REGIONAL ENGINEERING CONSULT Ltd
KG 11 AV Plot No. 81 Kimironko-Gasabo
Triumph House 3rd Floor Office #302
Phone:+250 788 561 954
PO Box 1166 Kigali Rwanda
Email recons_ltd@yahoo.com

Final Report

RESEARCH ON WOMEN TIME ALLOCATION IN RWANDA: CASE OF DOMESTIC BIOGAS DIGESTER IN GAKENKE DISTRICT

INSTALLATION, TESTING AND MONITORING OF DOMESTIC BIOGAS DIGESTER USING PIG DUNG AS FEED



Submitted to:

Sustainable Agricultural for Food Security and Economic Development (SAFE)

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LIST OF ACRONYMES

GHG:	Green House Gas
PE:	Polyethylene
PPR:	Polypropylene
PVC:	Polyvinyl chloride
RECONS:	Regional Engineering Consult
SAFE:	Sustainable Agricultural for Food Security and Economic Development
UV:	Ultra Violet

I. EXECUTIVE SUMMARY

1.1 Background

Rwanda's energy sector is characterized by over dependence on biomass energy resources, responsible for 85% of its energy needs. 99% of Rwandans use biomass as the main source of energy for cooking making biomass a very critical energy option across the country. Exploitation of biomass for energy is a major cause of destruction of forest resources that affects the environment, leads to water scarcity and floods and reduces agricultural productivity.

The expected results from implementation of a domestic biogas programme focuses on reduction of biomass resource depletion and a significant improvement in the quality of life of the participating families, the benefits relate to:

1) Saving of conventional fuel sources, mainly firewood;
2) Reduction of workload, especially of women and children;
3) Improvement in health and sanitation conditions, benefiting especially women and children;
4) Increase in agricultural production with proper utilization of slurry;
5) Employment generation;
6) Reduction in greenhouse gas (GHG) emissions.

While installation of biogas system based on cow dung has been widespread countrywide the construction of big based biogas systems has not yet been practiced while a number of families is rearing pigs in the rural areas of Rwanda. In this regards, Sustainable Agricultural for Food Security and Economic Development (SAFE) has undertaken an action research project aiming at reducing the workload of small scale farmers especially women through introduction of pig based biogas systems as an alternative cooking energy that will contribute to mitigate the challenges encountered by small holder farmers in increasing income and growing more food for a growing population in uncertain climatic and economic conditions.

1.2 Objectives of the project

The main objective of this project is to install domestic size biogas units using pig dung as feed materials which are expected to deliver the following services to the beneficiaries:

a) Provide adequate handling of pig dung thus contributing to the reduction of water borne diseases that would be caused by unsafe disposal of waste thus safe environment conditions for the surrounding environment,
b) Equip selected piggery raising households with additional alternative energy solution cooking thus reducing the work load of fetching firewood carried out by family member especially women who will secure more time to undertake other income generating activities,
c) Enhance small scale income generated from farming activities by applying the bio-slurry produced as a by-product of the piggery raising household biogas system as bio-fertilizer.

1.3 Implementation of the project

In the view of the above, Sustainable Agricultural for Food Security and Economic Development (SAFE) tasked the Regional Engineering Consult (RECONS) to undertake installation, testing and monitoring domestic biogas digester using pig dung as feed stock in

Gakenke District, this project was initiated as part of its core programme of inclusive economic development.

Following preliminary activities carried out in November 2015, field project activities started on 13/01/2016 and was concluded on 31st march 2016. In order to reach to the set objectives, RECONS Ltd. achieved the following services:

- Installation of three prefabricated domestic size biogas units of CANVAS model three locations including two (2) units in selected piggery raising households and one unit (1) at a selected youth led piggery raising cooperative;
- Provision of technical advice to selected farmer in the area of the project having both cows and pig to use pig dung as additional feed materials to improve performance of the system;
- Provision of basic knowledge on operation and maintenance project beneficiaries
- Conduct of monitoring activity to assess the performance of the installed systems.

1.4 Main findings resulted in implementation of this project included

1) The test project shown that installation of pig based biogas systems is feasible in the context of rural Rwanda for farmers rearing at least 4-6 pigs,
2) Small holders farmers were found to be able to run a household pig based biogas units a minimum loading of 10 kg of pig dung is sufficient to cover for basic cooking needs
3) Use of biogas by pig farming household was found to contribute significantly in reduction of the works load of family members especially women and children up to 3 hours and 37 min were reduced on daily for the workload of a woman in the project area,
4) Farmers who installed pig based biogas systems reported economic benefits linked to the reduction in spending on firewood and use of saved time for other productive activities, before installation of biogas systems 5,000- 12,000 RWF were spent on firewood and is reduced to only 1,000 RWF on a monthly basis.
5) Association of the pig and cow dung contribute to enhancing the production capacity of biogas systems as it provides additional feeding materials and contribute to ,

1.5 Key recommendations

1) Create awareness of the population on the benefits of installation of pig based biogas systems,
2) Encourage household keeping pigs to install biogas systems in order to harness the benefits of the technology, based on successful experience of the farmers from Gakenke Districts,
3) Upscale the programme around Gakenke District and beyond in areas where pig rearing is being practiced based on the results and practices achieved in Gakenke,
4) Conduct advocacy to be made to REG and Districts to incorporate pig based biogas system in the subsidy scheme in which farmers installing biogas systems are entitled to a subsidy support.

II. OVERVIEW OF BIOGAS TECHNOLOGY

2.1 Principles of biogas technology

Biogas technology, i.e. anaerobic digestion is biological method for degrading and stabilizing organic, biodegradable raw materials in special plants in a controlled manner. It is based on microbial activity in oxygen-free (anaerobic) conditions and results in two end-products: energy rich biogas and nutrient-rich digestion residue, i.e. digestate. Anaerobic degradation of biodegradable materials also happens in nature, e.g. in swamps, soils, sediments and in ruminant metabolism.

2.2 Comparison between biogas production from pig dung and cow dung

A study conducted by Aremu, M .O and Agarry S. E. from the Department of Chemical Engineering, Ladoke Akintola University of Technology, Ogbomoso, allowed production of biogas in four separate bio-digesters and fermentation carried out at temperatures between 27–35 °C and pH range of 6.2-6.8 for a period of 30 days on an equal volume of pig and cow dung with a total solid content of 8%.

The biogas produced during this period was collected by water displacement method and subsequently measured and tested by flame test, results showed that cow dung in bio-digesters in two recipient gave a cumulative average biogas volume of 4140 ml (138 ml/day) while pig dung in bio-digesters two remaining gave a cumulative average biogas volume of 4378 ml (145.9 ml/day) within 30th days of fermentation.

Results of this study show clearly that under the same conditions of pH and temperature the production of biogas from pig dung is slightly higher than the one from cow dung, given the fact that cow based biogas systems have been successful implemented in the context of Rwanda this reassures the viability of pig based biogas systems in rural Rwanda.

Comparison of Biogas production from Cow dung and Pig dung under Mesophilic condition.

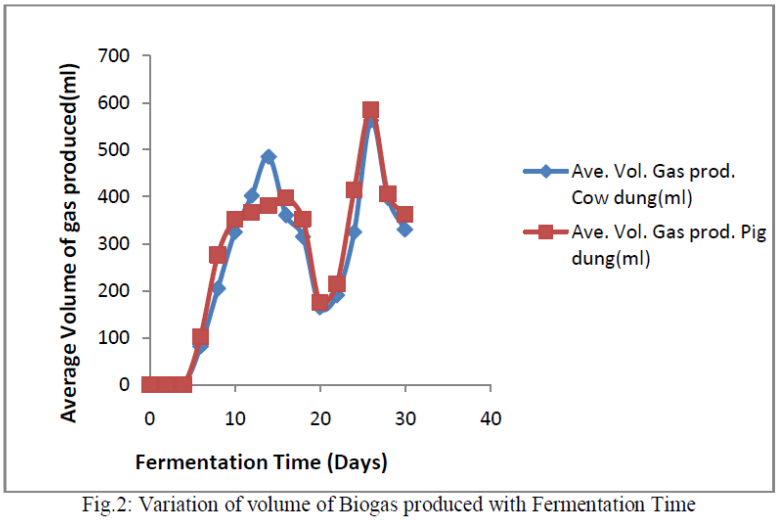

Fig.2: Variation of volume of Biogas produced with Fermentation Time

III. PROJECT AREA AND BENEFICIARIES

3.1 Beneficiary farmers

This testing phase of the project was carried out in Mugunga and Janja Sectors of Gakenke District at three locations, in which farmers had shown interest in taking part in the project by availing the land and allowing data collection in their household for the entire project time. Details of the three beneficiaries who installed the testing pig based biogas systems are:

SN	Name of the Household head	Sector	Number of animals
1	Niyibizi Jean Claude and Manirafasha Christine	Mugunga	4 pigs,2 piglets
2	Cooperative Icyerekezo cy'Urubyiruko	Mugunga	10 pigs and 8 piglets
3	Muhoza Claude	Janja	5 pigs and 8 piglets

3.2 Trained technicians

Along with the process of installation of the pig based biogas systems, three youth who had basic skills on installation of biogas systems received further hands-on trainings on installation, operation and maintenance of pig based biogas systems.

As the trained mason lives in the area where the installation were made, their capacity building not only provided to them opportunity to learn new skills also would significantly contribute to further expansion and sustainability of the programme in the area. Details of the trained youth are illustrated below:

SN	Name of the technician	Details and contacts	Training Site: Owner / Location
1	HAKORIMANA Jean Damascene Tel: 0782106470/ 0732105470	Village: Mwanza Cell: Gatwa Sector: Janja District: Gakenke	NIYIBIZI Jean Claude Village: Gacemeri Cell: Rutabo Sector: Mugunga
2	DUSHIMIRIMANA Joseph Tel: 0784675623	Village: Nyakagezi Cell: Gahinga Sector: Mugunga District: Gakenke	Cooperative ICYEREKEZO CY'URUBYIRUKO Village: Gacemeri Cell: Rutabo Sector: Mugunga
3	SEBAHINZI Papias Tel: 0785364187/0738174412	Village: Mwanza Cell: Gatwa Sector: Janja District: Gakenke	Muhoza Jean Claude Village: Mwanza Cell: Gatwa Sector: Janja

IV. INSTALLATION OF THE BIOGAS SYSTEM

4.1 Preliminary activities

a) Visits to the preselected farmers

Prior to start of installation activities field visits were carried out to the early marked sites to ensure that they fulfill all technical requirements and establish whether the beneficiary households are ready to undertake installation of the proposed system and are willing to participate both during installation and further in the operation stages.

b) Supply of digesters and accessories

Three (3) complete sets of Canvas model biogas plants were supplied by RECONS Ltd. to respective sites in Mugunga and Janja Sector. The material supplied to the three sites included:

- 3 units of PVC Canvas digesters
- 3 units of PE green houses shade
- 3 biogas stoves
- PVC pipes for inlet and outlets and accessories
- PVC pipes for gas plumbing from Digester to Kitchen and accessories
- PPR pipes for UV protection green house structure and accessories

4.2 Installation process for the biogas system

Installation of 3 prefabricated biogas unit of Canvas model of 5 m3 capacity was done successfully in three earmarked locations including two households and a youth cooperative, installation works of the biogas systems was achieved under the sequence below:

- Supply of installation and construction materials standards;
- Lay-out of digester and preparation of the terrain;
- Fixing the digester tank with the PPR pipes;
- Installation of inlet ring, link, elbows and pipes;
- Installation of outlet ring, link, elbows and pipes;
- Constructing inlet tank;
- Installation of pipeline, and fittings appliances;
- Construction of water drain;
- Testing for leakages;
- Mounting of PE Green house for UV radiation protection;
- Loading of the plant with the mixture of pig dung and water;
- Digging the slurry pit(s);

V. FINDINGS

Once installation of the biogas systems was completed operation and monitoring activities started, these focused mainly on providing beneficiary farmers the basic guidelines for proper operation of the installed systems, development and administration of operation monitoring tools, initial and daily loading of organic matters in the digesters and daily use of gas in the kitchen.

Monitoring tools were developed in a way that the can help collect data on the daily operation of the system, main data collected included the following:

- Details of the households
- Date of data collection
- Amount of pig dung collected
- Duration of the stove used and corresponding type and amount of food cooked
- Incident of gas stoppage during cooking if any
- Type of food given to the pigs
- Type of liquid used for dilution of the effluent

In order to achieve this, a spreadsheets were designed to collect data at household level and served for the basis to analyze some performance indicator, based on the data collection forms on Appendix 1, the following were the major results of gas use in the first month of operation of the installed systems.

5.1 **Feeding of the animals**

As part of the project implementation, the type of animal feed was closely observed and monitored in the digester, It was realized that the pigs were fed on mainly maize husks mixed with boiled cassava leaves, at a rate of 90 % of the meals given to the pigs contained boiled cassava leaves, this has been of great importance for the success of the project as the quality of pig dung produced contained less fibers compared to the pigs which have more grass in their deity. The presence of fiber in manure would lead to clogging of the digester.

5.2 **Loading of the biogas system**

The primary activity undertaken for operation of the installed system is the initial loading of organic matter, in the case of plants installed under this project, the initial loading of organic matter was achieved though introduction of pig dung mixed with water or pig urine, in total 320 kg of dung were used for an initial loading, after which farmers were advised to stop loading the system until the first gas production is achieved.

In addition in order to accelerate bacterial activity inoculation was achieved by adding 20 liters of effluent from a operating bio-digesters. Once gas production had started, the farmers proceeded with daily loading of the biogas plant which varied between 10 and 20 kg depending on the amount available in each of three homestead, at present, the highest daily quantity of

dung collected was 20 kg observed at the youth cooperative farm while for the two households an average of 10 kg of pig dung is being collected.

The number of pigs owned by the project beneficiaries vary between 4 and 6 in the household and around 10 at the cooperative. Therefore the average quantity of dung per adult pig can be estimated at 2.5 kg per day. This is should be taken as an estimate made in the context of this test project but values may change depending on the type of animals and their patterns.

5.3 **Daily use of produced biogas**

Results of the daily use of produced gas shown that all the cooking energy needs for a family of 3-4 as observed in the case of the system installed at the home of Niyibizi Jean Claude and Manirafasha Christine, who are now using only biogas to cover all their cooking needs and that for the pigs. On the other hand from the youth Cooperative Icyerekezo cy'Urubyiruko and the home of Claude Muhoza also shown that with a domestic biogas unit system you can cover for the energy needs for cooking meals for the animals in a small scale farm of 5-20 pigs.

The table below illustrate the time and quantity of food prepared using biogas and the time taken for cooking. Details of gas production and uses are provided on appendix I.

Type of food prepared using biogas	**Average Quantity (kg or liters)**	**Average Time used for cooking**
Banana	2.5	01:36
Beans	2.64	03:07
Cabbages and Carrots	1	01:00
Cassava Bread	1	01:15
Cassava leaves	3.46	02:29
Irish potatoes	2.7	01:24
Maize	2	02:05
Maize bread	0.75	00:47
Meat	1	01:10
Omelets	(8 eggs)	00:20
Pease	1	01:40
Porridge	2.5	00:55
Rice	0.5	01:00
Sweet Potatoes	3.2	01:43
Tea	2	00:53
Vegetables	2	00:44

Source: Results of the monitoring exercises

5.4 **Loading pig dung as additional materials**

As part of the project activities, RECONS had the task of advising a farmer who owned a malfunctioning biogas system in the area of the project Mr. Bahire Gaston farmer owning both cows and pig, but used to only feed his biogas plant using the cow dung which was not enough therefore his plant was not working properly.

Therefore despite the availability of a biogas system in his homestead, Bahire was advised on how he could use both cow dung and pig dung mixed together and is to use pig dung as additional input to increase the gas production and reduce on the dependence on firewood.

Before intervention of this project, and start introduction of pig dung as additional feed materials, the family had almost abandoned their system as its production levels were very low, currently they are satisfied with the result of the combination of feed materials.

5.5 **Improvements on construction of pens**

In order to collect maximum amount of pig dung, farmers are advised to improve their pens, the following are the areas to be focused on:

- It is important that the floor of the pen should slope so that excess water can run off allowing the pen to stay dry.
- If water does collect in the pen, it is important to dig a drainage furrow or ditch, leading out of the pen.
- Pigs always dung in the same place. Make sure that this mess is cleaned out daily to be able to collect dung for biogas plant loading and lessen the risk of disease.
- It's advised to construct a collection chamber for pig urine which can be mixed with pig dung thus reducing the amount of water needed for dilution of the dung.

5.6 **Proposed improvements on pig diet recommended for pig-based biogas system**

Diets based on pasture are high in fibre therefore not recommended for pigs that are feeding a biogas system, it is observed that, the more fibre in the diet the lower the digestibility, in general pasture should be 10% or less of their daily intake for best results.

Cereal grains must be processed–cracked, rolled or soaked for efficient digestion by the pig. If not cracked, pigs will eat whole grain but this will pass straight through and show in the manure. Grain that is processed is more easily digested by the pig and there is less feed wasted. The recommended particle size for pigs feeding is 0.7mm or 700 microns.

In the case of pigs reared in the project area in both Janja and Mugunga Sector of Gakenke District the main food given to the pigs is made of maize husks and soaked in boiled cassava leaves. This has a great advantage to the quality of manure produced hence favorable to the operation of the installed biogas systems as the percentage of pasture was very small thus contributing to low level of fibers in the manure.

VI. LESSONS LEARNT

After completion of the installation of the biogas system and collection of preliminary data were completed, in the next four weeks the project focused on collection of daily detailed data using developed tools, this provided information on the trend of operation for further dissemination and allowed room for establishment of mitigation measure for any challenges that may be encountered in the process.

6.1 **Proper loading of the digesters**

Farmers who installed biogas systems shown great commitment throughout the implementation of the project, and have not encountered many difficulties both in installation and initial operation activities. The only challenge mentioned by beneficiaries was linked to the collection of pig dung and fetching of water which was required for the initial loading of the system, however the amount of fresh pig dung required to start operating the digester approximately 320 kg and has to be gathered and loaded into the digester in order to allow first biogas production, given the fact that the average collection of dung in the selected household is estimated at 10 kg. For a household rearing 4-6 pigs without considering piglets it would require about 30 days to collect the amount of dung required.

As a mitigation measure, in this phase of the project, farmers were advised to collect additional dung from their neighbors which they would compensate in manure from the bio-digester once the system is in operation. To overcome this challenge in the future installation, farmers should be advised to start collection of dung for a period of at least 1 month prior to the start of installation to avoid delays in operating the installed bio-digester due to long time taken in dung collection.

6.2 **Use of Biogas**

Based on the results recorded through the monitoring exercise in all three sites, farmers appreciate the way they installed systems are operating, they are using biogas for cooking their meals but also preparing food for the pigs. They appreciate the benefits of using biogas in their home and have found more value in pig raring.

It was noticed that in the area, farmer are feeding their pigs mainly with cereals which mixed with cooked cassava leaves, preparation of the cassava leaves used to consume a lot of firewood but now they are able to cook it using biogas 3–4 hours are required to prepare a meal for up to 20 pigs.

For the three installations, it was observed that in two households, up to 10 kg of pig dung is collected every day while the cooperative gets up to 20 kg of pig dung, the amount of gas generated is sufficient to cover for all basic cooking needs of a medium households.

6.3 **Health and Hygiene benefits from using biogas**

One of the beneficiaries Ms. Christine Manirafasha said that before installation of biogas she used to suffer from eyes irritation and frequent respiratory diseases due to the smoke that

was filled all around the kitchen, after installation of a biogas system, the kitchen is free of smoke and she in no more suffering from respiratory and eyes problems.

She added that cleanness has considerably improved in her kitchen and on all utensils after string using biogas.

6.4 **Reduction of work load in households and youth cooperative**

The use of biogas has produced a number of benefits among the users, in terms of the works load among family members however, before installation of a biogas system the family of Jean Claude and transport it to his home, in addition his wife would spend at least 30 minutes every day cutting them into small pieces to be able to use them in the stove. In addition she had to spend more time cooking and not able to do any other thing as she was to check on the firewood continuously, currently she is able to leave food cooking regulate the amount of gas and go for other works such as farming and when she comes back having completed other duties she finds the food is ready.

6.5 **Reduction on expenditure on firewood**

In the month of march the family of Jean Claude and Christine used the stove for 94hours, the Icyerekezo cy'Urubyiruko youth cooperative used the stove for 90 hours while the household of Claude Muhoza used the stove for 44 hours, these number of hours not only translate in wood saved but also in time that can be used by the family members for other incoming generating activities as cooking on gas doesn't require the person cooking to remain in kitchen all the time as opposed to firewood.

In terms of spending, project beneficiaries revealed that they used to buy fire wood of 3,000 RWF to 12,000 RWF every month, after installation of the biogas system they are depending only on biogas to cover for their cooking energy needs. The amount of gas produced is expected to increase as the number of pigs reared increases, before installation of the biogas system beside many hours spent.

6.6 **Facility in preparation of meals during rainy season**

Manirafasha Christine, affirmed that another benefit she obtained from using biogas was that she is able to prepare meal even when it is raining, previously during rainy season, she had difficulties in preparing meals as wood was to wet therefore unable to burn.

VII. CONCLUSION

The project objectives were achieved through installation of 3 biogas units of canvas type, the installed systems will improve the way of handling of pig dung in the beneficiary households which would be scatted around the compounds but now is loaded in a biogas system on a daily basis, this will produce and additional source of renewable energy for cooking replacing firewood that was the only practice before introduction of biogas. However before use of biogas the beneficiary families used to spend between families, but also will significant improvement of hygiene and environmental conditions around the homestead.

Improved diet of the pigs containing processed grain is more easily digested by the pig and there is less feed wasted mixed with boiled cassava leaves a rate of (3:5) has been found to produce adequate pig dung for operation of a biogas digester, the recommended particle size for pigs feeding is 0.7mm or 700 microns.

After installation of use of biogas, the average cooking time in the model beneficiary household of Jean Claude and Christine has reduced to 3 hours 37 min per day from the previously used 5 hours before installation of the biogas system in addition to this at least 30 minutes were used every day cutting firewood into small pieces, while the cutting of trees was done by the husband, the cooking is the responsibility of the wife, therefore introduction of biogas has helped saving 1 hour 23 min on the daily schedule and due to cooking on gas Christine is able to become engaged in other productive activities as once gas is well regulated she doesn't need to keep around the stove as it used to be the case when using firewood.

In terms of spending beneficiaries revealed that, before installation of the biogas system beside many hours spent for fetching and cutting wood they used to spend 5,000–12,000 RWF per month, which they would safe for other uses,

Based on the installation and monitoring of the operation of the three installed biogas system based on small scale pig rearing with daily loading from 10 -20 kg of pig dung, it was found to be feasible and useful to the small holder farmer in the context of rural set up in Rwanda who can be able to cover for their cooking energy needs by use of biogas.

VIII. RECOMENDATIONS

With reference to the results obtained from this test project we recommend SAFE for the following further undertakings:

1) Create awareness among the farmers rearing at least on the benefits of installing biogas for their homes and development of the pig rearing project,

2) Encourage household rearing at least 5 pigs to install biogas systems in order to harness the benefits of the technology, based on successful experience of the farmers from Mugunga and Janja Sectors of Gakenke Districts who participated in this testing phase,

3) Up-scaling of the programme around Gakenke District in areas where pig rearing is being practices based on the results and practices achieved in Gakenke,

4) Share the experience of the pig based biogas test project with Rwanda Energy Group which is the leading institution mandated for research and development in the area of energy and other Districts who have the mandate of disseminating alternative energy solution to the population in order to incorporate pig based biogas system in the country wide biogas programme in which farmers installing household biogas systems obtain subsidy and technical support.

APPENDICES

A. Recorded performance data for installed systems

BIOGAS SYSTEM PERFORMANCE MONITORING FORM

Names of the beneficiries: Niyibizi Jean Claude and Manirafasha Christine
No. of the Digester: D1

Number of pigs: 4

Number of piglets: 2

DATE	**LOADING OF THE PLANT**	**COOKING**		**COOKING TIME**			**FEEDING OF PIGS (Y/N)**			**PIG DUNG DILUTION (Y/N)**	
dd/mm/yyyy	*Pig dung laded daily (kg)*	*Cooked meal*	*Kg*	*Start time*	*Stop time*	*Duration*	*Cassava leaves*	*Grass*	*Maize husks*	*Water*	*Urine*
01/03/2016	10	Cassava leaves	4	11h00	14h10	03:10	Y	Y	Y	Y	N
01/03/2016		Banana	2.5	16h30	18h05	02:35					
02/03/2016	10	Beans	2	7h00	10h00	03:00	Y	N	Y	Y	N
02/03/2016		Rice	0.5	11h00	12h20	01:20					
02/03/2016		Vegetables		12h30	13h02	00:32					
03/03/2016	10	Cassava leaves	3	8h11	9h50	01:39	Y	Y	Y	Y	N

DATE	**LOADING OF THE PLANT**	**COOKING**		**COOKING TIME**			**FEEDING OF PIGS (Y/N)**			**PIG DUNG DILUTION (Y/N)**	
dd/mm/yyyy	*Pig dung laded daily (kg)*	*Cooked meal*	*Kg*	*Start time*	*Stop time*	*Duration*	*Cassava leaves*	*Grass*	*Maize husks*	*Water*	*Urine*
03/03/2016		Meat	1	16h00	17h10	01:10					
04/03/2016		maize		9h20	11h25	02:05					
05/03/2016	15	Beans	2.5		11h40	04:10	Y	Y	Y	Y	N
05/03/2016		Beans	4	12h00	13h55	01:55					
06/03/2016	10	Peas	1	11h00	12h40	01:40	Y	N	Y	Y	N
06/03/2016		Banana	2	13h00	14h50	01:50					
07/03/2016	10	Cassava leaves	3	9h00	11h40	02:40	Y	N	Y	Y	N
07/03/2016		Irish potatoes	2.5	12h00	13h25	01:25	Y	Y	Y	Y	N
08/03/2016	10	Sweet potatoes	3	8h00	9h25	01:25	Y	N	Y	Y	N
09/03/2016	10	Banana	2.5	11h40	12h55	01:15	Y	Y	Y	Y	N
		Cabbadge and carrots	1	13h00	14h00	01:00					
10/03/2016	10	Beans	2.5	7h00	11h11	04:11	Y	N	Y	Y	N
		Sweet potatoes	3	11h20	13h20	02:00					
		Vegetables		13h30	14h12	00:42					
11/03/2016	10	Rice	0.5	12h00	12h45	00:45	N	N	Y	Y	N
		Vegetables		12h50	13h35	00:45					

DATE	**LOADING OF THE PLANT**	**COOKING**		**COOKING TIME**			**FEEDING OF PIGS (Y/N)**			**PIG DUNG DILUTION (Y/N)**	
dd/mm/yyyy	*Pig dung laded daily (kg)*	*Cooked meal*	*Kg*	*Start time*	*Stop time*	*Duration*	*Cassava leaves*	*Grass*	*Maize husks*	*Water*	*Urine*
		Omelette		13h40	14h00	00:20					
12/03/2016	10	Cassava leaves	3	10h00	12h20	02:20	Y	Y	Y	Y	N
		Cassava bread		13h00	14h15	01:15					
13/03/2016		Sweet potatoes	4	9h00	11h00	02:00	Y	N	Y	Y	N
	10	Vegetables		11h45	13h00	01:15					
14/03/2016	10	Beans and Sweet potatoes		8h00	13h30	05:30	N	Y	Y	Y	N
15/03/2016	10	Cassava leaves	4	7h00	9h00	02:00	Y	Y	Y	Y	N
16/03/2016	10	Sweet potatoes	3	11h00	12h30	01:30					
		Vegetables		12h40	13h00	00:20					
		Beans	2.5	9h10	12h00	02:50	N	Y	Y	Y	N
		vegetables and omelette		12h15	13h18	01:03					
17/03/1900	10	Irish potatoes	2.5	11h00	12h20	01:20	N	Y	Y	Y	N
		Rice	0.5	16h00	17h10	01:10					
		Vegetables		17h20	18h10	00:50					
18/03/1900	10	Poridge		6h15	7h00	00:45	Y	N	Y	Y	N

DATE	**LOADING OF THE PLANT**	**COOKING**		**COOKING TIME**			**FEEDING OF PIGS (Y/N)**			**PIG DUNG DILUTION (Y/N)**	
dd/mm/yyyy	*Pig dung laded daily (kg)*	*Cooked meal*	*Kg*	*Start time*	*Stop time*	*Duration*	*Cassava leaves*	*Grass*	*Maize husks*	*Water*	*Urine*
		Warm beans		7h05	7h55	00:50					
		Irish potatoes		11h30	12h45	01:15					
		Omelette		12h50	13h10	00:20					
		Warm water		19h00	20h00	01:00					
19/03/1900	10	Cassava leaves	3	6h00	7h45	01:45	Y	N	Y	Y	N
20/03/1900		Tea	2	6h07	7h00	00:53					
		Irish potatoes	3	12h00	13h10	01:10					
21/03/2016	10	Cassava leaves	4	7h00	9h00	02:00	Y	N	Y	Y	N
21/03/2016		Sweet potatoes	3	11h00	12h40	01:40					
22/03/2016	10	Beans	2	8h15	11h00	02:45	Y	Y	Y	Y	N
		maize bread	0.5	16h50	17h40	00:50	Y	N	Y	Y	N
23/03/2016							Y	Y	Y	N	N
24/03/2016		Porridge	3	6h00	7h05	01:05	Y	N	Y	Y	N
		Sweet potatoes		9h00	10h45	01:45					
		Cassava leaves	1	11h00	12h30	01:30					
25/03/2016	10	Irish potatoes	3	8h30	10h20	01:50	N	N	Y	Y	N

DATE	**LOADING OF THE PLANT**	**COOKING**		**COOKING TIME**			**FEEDING OF PIGS (Y/N)**			**PIG DUNG DILUTION (Y/N)**	
dd/mm/yyyy	*Pig dung laded daily (kg)*	*Cooked meal*	*Kg*	*Start time*	*Stop time*	*Duration*	*Cassava leaves*	*Grass*	*Maize husks*	*Water*	*Urine*
		Rice	0.5	17h00	17h45	00:45					
26/03/2016	10	Cassava leaves	3	7h00	8h50	01:50	Y	Y	Y	Y	N
		Maize bread	1	11h25	12h10	00:45					
		Vegetables		12h00	13h00	00:50					
27/03/2016	10	Beans	3	9h00	12h00	03:00	Y	Y	Y	Y	N
		Banana	3	12h15	13h15	00:45					
28/03/2016	10	Porridge									

BIOGAS SYSTEM PERFORMANCE MONITORING FORM

Names of the beneficiries: Cooperative Icyerekezo cy'Urubyiruko

No. of the Digester: D2

Number of pigs: 10

Number of piglets: 8

DATE	**LOADING OF THE PLANT**	**COOKING**		**COOKING TIME**			**FEEDING OF PIGS (Y/N)**			**PIG DUNG DILUTION (Y/N)**	
dd/mm/yyyy	*Pig dung laded daily (kg)*	*Cooked meal*	*Kg*	*Start time*	*Stop time*	*Duration*	*Cassava leaves*	*Grass*	*Maize husks*	*Water*	*Urine*
01/03/2016	30	Cassava leaves	4	10h00	13h00	03:00	Y	N	Y	N	Y
02/03/2016	20	Cassava leaves	4	6h00	10h00	04:00	Y	N	Y	N	Y
03/03/2016	20	Cassava leaves	4	11h00	14h00	03:00	Y	N	Y	N	Y
04/03/2016	20	Cassava leaves	4	11h00	14h00	03:00	Y	Y	Y	N	Y
05/03/2016	20					00:00			Y	N	Y
06/03/2016	20	Cassava leaves	4	11h00	14h00	03:00	Y	N	Y	N	Y
07/03/2016	20	Cassava leaves	4	11h00	14h00	03:00	Y	N	N	N	Y
08/03/2016	20	Cassava leaves	4	11h00	14h00	03:00	N	N	Y	N	Y
09/03/2016						03:00			Y	N	Y
10/03/2016	20	Vegetables	4	11h00	15h00	04:00	Y	N	Y	N	Y
11/03/2016	20					03:00			Y	Y	

DATE	**LOADING OF THE PLANT**	**COOKING**		**COOKING TIME**			**FEEDING OF PIGS (Y/N)**			**PIG DUNG DILUTION (Y/N)**	
dd/mm/yyyy	*Pig dung laded daily (kg)*	*Cooked meal*	*Kg*	*Start time*	*Stop time*	*Duration*	*Cassava leaves*	*Grass*	*Maize husks*	*Water*	*Urine*
12/03/2016	20	Cassava leaves	4	11h00	15h00	04:00	Y	N	Y	Y	
13/03/2016						00:00			Y		
14/03/2016						00:00		Y	Y		
15/03/2016	30					00:00			Y	Y	
16/03/2016	20	Cassava leaves	4	11h00	15h00	03:00	Y	N	N	Y	Y
17/03/2016	20	Cassava leaves	4	11h00	15h00	03:00	Y	N	Y	Y	N
18/03/2016	20					00:00			Y	Y	N
19/03/2016	20	Cassava leaves	4	11h00	15h00	03:00	Y	N	Y	Y	N
20/03/2016	30	Cassava leaves	4	12h00	15h00	03:00	Y	N	Y	Y	N
21/03/2016		Cassava leaves	4	11h00	15h00	03:00	Y	N	Y	N	N
22/03/2016	20					00:00			Y	Y	N
23/03/2016		Cassava leaves	4	11h00	15h00	03:00	Y	N	Y	N	N
24/03/2016		Cassava leaves	4	14h00	1700	03:00	Y	N	Y	N	N
25/03/2016	20	Cassava leaves	4	11h00	1500	03:00	Y	N	Y	N	Y
26/03/2016		Cassava leaves	4	11h00	1500	03:00	Y	N	Y	N	Y
27/03/2016	20	Cassava leaves	4	10h00	1300	03:00	Y	N	Y	N	Y
28/03/2016		Cassava leaves	4	12h00	1400	03:00	Y	N	Y	N	N

DATE	**LOADING OF THE PLANT**	**COOKING**		**COOKING TIME**			**FEEDING OF PIGS (Y/N)**			**PIG DUNG DILUTION (Y/N)**	
dd/mm/yyyy	*Pig dung laded daily (kg)*	*Cooked meal*	*Kg*	*Start time*	*Stop time*	*Duration*	*Cassava leaves*	*Grass*	*Maize husks*	*Water*	*Urine*
29/03/2016	20	Cassava leaves	4	11h00	1400	03:00	Y	N	Y	Y	N
30/03/2016		Cassava leaves	4	13h00	1600	03:00	Y	N	Y	N	Y
31/03/2016		Cassava leaves	4	12h45	1600	03:00	Y	N	Y	N	Y
01/04/2016		Cassava leaves	4	12h40	1600	03:20	Y	N	N	N	N
02/04/2016						00:00			Y		
03/04/2016	20	Cassava leaves	4	12h00	1500	03:00	Y	N	Y	Y	N
04/04/2016		Cassava leaves	4	13h00	1600	03:00	Y	N	Y	N	N
05/04/2016		Cassava leaves	4	11h00	1400	03:00	Y	N	Y	N	N

BIOGAS SYSTEM PERFORMANCE MONITORING FORM

Names of the beneficiries: Muhoza Claude

No. of the Digester: D3

Number of pigs: 5

Number of piglets: 8

DATE	**LOADING OF THE PLANT**	**COOKING**		**COOKING TIME**			**FEEDING OF PIGS (Y/N)**			**PIG DUNG DILUTION (Y/N)**	
dd/mm/yyyy	*Pig dung laded daily (kg)*	*Cooked meal*	*Kg*	*Start time*	*Stop time*	*Duration*	*Cassava leaves*	*Grass*	*Maize husks*	*Water*	*Urine*
02/03/2016		Cassava leaves	3	14h00	20h00	06:00	Y	Y	Y	Y	N
03/03/2016		Cassava leaves	3	15h00	20h00	05:00	Y	Y	Y	Y	N
04/03/2016	30	Cassava leaves	3	15h00	20h00	05:00	Y	N	Y	Y	N
06/03/2016	25	Cassava leaves	3	15h00	20h00	05:00	Y	N	Y	Y	N
07/03/2016	20	Cassava leaves	3	15h00	19h35	04:35	Y	N	Y	Y	N
08/03/2016	10	Cassava leaves	3	15h00	16h02	01:02	Y	N	Y	Y	N
09/03/2016	15	Cassava leaves	3	15h00	16h00	01:00	N	N	Y	Y	N
10/03/2016		Cassava leaves	3	14h30	15h40	01:10	Y	N	Y	Y	N
11/03/2016	20	Cassava leaves	3	16h02	16h50	00:48	Y	N	Y	Y	N
12/03/2016		Cassava leaves	3	16h30	17h20	00:50	Y	N	Y	Y	N
13/03/2016		Cassava leaves	3	15h40	16h20	00:30	Y	N	Y	Y	N

DATE	**LOADING OF THE PLANT**	**COOKING**		**COOKING TIME**			**FEEDING OF PIGS (Y/N)**			**PIG DUNG DILUTION (Y/N)**	
dd/mm/yyyy	*Pig dung laded daily (kg)*	*Cooked meal*	*Kg*	*Start time*	*Stop time*	*Duration*	*Cassava leaves*	*Grass*	*Maize husks*	*Water*	*Urine*
14/03/2016	20	Cassava leaves	3	15h10	16h00	00:50	Y	N	Y	Y	N
15/03/2016		Cassava leaves	3	13h10	14h40	01:30	Y	N	Y	Y	N
16/03/2016	15	Cassava leaves	3	17h50	19h00	01:10	Y	N	Y	Y	N
17/03/2016	10	Cassava leaves	3	18h10	20h00	01:50	Y	N	Y	Y	N
18/03/2016		Cassava leaves	3	17h00	18h30	01:30	Y	N	Y	Y	N
19/03/2016		Cassava leaves	3	13h15	14h00	00:45	Y	N	Y	Y	N
20/03/2016	25	Cassava leaves	3	14h30	15h10	01:20	Y	N	Y	Y	N
21/03/2016	20	Cassava leaves	3	14h15	15h00	01:25	Y	N	Y	Y	N
22/03/2016		Cassava leaves	3	15h18	16h02	01:44	Y	N	Y	Y	N
23/03/2016	15	Cassava leaves	3	16h00	16h50	00:50	Y	N	Y	Y	N
24/03/2016		Cassava leaves	3	17h10	17h40	00:30	Y	N	Y	Y	N
25/03/2016	10	Cassava leaves	3	13h20	14h00	00:40	Y	N	Y	Y	N

B. Photo gallery

Fig: Complete Canvas biogas systems installed at the youth piggery cooperative.

Fig 2: An inflated biogas digester after completion of the initial loading

Fig3: Pig in pen with adequate collection for pig dung and urine

Fig 4: Pig dung with high content of fibers not recommended for digester loading

Fig 5: One of the beneficiaries Christine Manirafasha preparing cassava leaves before cooking on biogas

Fig 6: Christine cooking on a biogas stoves installed at her kitchen

C. Glossary

Anaerobic digestion:-series of biological processes in which microorganisms break down biodegradable material in the absence of oxygen. One of the end products is biogas, which is combusted to generate electricity and heat, or can be processed into renewable natural gas and transportation fuels.

Biogas:-Combustible gas produced by the breakdown of organic matter during the anaerobic digestion process, in the case of this project, biogas will be produced from anaerobic digestion of pig dung.

Biomass:-Biological material from living, or recently living organisms, most often referring to plants or plant derived materials.

Canvas digester:-Flexible above- ground system that is simpler and less costly to build and operate of 6m x 3m plastic bag made of PVC tarpaulin.

Digestate: - material remaining after the anaerobic digestion of a biodegradable feedstock

Digester:-a container in which substances are treated with heat, enzymes, or a solvent in order to promote decomposition or extract essential components, in the case of this project the digester is used to decompose organic matter under anaerobic digestion and produce biogas and manure.

Greenhouse:-structure with walls and roof made chiefly of transparent material, such as glass or polyethylene sheets, in which regulated climatic conditions can be maintained.

Inlet ring:-coupling to which a pipe and pipe fitting are attached so that to allow the mixture of pig dung and water/ urine enter the digester.

Manure:- organic matter, mostly derived from animal feces which can be used as organic fertilizer in agriculture. Manures contribute to the fertility of the soil by adding organic matter and nutrients, such as nitrogen, that are trapped by bacteria in the soil

Outlet ring:-coupling to which a pipe and pipe fitting are attached so that to allow manure exit the digester.

pH:-a measure of how acidic/basic water is. The range goes from 0 - 14, with 7 being neutral. pH of less than 7 indicate acidity, whereas a pH of greater than 7 indicates a base. pH is really a measure of the relative amount of free hydrogen and hydroxyl ions in the water.

Renewable Energy: -Energy that comes from resources which are continually replenished such as sunlight, wind and biomass

D. References

Aremu, M .and Agarry S. E. (2012), Comparison of Biogas production from Cow dung and Pig dung under Mesophilic condition.

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International Fund for Agricultural Development IFAD (2012) Flexi Biogas systems: inexpensive, renewable energy for developing countries