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

Ndahimana Anaclet, Gwaya Abednogo, Diang'a Stephen

Abstract: ***An energy system is a system primarily designed to supply energy-services to end-users. The IPCC (Intergovernmental Panel on Climate Change) Fifth Assessment Report defines an energy system as "all components related to the production, conversion, delivery, and use of energy". To this end, Domestic biogas constructions have a direct positive effect on rural peoples' energy supply, environment, health and agricultural production. In fact, Construction companies construct 4, 6, 8, and 10 m3 Biogas plants that can solve cooking issues at household level. To date, 40 biogas construction companies and 21 biogas construction cooperatives have been conducting the biogas business in all the 30 administrative Districts of Rwanda. These biogas plants are operated through digestion of cattle dung, but also toilets can also be attached for sanitation purpose. Effective domestic biogas construction and maintenance management needs a program that oversees its deployment in rural areas. In these programs, multiple actors at different levels cooperate on the basis of proper institutional arrangements to provide access to sustainable energy for rural households raising livestock. The government implements the domestic biogas program through REG (Rwanda Energy Group), which provides subsidies for biogas constructions. From 2006 to 2013, the biogas was centralized and managed essentially from REG, Kigali office. Prior to the decentralization, the rural people were still underserved and some of the installed biogas digesters constructed were non-operational. However, since beginning of 2014, the biogas program decentralization has been initiated. To this regard, the 30 administrative Districts of Rwanda started taking 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 youth masons from all the 416 administrative sectors of Rwanda, this in a drive to complement existing biogas companies or bring biogas construction and maintenance services in some District with no private companies operating in this specific sector. Therefore, this research study will aim at determining if the biogas program decentralization from central level to Districts has contributed to more biogas constructions, thus increased access to energy by rural people. But also, if decentralization contributed to better maintenance of existing plants through improved services to beneficiaries. The target population will be the Rwanda Energy Group, District and biogas private company's staff who will be interviewed. In addition, a survey will be conducted for rural households already owning a biogas plant. At the end, the study should be able to determine whether there decentralization of the biogas program has led to closing gaps compared to the previous centralized system and if the decentralization has led to an increased number of domestic biogas constructions and better maintenance of 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.***

Index Terms: ***Energy systems, Program, Decentralization, Effective, Construction, Maintenance services***

I. INTRODUCTION

The Rwanda's rural household conditions surveys, underlines the reliance on bio-mass to meet energy needs. Currently around 85% of the overall primary energy consumption is based on biomass (Over 90% of all households using biomass for cooking), 11% on petroleum products (for transport, electricity generation and industrial use) and 4% on electricity (MININFRA,2013). 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. Rwanda has plans to promote the use of bio-digesters within households and government institutions with a target to deliver 100,000 bio-digesters by 2018 (Rwanda Energy Sector Strategic Plan 2017-2018). 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 (GHG). In most cases (more than 95 % of all households) it replaces firewood and agricultural waste as the principle source of energy for cooking (SNV). 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

Revised Manuscript Received on May 22, 2019.

Ndahimana Anaclet, Bachelor's of Science in Civil Engineering and Environmental Technology, KIST, Msc. Construction Project Management, (Ongoing), JKUAT.

Dr. Abednogo Gwaya, B.A(Bldg.Econ).U.O.N, MSc Civil Eng. Makerere. Ph.D (Const. Eng. & Mngt).JKUAT.

Dr. Stephen Diang'a, (Ph.D, Durban University).Member of BORAQS, Housing and Urban Planning, Architecture.

The majority of households own two or more cattle, used for milk, meat and dung production and for financial security. In 2012, private households 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 is kept in stables overnight, while a growing part is kept on zero grazing. At farms where stabling is practiced, farmers have access to water.

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.

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 digesters plants constructions of 6 – 10 m3 to be used by farmers able to feed at least 20kg dung per day into the digester(Dekelver G.,Ndahimana A.& Ruzigana S. ,2006).

There was a 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 are 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. As mentioned above, the Ministry of Infrastructure later on set even more ambitious targets of 100,000 bio-digesters by 2018 (Rwanda Energy Sector Strategic Plan 2017-2018).

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 the 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 this 15 technicians only.

Again, there are also claims that the some of the installed biogas digesters are underperforming or totally non-operational. The actual Minister James Musoni has warned that he will blacklist inefficient contractors involved in bio-gas projects for failure to deliver on time or compromise 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 construction well maintained

Since 2014, decentralization of the biogas program has been initiated by REG. 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.

The objectives of the domestic program decentralization aimed transferring responsibilities to Districts, thus:

1) Reduction of the administrative work load 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

The target population for this study was REG, District and biogas private company's staff who were interviewed to actually investigate how effective the biogas program has become with decentralization.

In addition, a survey was conducted for rural households already owning a biogas plant to know if constructors are able to assist with maintenance services.

1.1. The Biogas Technology

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.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

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)

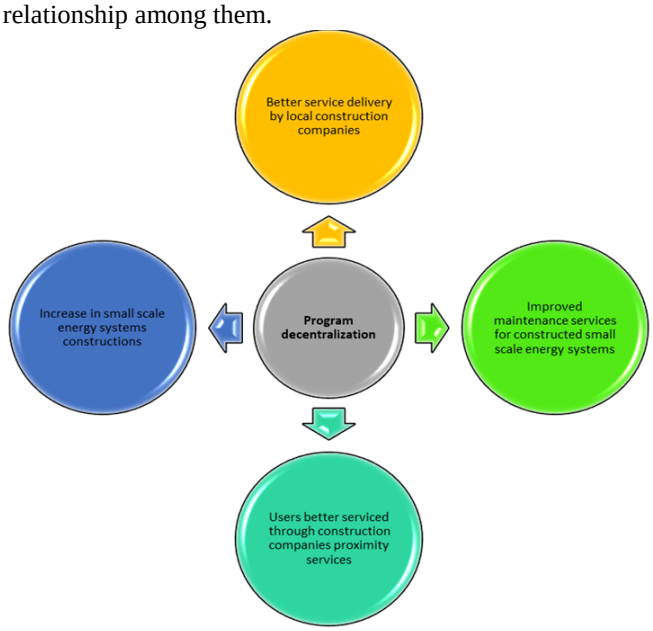
Different sizes of digester volume require a different amount of feeding. For example, in order to operate a 6m3 digester (initially the most common size used in Rwanda), an amount of at least 2-3 cattle is required, corresponding to a minimum of 40 kg dung per day. This can lead to a biogas production sufficient for 3 hours of cooking or 9 hours light on daily basis. (SNV, 2010).

1.2. Functions of a Biogas Programmed

National biogas programmes require a wide range of functions to be executed in a comprehensive and coordinated manner (SNV). 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.

1.3. Conceptual framework

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



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.

II. RESEARCH METHODOLOGY

2.1. Introduction

This section provides background information in relation to the method that was used in obtaining the needed data. Therefore, 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.

2.2. Research Design

Population for the study

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 would also be obtained through interviews with biogas construction companies operating in the District of Bugesera and District officials in charge of Infrastructure and biogas.

The researcher selected Bugesera District among the 30 District of Rwanda, as one of District with a bigger number of households who built a biogas plant (539 Households), since the program started in 2006 up to 2015/2016 fiscal year. In total 9143 domestic biogas plants had been built, with Kirehe District having built the highest Number 732 and Nyarugenge District the least 38(NDBP).

The target population has been identified by the sampling method but still in these Two (2) selected districts namely Kirehe and Bugesera.

3.3. Sample and Sampling Techniques

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 (307 for before and 525 after decentralization) and 603 in Bugesera including 160 for before and443 after decentralization. The list were drawn from all the beneficiaries since the start of the domestic biogas program in January 2006 until 2016/2017 fiscal year (Ending with 31st 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 Solvin's formula:

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

Where N= Total population

η = Sample size; e = the margin of error; N= 1435;e = 0.1;η = 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 process of selecting respondents for this study was a major exercise as we are dealing with different categories of population and then we came up with the sampling frame as shown below:

Table 1: Number of sampled population and Key informant persons for the interview

Population category	Population in Kirehe and Bugesera Districts	Sampling Procedure	Sample		N° of interviewees
Households owned a biogas plant before decentralization(2006- Dec 2013)	539	Random sampling	42(21 Kirehe&21 Bugesera)		36
Household owned a biogas plant after decentralization(Jan 2014-June 2017)	732	Random sampling	51(25Kirehe&26Bugesera)		43
District officials	2	Judgmental	2		2
Biogas construction companies /Cooperatives	2 cooperative and	Judgmental/ Purposive	2 cooperatives	4 companies	10
NDBP/REG staff (National level)	2	Purposive	2		2
Total	1,271		103		93

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.

2.4. Data Collection 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.

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.

The interviews with NDBP/REG staff and Districts Biogas Officers as **key informant Interview (KIIs),** a check-list have been developed in order to get more information at a wider and national scope.

While on the field, a researcher used unstructured observations to check if the information as given during the interview are correct or compromising especially at the household level, where biogas plants were constructed.

2.5. Data Collection Procedures

This study used quantitative and qualitative data collection in the framework of the research design. Questionnaires were developed mainly to collect quantitative information for 81 biogas owning households, particularly for the assessment of service ratings and other key indicators. On the other side, qualitative information were collected through focus group discussion and 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:

I. 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…

II. With biogas companies and masons, through the open ended questionnaires:
   1. General information about company or mason
   2. Number of biogas plants constructed
   3. Quality delivery of biogas construction
   4. Maintenance services provided a year after works had been completed

III. For District office staff through the key informant interview for wider and in depth insights

The focus was on the Program background, increased access and numbers of biogas plants constructed, as well as quality reports/maintenance interventions overview.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

IV. For NDBP/REG staff through the key informant interview for wider and in depth insights of the implementation process and other relevant information on the project.

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 were obtained from REG/NDBP reports, District reports, SNV and other published and unpublished materials.

The researcher adequately administered and supervised the data collection process and checked the quality of the returns to avoid bias and errors on the spot.

Concerning the data validity and reliability, the content validity method was used to assess the validity of the questionnaire and interview guide. Five people knowledgeable about the themes of the study were asked to judge each question either as relevant.

2.6. Data Processing and Analysis

This 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. In this respect, the researcher meticulously scrutinized the answers from the respondent to avoid mistakes. Also, the researcher had to ensure that responses from the respondent had a high degree of consistency and reliability. Quantifiable data were tabulated and analyzed with Micro Soft Excel.

All the way through 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 assignment.

III. RESEARCH FINDING AND DISCUSSIONS

This section presents the findings of this research and their discussions in relation to the research objective and questions. After the different interviews, we had with different respondents (Biogas users) and key informants including Biogas cooperatives/companies, Districts Officers in Kirehe and Bugesera Districts as the study areas, plus REG (Rwanda Energy Group) Agents, especially the ones involved in the implementation of biogas promotion in the rural areas.

3.1. Number of Biogas digesters built in the Districts

The study's findings show that from the data collected on the field, the highest number of the biogas installed is the ones installed after decentralization as shown in the table and the chart below. The number of biogas installed in Kirehe after is 26 while the number of the biogas installed before is 21. The same case in Bugesera, the number of biogas installed after decentralization is 18 while only 15 are installed before among the respondents as selected and interviewed.

Table2 Number of biogas constructed

Districts	Before	After
Kirehe	21	26
Bugesera	15	18

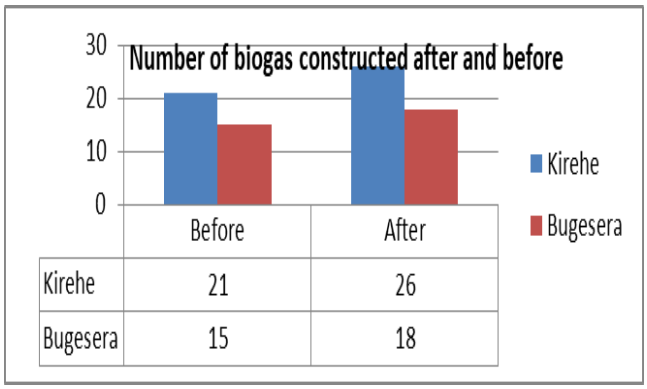


Figure 1 : Number of biogas constructed before and after

The increasing number of the biogas installed after decentralization has been influenced by the role played by different stakeholders including the local masons and local authorities as they work closely to mobilize local community in using biogas.

The information obtained from the District Officers, Companies 'owners and REG Staff confirmed the data from the households interviews because the collaboration of the different authorities at the different level at decentralized level (District, sectors, cells), contributed more into the increasing of the biogas' number into the community due to the fact that most of the administrative sectors had biogas promotion into their performance contracts "Imihigo" and this led to an increased role in community mobilization.

On the other side, desk studies and qualitative data from Districts and REG staff, have contributed to further confirm the increase in numbers of domestic biogas plants after decentralization.

In Bugesera and Kirehe Districts, the Districts and REG databases registered growth in numbers of digesters built:

Table 3: Number of digesters Built in Bugesera and Kirehe District before and after decentralisation

Number of domestic biogas plants before and after decentralisation in Bugesera and Kirehe Districts		
District	Before: 2006-2012	After:2013-2017
Kirehe	306	526
Bugesera	163	440
Total	**469**	**966**

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

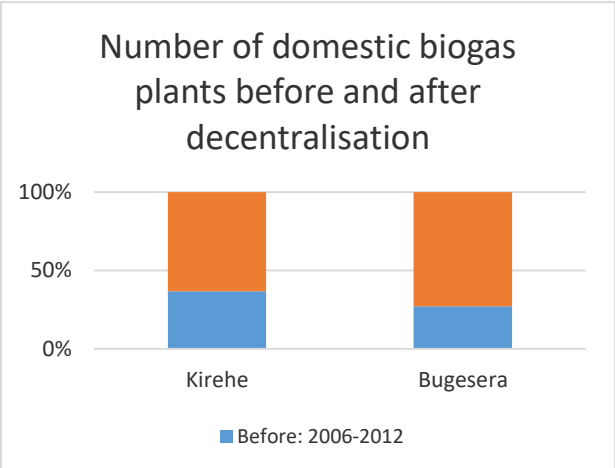


Figure 2: Number of digesters Built in Bugesera and Kirehe District before and after decentralization

Hereunder, a table presenting similar trend countrywide (All the 30 Districts of Rwanda):

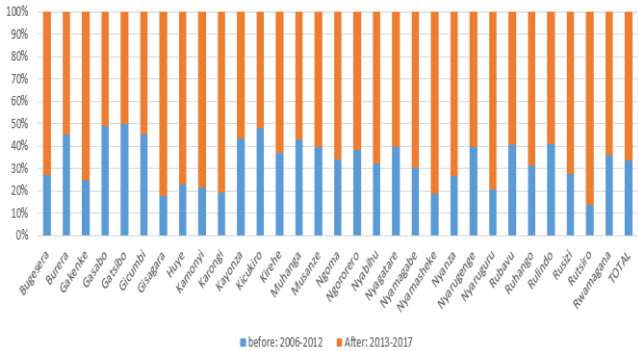


Figure 3: number of digesters built per District before and after decentralization

3.2. Construction Quality

This subsection includes the information on how beneficiaries appreciated the quality of the construction. When comparing before and after decentralization, there is a positive construction quality appreciation after decentralization.

Table 1: Number of households satisfied with biogas quality

Districts	Before	After
Kirehe	**21**	**23**
Bugesera	**14**	**18**

Figure 4: Number of households satisfied with biogas quality

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 contract life-time. They all acknowledged positive contributions by actors mobilized with decentralization, these being District based companies, builder cooperatives and local masons, to this regard.

3.3. Maintenance services by District Biogas builder cooperatives, established with Decentralisation

This subsection provides us with the information on the District biogas cooperatives' intervention especially for the maintenance of the biogas. Also as a reminder that these District based biogas cooperatives were established after decentralization.

The data from the respondents indicates that 46 biogas users in Kirehe District including 21 of "Before" and 25 of "After" received the assistance for the Cooperative technicians for the maintenance of their biogas while 29 biogas users including 13 of "Before" and 16 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: Data on cooperatives intervention in maintenance

Districts	Before	After
Kirehe	21	25
Bugesera	13	16

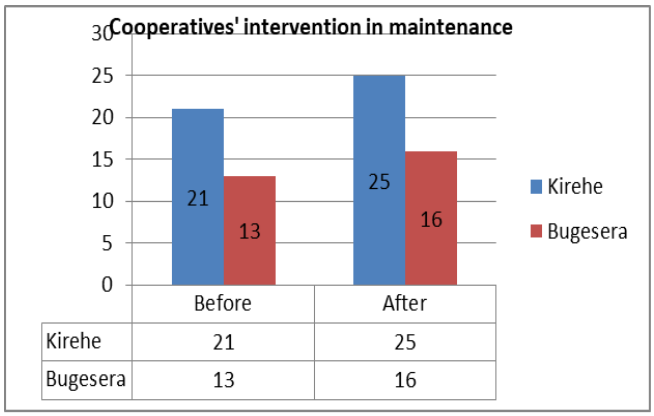


Figure 4: Data on cooperatives intervention in maintenance

3.4 Districts' implication in biogas implementation (Decentralized level)

The implication of the Districts in the biogas implementation especially in the supervision of the construction activities. This question was asked "Who supervised the company/masons/cooperative works?" to all 47 biogas users in Kirehe and 33 in Bugesera.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

The data from the study shows that a greater number of the respondents testify the implication of the Districts in supervising the implementation of the biogas construction either in Kirehe (43 out of 47) or in Bugesera (all 33 interviewed testified this).From these data, we may say that Districts have been involved in the biogas promotion before as after the decentralization.

Table 5: Data on district implication in supervision of the implementation

Districts	Before	After
Kirehe	17	25
Bugesera	15	18

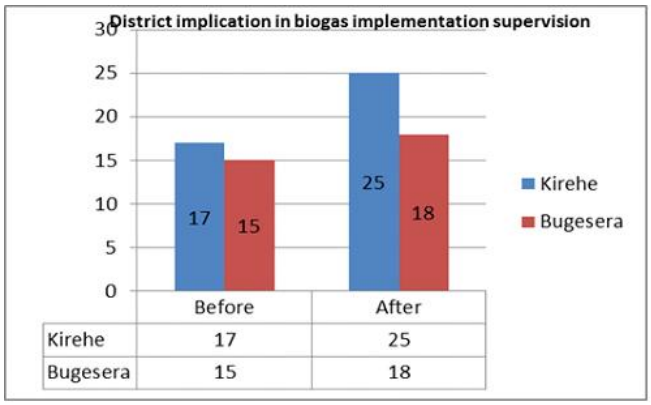


Figure 5: Data on district implication in supervision of the implementation

3.4. REG, EDCL/EWSA/NDBP supervision in biogas implementation (Central level)

This subsection gives the information on the role of REG, EDCL/EWSA/NDBP in the supervision of biogas implementation. From the data collected during the study, there is no role of REG**, EDCL/EWSA/NDBP** in the supervision of biogas implementation and this is because their implication was required only "Before" not after the decentralization, the supervision was ensured by the Districts.

Table 6: REG, EDCL/EWSA/NDBP supervision

Districts	Before	After
Kirehe	9	0
Bugesera	0	0

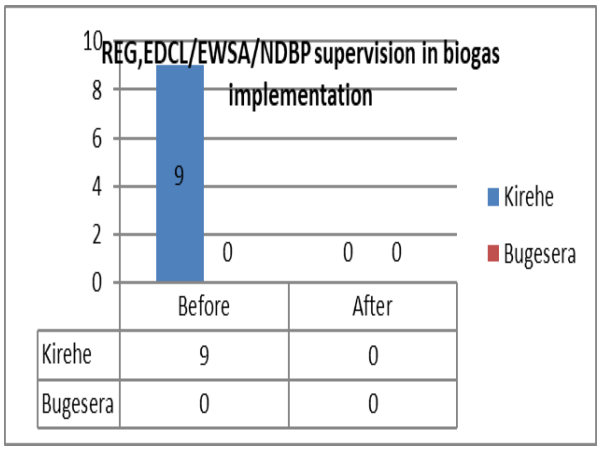


Figure 6: REG, EDCL/EWSA/NDBP supervision

The study conducted shows a very positive development though decentralization of the program, as the number of biogas plant constructed doubled from 3358 before decentralization to 6662 after decentralization. Which is quite an impressive increase keeping in mind that the period before decentralization was 7 years (2006-2012), while after decentralization, it is only 5 years (2013-2017). 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 which 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 quality of construction and services provided by construction companies and when comparing before and after decentralization, there is a positive construction quality appreciation after decentralization.

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 contract life-time. They all acknowledged positive contributions by District companies, builder cooperatives and local masons to this regard.

The study also confirmed the positive role of District biogas cooperatives' intervention especially for the maintenance of the biogas. Also, as a reminder that these District based biogas cooperatives were established, as one of the decentralization drive and localized services. The data from the respondents indicates that the majority of respondent 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, showing the positive impact of the biogas program decentralization, which has put an emphasize on empowering local masons and grouping them into viable cooperatives.

The study also acknowledged 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.

The data from the study shows that a greater number of the respondents testify the implication of the Districts in supervising the implementation of the biogas construction.

On the other side, the study noticed, that the central level-REG was no longer involved in implementation, as very few respondents could acknowledge their involvement into mobilization, construction and maintenance. However, the interviewed staff of REG and District confirmed their role at more policy, planning and resources mobilization level.

IV. CONCLUSION

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

The first question 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.

The second research question 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 into maintenance, after they were established, as one of the decentralization drive. District and REG staff confirmed less defect and non-operational biogas plants, as per the period before decentralization. However, some other elements may have positively influenced, as well, such as the new design plastic digesters on the market which are easy to maintain.

Last but not least, the third research question was about finding out if program decentralization was a suitable model for small scale energy systems construction and maintenance and according to the above findings, there are positive signs that program decentralization was effective and can serve to also upscale 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 dependence and a move towards self-reliance in sources, while increasing the level of services to the local community.

V. RECOMMENDATIONS

The results from this study have shown that the decentralization of the biogas program has impacted positively on increasing the numbers of biogas plants constructed, thus increasing energy production for cooking. The study has also shown that localized capacity for biogas construction services and maintenance brought by the program decentralization, has impacted positively on the maintenance of already installed biogas plants, reducing the numbers of non-operational biogas plants.

To this regards, we recommend further capacity building for District level actors and continued program decentralization to lower spheres of the public administration, at least to sector level. We also recommend further strengthening of local construction companies, construction cooperatives and local masons, in order to provide better services and reach out to more people, in alignment to the government drive to facilitate the construction of 100,000 biogas digesters by end 2018.

We also see the decentralization of the domestic biogas program in Rwanda, as a model that can be replicated for effective small scale energy systems construction and maintenance management in Rwanda and other countries, especially in Africa.

However, there is a relevant need to further enrich this study by extending it to other Districts that were not covered by this study. In addition, the study couldn't further analyze all the drivers of the biogas program decentralization successes such as biogas plant cost reduction, introduction of alternative designs, etc,… which could be further investigated.

It would be also be very valuable, to conduct studies on how the lessons of the biogas program decentralization can be introduced and replicated to other small scale energy systems dissemination or even beyond the energy sector, especially in the rural development context and agenda.

ACKNOWLEDGEMENT

I attribute the success of this research to the entire department of Construction Management teaching staff for their genuine feedback during presentation at different stages of this research, to my dedicated supervisors, Dr.Gwaya Abednogo and Dr Diang'a Stephen, for their selfless input and commitment throughout this research and everyone else who played a significant role towards the completion of this research.

REFERENCES

1. MININFRA (2016, June).Rwanda Rural Electrification Strategy. Rwanda
2. MININFRA (2013).Rwanda Energy Sector Strategic Plan (2013-2018). Rwanda
3. NATIONAL INSTITUTE OF STATISTICS (2012).Fourth Population and Housing Census. Rwanda
4. DEKELVER G., NDAHIMANA A.& RUZIGANA S.(2006, September).Implementation Plan National Program on Domestic Biogas in Rwanda. Kigali, Rwanda
5. REPUBLIC OF RWANDA (2013).District IMIHIGO Evaluation Report 2012-2013.Rwanda
6. WORLD ENERGY OUTLOOK(WEO 2016).Biomass database
7. WORLD ENERGY OUTLOOK(WEO 2016).Electricity Access database
8. AFRICAN DEVELOPMENT BANK(2013).Rwanda Energy Sector Review and Action Plan
9. MINISTRY OF LOCAL GOVERNMENT (2012). Rwanda Decentralization Policy. Rwanda
10. MINISTRY OF LOCAL GOVERNMENT (2013).Governance and decentralization sector strategic plan 2013/14-2017/18. Rwanda

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

11. JAN LAM ,FELIX TER HEEGDE(2010).Reader for the compact course domestic biogas technology and mass dissemination
12. UNDP (2014). Decentralized Governance for Development: A Combined Practice Note on Decentralization, Local Governance and Urban/Rural Development
13. RWANDA INSTITUTE OF STATISTICS(2012).Integrated Household Living Conditions Survey (EICV 3).Rwanda
14. http://www.fao.org/docrep/005/y2006e/y2006e05.htm#fn17
15. Farrah Ahamad, Simon Boehler, Zahra Khan,Ruvinda Pilapitiya(2014).The politics of Decentralized Service Provision-A conceptual Framework. Washington, USA.
16. YAMANE T(1967).Statistics: An introduction Analysis. NewYork
17. PROF.FRANCOIS MARCHAL (2013). Sustainable Energy Systems :A Process System Engineering Perspectives. Suisse
18. JULIA TERRAPON, CARMEN DIENST, JULIAN KONIG, WILLINGTON ORTIZ (2014).How effective are small-scale energy interventions in developing countries? Results from a post-evaluation on project-level. Germany

AUTHORS PROFILE

Ndahimana Anaclet: Bachelor's of Science in Civil Engineering and Environmental Technology, KIST, Msc. Constrution Project Management,(Ongoing), JKUAT.

Dr. Abednogo Gwaya: B.A (Bldg.Econ).U.O.N,MSc Civil Eng. Makerere.Ph.D (Const. Eng.&Mngt).JKUAT. Specialization: Construction Project Management, Civil Engineering Construction, Contract Documentation, Project Management modeling, Project procurement Systems and General Quantity Surveying.

Dr. Stephen Diang'a (Ph.D, Durban University).Member of BORAQS, Housing and Urban Planning, Architecture.