addition, 10% of the completed digesters were not producing gas at all, while 25% of digesters owners were not satisfied with the volume of produced biogas (Arjun, 2013).

Since 2014, decentralization of the biogas program has been initiated by REG and SNV (The Netherlands Development Organization). This drive aimed at bringing effectiveness for an increased number of biogas constructed, but also better maintenance services. The program activities started being decentralized, whereby the 30 administrative Districts of Rwanda took the lead in its implementation (SNV, 2016, para. 5).

2.6.2. The Concept of Decentralization

According to the (United Nations Development program,2014) practice note on decentralization and development, decentralization refers to the restructuring of authority so that there is a system of co-responsibility between institutions of governance at the central, regional and local levels according to the principle of subsidiarity. Based on such principle, functions (or tasks) are transferred to the lowest institutional or social level that is capable (or potentially capable) of completing them. Decentralization relates to the role of, and the relationship between central and sub-national institutions, whether they are public, private or civic.

There are four main types of decentralization:

1. Political decentralization: transfers political power and authority to sub-national levels such as elected village councils and state level bodies. Where such transfer is made to a local level of public authority that is autonomous and fully independent from the devolving authority, devolution takes place.

2. Under fiscal decentralization: some level of resource reallocation is made to allow local government to function properly, with arrangements for resource allocation usually negotiated between local and central authorities.

3. Administrative decentralization: involves the transfer of decision-making authority, resources and responsibilities for the delivery of selected public services from the central government to other lower levels of government, agencies, and field offices of central government line agencies. There are two basic types.

   Deconcentration is the transfer of authority and responsibility from one level of the central government to another with the local unit accountable to the central government ministry or agency which has been decentralised.

   Delegation, on the other hand, is the redistribution of authority and responsibility to local units of government or agencies that are not always necessarily, branches or local offices of the delegating authority, with the bulk of accountability still vertical and to the delegating central unit.

4. Finally, divestment or market decentralization transfers public functions from government to voluntary, private, or nongovernmental institutions through contracting out partial service provision or administration functions, deregulation or full privatization.

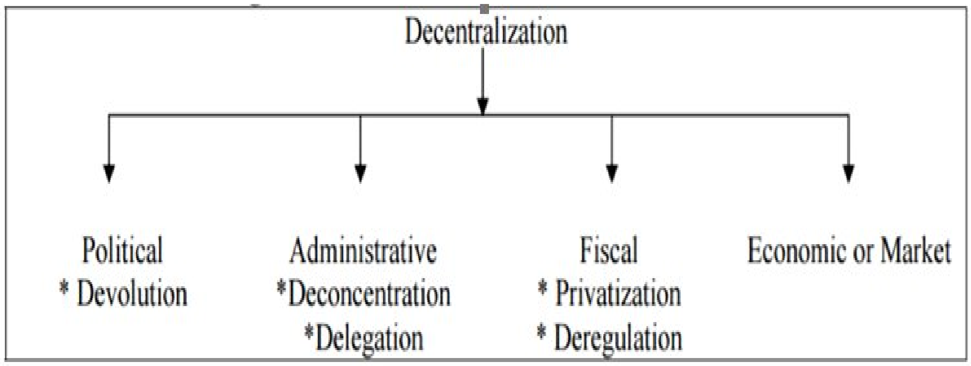


Figure 2.10: Decentralization Framework (Braun, 2000)

2.6.3. Decentralization of the Energy System

Decentralization of an **energy system** is a challenge for the system planning and the management of the energy infrastructure. A central government cannot direct this process although it can seek to provide incentives. The onus for promoting, delivering and coordinating energy decentralization is likely to fall on local government. Because they tend to be smaller, decisions can be taken quickly and their structure can adapt more quickly to new situations, as compared to larger and more bureaucratic national governments (Puppim, 2002).

According to the Low Carbon Green Growth Roadmap (Low Carbon Green Growth, 2012), a decentralized energy system is characterized by locating of energy production facilities closer to the site of energy consumption. A decentralized energy system allows for more optimal use of renewable energy as well as combined heat and power, reduces fossil fuel use and increases eco-efficiency. A decentralized energy system is a relatively new approach in the power industry in most countries. Traditionally, the power industry has focused on developing large, central power stations and transmitting generation loads across long transmission and distribution lines to consumers in the region. Decentralized energy systems seek to put power sources closer to the end user. End users are spread across a region, so sourcing energy generation in a similar decentralized manner can reduce the transmission and distribution inefficiencies and related economic and environmental costs.

The strengths of using a decentralized energy system are as follows:

a) Environmental: The decentralizing of electricity production also increases the overall heat and power system's efficiency and thereby reduces harmful greenhouse gas emissions.

b) Economic: Distributed generation sources often have lower capital costs per project, compared to large central power plants. In some circumstances, off-grid distributed generation can reduce the need for expensive transmission and distribution network expansion. Also, lower losses through the lengthy transmission of electricity increases eco-efficiency. Reducing losses in transmission and distribution and the incremental addition to capacity through distributed generation can help defer investment in large central power plants. The decentralized siting of energy generation facilities requires decentralized businesses to construct, operate and maintain the facilities, creating opportunities for local business and job creation.

c) Technical: Distributed generation projects provide planning flexibility due to their small size and short construction lead times, compared to larger central power plants. In addition, a decentralized energy system may be a way to energy efficiency measures. Increased information about energy flows from smart meters can make consumers more conscious of their use. Through on-site energy production, consumers of energy become producers and have a greater economic stake in efficient production and consumption.

d) Social: A decentralized system, particularly through the use of isolated, off-grid units and mini-grids, are suitable in rural areas where the population density is low. Often much more economically feasible than central grid build outs, decentralized approaches can achieve rural electrification faster.

On the other side, inappropriateness of technology, unavailability of skilled manpower for maintenance, unavailability of spare parts, high cost, lack of access to credit, poor purchasing power and other spending priorities, unfair energy pricing, lack of information or awareness, and lack of adequate training on operation and maintenance of decentralized renewable energy systems are found to be the most critical barriers. Long-term conducive policies, appropriate regulatory framework, financial incentives (capital subsidies and soft loans) to users, technology and skill development, internalization of externalities in the cost of energy, withdrawal of subsidies presently being given to fossil fuels, development of specialized institutions, cooperation with international agencies, participation of local community and awareness generation have been recommended for increased dissemination of decentralized renewable energy systems(Yaqoot,2015).

2.6.4. Decentralization Policy in Rwanda

Rwanda first adopted the Decentralization Policy in May 2000, formulated after a series of dialogue sessions with citizens and consultations with experts on how Rwandans could turn their page permanently for the better in terms of good governance and wellbeing in which Rwandans themselves would be in-charge of their destiny (Ministry of local government, 2012).

The Rwanda decentralization sector strategic plan states that the overall objective of Decentralization is to deepen and sustain grassroots-based democratic governance and promote equitable local development by enhancing citizen participation and strengthening the local government system, while maintaining effective functional and mutually accountable linkages between central and Local Governments entities.

During the first phase (2001-2005), decentralization helped us democratize leadership and create platforms for nurturing leaders, mostly women and youth, who had hitherto been excluded from their governance. Women who back then were reluctant to take up leadership positions created by affirmative action, now confidently stand for elective positions and gender is no longer a barrier to leadership. During the second phase (2006-2010), stronger local government structures have been set up through reforms, with performance innovations such as Imihigo and platforms for community mobilization, accountability and participation. Because Government has been transferred down to the people, community participation and ownership of development programmers has increased. The biggest change has been in the mindsets of the leaders and the led (Ministry of Local Government, 2012).

The last phase of decentralization is working to consolidate what has been achieved thus far in decentralization, including further improving and strengthening the IMIHIGO. Imihigo is a Rwandan home-grown performance Management tool where Government Ministers and District Mayors sign performance contracts on behalf of citizens with His Excellence the President of Rwanda. The main objective of the evaluation is to assess the performance against the targets, identify challenges encountered, establish gaps and give recommendations to inform the future generation of the Government of Rwanda imihigo planning and implementation process (Ministry of Local Government, 2012).

The Governance and Decentralization strategic plan, states that Sectoral decentralization is being undertaken differently depending on the sector and specific service or function. Education, health, agriculture and infrastructure sectors have established direct presence at provincial and district levels, but many of the sectoral service functions are parallel and have not integrated with local government systems. Nonetheless, they recognize the importance and ability of the local government system to deliver – through IMIHIGO (Performance agreements) and a well networked local government structure (Ministry of Local Government, 2013).

Hereunder, thematic sectors ranked per service delivery quality, following first phases of decentralization:

No.	***Service Sector/Area***	***Rating in Percentage***
1.	Service delivery in Local Government	77.27%
2.	Service delivery in justice sector	69.95%
3.	Service delivery in land sector	73.15%
4.	Service delivery in agriculture sector	77.70 %
5.	Service delivery infrastructure sector	52.8%
6.	Service delivery in Health Sector	75,73 %
7.	Service delivery in Education Sector	80,25 %
8.	Service delivery in Water Sector	56.70 %
9.	Backlogs of court cases awaiting trial for more than 6 months	62%

Table 2. 1: Quality of Service Delivery Rating in Selected Sectors (MINALOC 2013).

2.6.5. The national Domestic Biogas Program Decentralization Status

A semi-autonomous operating national programme office plans, coordinates, monitors on a national level and disburses subsidies. They cover the promotional, training and technical monitoring work. The actual construction is done by individual masons in young programmes and by established biogas companies in more mature programmes (Lam, 2010).

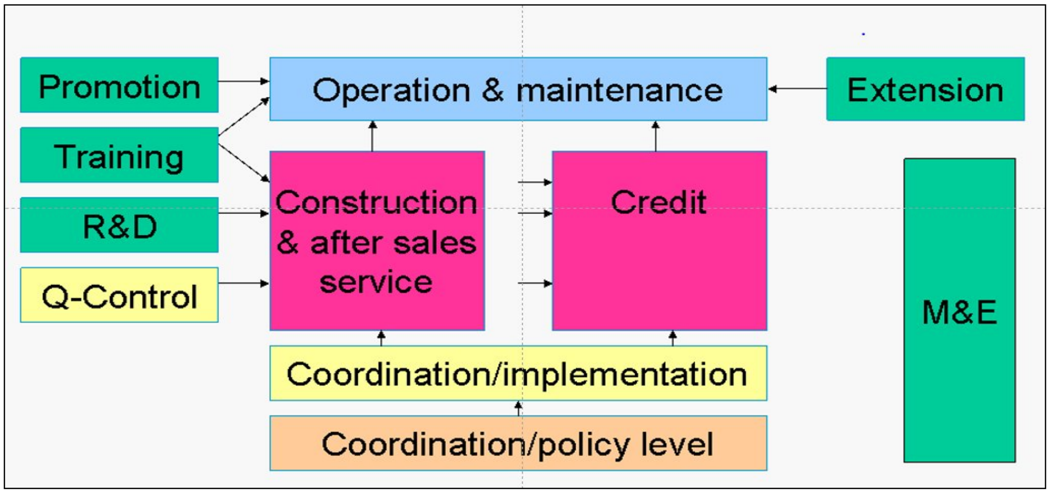


Figure 2.11: Functions of a National Domestic Biogas Program (Lam, 2010)

National biogas programmes require a wide range of functions to be executed in a comprehensive and coordinated manner. Examples of such functions are promotion and marketing, financing, construction & after sales, operation & maintenance, quality control, training & extension, research & development, monitoring & evaluation, and programme management (APPENDIX IX: Functions of a domestic program).

On the other hand, the domestic biogas program unit at REG has a central coordination unit and decentralized staff based in districts (1 field technician per two Districts).The program funds comprises program costs and subsidy funds allocated to farmers. Most of the payments were done through administrative sector SACCOs (Village level financial institutions) in order to smoothen payment procedures.

Until 2013, 46 private construction companies were trained and supported to conduct the biogas business in rural areas. A flat rate subsidy of 300,000 RWF per digester has been proposed to motivate the farmers to install a bio digester.

a) Rationale for the Energy Program Decentralization in Rwanda

The objectives of this energy program decentralization aimed transferring responsibilities to Districts (Ministry of Local Government 2007), thus specific to the domestic biogas program achieving the below:

1. Reduction of the administrative workload on the NDBP central office in Kigali, especially the contracting and payment aspects for the construction activities
2. Increased the responsibility of the local authorities for the implementation of the biogas program
3. Increased capacity at the district level by providing the necessary means to implement the commitments in their annual performance contract
4. Introducing proximity services towards access increase and better maintenance services for already installed biogas plants
5. Contribution towards the Government's decentralization policy by transferring funds from the line ministry to the districts

Hereunder, two Figures, explaining the Domestic Biogas Program Function before Decentralisation, mainly managed from national level and the same program after decentralisation, managed mostly from District and local levels.

In the first figure, the Rwanda Energy Group (REG) is the implementer and coordinates activities in all the 30 District of Rwanda, including following-up on private companies, SACCO activities and user satisfaction:

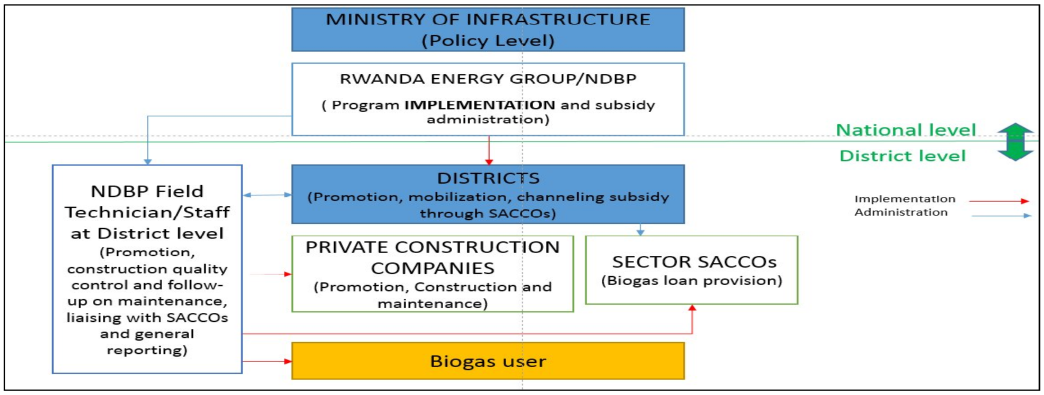


Figure 2.11: Functions of a Rwanda Domestic Biogas Program (NDBP) Prior to Decentralization

As per t the figure below, each of the 30 Districts of Rwanda, takes the lead in coordination and implementation, including following-up on private companies, SACCO activities and user satisfaction. The central level would only transfer subsidy funds and general monitoring:

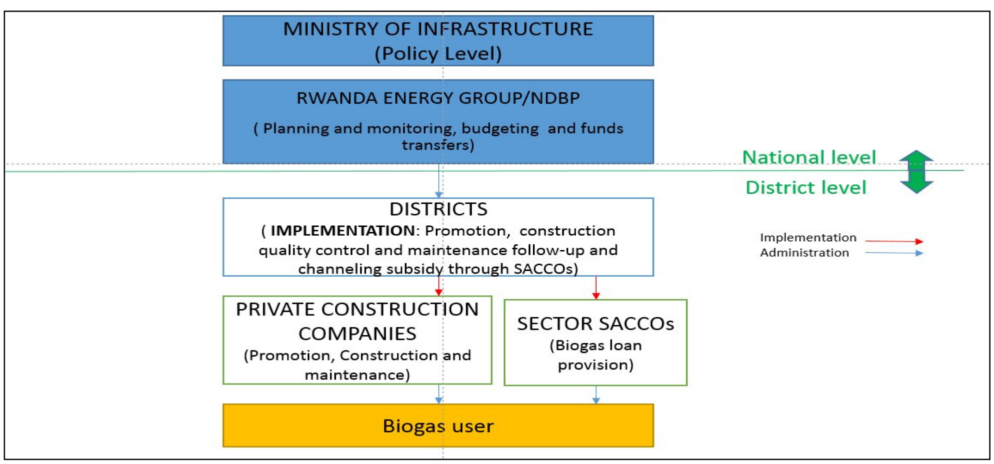


Figure 2.12: Functions of a Rwanda Domestic Biogas Program (NDBP) after Decentralization

a) Status of the Domestic Biogas Program Decentralization

Since 2014, decentralization of the biogas program has been initiated by REG and SNV (The Netherlands Development Organization). This drive aimed at bringing effectiveness for an increased number of biogas constructed, but also better maintenance services. The program activities started being decentralized, whereby the 30 administrative Districts of Rwanda took the lead in its implementation.

Now Districts are leading the biogas program implementation with a link to their biogas performance targets (Ministry of Local Government, 2013b).

In the decentralization drive, at least 2 masons have been trained in biogas construction in each of the 416 administrative sectors of Rwanda, in order to give capacity to local entities in terms of biogas construction and maintenance. Those masons were grouped into District level biogas construction cooperatives (SNV, Appendix VI) and District level companies (SNV, Appendix V) that are now under District direct contracting and supervision.

District staff have been capacitated in relation to biogas markets contracting, biogas loans and subsidy administration, as well as biogas sites construction quality control, after sales services and maintenance.

b) Biogas Program Functions under the Scope of this Research

All the functions of a National Domestic Biogas Program (APPENDIX IX) were not covered by the study. This table hereunder, captures the functions of the National Domestic Biogas Program in Rwanda, that were relevant and under scope to this study. The table links the functions to the specific objectives of the study, towards further analysis:

Table 2.2: Functions of a Rwanda Domestic Biogas Program and Activities under Scope of this Research

FUNCTION AND RATIONALE	ACTIVITIES
Coordination at implementation level **Is related to both specific objectives number 1,2 and 3**	• annual plan and report formulation; • administration of the biogas activities; • certification of construction companies; • registration of constructed plants; • Monitoring and evaluation;
Promotion & extension services at community and household level **Is related to specific objective 1 and 3**	• awareness raising, technical advice on digester size and capacity, advice on effluent use, financial advice, …;
Construction, after sales service (ASS) **Is related to specific objective 2 and 3**	• Procure District level entrepreneurs/Cooperatives trained in bio digester construction • Supervise construction works
Operation and maintenance **Is related to specific objective 2 and 3**	• Biogas plant operation and maintenance, simple trouble shooting; • Maintenance works.

2.7. Theories Related to Program Decentralization and Project Management

Prior to the Rwanda Domestic Biogas Programme decentralization, the programme was significantly lagging behind its output targets numbers. One of the main challenges to achieving the targets was the delay in gearing the programme towards a truly localized and dissemination-focused organization (Heegde, 2009). In addition, 10% of the completed digesters were not producing gas at all, while 25% of digesters owners were not satisfied with the volume of produced biogas (Arjun, 2013).

Since 2014, decentralization of the biogas program has been initiated by REG and SNV (The Netherlands Development Organization). This drive aimed at bringing effectiveness for an increased number of biogas constructed, but also better maintenance services. The program activities started being decentralized, whereby the 30 administrative Districts of Rwanda took the lead in its implementation (SNV, 2016, para. 5).

In fact, sub-national governments around the world play a fundamental and increasing role in provision of infrastructure. This appears to be a trend which is unlikely to change in the foreseen horizon (Frank, 2014).

To this regard, maintenance of roads, irrigation channels and equipment, and other basic physical infrastructure is sometimes done better by local governments or administrative units, when they are given adequate funds and technical assistance, than by central agencies, which cannot easily monitor deterioration or breakdowns. Indeed, for some activities, decentralization could increase the efficiency of central ministries by relieving top management of routine, repetitive tasks and allowing them more time to plan and monitor programs that absolutely require central direction or control (Rondinelli, 1983). On the other end, operations and maintenance activities could conceivably be undertaken by a higher level of government, a local government or the private sector, while it is believed that the private sector options should be pursued to the extent possible, as should decentralization of operations and maintenance (William, 2014).

Elsewhere, in order to benefit from the potential of national policies to expand energy access, governments need to integrate existing energy initiatives into national decentralization and sectorial programs and also ensure that energy access priorities are incorporated into decentralized local government processes (Havet, 2009).

2.8. Literature Gap

The literature available and reviewed mainly focuses on decentralized energy systems, characterized by shifting energy production facilities closer to the site of energy consumption (Reference to section 2.6.3). However, there are clearly literature gaps when it comes to programs decentralization for small scale energy systems, specifically in terms of effective Programs/project implementation. On the other hand, the literature gap is wider, when it comes specifically to the domestic biogas program decentralization and its effects on access and maintenance. In addition, the suitability of the biogas program decentralization model has not yet been established. Questions are to which extent the program decentralization model analyzed under this study has aided to achieve the objective of increased production of energy and better maintenance services.

The study should be able to determine whether the decentralization of the biogas program has led to closing ineffectiveness gaps compared to the previous centralized system and if there was an increased number of domestic biogas constructions and better maintenance services for existing biogas constructions. The study would be able to provide recommendations that would be applied in order to further improve the domestic biogas program, but also come out with a model that could be replicated for other Small Scale Energy systems.

2.9. Theoretical Framework

The link between decentralization and improved service delivery is that decentralization aims at an economic and political system that responds more closely to people's preferences and requirements (Lawrence. 2001). In fact, by bridging the gap between suppliers and users of goods and services, decentralization measures are expected to achieve three major objectives:

1. Improved **efficiency** in service provision
2. More **transparency** of service providers
3. Better **accountability** to service users.

The theoretical framework below, which is assumptions and associations of ideas, which people adopt in interpreting a phenomenon, discussing an issue, or deciding on a course of action, summarizes the anticipated effects of decentralization on programs.

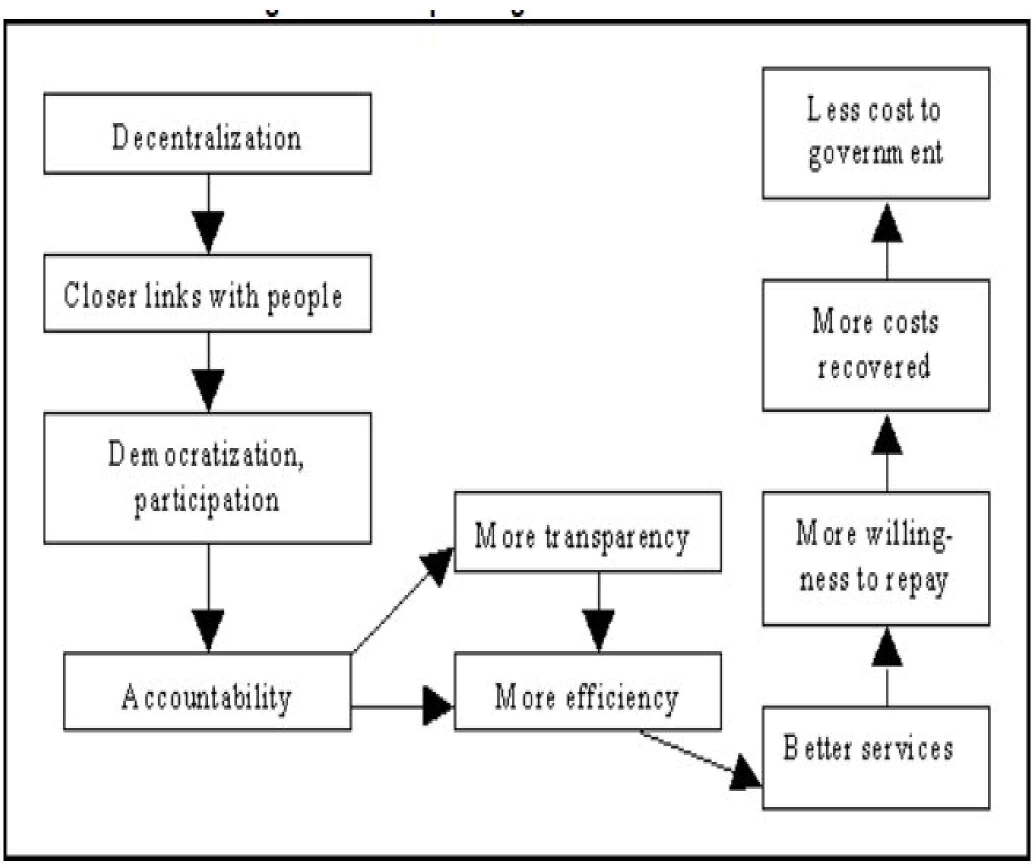


Figure 2.14: Decentralization Theoretical Framework (Lawrence, 2001)

On the other hand, another framework for the analysis of decentralized services provision was provided by group researchers (Ahmad, 2005), as per the below:

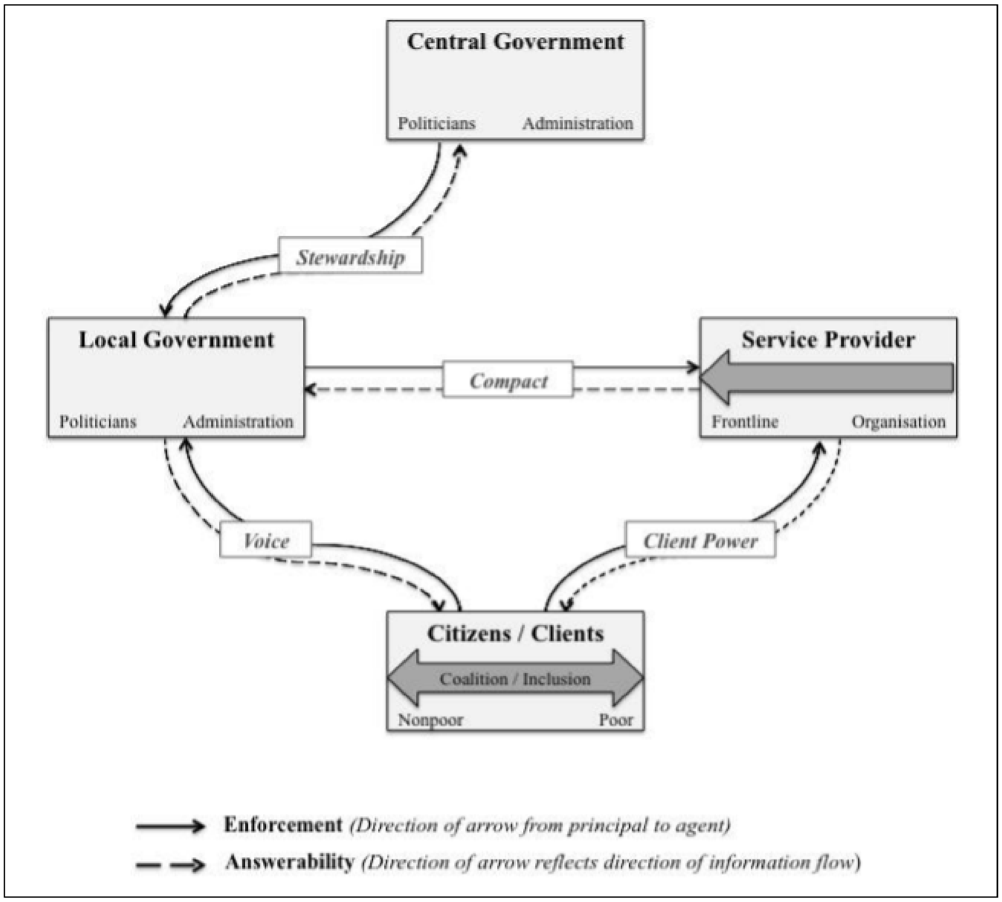


Figure 2.13: Framework for the Analysis of Decentralized Services Provision (Ahmad, 2005)

Furthermore, decentralization of the **energy system** is also a challenge for system planning and the management of energy infrastructure. A central government cannot direct this process although it can seek to provide incentives. The onus for promoting, delivering and coordinating energy decentralization is likely to fall on local government. Because they tend to be smaller, decisions can be taken quickly and their structure can adapt more quickly to new situations, as compared to larger and more bureaucratic national governments (Puppim, 2002).

2.10. Conceptual Framework

The following conceptual framework shows the main issues to be studied, the key factors or variables and presumed relationship among them.

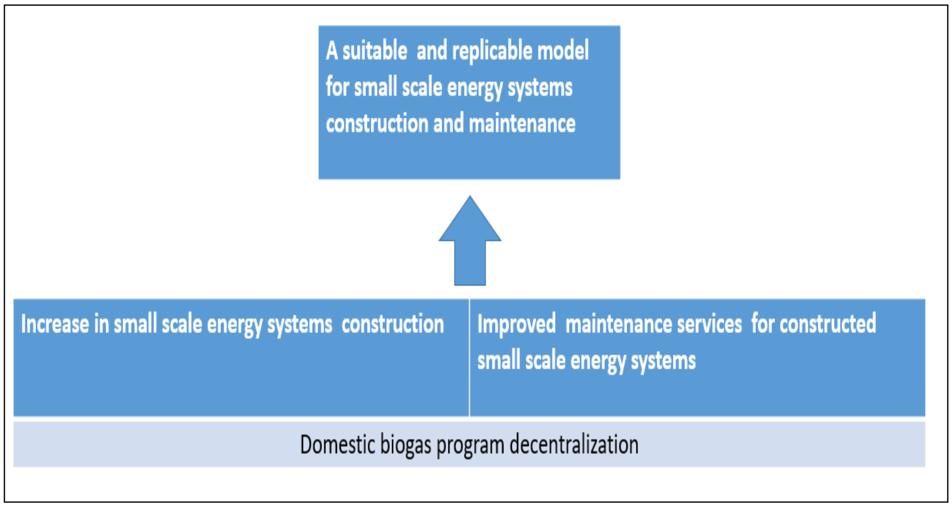


Figure 2. 14: Conceptual Framework

The conceptual framework here above, shows that the decentralization of the domestic biogas program would lead to increase biogas systems delivery and improved maintenance services for constructed small scale biogas systems, which would contribute if well proven by this study, to developing a model for small scale energy systems delivery through program decentralization, that can be upscale and applied to small scale energy systems in general. The above would also prove what was outlined by the theoretical framework that 'decentralization measures are expected to achieve improved efficiency in service provision and Better access and accountability to service users.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Introduction

This chapter presents the methods that were used in obtaining the needed data and analyzing them. It discusses the research design, the study area, the target population, the sample design/the sampling techniques and sample size, data collected, data sources and method of collection, as well as the data management and statistical analysis. In the light of the above-mentioned research considerations and in reference to the research questions, the study was conducted in two parts in order to effectively address the research objectives. The first part considers access to and construction of the biogas plants, while the second part considers maintenance services for these biogas plants.

3.2. Research Design

Research methodology is a way to systematically solve the research problem. It may be understood as a science of studying how research is done scientifically. It is necessary for the researcher to know not only the research methods/techniques but also the methodology (Patel 2019). This study is a comparative survey of two Districts Bugesera and Kirehe. These two Districts were selected as exemplifying cases of the implementation of the biogas program decentralization in Rwanda, based on the fact that both Districts had the biggest number of domestic biogas plants before decentralization, thus presenting a considerable sample basis for research (APPENDIX X: Number of Domestic Biogas plants before Decentralization). Their characteristics are detailed in section 3.3 later. Additionally, the study is evaluation research; it does a before-and-after analysis of the scenarios of construction and maintenance management actions in each of the two Districts.

In this context, a mixed-methods design, offers the best chance of answering research questions by combining two sets of strengths while compensating at the same time for the weaknesses of each method. Consequently, mixed-method research designs are becoming increasingly relevant to addressing impact research questions (Dawadi, 2021). In fact, the term “mixed methods” refers to an emergent methodology of research that advances the systematic integration, or “mixing,” of quantitative and qualitative data within a single investigation or sustained program of inquiry. The basic premise of this methodology is that such integration permits a more complete and synergistic utilization of data than do separate quantitative and qualitative data collection and analysis (Wisdom, 2013).

Therefore, this study applied a mixed-methods research methodology. Whereby, both quantitative and qualitative methods of data collection and analysis were adopted.

Although much of the data were quantitative (Collected from biogas plants users), the researcher considered it necessary to add qualitative data-Interviews and focus groups discussions (From the government officials and construction companies), in order to compliment the biogas user’s data.

3.3. Desk Work and Field Work

A desk review was undertaken where programs and policies contributing to small scale energy systems and biogas were identified. The scoping study assessed the extent to which existing decentralization policies have contributed to improved services at District level. The review focused on policy documents, national reports, sector reports, district reports and other relevant documents.

The field data collection work was conducted in Bugesera District, where biogas was also promoted under the National Domestic Biogas Program since 2009. Since 2014, with the decentralization of the program, Bugesera like any other District has taken the lead into implementation of the biogas program decentralization and contracted biogas private companies to build biogas plants. However, Kirehe and Bugesera Districts had achieved the biggest number of domestic biogas built before decentralization, hence the basis to choosing the two districts for this research (APPENDIX X: Number of Domestic Biogas plants before Decentralization).

Bugesera is one of seven Districts of the Eastern Province in Rwanda. It covers a total surface area of 1337 Km^2. The district is composed of 15 Sectors, 72 Cells and 581 Villages with a total Population of 363,339 people, where 177,404 are males and 185,935 are females. (General Population census: 2012). According to Integrated Household Living Conditions Survey, EICV 3(National Institute of Statistics, 2012), about 52% of the population in Bugesera district is identified as non-poor, 20% as poor (excluding extreme poor) and more than a quarter (28%) as extreme-poor.

In Bugesera district, again according to EICV 3, 4.3% of households use electricity as their main source of lighting. On average in Rwanda, urban areas have 46.1% of households using electricity as their main source of lighting, while it is only 4.8% in rural areas and 10.8% at national level.

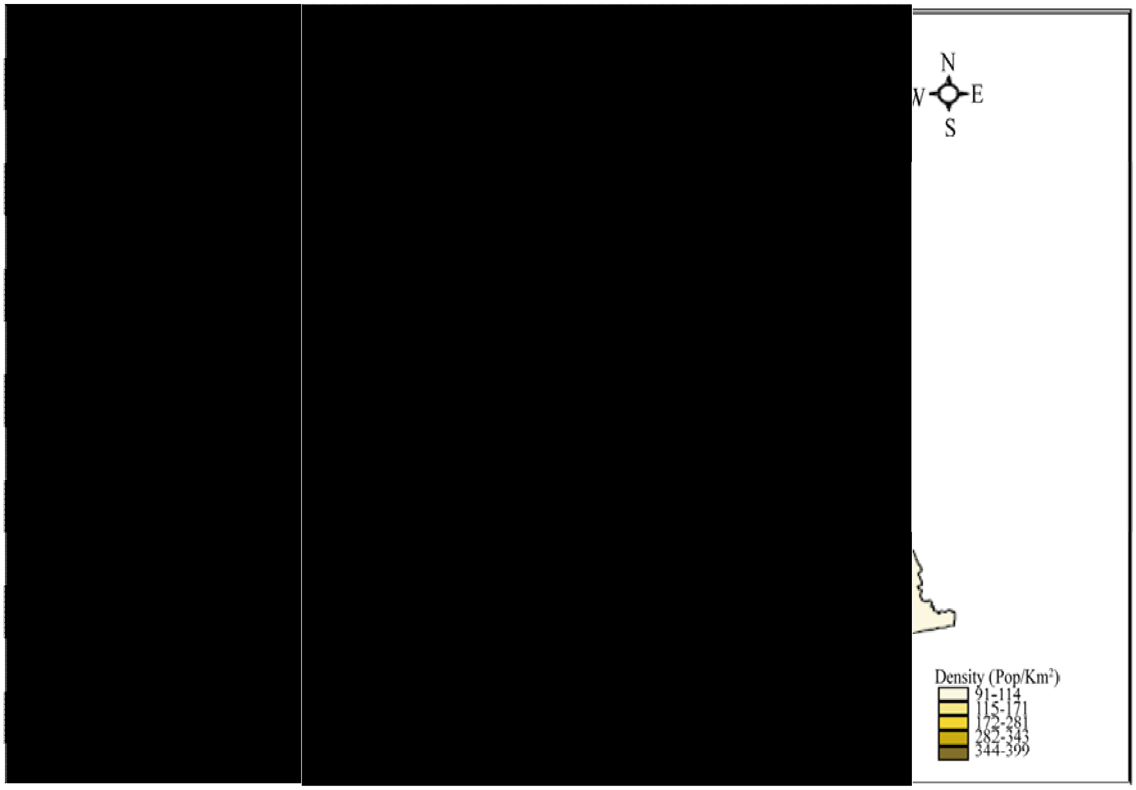


Figure 3.1: Administrative Map of Bugesera District

In addition to Bugesera, the study was undertaken in Kirehe District. Kirehe District is one of 30 districts in Rwanda located in the Eastern Province. It is divided into 12 sectors: Gahara, Gatore, Kigarama, Kigina, Kirehe, Mahama, Mpanga, Musaza, Mushikiri, Nasho, Nyamugari, Nyarubuye (Wikipedia, 2014). Kirehe district extends to the surface of 1,175.6 km² with a total population of 338,562 (162,388 male, and 176,174 female inhabitants). The density is equal to 289.5 inh./km² (National Institute of Statistics Rwanda, 2014)

The primary sources of energy used for lighting by households were categorized as follows: electricity, oil lamp, firewood, candle, lantern, battery, and other unspecified sources. In Kirehe district, 1.6% of households use electricity as the main source of lighting, ranking the district last compared to other districts in the same province. On average, urban areas have 46.1% of households using electricity as the main source of lighting, while it is only 4.8% in rural areas and 10.8% at national level.

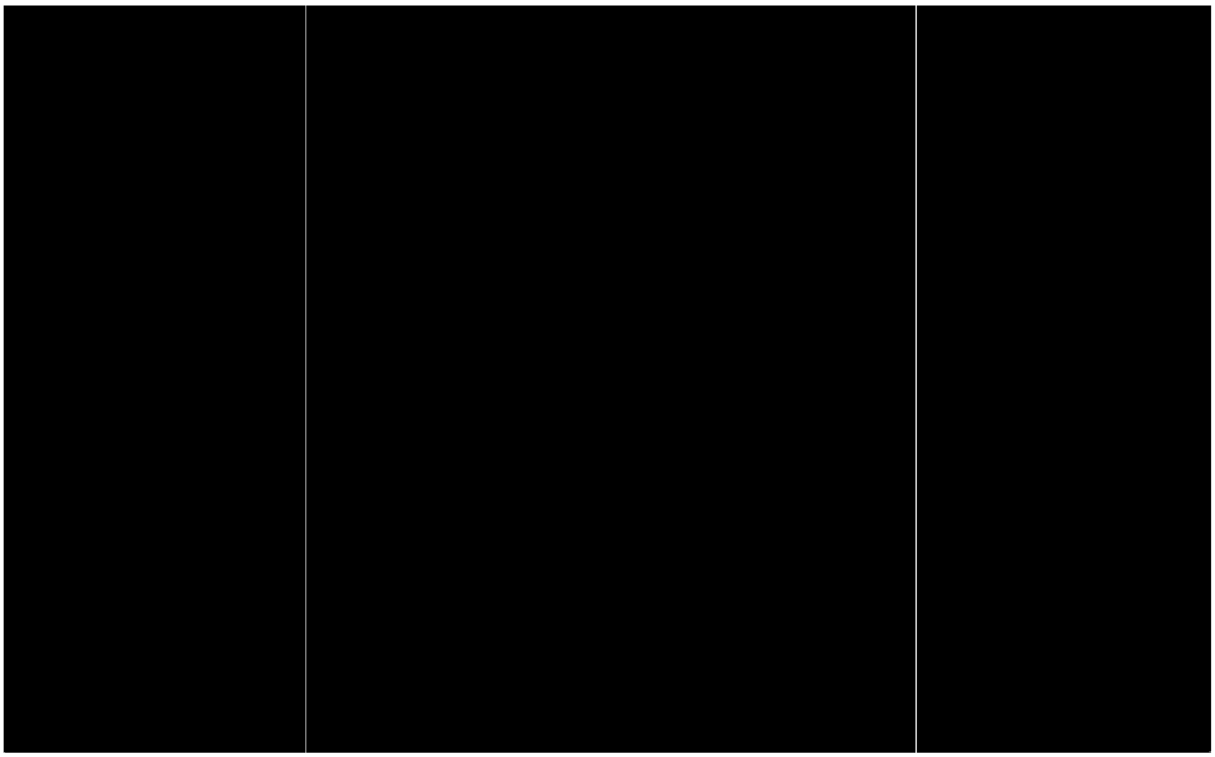


Figure 3.2: Administrative Map of Kirehe District

3.4 The Target Population

Target population is defined as aggregate or totality of objects or individuals, having one or more characteristics in common that are of interest to the researcher and where inferences are to be made (Amin, 2005).

The target population surveyed in this research is biogas users:

1. Biogas users who acquired a biogas plant before decentralization, as control group
2. Biogas users who acquired a biogas plant after decentralization

Qualitative data was obtained through interviews with biogas construction companies operating in the District of Bugesera and District officials in charge of Infrastructure and biogas.

In total 3,356 domestic biogas plants had been built (APPENDIX X), since the program started in 2006 and up to 2006/2012 fiscal year. Kirehe District having built the highest Number with 307 biogas plants built, while Bugesera District was the second with 160 domestic biogas plants .On the other side, Nyarugenge District was the one with the least domestic biogas plants constructions with only 17 biogas plants (NDBP). The researcher therefore selected Kirehe and Bugesera Districts, among the 30 District of Rwanda, as exemplifying cases for the implementation of the biogas program decentralization, since they had a bigger number of domestic biogas plans installed (APPENDIX X), prior to the decentralization of the domestic biogas program.

3.5 The Sample Design

Kenneth (1978) defines a sample as a subset or a portion of the total population. Sampling is necessary when a population is large. Due to time and cost constraints, it was not possible to conduct the research on the entire population. The sample size that was used for the study consists of a number of respondents that were selected from the entire targeted population.

In relation to the target population, the initial list of the biogas users has a total of 1,435 beneficiaries including 832 in Kirehe, including 307 for before and 525 after decentralization and 603 in Bugesera including 160 for before and 443 after decentralization. Reference to the table below:

Table 3. 1: Numbers of Biogas Plants per District, Before and After Decentralization of the Domestic Biogas Programme (APPENDIX XI)

	Bugesera	**Kirehe**	**Total**
Before	160	307	467
After	443	525	968
Total	603	832	1435

The lists were drawn from all the beneficiaries since the start of the domestic biogas program in January 2006 until 2016/2017 fiscal year (Ending with 31^{st} June 2017). These two Districts are the first two on the list of the 30 Districts to have built more domestic biogas digesters in the mentioned period.

A sample size of 93 respondents was calculated using Slovin's formula (Susanti, 2019) and in this regards the margin of error of e = 0.1 was chosen by the researcher (Over an e= 0.05), based on available financial resources to conduct the study, further deeper investigations maybe be applied later with other studies on the matter: Formula:

$$\eta = N/1+N\ (e)^2$$

Where

N= Total population

η = Sample size

e = the margin of error

N= 1435

e = 0.1

$\eta = 1435/1+1435\ (0.1)^2 = 1435/1+14.35 = 93$

From the above calculation, the sample size was at least 93 respondents.

The respondents for the interview were selected randomly form all the listed households' owning a biogas plants as from 12 administrative sectors (Imirenge) of Kirehe District(Gahara, Gatore, Kigarama, Kigina, Kirehe, Mahama, Mpanga, Musaza, Mushikiri, Nasho, Nyamugari, Nyarubuye) and 15 administrative sectors of Bugesera District (Gashora, Juru, Kamabuye, Ntarama, Mareba, Mayange, Musenyi, Mwogo, Ngeruka, Nyamata, Nyarugenge, Rilima, Ruhuha, Rweru and Shyara).

The random sampling through MS Excel provided us with a list of 93 beneficiaries including "Before Decentralization" 21 in Kirehe and 21 in Bugesera and "After Decentralization" 25 In Kirehe and 26 in Bugesera. The sampling was done using Excel sheet formula: =Rand () taking the first 93 respondents on the list.

The process of selecting respondents for this study was a major exercise because it dealt with different categories of population. Finally, it came up with the sampling frame on Table 3.1.

Table 3. 2|: Number of Sampled Population and Key Informant Persons for the Interview

Population category	Population in Kirehe and Bugesera Districts	Sampling Procedure	Sample size	
Quantitative method				
Households owned a biogas plant before decentralization (2006- Dec 2013)	467	Random sampling	42(21 Kirehe& 21Bugesera)	
Household owned a biogas plant after decentralization (Jan 2014-June 2017)	968	Random sampling	51(25Kirehe &26Bugesera)	
Sub-Total	1435		93	
Qualitative method				**N^{o} of interviewees**
District officials	2	Judgmental/Purposive (Districts officers in charge of biogas implementation)	2	**2**
Biogas construction companies /Cooperatives	2 cooperative and 4 companies	Judgmental/Purposive (cooperatives and companies more active in the two Districts of |Bugesera and |Kirehe)	2 cooperatives 4 companies	**6**
NDBP/REG staff (National level)	2	Purposive (NDBP/REG Officers in charge of biogas implementation)	2	**2**

While the targeted biogas households provided information from the biogas user perspective, the district staff, REG/NDBP staff, biogas construction company owners / Biogas construction cooperative leaders provided additional qualitative information that have further enlighten the research.

3.6 Research Instruments

In order to cope with the study nature, various instruments were used such as closed ended questionnaires that were developed and used to collect primary data all along the research at biogas owner's household level, as shown in Appendix I (Household questionnaire).

During the discussion with biogas company's owners and masons, an open-ended questionnaire was developed and in addition focus group discussions were held to complete the individual data as collected before, as shown in Appendix II (Interview guide-Construction companies).

The interviews with NDBP/REG staff and Districts Biogas Officers as key informant Interview (KIIs), a checklist has been developed in order to get more information at a wider and national scope, as shown in Appendix III (Interview Guide-District staff) and Appendix IV (Interview guide REG/EDCL staff). The researcher visited 6 homesteads where biogas plants were built in Kirehe and Bugesera districts to test the research instruments.

3.7 Data Collection and Analysis Procedures

3.7.1 Data Sources:

This study used quantitative and qualitative data collection in the framework of the research design. Questionnaires were developed mainly to collect quantitative information for 93 biogas owning households, particularly for the assessment of service ratings and other key indicators. On the other hand, qualitative information was collected through KIIs with well elaborated interview guide/check list, in order to provide a comprehensive picture of the user, companies and policy level experiences.

To provide the required primary data, the following tools and content have been considered:

a) For household data collection, through the closed ended questionnaire:

    1. General information about household and family members
    2. When the biogas plant was constructed, size and type
    3. Information on acquisition of the biogas plant
    4. Construction which built the biogas plant and satisfaction on services provided
    5. Information on maintenance visits by biogas Construction Company, etc…

b) With biogas companies and masons, through the open-ended questionnaires:

    1. General information about a company or a mason
    2. Number of biogas plants constructed
    3. Quality delivery of the biogas construction
    4. Maintenance services provided, in a period of a year, after construction works had been completed

c) For District office staff, through the key informant interview: he focus was on the Program background, increased beneficiary access and numbers of biogas plants constructed, as well as quality reports/maintenance interventions overview.

d) For NDBP/REG staff, through the key informant interview: The focus was on the Program background, increased access and numbers of biogas plants constructed, as well as quality reports/maintenance interventions overview.

In addition, secondary data was obtained from REG/NDBP reports, District reports and other published and unpublished materials.

3.7.2 Data collection process: The quantitative survey with biogas owners were conducted at their respective households. The researcher had communicated to the respondents beforehand to ensure good preparations.

During the field work, the researcher adequately administered and supervised the data collection process and checked the quality of returns to avoid bias and errors. In addition, in the course of this study, interviews were conducted either through the open ended questionnaires or through the key informant interview (KIIs). To this regard, the researcher arranged meetings with the respondents at convenient places and the discussions were guided by the interview guides (As described under section 3.6) during the face-to-face interviews, the researcher captured information by note taking and then used them to complete the quantitative survey.

3.7.3 Data Validity and Reliability

Concerning the data validity and reliability, the content validity method was used to assess the validity of the questionnaire and interview guide. Five people conversant with the subject were requested to judge each question as valid. Thereafter, the content validity index (CVI) was calculated from the formula below (Polit 2007):

n: number of items declared valid in the questionnaire

N: Total number of items

CVI=n/N

= 25/26(0.96) for the household questionnaire and 11/12 (0.846) for the construction companies interview guide.

Since the CVI of both instruments are greater than 0.7, both instruments proved to be irrefutably valid and, as well as, ready for data collection.

The reliability of the questionnaire and interview guide was tested using the Cronbash Alpha Coefficient method (Tavakol, 2011). Alpha Coefficient was calculated using the formula below:

The reliability

$$\alpha = \frac{}{-1} + (1 - \frac{\varepsilon Vi}{})$$

n=number of questions

Vi=Variance of scores on each question

Vtest= Total variance of overall scores on the entire test

The reliability coefficient of the questionnaire is 0.87, while the one of the interview guide is 0.83. As the reliability questionnaire is greater than 0.7, both instruments proved reliable and hence ready for data collection.3.7.4 Data analysis

As the data was collected from the field, all the information especially from the households' survey was entered into a prepared excel template with respective codes for statistical analysis. The KIIs scripts were developed and then analyzed.

The data analysis involved statistical description of the coded and distributed data, statistical indicators such as frequencies and percentage that were used to show the significance of different variables to the research questions. Simple tables and graphs were used.

The data processing was conducted scientifically and systematically. To this regard, the researcher meticulously scrutinized the answers from the respondents, in order to avoid mistakes. Also, the researcher had to ensure that responses from the respondents had a high degree of consistency and reliability. Quantifiable data was tabulated and analyzed with Micro Soft Excel.

3.8 Ethical Considerations

Throughout the study, the researcher interacted with biogas owner's household members and other respondents, including private construction companies' staff and owners, as well as government officials. Objectivity and a high sense of confidentiality guided the researcher from the beginning to the end of this research.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the findings of the research and their discussion in relation to the research objectives and questions. It presents the data collected, and analysis, interpretation and discussions of findings, in relation to changes in numbers and quality of the biogas systems construction and status of the maintenance services for constructed biogas systems. This is in relation to the before and after situations of the domestic biogas program decentralization.

4.2 Research Respondents' Domestic Biogas Plants Construction Period

During the data collection, the question "Year digester built**"** was asked to 46 biogas users in Kirehe and 47 biogas users in Bugesera, and it appeared that a bigger number of digesters were built after the biogas program decentralization. The Figure 4.1 further illustrates the number of biogas plants constructed before and after decentralization, as per the interviewed biogas users.

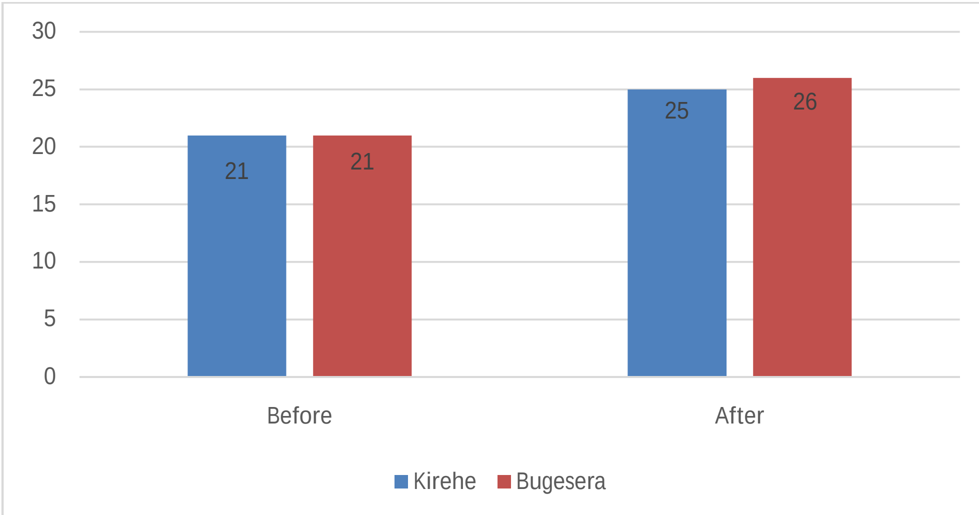


Figure 4.1: Number of Digesters Built in Kirehe and Bugesera Districts Before and After Decentralisation, as per the Sampled Group

In relation to the research objective 1, the higher number of the biogas installed after decentralization has been caused by the role played by different stakeholders from decentralized entities. .The information obtained from the District Officers, Companies owners and REG Staff confirmed the data from the households interviews, informing that the collaboration of the different authorities at decentralized level (District, Sectors, Cells), contributed to the the increasing of the biogas' numbers into the community, due to the fact that most of the administrative sectors had biogas promotion into their performance contracts "Imihigo" and that this led to their increased involvement in community mobilization. This was a direct result of the decentralization drive, in fact to further promote biogas, it was recommended that local governments needed to put more emphasis on District biogas targets during District Performance Contract (Imihigo) formulation and implementation to include biogas dissemination (District IMIHIGO Evaluation Report, 2012-2013).

4.3 Number of Biogas Plants Constructed in the Districts

Reference to the research objective 1, Desk studies and qualitative data from Districts and REG staff, have further confirmed the increase in numbers of domestic biogas plants after decentralization. The study shows that in Bugesera and Kirehe Districts, the Districts and REG databases registered growth in numbers of digesters built, after the decentralization of the program. In fact, the number of biogas plants installed in Kirehe after decentralization was 525 while the number of the biogas installed before was 307. The same case in Bugesera District, where the number of biogas installed after decentralization was 443, while only 160 biogas plants had been installed before decentralization.

The figure 4.2, further illustrate the increase in number of digesters after the decentralization of the program:

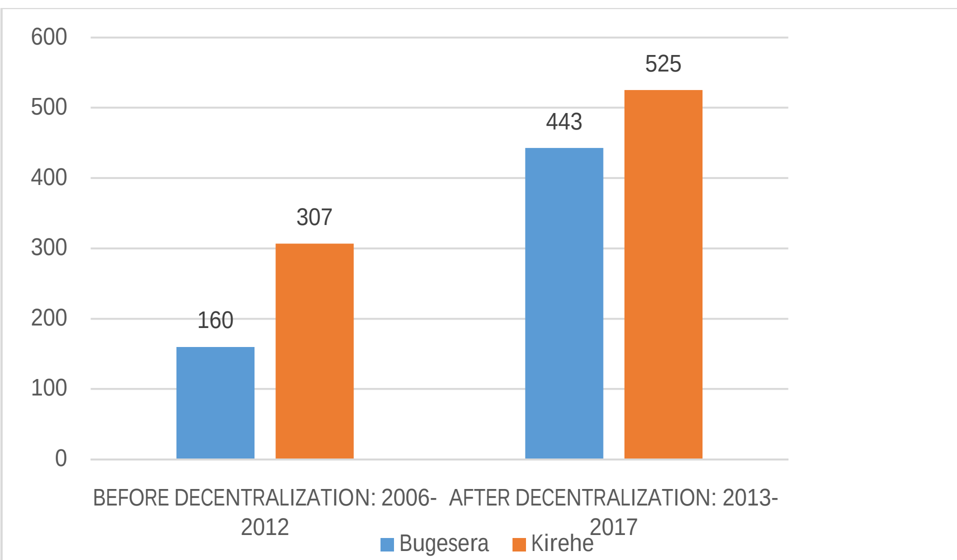


Figure 4.2: Number of Digesters Built in Kirehe and Bugesera Districts Before and After Decentralisation

Data from REG show that it was the same growth evolution after the decentralization of the program (Figure 4.3), in all the 30 Districts (APPENDIX XI: Number of Domestic biogas plants before and after decentralization, 30 Districts).

The Figure below, further illustrates the increase of biogas plants built countrywide:

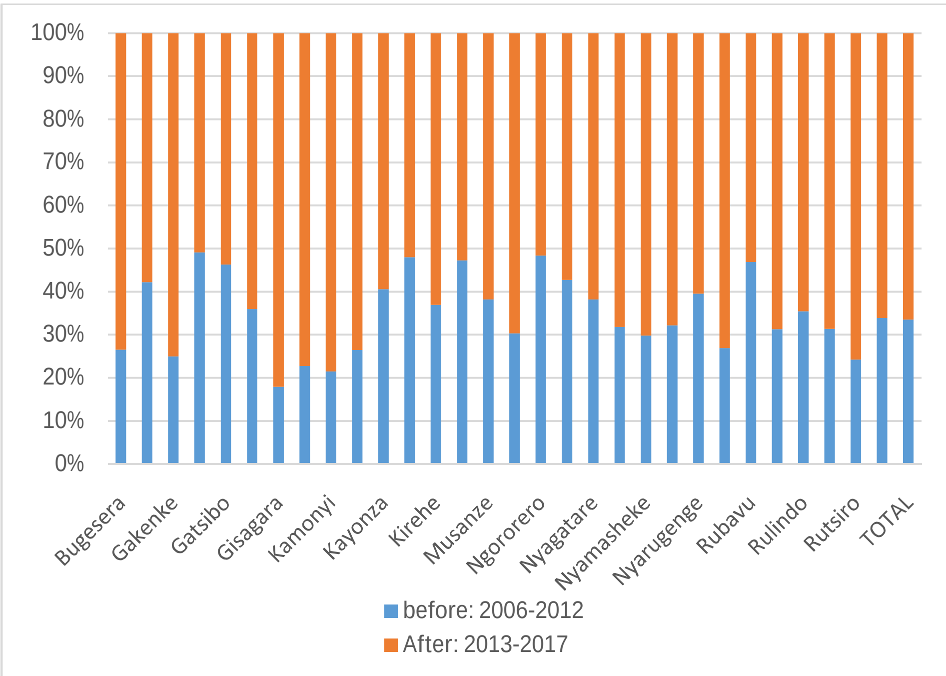


Figure 4.3: Number of Digesters Built per District Before and After Decentralisation

The study conducted shows a very positive development though decentralization of the program, as the number of biogas plant constructed doubled from 3356 before decentralization to 6664 after decentralization. Which is quite an impressive increase keeping in mind that the period before decentralization was 7 years (2006-2012), while the period after decentralization, only lasted for 5 years (2013-2017). In fact, the decentralization of the biogas program increased access to the underserved population and brought the necessary momentum to reaching the targets of number of digesters set by the government. In fact, the national target of 100,000 biogas plants by year 2018(Rwanda energy sector strategic plan 2017-2018) had remained an elusive dream. Again, the Rwanda biomass strategy (2018-2030), re-emphasized the commitment of the government to promote biogas, as a viable solution to replacing the 3-stones firewood (Ministry of Infrastructure 2019).

4.4 Biogas Users Satisfaction in Terms of Output

In the addition to the number of biogas plants installed before and after decentralization, the researched checked from the biogas users their satisfaction in terms of the output of the biogas installed in their respective households, also in reference to the research objective 1.

The results from the field (Table 4.1) indicated that there was no big difference in terms of number of biogas beneficiaries users' satisfaction, as in Kirehe District 96 % from "***after***" were satisfied, while in Bugesera District 96% from "***after"*** were satisfied with the output of the biogas plant. Looking at "Before", in Kirehe District, 100% were satisfied, while in Bugesera District 95% were satisfied too. These figures are not giving us a considerable difference in terms of "Output satisfaction".

Table 4.1 : Number of Biogas Users Per Biogas Plants Outputs Satisfaction

Districts	**Before decentralization**	**Percentage**	**After decentralization**	**Percentage**
Kirehe	21	100%	24	96%
Bugesera	20	95%	25/26	96%

However, from the key informant interviews, REG and District staff, it was observed that there were decreasing numbers of claims in terms of non-operational biogas plants, due to closer maintenance services that are provided by masons locally trained, as a result of the domestic biogas program decentralization. In fact, prior to decentralization, 10% of the completed digesters were not producing gas at all, while 25% of digesters owners were not satisfied with the volume of produced biogas (Arjun, 2013).

4.5 Construction Quality of the Biogas Plants

Also, in reference to the research objective 1, this section includes information on how beneficiaries appreciated the quality of the construction, while comparing this to before and after decentralization. As per the respondents (Table 4.2), it was noticed that there was a much more positive construction quality appreciation after decentralization, reference to the table below:

Table 4.2: Number of Households Satisfied with the Biogas Plants Construction Quality

Districts	Before decentralization	Percentage	After decentralization	Percentage
Kirehe	21	100%	24	96%
Bugesera	14	66%	25	96%

In addition, through key informant interview, REG and District staff, confirmed better quality services by construction companies and biogas builder cooperatives, as compared to the period before decentralization, whereby some companies with no local presence in the District were providing poor services and were not able to monitor the biogas operations after the contract life-time. It was however confirmed that capacity building for local companies was a continuous process. In fact, before the biogas program decentralization, there were claims that the some of the installed biogas digesters were underperforming or non-operational. The former Minister James Musoni had warned to blacklist inefficient contractors involved in bio-gas projects for failure to deliver on time or compromise on quality (Newtimes, 2014-11-25). The respondents acknowledged positive contributions by District companies, builder cooperatives and local masons to this regard.

4.6 Cooperatives' Intervention in Maintenance

In reference to the research objective 2, this section provides us with the information on intervention of the cooperative in maintenance of the biogas plants. In fact, these District based biogas cooperatives were established after the decentralization. The data from the respondents (Table 4.3) indicates that 44 biogas users in Kirehe District, 100% of "Before" and 96% of "After" received the assistance from the Cooperative technicians for the maintenance of their biogas, while 44 biogas users in Bugesera Districts, 95% of "Before" and 92% of "After" got assisted by the cooperatives' assistance for the maintenance in Bugesera. This shows clearly that the Cooperatives played a big role in the maintenance (after sale services) of the biogas which means that the Decentralization facilitated biogas users in getting "after sales services".

Table 4.3: Data on Cooperatives Intervention in Maintenance

Districts	Before decentralization	Percentage	After decentralization	Percentage
Kirehe	21	100%	24	96%
Bugesera	20	95%	24	92%

The key informants including REG staff, construction companies and District Officers confirmed the biogas maintenance services had considerably improved, as compared to before the decentralization. It was observed that the masons are everywhere in the administrative sectors and were equipped with the necessary technical skills to repair and/or replace any damaged biogas component. In fact, prior to decentralization, 10% of the completed digesters were not producing gas at all (Arjun, 2013), which was again was sign of poor maintenance services.

4.7 Involvement of the District in the Implementation of the Biogas Program Decentralization Policy

In line with research objective 3, the involvement of the districts in the biogas decentralization policies implementation, especially in the supervision of the construction activities was also investigated. The following question was asked: “Who supervised the company/masons/cooperative works?” to all 46 biogas users in Kirehe and 47 in Bugesera. The data from the study shows that a greater number of the respondents testified on the closer involvement of the districts into supervising the implementation of the biogas construction, mainly after the decentralization of the biogas program. The study shows (Table 4.4) that the respondents who owned a biogas plant before decentralization, saw little involvement of Districts for the supervision of the biogas construction works (33% in Kirehe District and 38% in Bugesera District). On the other side, the respondents who owned a biogas plant after decentralization saw closer involvement of the districts for the biogas construction activities supervision (96% in Kirehe District and 96% in Bugesera District). From these data it can be said that Districts have been greatly involved in the supervision of the constructions, mainly after the decentralization of the biogas program.

Table 4.4: Data on District Implication in Supervision of the Implementation

Districts	Before decentralization	Percentage	After decentralization	Percentage
Kirehe	7	33%	24	96%
Bugesera	8	38%	25	96%

In fact, prior to the decentralization, Districts had been requested to take full ownership and management of bio-gas projects if they are to realize their objectives and benefit Rwandans, James Musoni, the Minster for Infrastructure, had said'(Newtimes, 2014-11-25).

4.8 Central Government Suspension in the Biogas Program Implementation

In reference to research objective 3, this section gives the information on the role of REG, EDCL/EWSA/NDBP in the supervision of biogas implementation. In reality, from the data collected in the course of the study (Table 4.5), there was no direct involvement of REG**, EDCL/EWSA/NDBP** in the supervision of the biogas implementation and mainly because their involvement was only required "Before" and not 'After' the decentralization of the biogas program; the supervision work was thereafter taken over by Districts as highlighted in section 4.7 earlier.

Table 4.5: REG/EDCL/EWSA/NDBP Supervision

Districts	Before decentralization	Percentage	After decentralization	Percentage
Kirehe	9	42%	0	0%
Bugesera	8	38%	0	0%

Originally, especially before decentralization, there were lengthy procedures, as most of the works were handled by REG at central level in Kigali.

4.8 Comparison of Findings with Existing Knowledge

In relation to objective one of the research, prior to the Rwanda Domestic Biogas Programme decentralization, the programme was significantly lagging behind its output targets numbers. In fact, by 2013 again it is clear that the programme had achieved only about 15 percent of its originally intended target. One of the main challenges to achieving the targets was thought to be the delay in gearing the programme towards a truly localized and dissemination-focused organization (Rwanda Domestic Biogas Programme Mid-term Review, 2009). However, there were still literature gaps, and the question was to which extent the program decentralization model analyzed under this study has aided to achieve the objective of increased production of energy. To that regard, the research conducted shows a very positive development though decentralization of the program, as the number of biogas plant constructed doubled from 3356 before decentralization to 6664 after decentralization. In fact, the decentralization of the biogas program increased access to the underserved population and brought the necessary momentum to reaching the targets of number of digesters set by the government.

Again, in addition to the research objective two, it was found that about 10 percent of the completed digesters were not producing gas at all while 25 percent of digester owners were not satisfied with the volume of production (IOB Evaluation of the impact of Rwanda's National Domestic Biogas Programme, 2013). However, there were still literature gaps, and the question was to which extent the program decentralization model analyzed under this study has aided to achieve the objective of better maintenance services. The study checked for the biogas user's satisfaction and reduction of claims which was very positive, as well as improved maintenance services from biogas companies and cooperatives.

In line with the research objective three, one of the main challenges to achieving the targets was thought to be the delay in gearing the programme towards a truly localized and dissemination-focused organization (Rwanda Domestic Biogas Programme Mid-term Review, 2009). However, the suitability of the biogas program decentralization model has not yet been established. On this subject, the study confirmed the increased ownership and involvement of District and other local authorities, in terms of mobilization, construction supervision and advocacy for better maintenance services by local masons, biogas cooperatives and companies. A greater number of the respondents testify of the involvement of the districts in supervising the implementation of the biogas construction. The study also observed increase local presence and proximity services for biogas companies and cooperatives.

4.9 Conclusion

In brief, the domestic biogas development in Rwanda has been improved significantly, by adopting the decentralization policy. A greater number of biogas plants, higher level of biogas user satisfaction and higher quality of the construction and maintenance services are evident benefits. All the same, the national target of 100,000 biogas plants by year 2018(Rwanda energy sector strategic plan 2017-2018) remains an elusive dream, as it has been even delayed further until now. However, the Rwanda biomass strategy (2018-2030), re-emphasized the commitment of the government to promote biogas, as a viable solution to replacing the 3-stones firewood (Ministry of Infrastructure, 2019). The policy makers and implementers should re-strategize.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents a summary of the research findings and conclusions drawn from them, in respect of each of the study objectives of the study. It also gives recommendations of the study for improvement of the biogas programme, and gives suggestions for further study.

5.2 Summary of Findings

This study intended to determine whether the decentralization of the biogas program has led to closing gaps compared to the previous centralized system and whether the decentralization has led to an increased number of domestic biogas constructions and better maintenance of existing biogas constructions. The study should provide recommendations that can be applied in order to further improve the domestic biogas program. The study finding shows a very positive development though decentralization of the program, as the number of biogas plant constructed doubled from 3356 before decentralization to 6664 after decentralization. This is quite an impressive increase, keeping in mind that the period before the decentralization of the biogas program was 7 years (2006-2012), while the period after decentralization of the biogas program, that was considered by this study was only 5 years (2013-2017), as confirmed by the documented governments (Districts) records. This was also confirmed by biogas owning households, referring to neighbors who constructed biogas plant before or after decentralization.

On top of the number of biogas installed before and after decentralization, the study also checked from the biogas users their satisfaction in terms of the biogas plant output of the already installed biogas plants into their respective households, which was positive for both the beneficiaries who acquired a biogas plant before and after decentralization. However, through key informant interview, REG and District staff, confirmed the decreasing numbers of claims in terms of non-operational biogas plants, due to closer maintenance services that are provided by masons locally trained, as a result of the domestic biogas program decentralization.

The study also checked the user’s satisfaction in terms of the quality of construction and services provided by construction companies. Comparing before and after decentralization positions, there is a positive construction quality appreciation after decentralization. In addition, through key informant interviews, REG and District staff confirmed better quality services given by construction companies and biogas builder cooperatives, as compared to the period before decentralization. It was however confirmed that capacity building for local companies was a continuous process. In older days, some companies with no local presence in the districts were providing poor services and were not able to monitor the biogas operations after the contract lifetime. The interviewees acknowledged positive contributions by District companies, builder cooperatives and local masons in this regard.

The study also confirmed the positive role of District biogas cooperatives’ intervention especially in the maintenance of the biogas plants. Moreover, these District based biogas cooperatives were established as one of the decentralizations drives and localized services. The data from the respondents indicate that the majority of respondents got assistance from the district biogas cooperatives in relation to maintenance services. This shows clearly that the Cooperatives played a big role in the maintenance (and after sale services) of the already constructed biogas plants. This shows the positive impact of the biogas program decentralization, which has put emphasis on empowering local masons and grouping them into viable cooperatives.

The study also observed the increased ownership and involvement of District and other local authorities, in terms of mobilization, construction supervision and advocacy for better maintenance services by local masons, biogas cooperatives and companies. A greater number of the respondents testify of the involvement of the districts in supervising the implementation of the biogas construction. Finally, it was observed that the central level-REG was no longer directly involved in the biogas policy implementation, as very few households' respondents could acknowledge their involvement in the mobilization, construction and maintenance. However, the interviewed staff of REG and District highlighted their role at more policy, as being more of policy, planning and resources mobilization at the national level.

5.3 Conclusions

To achieve the main objective of the study, the following research objectives were answered by the research findings and interpretation:

5.3.1 Effects of Decentralization towards Increasing the Number of Constructed Small Scale Biogas System and Energy Production

The first objective was to assess the effect of the domestic program decentralization towards increasing the number of constructed small scale biogas systems and thus energy production. The study results have clearly shown that the number of digesters had almost doubled after the decentralization of the program, even though some other elements such as reduction of costs could have played a positive role, as well. The study results also have shown that the end-users were satisfied with the biogas plants outputs in terms of gas production, which leads to confirming an increase in energy production for cooking.

5.3.2 Effect of the Domestic Biogas Program Decentralization on Improved Maintenance Services for the Already Constructed Small Scale Biogas Systems

The second research objective was about assessing the effect of the domestic biogas program decentralization on improved maintenance services for already constructed small scale biogas systems. The results of the study have shown satisfaction in terms of the quality of biogas plants built and maintenance of existing biogas systems, which was also confirmed by companies themselves, District and REG staff. In addition, the study has found that the district based biogas builder's cooperatives have been playing a big role in maintenance of the biogas plants, after they were established as one of the decentralization drives. District and REG staff confirmed less defect and non-operational biogas plants, as per the period before decentralization. It was also confirmed that capacity building for local companies and masons was a continuous process.

However, some other elements may have positively influenced, as well, such as the new design plastic digesters on the market which are easier to maintain.

5.3.3 Whether Program Decentralization Was a Suitable Model for Small Scale Energy Systems Construction and Maintenance

The third research objective was about finding out if program decentralization was a suitable model for small scale energy systems construction and maintenance. According to the above findings, there are positive signs that program decentralization was effective and can serve to upscale also other small scale energy systems construction and maintenance. The study confirmed that through the application of this model there could be further reduction in energy dependency and a move towards self-reliance in sources, while increasing the level of services to the local community.

5.3.4 Overall Conclusion

In brief, the program decentralization for the domestic biogas plants construction and maintenance has worked well in Rwanda. However, the aspirations of the Rwanda energy sector Strategic Plan 2017-2018, which was 100,000 biogas plants is far from being achieved. Perhaps, more resources should have been dedicated into the implementation of the decentralization policy.

5.4 Recommendations

In the light of the research findings and conclusions made, this study makes recommendations as follows: -

5.4.1 Increasing the number of constructed small-scale biogas system and thus energy production

Program decentralization should be continued to lower spheres of the public administration, at least to sector level, which will go hand in hand with further capacity building for increasing local level actors.

5.4.2 Improved maintenance services for already constructed small scale biogas systems

Further strengthening of local construction companies, construction cooperatives and local masons should be done in order to provide better services and reach out to more people, and eventually achieve the government aspirations.

5.4.3 Domestic biogas program decentralization as a suitable model for small scale energy systems construction and maintenance

The decentralization model of the domestic biogas program should be further utilized and up-scaled in Rwanda. In fact, the study has provided positive indications that it is a model that can be replicated for other small scale energy systems construction and maintenance management in the country.

5.5 Suggestions for Further Study

There is the need to enrich this study by extending it to other Districts of Rwanda that were not covered in the study. In addition, the study could not analyze in detail some of the drivers of the biogas program decentralization successes, such as the biogas plant cost reduction, introduction of alternative designs, and faster and flexible loan access. These drivers should be further investigated. It would also be very valuable to conduct studies on how the lessons of the biogas program decentralization can be useful to the improvement of the other small scale energy systems in Rwanda and other parts of Africa. Finally, exploration should also be made on the application of the decentralization model to other thematic sectors.

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APPENDICES

Appendix I: Household Questionnaire

Date of discussion	**………………/…………………./2017**
Respondent Name	
District	
Sector	
Cell	
Year digester built	

HH information

1. **Head of family sex**
   a. Male
   b. Female
2. **Age group**
   a. Under 21 years
   b. Between 21-35 years
   c. Above 35 years
3. **Family size**

a. 1 to 5 people
b. 5 to 8 people
c. More than 8 people

4. Number of cows

a. 1 to 2 cows
b. 2 to 4 cows
c. More than 4 cows

5. Use of biogas plant

a. cooking
b. cooking and lighting

6. Cooking patterns(#)

a. Once a day
b. Twice a day
c. More than twice a day

Access to biogas plants

7. What type of digester was constructed?

a) Fixed dome type
b) Canvas plastic type
c) Fiber glass

8. What is the size of the biogas plant

a. 4 m3
b. 6 m3
c. 8 m3 or 10 m3

9. How did you get information on biogas plant opportunities?(more options are acceptable)

a. Local Authorities or NGOs

b. REG/EDCL/EWSA/NDBP
c. Biogas company (Masons)
d. Other (specify…………..)

10. In which way the one who provided information used to provide you with information?

11. **What are the most effective ways to mobilize your neighbors to acquire a biogas plant? And why?**
    a. Through local authorities mobilization(Sector ,cell, District)
    b. Through interactions with private companies
    c. Through EDCL (REG,EWSA) campaign

12. **When most of your neighbors did got access to a biogas plant?**
    a. Between 2006 and 2013
    b. Since 2014 upwards

13. **Did you get access to any other energy technology all along biogas/Biogas with other kits**
    a. Solar lantern
    b. Biogas light
    c. Solar system

Household satisfaction questions:

Grade	1 Not at all	2 Slightly satisfactory	3 Moderate	4 Good	5 Excellent
14. Would you advise you neighbor to start procedures to acquire a biogas plant (from his/her experience) and why?					

15. Are you satisfied with biogas energy output at your household level? Why?(reasons)					

Construction quality and operation

16. Who constructed the biogas plant?

a. Biogas company

b. Biogas individual mason (specify where he is belonged)

c. Biogas cooperative

17. Did the company/Mason/Cooperative build the biogas plant within agreed contractual schedule?(14 days fixed dome/3 days for the canvas &Fiber glass models)

a. Yes

b. Delayed a bit

c. No at all

18. Who supervised the company/masons/cooperative works?

a. Nobody

b. Distict/Sector

c. REG/EDCL/EWSA/NDBP

Company service level of satisfaction questions

Grade	**1 Not at all**	**2 Slightly satisfactory**	**3 Moderate**	**4 Good**	**5 Excellent**

19. Did the company/Mason/Cooperative build the biogas plant within agreed contractual costs? (400’000Frw for Canvas while 550’000[4m3] and 1’100’000[10m3]					
20. Did the company/Mason/Cooperative build the biogas plant with quality?					
21. Were Users instructed on operation and minor repair works?					

Private companies/Cooperative/Masons maintenance and after sale services

ement between
uarantee)

a. Yes
b. No

23. How many visits did the biogas companies/masons/cooperatives conduct after construction and primary feeding were completed?

a. 0
b. Between 1 and 3
c. More than 3

24. In case of dysfunctions (if this happened), who conducted the maintenance and repair works?

a. Nobody

b. The company, cooperative or masons

a. Other (specify……….)

25. Who urged companies/masons/cooperatives to provide aftersales services including maintenance?

a. Nobody

b. The District/Sector

c. REG/EDCL/EWSA/NDBP

d. Others (specify………………..)

Appendix II: Interview Guide- Construction Companies

Date of discussion	**………………/………………….../2017**
Respondent Name	
Company/Cooperative	
Position	
District	
Respondent Telephone	

Company/Cooperative information

1. **Age group**
   a. Under 21 years
   b. Between 21-35 years
   c. Above 35 years
2. **When did you start the biogas construction activities**
   a. Between 2006 and 2013
   b. Since 2014 upwards
3. **Number of digesters built (from the time you started)**
   a. Between 1 and 20
   b. Above 20
4. **What type of digester constructed?**
   d) Fixed dome type (#)
   e) Canvas plastic type(#)
   f) Fiber glass(#)

5. **What is the size of the biogas plant mostly constructed**
   d. 4 m3
   e. 6 m3
   f. 8 m3 or 10 m3

Access to biogas plants

6. Did Decentralization of the biogas program contribute to increased numbers of people accessing biogas plants?
7. Did decentralization of the biogas program contribute to optimizing your mobilization, promotion and marketing investments? (Getting more from small investments) and how?
8. Did decentralization of the biogas program contribute to enhanced collaboration with local government towards increased access for biogas digesters and other energy services? (solar)

Construction quality and operation

9. Did the decentralization of the biogas program contribute to *timely contracting* and *payment* of construction companies? Why?
10. Did decentralization of the biogas program contribute to **improved quality in construction**? and why?
11. Did decentralization of the biogas program contributed to the availability of biogas construction accessories? And how?

Private companies/Cooperative/Masons maintenance and after sale services

12. Do you think the decentralization of the biogas program brought proximity for better maintenance services of already installed biogas plants? How many maintained?
13. Did the decentralization of the biogas program contribute to building a feedback channel from users to construction companies towards better maintenance services?
14. How frequent do you get feedback from biogas users?

Appendix III: Interview Guide- District Officer

Date of discussion	**………………/…………………./2017**
Respondent Name	
Position	
District	
Respondent Telephone	

Access to biogas plants

Did Decentralization of the biogas program contribute to increased numbers of people accessing biogas plants?

15. Did decentralization of the biogas program help District to achieve its energy access targets?reasons why and typical examples
16. Did decentralization of the biogas program contribute to enhanced collaboration with construction companies towards increased access for biogas digesters and other energy services?

Construction quality and operation

17. Did the decentralization of the biogas program contribute to close supervision of construction companies? Why and How?

18. Did decentralization of the biogas program contribute to improved quality in construction? Why? And How?
19. Did decentralization of the biogas program contributed to the availability of biogas construction accessories? And how?

Private companies/Cooperative/Masons' maintenance and after sale services

20. Do you think the decentralization of the biogas program brought proximity for better maintenance services of already installed biogas plants?
21. Did the decentralization of the biogas program contribute to less construction and operational defects, thus less claims from beneficiaries?
22. How frequent do you get feedback from biogas users?

Appendix IV: Interview Guide- REG/EDCL Staff

Date of discussion	**……………../…………………./2017**
Respondent Name	
Position	
strict	
Respondent Telephone	

Access to biogas plants

23. Did Decentralization of the biogas program contribute to increased numbers of people accessing biogas plants?
24. Did decentralization of the biogas program further contribute to reaching the national targets

Construction quality and operation

25. What were the challenges in terms of supervision of construction companies before the biogas program decentralization

Private companies/Cooperative/Masons maintenance and after sale

26. Do you think the decentralization of the biogas program brought proximity for better maintenance services of already installed biogas plants?
27. Did the decentralization of the biogas program contribute to less construction and operational defects, thus less claims from beneficiaries?

Appendix V: Private Biogas Construction companies

NBR	COMPANY	MANAGER/OWNER
1	ABC	NAHAYO J.M.Vianney
2	ACBP	SHYIRAMBERE Manasse
3	ADBC	BOSENIBAMWE J.Baptiste
4	AEDE	NIYIGENA Aimable
5	BDCS	NZABARUSHIMANA Jeremie
6	BETRAP	TWAGIRMANA JOSEPH
7	BUCLINO	BUCYEYE Lin
8	CBC	NDAYISABA Maurice
9	CEE	MUNYABUGINGO Abdoul Karim/Kirehe
10	CNV	ZIGIRANYIRAZO Protais
11	COBITEC	Havugimana Olivier
12	COGECOMO	HABIMANA Valens
13	DOBIPRO	Kayigi Celestin /Bugesera
14	ECNV	NIYONSABA Vianney
15	ECOGQ	SIKUBWABO Anicet
16	ECOHEB	BIKORIMANA Azarias
17	ECOPEF	SIKUBWABO Anicet
18	ECOSM	MBARUSHIMANA Emmanuel
19	ECOTN	NTEGEREJEMUKIZA Andre
20	EDICEBIO	Fasasi Diplomat Noor
21	EECO	MUKIZA Epaphrose
22	ESA	NIKUZWE Chantal
23	FRECOM	NIYONKURU Rose
24	GICOF	NTABARESHYA Anaclet
25	GLAS	NZARURINDA Jean Damascene

26	JOHN ENGINEERING	
27	JTS	UWIMANA Janvier
28	MAGECO	UWAMAHORO Dieudonne/ Bugesera
29	MCC	NDAYISABYE Marc Leon
30	MOSECO	KARABARANGA Vedaste
31	MTC	BASHIMWE Valentin Methode
32	NEC	NIZEYIMANA J.Damascene
33	NECC	NGENDABANGA Fidele
34	NMEC	MANISHIMWE Viateur
35	RCBP	MUNYABERA Venuste
36	RCC	NZARAMBA Jean Pierre
37	RECONS	NKUSI Gilbert
38	RENITECH	SIBOMANA Joseph
39	SACO	NIYIBIZI Frederic
40	SCCO	MUJAWAMARIYA Eugenie
41	SEEPIC	MURAGIJIMANABoniface
42	SOGELCO	MUSONERA J.Damascene
43	TEBA	RULINDA Ernest
44	ACSES-I	SHINGIRO Ehudi
45	ATLAS CONSTRUCTION	KAMALI Gilbert
46	BIOMOC	NDAYITEGEYE Rafiki
		Vedaste Havugimana/Bugesera

Appendix VI: Biogas Construction District Cooperatives

SN	NAME OF COOP.	LOCATION/DISTRICT
1	COOPERATITVE TURENGERE IBIDUKIKIJE TWUBAKA BIOGAZ BURERA (COTITBBU)	BURERA
2	COOPERATITVE DES TECHINICIENS DE BIOGAZ ET BATIMENT DE GISAGARA (CO.TE.BI.BA.GI)	GISAGARA
3	COOPERATITVE TURENGERE IBIDUKIKIJE TWUBAKA BIOGAZ HUYE (CO.TI.T.BIO.HU)	HUYE
4	’’KOPERATIVE IRENGERA IBIDUKIKIJE TWUBAKA BIOGAZ KAMONYI (CO.KI.BI.K),	KAMONYI
5	COOPERATITVE IREME RYA BIOGAZ KIREHE (COIBKI)	KIREHE
6	MUHANGA BIOGAZ CONSTRUCTORS COOPERATITVE (MBCC)	MUHANGA
7	COOPERATIVE DE CONSTRUCTEURS DE BIOGAZ KIVUMU (CCBK) Musanze	MUSANZE
8	COOPERATITVE TERIMBERE BIOGAZ TURENGERA IBIDUKIKIJE NGOMA	NGOMA
9	COOPERATITVE TWUBAKE BIOGAZ TUBUNGABUNGA IBIDUKIKIJE	NGORORERO

	NGORORERO	
10	COOPERATITVE TWUBAKE BIOGAZ TURENGERE IBIDUKIKIJE NYAMAGABE (CO.TI.BIO.TI.NYA)	NYAMAGABE
11	RULINDO BIOGAZ CONSTRUCTORS COOPERATIVE (R.C.B.C)	RULINDO
12	COOPERATIVE OF BIOGAZ CONSTRUCTORS OF RUTSIRO (CO.BI.CO.RU)	RUTSIRO
	Cooperative	Bugesera

Appendix VII: Quality Standards for the Installation of Modified GGC Model of Biodigester, SNV.

SN	Standards	Tolerances	Type of Default
	Standards in Household, Size and Site Selection		
1	One biodigester per household	Separate kitchen per biodigester.	Critical
2	Construction site not far from kitchen	Distance from kitchen not more than 20 meters.	Minor
3	Construction site not far from cattle shed or pig sty	Distance from cattle shed or pig sty not more than 20 meters.	Minor
4	Components of the biodigester adequately far from existing structures or trees	Plant components should be at least 2 m away from existing structure or trees.	Major
5	Enough space for biodigester	Enough space to orient the plant location and slurry pits.	Major

SN	Standards	Tolerances	Type of Default
	construction as per drawing		
6	Correct size of plant based upon the availability of feeding materials	At lease 5 kg of dung available per cubic meter capacity of biodigester.	Critical
7	No plant fed with night-soil only	Inlet tank should be constructed and used	Critical
8	Approved model of biodigesters	Modified GGC plant as per the design and drawing	Critical
	Standards on Construction Materials and Appliances		
9	Good quality bricks	Best quality locally available. Well baked, regular in size, free from cracks and broken parts.	Major
10	Good quality sand	Not contain more than 3% impurities as determined by bottle test.	Major

SN	Standards	Tolerances	Type of Default
11	Good quality cement	Fresh, free from lumps, best locally available.	Major
12	Good quality aggregate	Angular, of regular size not more than 2 cm and free from dust or impurities.	Major
13	Good quality MS Rod	Free from heavy rust and at least 8 mm diameter.	Major
14	Good quality acrylic emulsion paint	Approved by the quality control authority.	Major
15	Good quality inlet pipe	PVC, concrete or Polyethylene pipe 10 cm diameter.	Major
16	Good quality water	Clean and free from suspended particles.	Major
17	Good quality dome gas pipe	The size bigger than 15 mm diameter with the elbow properly sealed in the workshop. Length - 60 cm.	Major
18	Good quality main gas valve	Approved by the quality control authority.	Major
19	Good quality pipes and fittings	½" GI or 20 mm PVC pipe of best quality locally available.	Major

SN	Standards	Tolerances	Type of Default
20	Good quality water drain	As approved by the quality control authority.	Major
21	Good quality gas tap	As approved by the quality control authority.	Major
22	Good quality connecting pipe	Either neoprene rubber hose or good quality plastic pipe as approved by the quality control authority.	Major
23	Good quality gas stove	As approved by the quality control authority.	Major
24	Good quality gas Lamp	As approved by the quality control authority.	Major
25	Good quality mixing devise (optional)	As approved by the quality control authority.	Minor
	Standards on Construction		
26	Only trained masons carry out the construction work	The mason registered in the program office after successfully completing the required training courses on	Critical

SN	Standards	Tolerances	Type of Default
		biodigester construction	
27	Correct cement, sand, aggregate ratio	For all masonry works and plastering, the ratio is 1:3 (cement:sand). The ratio of concreting in dome (gas holder) is 1:2:3 (cement:sand:aggregate).	Major
28	Biodigester appropriately placed under the ground	The depth of digging as per drawing. Maximum allowable deviation by ±5 cm from the standard. If because of high water table or rocky strata the depth is not adequate proper justification to be provided. In this case, proper stabilisation measures are provided around the structure.	Major
29	Correct diameter of the digester	The diameter of the completed biodigester not to differ by ±1% from the standard.	Major
30	Accuracy plum of digester wall	Vertical wall with plum not differed by ±1 cm	Major
31	Correct height of	The height of bottom of the	Major

SN	Standards	Tolerances	Type of Default
	the position of the bottom of the inlet pipe	inlet pipe from the collar not to differ by ±2 cm from the standard.	
32	Correct height of the manhole	The height of manhole at the top of the opening not to differ by ±2 cm from the standard.	Major
33	Correct height – top of manhole to floor of outlet (I-H)	The height between top of manhole to the floor of outlet not to differ by ±2 cm from the standard.	Major
34	Proper plastering of inside of the digester	The finished surface is properly finished and smooth.	Major
35	Digester floor smooth and levelled	The finished surface is smooth and no level difference	Minor
36	Proper back-filling in the outside of the wall of digester	The space between natural soil and the digester wall is filled with soils and compacted well. The height of back-filling is at least equal to 30 cm from the top of the dome.	Major

SN	Standards	Tolerances	Type of Default
37	Correct diameter of the gas holder	The diameter of the gas holder of the completed biodigester not to differ by ±1% from the standard.	Major
38	Correct height of the gas holder	The height not to differ by ±2% from the standard.	Major
39	Correct positioning of the dome gas pipe	The location of the dome gas pipe to be at the centre. Maximum allowable deviation is 2% of the diameter of the digester.	Major
40	Proper plastering inside the gas-holder	Gas holder is treated with 5 layers of plastering as indicated in the construction manual. The finished surface is smooth and free from cracks.	Critical
41	Proper top-filling over gas holder	The height of top-filling is at least equal to 45 cm from the top of the dome.	Major
42	Proper length, breadth and height of outlet tank	The length, breadth and height of outlet tank not to differ by ±2% from the standard.	Major

SN	Standards	Tolerances	Type of Default
43	Proper volume of outlet tank	The volume of outlet tank not to differ by ±5% from the standard.	Major
44	Proper plumb of the outlet walls	The plumb of the finished surface not to be more than ±0.25 cm ‘in’ or ‘out’.	Major
45	Outlet floor properly finished	The floor is smooth, properly plastered and the level difference not to differ by ±0.2%.	Minor
46	Properly casted outlet slabs	The thickness of the outlet slab not to differ by ±0.5 cm. The length and breadth of each panel not to differ by ±2 cm from the standard.	Major
47	Proper size of overflow opening	The length and height of overflow opening not to differ by ±2 cm from the standard.	Major
48	Correct positioning of outlet tank	The centre line of outlet, manhole, digester and inlet pipe is located in one straight line. The deviation not to differ	Major

SN	Standards	Tolerances	Type of Default
		by 2 cm.	
49	Proper backfilling against the outlet walls	The outside of the outlet walls is properly compacted with rammed soil to prevent soil erosion.	Major
50	Correct height of inlet tank	The height of inlet tank not to differ by ±5 cm from the standard.	Major
51	Correct positioning of the inlet pipe	The inlet pipe is placed at the near end to the digester so that inserting of pipe or pole is possible. It discharges exactly at the hart line (imaginary line that joins centre of digester, manhole and outlet tank).	Major
52	Proper finishing works of inlet tank	The plaster surface is smooth and free from cracks.	Major
53	Positioning of the inlet chamber	The floor of the inlet chamber is at least 15 cm higher than the bottom of overflow opening in the outlet tank.	Major
54	Correct positioning	Pig manure and urine flow by	Major

SN	Standards	Tolerances	Type of Default
	of collection chamber for maturating pig manure	gravity to the collection chamber.	
55	Positioning of the collection chamber	The floor of the collection chamber is at least 15 cm higher than the bottom of overflow opening in the outlet tank.	Major
56	Correct positioning of inlet pipe from the latrine attached to biodigester	The inlet pipe discharges within the location of 30% from the hart-line	Major
57	Correct positioning of the pan level	The pan level of the latrine is at least 20 cm higher than the bottom of overflow opening in the outlet tank.	Major
58	Correct sizes of turret	The length, breadth and height (diameter in the case of circular turret) of the turret not to differ by ±2 cm from the standard.	Minor
59	Correct fitting of	No fittings in between elbow	Critical

SN	Standards	Tolerances	Type of Default
	main gas valve	in the dome gas pipe and the main valve. The joint is properly sealed with Teflon tape and good quality adhesive.	
60	No unnecessary fittings in the pipeline	Pipeline contains minimum joints as required. No unions are used.	Major
61	Proper burial of pipeline	The pipeline is buried to at least 30 cm where possible. It is protected well with clamps and covers where burial is not possible.	Major
62	Water drain able to drain the whole quantity of condensed water	The profile of pipeline is maintained properly so that the whole quantity of accumulated water is easily drained.	Major
63	Water drain protected in a well maintained chamber	The size of the chamber is such that it is easy to operate water drain and rain water does not enter into it. The pit is provided with a good cover.	Major
64	Correct fitting of	The gas tap is placed in	Major

SN	Standards	Tolerances	Type of Default
	gas tap	convenient place and the joint is sealed with Teflon tape and good adhesive.	
65	Correct fitting of gas stove	The connecting pipe from gas tap to the stove is correctly fitted to avoid the gas leakage.	Major
66	Correct fitting of gas lamp	The gas lamp is located in safe and convenient place. The joint is sealed with Teflon tape and good adhesive.	Major
67	Correct Fitting of gas-pressure meter	The pressure meter is installed near the point of application of gas.	
68	Proper construction of slurry composting pit	2 compost pits at least equal to the volume of biodigester are constructed as per the standard dimensions	Major
69	User's instructed on operation and minor repair works	At least one member from the user's household is provided with proper orientation on operation and minor maintenance of biodigester	Major

SN	Standards	Tolerances	Type of Default
70	Provision of instruction book let	Instruction booklet is provided to the users	Critical
71	Guarantee and After-sale-service provisions	Guarantee Certificates of 2 years in structural part and 1 year in pipeline and appliances is provided by the installer to the users	Critical

Appendix VIII: Companies' conditions and responsibilities to adhere to becoming biogas companies

Companies wishing to become biogas construction companies and willing to cooperate with the programme seek recognition from the National Domestic Biogas Programme(Lam,2010).

Such recognition is be subjected to a series of strict conditions and responsibilities to adhere to , such as:

a) approval of standard design and sizes of biogas plants;

b) using only domestic biogas program trained supervisors and masons for the construction of biogas plants;

c) construction of biogas plants on the basis of detailed quality standards;

d) provision of quality biogas appliances (pipe, valve, water trap, stove);

e) providing proper user training at the household level (especially to female members) and provision of a user instruction manual;

f) provision of guarantee on appliances (one year) and the structure of the biogas plant (three years), including one maintenance visit every year during the guarantee period;

g) timely visit to the biogas plant in case of a user complaint;

h) timely provision of completion and yearly maintenance reports to the NDBP;

i) proper management and administration;

j) company registered with the local chamber of commerce and industry;

k) a link with the rural setting (e.g. presence in the districts where construction takes place).

These conditions are laid down in detail in a contractual agreement between the Construction Company and the Biogas Programme.

Appendix IX: Functions of a domestic biogas program and activities

Table 2.3: Functions of a Domestic Biogas Program and activities (Dekelver, 2006)

FUNCTION	ACTIVITIES
Promotion & extension services at community and household level	• awareness raising, technical advice on digester size and capacity, advice on effluent use, financial advice, …;
Credit provision	• making the required credit available;
Construction, after sales service (ASS)	• local entrepreneurs trained in bio-digester construction by the NDBP; • promote the use of female masons;
Operation and maintenance	• daily plant operation and maintenance, simple trouble shooting;
Construction quality control	• development of quality standards for plant construction and After sale services; • quality control on the construction and the after sale services provided by the private entrepreneurs;
Training	• development of training materials; • training of trainers (supervisors); • technical training (masons); • private enterprise development (biogas companies);

Table 2.3: Functions of a Domestic Biogas Program and activities (Dekelver, 2006)

	• user training;
Applied R&D	• plant design and appliances; • appropriate use of the plant's effluent; • developing training and extension methods;
Coordination at implementation level	• annual plan and report formulation; • registration of constructed plants; • registration of annual After sale services; • channeling and administration of subsidies; • certification of construction companies; • contracting of organizations for tasks as stipulated in the annual plan; • administration of the biogas office; • coordination of training and extension; • social inclusion and gender mainstreaming; • M&E;
Coordination at Government / policy level	• mobilization of funds; • integration in existing programmes and policies; • monitoring.

Table 2.3: Functions of a Domestic Biogas Program and activities (Dekelver, 2006)

Financing	• farmer's contribution; • subsidy • credit;

Appendix X: Number of Domestic biogas plants before, 30 Districts (Domestic Biogas Program Database)

District	Before decentralization: 2006-2012
Bugesera	160
Burera	154
Gakenke	129
Gasabo	136
Gatsibo	130
Gicumbi	120
Gisagara	82
Huye	58
Kamonyi	73
Karongi	60

Kayonza	153
Kicukiro	48
Kirehe	307
Muhanga	121
Musanze	158
Ngoma	152
Ngororero	60
Nyabihu	82
Nyagatare	159
Nyamagabe	146
Nyamasheke	78
Nyanza	91
Nyarugenge	17

Nyaruguru	70
Rubavu	60
Ruhango	86
Rulindo	153
Rusizi	59
Rutsiro	56
Rwamagana	153
TOTAL	**3356**

Appendix XI1: Number of Domestic biogas plants before and after decentralization, 30 Districts (Domestic Biogas Program Database).

Table 4.3: Number of Domestic biogas plants before and after decentralization, 30 Districts (Rwanda National Domestic Biogas Program).		
District	**Before decentralization : 2006-2012**	**After decentralization: 2013-2017**
Bugesera	160	443
Burera	154	211
Gakenke	129	388
Gasabo	136	141
Gatsibo	130	151
Gicumbi	120	267
Gisagara	82	375
Huye	58	197

Table 4.3: Number of Domestic biogas plants before and after decentralization, 30 Districts (Rwanda National Domestic Biogas Program).		
Kamonyi	73	267
Karongi	60	167
Kayonza	153	224
Kicukiro	48	52
Kirehe	307	525
Muhanga	121	135
Musanze	158	256
Ngoma	152	349
Ngororero	60	64
Nyabihu	82	110
Nyagatare	159	257

Table 4.3: Number of Domestic biogas plants before and after decentralization, 30 Districts (Rwanda National Domestic Biogas Program).		
Nyamagabe	146	313
Nyamasheke	78	184
Nyanza	91	192
Nyarugenge	17	26
Nyaruguru	70	231
Rubavu	60	68
Ruhango	86	189
Rulindo	153	279
Rusizi	59	129
Rutsiro	56	175
Rwamagana	153	299

Table 4.3: Number of Domestic biogas plants before and after decentralization, 30 Districts (Rwanda National Domestic Biogas Program).		
TOTAL	**3356**	**6664**
TOTAL ALL BY JULY 2017		**10020**

Appendix XII: Cover Letter

COVER LETTER

Dear Esteem Respondent,

We value your time, potential and contribution to this research, your comebacks to this questionnaire is of paramount importance towards achieving real results hence we guarantee that all information provided related to such research will be kept confidential and will never be elaborated for any other purposed apart from academic use and consideration as an outcome of the academic research or paper and the document will be shared to you as far is it is fully completed.

This questionnaire is part of the Master of Science in Construction Project management thesis entitled "**SMALL SCALE ENERGY SYSTEMS CONSTRUCTION AND MAINTENANCE MANAGEMENT THROUGH PROGRAM DECENTRALIZATION, A CASE STUDY OF THE RWANDA DOMESTIC BIOGAS PROGRAM**" at Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya.

All the information related to the acquisition, construction, operation and maintenance of the biogas systems are of paramount importance to this study.

We thank you for your contribution!

Anaclet Ndahimana.

Appendix XIII: Research letter

RESEARCH LETTER

Title of the research project:

SMALL SCALE ENERGY SYSTEMS CONSTRUCTION AND MAINTENANCE MANAGEMENT THROUGH PROGRAM DECENTRALIZATION

A CASE STUDY OF THE RWANDA DOMESTIC BIOGAS PROGRAM

Objective of the study: The general objective of the study is to assess if program decentralization is a suitable model for small scale energy systems construction and maintenance.

1. I …………………………………………………………………………………….hereby accept to participate in this research as per explanation given to me by Ndahimana Anaclet as a post graduate student from Jomo Kenyatta University of Agriculture and Technology .

2. The nature and objective of the research was explained to me and I understand them.

3. I understand the right to choose whether or not to participate in the research and that the information furnished will be handled confidentially. I understand that the results of the investigation will be published for academic purpose.

Signed

____Date__________________________

__