Performance assessment of Institutional Biogas systems in Rwanda
Report

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I. EXECUTIVE SUMMARY

The biogas technology was launched in Rwanda at the end of 1990s in search of an alternative energy for cooking and lighting and as an environment conservation strategy. Especially KIST/CITT has been at the forefront of the development and installation of biogas technology in Rwanda. At the beginning, the biogas systems attracted large institutional consumers like prisons not only for cooking purposes but also for improvement of hygiene and sanitation, the reduction of firewood consumption and hence deforestation pressures. In particular the Government's biogas program for prisons has drawn international attention and recognition. In addition , a number of other institutions such as schools, hospitals, missions and other communities also constructed biogas systems since 2000. However, little is known of the overall performance of these biogas systems.

In September 2008, IBC-Rwanda was contracted by GTZ to carry out a performance assessment of institutional biogas systems in the country. The main objective was to collect baseline data and to set up a data base providing an overview of the institutional biogas systems in Rwanda and to assess the operational and maintenance practices which may provide lessons for possible future investment programs in the sector. A survey team visited and collected data from all institutional biogas systems that could be identified in the country.

The survey found that 28 biogas systems have been installed in institutions since 2001 while another 8 are under construction. Of the total of 36 units, 13 were installed in secondary schools, 11 in prisons, 7 in community households, 2 in military camps, 2 in training centers and one in a hospital. KIST/CITT has played a leading role not only in the development of the technology but also as a contractor as it has build 24 out of the 36 systems in the country (five of these are still to be completed). Over the last years, some private companies have entered the market, first under supervision of CITT but now also implementing independent contracts.

In 14 (50%) of the 28 operating biogas digesters only human waste is being used (typically for the prisons and some schools) while others use a combination of human and animal waste, mainly cow dung. It has been found that 11 of 28 completed digesters operate very well, 5 operate with major defects while 6 were abandoned or even never operated due to wrong design. The survey found that schools were the worst performers with only 2 out of 10 installed systems in operation.

The major causes for malfunctioning of the systems were found to be lack of commitment of the management and/or a lack of a qualified biogas operator and this was found more the case in the bigger institutions than in small systems operated by missions and farms.

There is also a serious shortage of technical support to assist institutions in carrying out simple modifications and reparations of leakages and damaged stoves. More capacity is required in this area to ensure that the existing systems function properly which will give confidence to other institutions to follow the example.

The costs of the systems vary mainly according to the size of the digesters but are also dependent on the additional constructions that such as toilet blocks. Digesters of 32 mtr^3 in community households were built for Rwf 5 million while the Mapanga Prison system of 1000 mtr^3 was over Rwf 150 Million. Unit prices varied between Rwf 80,000 to 150,000 per mtr^3 but this much influenced by the extra requirements.

The savings in consumption of firewood was biggest in the community households where in some case all cooking was done on biogas. Performance in schools has been difficult to measure as the systems did not function properly and the survey estimates an overall reduction of 5% only for those institutions. Prisons performed much better and it is estimated that over the 8 prisons that use biogas, the average savings in firewood use have been 19%. However, with better management and repair of simple technical faults, this can easily be raised to 30% and more. The returns on investment are high as showed in the example of Remera and Kabutare prisons which invested Rwf 41 and 77 million respectively in the biogas system and makes an annual saving of about Rwf 12 and 14 million in firewood consumption.

In addition to the high financial returns, there are additional advantages of biogas which have not been calculated in the survey but include the positive effects on the hygienic and sanitation conditions around the institutions, the reduction of health risks of staff working in the kitchen which are normally exposed to smoke inhalation and the reduced firewood requirement which causes deforestation and environmental degradation.

Conclusions

The survey shows that the performance of institutional biogas systems is highly related on the one hand to the involvement and the follow-up of institution managers and on the other hand on the skills of internal operators and on technical and maintenance support availed. For all institutions visited there is a strong need of more technical support.

For the success of institutional biogas systems more trainings on usage and maintenance issues have to be conducted to local technicians and a system of quality control (of design and construction) has to be established in order to guarantee the efficiency of digesters and appliances.

There is a potential market for institutional biogas systems in the remaining prisons (five units were identified) but also in the over 600 secondary schools, especially those with boarding facilities, and larger hospitals. Biogas will assist both in the provision of a cheap and convenient source of energy as well as make a significant contribution towards the improvement of sanitation and environment.

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LIST OF ABBREVIATION AND ACRONYMS

CITT	: Centre for Innovation and Technology Transfer
GTZ	: Deutsche Gesellschaft f für Technische Zusammenarbeit
IBC	: International Business Centre
IRST	: Institut de Recherche scientifique et Technologie
KIST	: Kigali Institute of Science and Technology
LPG	: Liquefied Petroleum Gas
LWF	: Lutheran World Federation
MININFRA	: Ministry of Infrastructure
NGO	: Non-Governmental Organization
RWF	: Rwandan Francs

II. INTRODUCTION

Biomass is by far the most important source of primary energy in Rwanda counting for 85% of the national needs while the rest is provided by hydro electricity and imported fuel oils. Over 99% of the households use biomass for cooking, even those which have access to electricity. There is a big pressure on the available woodlots, plantations and natural forests and there are many studies indicating that large scale deforestation has a serious effect on the environment. On the way to reduce the dependency on those wood resources is the use of biogas for cooking purposes. The government has promoted biogas as an alternative energy for cooking and lighting since the end of 1990s.

During this past decade a number of biogas systems have been constructed in Rwanda especially for prisons considered among the largest consumers of fuel wood in Rwanda. The Government biogas program for prisons has attracted international attention and recognition of various stakeholders in development and environment protection. Attracted by the success of prison biogas systems, some secondary schools, religious convents (monasteries) and large dairy farms, also have installed digesters using cow dung and human waste to produce gas for cooking purpose. The Centre for Innovation and Technology Transfer (CITT) of Kigali Institute of Science and Technology (KIST) has played an important role as an innovator of the biogas systems in Rwanda but also as a contracting agency for constructing most of the larger units in the country. During this period, private companies and individuals have been trained by CITT and have adapted the technology, often starting as sub-contractor to CITT, but are now working for different clients countrywide.

The Rwandan Government agencies and development partners are interested in getting the full list of institutional biogas system installed nationwide as well as their performances and impacts on the cost of fuel wood for cooking and environment protection. It is in that framework that GTZ in partnership with MININFRA has contracted a consultancy company, IBC-Rwanda, to conduct the survey on the performance of public biogas installations.

This survey provides baseline information of the digesters constructed during the past decade. The information in the first place provides lessons from the experiences of the past decade and contributes towards the development of a more detailed plan for dissemination of biogas systems for schools, hospitals and other public institutions.

III. ASSESSMENT

1. Objectives of the consultancy

The objective of the assignment was to collect baseline data providing an overview of the institutional biogas systems in Rwanda and make a first assessment of the operation and maintenance practices which will provide lessons for a possible future program. See **Appendix 1: Terms of Reference**

2. Approach and methodology

a) Assignment Components

The assignment included six main activities:

- Design of a survey questionnaire which covers the requirements for information as requested by the client;
- Verify and update the list of institutional biogas systems (above 30 mtr3);
- Visits to all the listed institutional biogas systems (above 30 mtr3) and collect the required data as indicated in the survey questionnaire;
- Set up of a SPSS data base with overview of all data collected;
- Compile and analyze data;
- Provide a brief summary report of the work undertaken;

b) Design of survey questionnaire

The evaluation team jointly constructed and agreed the questionnaire (Appendix 2) that would elicit quantitative and qualitative data about the biogas systems.

Information collected could be summarized in 5 topics:

- Basic data of the institution : identification, GPS location, contacts, source of feeding materials, ;
- Bio-digester- Construction, technical, costs, feeding and maintenance data;
- Energy supply and use: biogas, and other sources of energy; situation before and after
- Use of slurry;
- Impact on eating/ cooking habits, health and environment

c) Data collection methods:

- Formal and semi-formal interviews have been used to collect data during the field visits of the institutions. In addition some information were collected by telephone;
- The research team had visited all biogas installations and some photographs were taken to illustrate the state of installations;
- GPS data were also recorded to locate each institution;
- Desk study of relevant documents especially digesters construction contracts.

d) Research team and Fieldwork

The research team was composed by the team leader, a biogas specialist; a data collector and a driver. During 15 days, from 10 to 25 September 2008, the research team had visited 36 public institutional biogas installations and third of them were not unknown/ located before the beginning of the assessment. Visited institutions were located in all provinces within 20 districts of 30 (S**ee Appendix 10: Map of Rwanda and visited institutions)**.

e) Data Compilation, Interpretation and Analysis

Primary and secondary data collected from different sources were compiled in SPSS matrix. Photographs were also brought together in a softcopy file while some of the most were inserted in the report to illustrate particular issues.

The Consultant has produced a database in SPSS software including all expected information. From the database and secondary data which are not included in the database. The consultant had brought out basic data of visited institutions, information on digester construction, use of gas, fuel wood and slurry. Furthermore, he drew out technical and managerial problems encountered by institutional biogas systems. Finally he showed up challenges and lessons learnt from the survey.

f) Final report

This report is a brief documenting report which highlights the methodology of the work, main findings of the survey as well as challenges, lessons learnt and potential replication for Biogas installations in Rwanda. It also includes also the conclusion, recommendations and appendixes.

g) Limitation

In some institutions, there were no details about of the cost of each biogas components. Only the information about the total cost was available. In other cases, they have no idea about the size and the contractor of the biogas system. These did not allow us to analyse in deep the disparity of construction cost of institutional biogas systems, builder contractor, etc.

IV. FINDINGS OF THE SURVEY

1. Institutional Biogas systems installations

a) Type of institutions visited and Completion date of construction

At the beginning of this decade, only prisons were interested in biogas system installation due to their high consumption of the fuel wood, sanitations and environmental problems including bad smell. Thereafter, secondary schools, hospitals and Missions (religious people) have been interested in biogas system installation.

The research team found that 28 biogas systems had been installed since 2001 up September 2008 and 8 are still under construction. Table 1 below provides an overview while more details can be found in **Appendix 3: Length of operation of digesters.**

Table 1: Length of operations

Completion date of construction	Number of institutions
2001	4
2002	1
2003	1
2004	3
2005	6
2006	8
2007	1
2008 (Up to Sept.)	4
Under construction	8
Total	**36**

b) Locations of the digesters

At the time of the study, among 36 institutional biogas system visited 13 were installed in secondary schools, 11 in prisons, 6 in religious Missions, 2 in training demonstration farm centers, 1 in hospital and 2 in military camps.

The table below provides an overview of the installations visited during the assignment. It shows that the Southern Province and Kigali City have the largest numbers of systems.

Table 2: Overview of Digesters

Province	Schools	Prisons	Hospitals	Others	Total
Kigali City	1	2		7	9
Eastern	4	3			7
Northern	3	1			4
Southern	5	5		1	12
Western		1	1	2	4
Totals	**13**	**11**	**1**	**11**	**36**

Note: For more details, see **Appendix 4: List of biogas institution per district and province**

c) Number of people served by the digester

The number of people served by the biogas systems varies according to institution;

- For prisons, the size of their population has extensively varied since 2003 with the release of a significant number of prisoners suspected of genocide crimes. In September 2008 the population of 11 visited prisons varied between 1,812 and 7,582 and the average number of the population is 4,705.
- For secondary school, it varies from 236 to 804 students and the average of secondary school size is 514 students.
- For religious missions and large institutional type households; the number varies from 5 to 17 and the average of their size is 11;

d) Livestock connected to the biogas systems

23 operating systems of the 28 institutions visited do have cows and the dung is used for the biogas digester feeding. The average number of cows for each institution is 11 (varying from 1 to 23 cows). Pigs are owned only by 5 of 28 institutions with operating biogas systems. Even if the average number per institution is 37, pigs' wastes are not used as feeding materials for biogas systems.

1. Construction details of the digesters

a) Size in mtr^3 volume

The sizes of digester were mostly fixed according to the quantity of feeding materials and size of each institution. However, 3 cases were found during the field visits where the construction did not take into consideration the quantity of the feeding materials available, the size of the institution and the digester construction technology. The size of the digesters varies as follows:

1. Digester of 16m^3 to 40 m^3 was installed in community households and Religious Missions
2. Secondary schools opted for digesters with the capacity of 60 to 76 m^3. In 3 secondary schools, a digester of 100m^3 for each was constructed. Those digesters have never operated due to wrong design (oversized).
3. Large digesters of 200 to 1250 m^3 were constructed in prisons.

Note: For larger biogas systems, it is recommended to construct in number of digesters in series. The construction in series allows the increase of the retention time as well as facilitation of micro bacterial activities to yield gas. Also the construction of smaller domes is simpler as it reduces the risks for collapsing and leakages. For instance in the prisons, the systems are made out of digesters of 100 mtr^3 each installed in series. Similar constructions have been used in schools and other larger institutions.

b) Building contractor

KIST/CITT is the pioneer of biogas technology in Rwanda and has been by far the most important building contractor of the institutional biogas systems. It has contracted 68% i.e. 24 of the 36 systems, small and large, visited during the survey. The table below shows the number and size of institutional

Table 3: Number and Size of Biogas system installed in each type of institution

	ACSESS		CRET sarl		GBTC		IRST		KIST/CITT		REC		Individual	
	Number of institutions	Size in m^3	Number of institutions	Size in m^3	Number of institutions	Size in m^3	Number of institutions	Size in m^3	Number of institutions	Size in m^3	Number of institutions	Size in m^3	Number of institutions	Size in m^3
Secondary school	-	-	2	60	-	-	1	100	7	60-76	3	100	1	-
Prison	1	300	-	-	-	-	-	-	10	200-1250	-	-	-	-
Hospital	-	-	-	-	-	-	-	-	1	30	-	-	-	
Community HH	-	-	3	32- 60	1	30	-	-	-	-	-	-	-	-
Individual HH	-	-	-	-	-	-	-	-	2	16	-	-	-	-
Others	-	-	-	-	-	-	-	-	4	16-30	-	-	-	-
Total	**1**	**300**	**5**	**32-60**	**1**	**30**	**1**	**100**	**24**	**16-1,250**	**3**	**100**	**1**	**-**

KIST/CITT had almost the monopoly in digesters construction up to the year 2005. Since that year new companies and individuals emerged in digester building business not as subcontractors to KIST/CITT but as independent contractor themselves of medium biogas systems as shown in the table above. Some of these companies were established by ex-CITT staff. This is for instance the case of CRET sarl which build 5 digesters since 2006.

The table below shows the building contractors and completion date of biogas system.

Table 4: Building contractors for institutional biogas systems

Building contractor	Construction Completion date									Total
	2001	2002	2003	2004	2005	2006	2007	2008	Under construction	
ACSESS	0	0	0	0	0	0	0	0	1	**1**
GBTC	0	0	0	0	0	0	0	1	0	**1**
IRST	0	0	0	0	1	0	0	0	0	**1**
REC	0	0	0	0	0	2	0	0	0	**2**
Individual	0	0	0	0	0	1	0	0	0	**2**
CRET sarl	0	0	0	0	0	1	0	2	2	**5**
KIST/CITT	4	1	1	3	5	4	1	0	5	**24**
Total	**4**	**1**	**1**	**3**	**6**	**8**	**1**	**4**	**8**	**36**

IRST and REC (ETO Gitarama) have constructed 3 digesters in total but none ever operated because their design was wrong (See the section of technical and managerial problems). ACSESS Company was contracted to build a digester of 300 m^3 in 2008 in the new prison of Butare and the construction works are not yet finished. GBTC was contracted to build a digester of 30 mtr^3 in a community[1] household.

c) Costs per digester and mtr^3

Note: The cost of construction of a biogas system depends on the size of the digest, the raw materials needed for the construction of a biogas system including digester, stoves, pipes and other accessories (see **appendix 5: List of for the needed materials to install a biogas system**). The cost of those materials varies in term of time, inflation, quantity purchased and location. In most cases, supplementary construction like toilets, water tanks are built to allow digesters to operate well.
To compare costs per digester, we assume that:

- The inflation rate remains constant.
- The unit cost means the total cost of biogas installation including digesters, accessories and other complementary construction divided by the size of digester; it is expressed in Rwfr per mtr^3.

[1] Community households represent mainly religious missions

The table below shows the costs of institutional biogas systems. These costs are based on the data made available to the research team and should only be taken as best estimates. The figures are rounded in the table below are rounded.

Table 5: Costs of biogas systems

Building Contractor	Cost in Rwf/ Size in m^3	Secondary school	Prison	Hospital	Community HH	Individual HH	Others
ACSESS	Total Cost		48 million				
	Size		300				
	Costs/mtr^3		***160,000***				
CRET sarl	Total Cost	16 million			5- 8 million		
	Size	60			32-60		
	Costs/mtr^3	***267,000***			***133,00 – 156,000***		
GBTC	Total Cost				3 million		
	Size				30		
	Costs/mtr^3				***100,000***		
IRST	Total Cost	5 millions					
	Size	100					
	Costs/mtr^3	***50,000***					
KIST/CITT	Total Cost	8 – 23 million	41 – 154 million	5 million		1 – 1,5 million	3 – 3.4 million
	Size	60-76	200-1,000	30		16	16-30
	Costs/mtr^3	***140,000-303, 000***	***204,000-155, 000***	***167,000***		***71,000-94,000***	***188,000-113,000***
REC	**Total Cost**	8- 11 million					
	Size	100					
	Costs/mtr^3	***80,000-110,000***					
Individual	**Total Cost**	-					
	Size	-					
	Costs/mtr^3						

- **The costs of Prison biogas systems**

Prisons paid between Rwfr 40 and 154 millions to install biogas systems of 200 m3 and 1250 m3. Unit costs vary from Rwfr 58,000 to Rwfr 230,000 per m^3. The average unit cost for prison biogas system was Rwfr 131,000 per m^3. These costs include complementary accessories like pipe, stoves, tanks, toilets, etc. The difference in costs is mainly due to the number of complementary construction for each institution. The table below shows the costs of prison biogas system;

	Prison	Completion date of construction	Total cost in Rwfr	Size in mtr^3	Unity cost
1	Mpanga	2006	154,592,280	1000	154,592
2	Nsinda	Under construction	141,099,971	1200	117,583
3	Cyangugu	2001	138,106,250	600	230,177
4	Gitarama	2005	111,225,030	1250	88,980
5	Rilima	2005	95,045,120	800	118,806
6	Miyove	Under construction	81,278,943	400	203,197
7	Kabutare I	2005	76,624,256	600	127,707
8	Gikongoro	2007	60,000,000	376	159,574
9	Kabutare II	Under construction	48,000,000	300	160,000
10	Remera	2006	40,810,280	700	58,300
11	Nyagatare	2004	Unknown	200	

- **The costs of school biogas systems**

As it is shown above, biogas system of 60 to 100 **mtr^3** were installed in secondary schools. The construction costs vary between Rwf 5,000,000 and 23,000,000 and the cheapest unit cost was Rwfr 50,000 per m^{3}and the expensive one was Rwfr 302,632 per **mtr^3**. The difference in the unit cost is largely due to the complementary constructions like tanks, toilets, retaining walls, etc built in some schools.
For example, the construction cost of Rwaza secondary school was increased by the construction of a retaining wall due to the topography of Rwaza; the unit cost goes up to Rwfr 302,632 per **mtr^3** while the average construction unit cost for secondary school biogas system was Rwfr 158,619.

- **The costs of Households biogas systems (individual and community)**

The costs of the construction of small biogas systems of 16-32 m^3 for individual household were Rwfr 1,129,260 to 1,500,000 while community households paid between 3,000,000 to Rwfr 8,000,000 for biogas systems of 30 to 60 m^3. The average unit cost for individual household was 82,164 while community households paid on average Rwfr 145,287 per **mtr^3**.

The unit cost for individual household biogas system is cheaper than prison and school biogas systems unit cost because there are no supplementary constructions like toilet and tanks were built in individual household. Even if there were no complementary constructions built in community household, their unit costs were higher than which paid by prisons. Recall that all community household biogas systems were built by private companies newly created.

- **The costs of biogas systems for other institution**

Institutions like farm training centers paid Rwfr ***112,597*** to ***187,500 for biogas systems of*** 16 to 30 **mtr^3** and the average unit cost was Rwfr 138,650 per **mtr^3**.

a) Feeding materials and liquid

Cow and human waste are mainly used and can be separately used or in combination. Among 28 visited institutions which installed a biogas system, 3 have never operated and did use neither human nor cow dung. 14 of 28 which represent 50% of all completed digesters use human waste as feeding materials, 5 use cow dung and 6 combine human and cow waste to feed their digesters.

The table below shows feeding material for each institution.

Table 6: Feeding materials used in each type of institution visited

	Feeding material				Total
Institution Type	**Never operate**	**Human waste**	**Cow**	**Human and Cow waste**	
Secondary school	1	6	0	3	10
Prison	0	6	0	1	7
Hospital	0	1	0	0	1
Community household	0	0	3	0	3
Individual household	0	0	1	1	2
Farm	0	0	1	0	1
Military Camp	2	0	0	0	2
Training Center	0	1	0	1	2
Total	**3**	**14**	**5**	**6**	**28**

Human wastes are mainly used for big institutions like prisons and schools. Households (individual and community) use cow dung as feeding material and some of have connected the digester to toilets. (e.g.: Shyira hospital).

Water and urine are used as mixing liquid for all institutions expect 3; these are Assumption Nuns of Kabuye, Gako Organic Farm training Center and Frère Saint Gabriel of Kigali. Water is available at the places for all institutions except College Saint Jean de Nyarusange.

3. Biogas plants management and problems encountered

a) Management

Apart from in the prisons, people who are in charge of feeding the digester combine that activity with other activities and especially cow feeding. Their pay varies between Rwfr 10,000 and Rwfr 30,000 per month and the average monthly pay is Rwfr 18,875. Those “operators” have better understanding how the biogas system works than any other members of the institution. In prisons, the head of digester feeding team is automatically the one who is in charge of all issues related to biogas including reparation and maintenance. There are no internal technicians trained on maintenance and reparation in any of the institutions.

The maintenance and reparation are assured by people who are trained on the spot during the construction period except in the Mpanga Prison. The prisoner, who is head of the biogas team at Mpanga prison, said that he was trained by the German Cooperation in 1980s in Burundi. That prisoner is also the person who is called to offer technical support in almost all prisons when serious issues of maintenance arise.

For institutions other than prisons, the maintenance and reparation are assured by the private companies which have constructed their digesters. For missions or school managed by the religious people the follow-up of activities related to biogas is assured by one of mission members in charge of management.

Lesson learnt:

- Biogas systems perform excellently in the institutions where their senior managers, household member are concerned with biogas system and assure day to day follow up. See **Appendix 7: Biogas system management versus performance.** It has been found that 11 biogas systems which perform very well are managed by the head/manager of the institution or a household member. Other are operating with serious technical problem or not operating at all because either there is nobody who is in charge of biogas system management or the "operator" has left the institution.

- In the most cases, biogas systems installed in community households (Missions, farms) perform much better compared to other institutions while ones installed in schools are the worst managed (4 stopped operating, 4 were constructed but never operated and one is operating with major problems).
  This could be explained by factor that in some schools those who initiated the biogas system (usually the headmasters or school managers) were no longer there and the newly appointed responsible persons are not very interested in biogas systems. In prisons, the success of the biogas system is highly related to the skills of the prisoner in charge of biogas system and willingness of the responsible officer to buy materials for maintenance and call upon technical support when a serious technical risen. See **Appendix 7: Biogas systems management versus performance**

At the time of the study, only 16 (57%) digests of 28 built were operating and out of them 11 functioned very well, 5 operate with major defects, 6 units stopped functioning while 6 have never operated (*Abandoned, Wrong design)*.

The table below shows the operating condition of the digesters. The operational performance was assessed based on performance criteria. See **Appendix 8: Biogas systems performance indicators**

Table 7: Operation condition of the digesters

Institution Type	Operating very well	Operating but with major problems	Operating stopped	Never operated	Not yet started	Total
Secondary school	1	1	4	4	3	13
Prison	4	4	0	0	3	11
Hospital	0	0	1	0	0	1
Others(including HH)	6	0	1	2	2	11
Total	**11**	**5**	**6**	**6**	**8**	**36**

Working	Not working

b) Main types of technical problems accounted by the institutional biogas systems

The survey team found a number of technical problems that account for the no or poor performance of the institutional biogas systems. Below section provide details of the main problems encountered by the research team.

- *Lack of technicians and technical support*

The lack of skilled technicians in biogas systems maintenance is a serious problem and the most of institutions have to wait for CITT technicians to come for repair and in most cases they delay due to bureaucracy and lack of enough technicians.

- *Blockage of biogas system*

Flow of the wastes on the open space at Remera prison

Biogas system blockage is one of the most common and worst problems and mainly caused by the introduction of solid materials in the system. When it occurs, it blocks the entire system and causes the back flow of the slurry in the out let or other parts of the system. The blockage can also cause the forced removal of the gas outlet cover, leading to the flow of the wastes on the open space, consequently creating bad smells around the digesters.

This kind of technical problem was observed at Remera and Cyangugu Prisons. At Cyangugu prison the problem had persisted for about 2 weeks resulting from closing one of the digesters for maintenance. At Rwaza Secondary School, the blockage of the system is quiet often due to the female students who throw hygienic tissues into the toilets. The school management tries to sensitize the students on the behaviour change but the problem persists due to new students who join school every year.

- *Leakage at the gas outlet pipe*

The leakage at the outlet pipe at the Ecole Secondaire Ste Bernadette de Kamonyi

The leakage at the outlet pipe is due to poor sealing using clay or takes place when the clay used for sealing is worn out. The leakage was also noticed in other components of the biogas system such as the valves due to poor connection (refer to picture Kamonyi ST Bernadette3), the hose pipes which are defected or the clips which are not adequately tightened. The leakage results in losing the gas in the digester; hence the whole biogas system is affected.

Many of the institutions face minor gas leakage such as: Rilima prison, APENA Secondary school, Kabutare Prison, Gitarama Prison. However, at the Ecole Secondaire Ste Bernadette de Kamonyi, the whole system has been stopped due the leakage at the gas out let pipe and also the toilets have been closed.

- *Low gas production*

A gas stove transformed into a fuel wood stove because the gas is not sufficient to operate the stove at APENA School

At the design phase of a digester, the number of cows or people is very important as it forms the basis of the dimension and capacity of the digester. Hence, the gas to be produced is calculated based on the loading rate. The low gas production is then caused by incorrect sizing of the digester, introduction of non biodegradable matters, leakage, and reduction or increasing of the loading rate and volume.

The low production of gas at APENA School is due to the leakage at the outlet cover.

At Petit Séminaire Kabgayi and Institut Don Bosco de Kabarondo, the low gas production is very common and may be due to a wrong design of the digesters or a lot of water used during flushing respectively.
Particularly in most of the prisons, the change in number of prisoners creates a low gas production. For instance for Cyangugu prison, the low gas production is due to the decrease of the number of prisoners compared to the initial design number of prisoners. This can be solved by reducing the number of operating digesters of 100 m^3. This means that some digesters must be closed.

- *Defected components: burners, chimneys and connectors*

Defected chimney at the Ecole Secondaire Ste Bernadette de Kamonyi

Defected stove at Cyangugu Prison

The quality and efficiency of the biogas cook stoves play a vital role for as far as the quantity of gas is concerned. Hence the defected chimneys, burners and connectors cause the use of big amount of biogas.

In most of prison, where the cooking time is high, stove, chimneys and connectors are completely defected and need to be replaced especially at Gitarama and Cyangugu prisons.

- *Flow of slurry in the gas pipe*

The biogas system is designed in such a way that the slurry and the gas have separate outlets, inlets and pipes. It is uncommon to find them mixed up in the system. Such a case has been observed at Carmelites Nuns Centre in Cyangugu, whereby the slurry entered the gas pipe. The suspected reason is that the gas outlet cover was installed at a lower level than the prescriber one. This can be fixed by increasing the gas out let level.

- *Scum formation (Cyangugu and Gikongoro Prison)*

Scum formation in the digesters at Cyangugu Prison

The scum formation in the digesters is merely due to the introduction of non degradable light materials which accumulate at the top of the surface of slurry in the digester. In addition, for cow dung fed digesters, the scum formation results from poor mixing of the dung. As a result of scum formation, there is a significant decrease in the gas formation.

One of the methods of scum removal formation is by mechanically stirring the slurry inside the digester and where the scum is very thick by removing it completely from the digester after cutting it into small pieces.

Scum formation was observed at Cyangugu prison in one 100m³digester and at Gikongoro prison in 2x 30m³ digesters.

- *Non operating biogas systems*

Under this category of biogas systems having technical problems, one may classify them as follows:

- *Wrong design*

It has been observed that due to poor or wrong design, many biogas digesters are not working at all since they were installed. This is mainly due to over sizing the digesters with respect to the number of people/cows designed for, or with no other consideration, the contractor decides to just construct a digester without planning or calculation.
This was observed at ETO Gitarama (100m³ x 1 constructed in 2005 by IRST), Ecole Technique Kabgayi (100m³ x 1 constructed by REC-ETO Gitarama in 2007) and Ecole St Jean de Nyarusange (100m³x 1 constructed by REC-ETO Gitarama in 2006). REC ETO Gitarama as many other companies is a private company dealing with construction of biogas plants but the whole team is composed of those technicians who have no expertise in institutional biogas plants planning, designing and construction.

- *Abandoned biogas systems*

Some biogas plants which were successfully installed have been completely abandoned and hence not working at all.

Abandoned digester at Air Force Camp/former KIST Hostels

The institutions where the systems have been abandoned include:

- Lycée de Kigali, constructed in 1999, it was abandoned and not in use since then. This was due to the lack of follow-up.
- Kicukiro Hostels (KIST) by the time, the digesters were constructed, the premises was used as hostels for KIST students but the biogas system is not operating. Currently, the buildings are used as Airforce military camp.
- Kibuye hospital constructed a biogas system in 2005 but it worked only for about a year and stopped working since the end of 2007 (refer to pictures Kibuye Hospital 1 and 4). Since then, the management of the hospital did not put efforts on looking for technicians who can repair it. The monitoring of one year by KIST/CITT ended in 2006.

- *Inappropriate toilet systems*

In some institutions, the biogas systems do not operate due to inappropriate toilets systems. The flushing toilets for instance release a lot of water; hence the gas formation is not enhanced. Such problem can be solved by construction of appropriate toilets. This is the case observed at ETO Gitarama but this problem is combined of that of digester wrong design in that institution; the whole system has to be rebuild

Another problem is the waste water disposal system which mixes all the waste water from kitchen, bathrooms and toilets. This also creates a problem of biogas formation due to that mixture of waste water, soaps and toilets papers. Such a case was observed at Don Bosco institute of Kabarondo.

This can be solved by constructing other toilets or by changing the flushing system of the existing one and separate the water from showers which contains a lot of soap.

- *Iron sheets defection*

Iron sheets of the kitchen with gas stoves corrode very fast compared to the kitchen with firewood stove.

Iron sheet defection of kitchen with gas stove at Mpanga Prison

4. The impact of the use of biogas on public institutions

a) Operating hours and cooking times per day

The institutional gas is mostly used for cooking and the operating hours vary from institution to another. In prisons, 2 to 10 gas stoves operate from 3 to 20 hours per day and in average the 6 gas cooking stoves operate 7 hours per day. Of the 13 secondary schools visited only 2 were operating at the time of assessment. Three gas stoves for each operate 1 and 5 hours per day. The gas is mostly used for boiling drinking water. 2 to 5 gas stove installed in Community households (Missions/congregations, households) operate between 8 to 14 hours per day. (See **Appendix 8: Operating Hours for cooking/ day for each type of institution).**

Note: The capacity of stoves varies from institution to another:

- Stoves with the capacity of 2 to 40 litres are installed in community households
- Stoves of the capacity of 100 to 500 litres are installed in secondary schools;
- Stoves of the capacity of 500 to 1000 litres are installed in prisons.

b) Change in cooking habits

Community households have seen their times and meals cooked per day increased while other institutions did not observe similar changes. This is due to the fact that the number of times for cooking (3 times in secondary schools and 2 times in prisons) and eating (3 times in secondary schools and 2 times in prisons) are independent to supply of energy for cooking.

c) Reduction in Fuel wood use in different institutions;

During the survey data were collected on the consumption of fuel wood before and after the installation of biogas systems. The sections below provide an overview of the changes in fuel wood use for the different institutions.

- **Reduction in fuel wood use in Prisons**

As it can be seen in the table below prisons consumed 236-990 steres per month before biogas installation. With the installation of biogas stems, the quantity of firewood consumed monthly varied between 200 to 819 steres and the average level of reduction is 19% in prison institutions.

Table 8: Quantity of firewood consumed monthly before and after biogas installation and saved money after biogas installation

Prison	Quantity in stere used before and after biogas installation (per month)				Estimated savings in fuel wood expenditures in Rwfr	
	Before	*After*	*Reduction in steres*	*Reduction in %*	*Monthly*	*Annually*
Cyangugu	451	331	120	27	774,720	9,296,640
Gikongoro	427	427	0	0	-	-
Gitrarama	990	780	210	21	1,355,760	16,269,120
Kabutare	830	650	180	22	1,162,080	13,944,960
Mpanga	939	819	120	13	774,720	9,296,640
Nyagatare	236	200	36	15	232,416	2,788,992
Remera	680	530	150	22	968,400	11,620,800
Rilima	600	445	155	25	1,000,680	12,008,160
Total	**5153**	**4182**	**971**	**19**	**6,268,776**	**75,225,312**

Note: It is assumed that the cost of stere is Rwfr 6,456

The table above shows that the overall reduction of firewood in prisons has been limited to 19% which is much lower that the expectations. Reasons for this limited reduction of fuel wood use are highly related to the technical and managerial problems encountered. A few of the most important problems in the different prisons are listed below:

- At Cyangugu prison, only 4 gas stoves of 9 installed are operating and the one of digester is not operating due to the formation of scum. This reduces the production of the gas and increase the quantity of firewood used.
- The biogas system of Gikongoro prison is almost not operating due to the formation of scum in the one of digesters;
- 7 of 10 biogas stove of Gitarama prison biogas system are out of use and one of digester of 100 m^3 do not function;
- The utilisation of the biogas at Kabutare prison is not only disturbed by the leakage at the out let but also reduced as 2 of 6 gas stoves do not work;
- In Mpanga prison, the number of gas stoves is not sufficient; while the system has the capacity to produce biogas gas which can operate at least 7 gas stoves, only 4 are installed;
- In Nyagatare prison, gas is not used because gas stoves were damaged and were not repaired. Only one small gas stove is operating;
- Leakages of the gas and blockage of the biogas system at Remera prison reduce the gas produced.

- The Rilima prison biogas system does not produce gas at it maximum capacity due to the leakages of gas at the outlet level, pipes, vans, etc.

The average cost of a stere is Rwfr 6,456. Based on the table 8, the total costs savings for fuel wood would be Rwf 6,3 million per month or Rwf 75 million per year for all prisons. The table below shows prisons operating *Biogas system Investments versus the estimated money saved from reduction of firewood used before*

Table 9: Biogas investment versus estimated savings in fuel wood expenditures

	Prison	Total cost in Rwfr; investment	Estimated Annual savings in fuel wood expenditures in millions of Rwfr	Investment return period in years
1	Mpanga	154,592,280	9	17
2	Cyangugu	138,106,250	9	15
3	Gitarama	111,225,030	16	7
4	Rilima	95,045,120	12	8
5	Kabutare I	76,624,256	14	5
6	Remera	40,810,280	12	4
7	Nyagatare	Unknown	3	-

The savings in fuel wood expenditures can be compared directly to the investment costs.

For instance the biogas system in the Remera and Kabutare prisons are estimated Rwf 41 and 77 million respectively. The savings in fuel wood are 22% for each prison and this yield annual savings of nearly 12 and 14 million in that order. Comparing investment costs and annual fuel wood expenditures of those two prisons, the costs of fuel wood saved annually can pay their whole biogas systems within 4 years in case of Remera prison and 5 years in Katabure Prison.

In Gitarama and Rilima where the savings in fuel wood are 21% and 25% in that order, the investment return back period is for 7 and 8 respectively.

This makes investment returns of the prison biogas system highly effective based only on reduction of fuel costs and not counting all the other positive but less tangible benefits such as environmental impacts, improvement of health and convenience.

At Mpanga and Cyangungu prison the investment cost return back period is beyond 15 years. This period can be reduced at Mpanga prison by installation of more stoves. Cyangugu prison can reduce its investment costs return back by installation of new stoves and other accessories and assuring proper maintenance of biogas system.

- **Reduction in use of fuel wood in Secondary schools**

Secondary schools did not observe any change in the quantity of fuel wood consumed before because their biogas systems do not perform well. This is mainly due to the lack of follow-up and maintenance on one hand and lack of sufficient feeding materials (human waste) on the other hand.

A part from some school like Rwaza, Groupe Scolaire du Bon Conseil and APENA Secondary Schools that have seen the firewood used before biogas installation reduced to 11,1%, 6,6% and 4.5%respectively. The average reduction in secondary school is 5%.

- **Reduction in use of fuel wood in Community Households**

Households (Individual and Community) consumed 3 to 8 steres and the monthly average of firewood consumption was 3.7 steres. Households have observed a monthly reduction of fuel wood which varies from 0-4 stere. The level of reduction is beyond 80% and in some cases households shifted their cooking energy source completely from fuel wood to biogas (e.g. Nsenga Farm, Shyira, Frere Saint Gabriel, etc) .

d) Convenience of cooking activity

In most institutions visited, firewood is the main source of cooking energy. Using firewood for cooking create other activities which include wood cutting, and time for lighting. In the most institution there are people who are paid for tree cutting and those who wake-up early to prepare breakfast. With the installation of the biogas systems the number of people in charge of wood cutting was reduced and the preparation of breakfast or drinking water becomes easier.

e) Cleanliness, Environment and drinking water

The biogas installations in large institutions especially prison have facilitated the toilet waste management and eliminated the smell around institutions especially prison. In few secondary schools, the gas is mostly used for boiling drinking water. Even if there is no eye infection reported during our visits or any other respiratory diseases, people working in the kitchen of Rwaza Secondary School and Groupe Scolaire du Bon Conseil say that there is no ash and disturbing smoke in the kitchen where installed gas stoves.

The biogas installation significantly improves the living environment due to less or no smells, improved hygienic conditions and reduction of indoor smoke disturbance.

f) Use of slurry

Most of the institutions visited which have started using biogas agree that the slurry is better than the cow dung used before. Nevertheless more scientific tests have to be done in order to confirm those statements.

Institutions visited said that the biogas has impacted their life in two main areas;

1. Reduction or suppression of cost/ quantity of fuel wood used and
2. Increase of cleanliness, sanitation and environment protection and conservation.

5. Potential for replication for Institutional Biogas installations in Rwanda

So far only a very limited number of public institutions in Rwanda (36 according to this survey) have or are installing digesters using human and animal waste for the production of biogas for cooking purposes. There are many opportunities among schools (especially boarding schools), training centres, communities and hospitals. The paragraphs below provide some of the factors that may help decision makers who are considering the potential in their areas.

a) Assumptions[2]

- Wastes of an average of 1, 000 people can operate a digester of 100 m^3 capacity. *Ceteris paribus*, a digester of 16 m^3 will need 160 people to operate while 30 and 60 m^3 can operate with waste of 300 and 600 people respectively;
- A stove of 1000 litres is operated by a digester of 100 m^3 while 60 m^3 digester can operate a stove with the capacity which goes up 500 litres;
- For large institutions like prisons a stove of 1,000 litres serve 362 prisoners. This means that 1,000 people are served by 3 stove on average;
- 5 cows operate a digester of 16 m^3 and serves 15 people;
- Cow dung and human waste can be combined to produce gas either for large or small institutions;
- A stove of 1,000 litres consume 350 kg per day;

b) Based on assumptions above:

- Large institutions (like prisons and large learning institutions) which host 1,000 to 2,000 people can install a biogas system made up by 3 digesters of 30 to 60 m^3 each. While biogas systems of 300 m^3 and beyond can be built in institutions with the population beyond 3,000 people. More 100 m^3 digester for an increase of 1,000 prisoners should be built[3]. *Ceteris paribus*, this can reduce the quantity and the cost of fuel wood used for cooking of at least 20% for each institution. In addition, the problem of waste management can be solved at once. This

[2] Assumptions made based on primary and secondary data
[3] It is advisable to built digester in series in order to allow/maximize the production of gas.

happened to the 4 prison biogas systems which operate very well (Cyangugu, Gitarama, Mpanga and Remera).

- Medium institutions (especially secondary schools), of 200 to 1,000 people, can built digesters of 16 to 90 m^3. Digesters with the capacity beyond 16 m^3 must be built in series of 2 or 3 digesters. This can contribute to the cooking energy needs at the level of 20% as it is for large institutions.

- The gas produced by human waste in large and medium institutions can be increased by using cow dung. This will also help to increase the stability of the feeding rate, especially for schools where human waste reduces during weekend and holidays.

- With 5 (improved breed) cows, a community household of 15 people can see its cooking needs covered at 100% by the biogas. This is also demonstrated in the national domestic biogas program which recommends 2 – 3 cows for a family of 5 – 6 persons.

c) Potential clients for institutional biogas systems

Prisons, schools and tea factories are considered as the largest consumers of firewood. At the beginning of this decade prison chose biogas technology as an alternative to reduce the firewood used for cooking purposes. This was facilitated by the availability of free digester feeding material which is human waste. Even if schools have a significant number of people living within them, they were not sensitized and interested in biogas system installation.

According to KIST/CITT staff, 5 new prison biogas systems are going to be installed in Butamwa, Gikombe, Karongi, Ngarama and Zaza prisons. As prisons are few and some are going to be closed because of the reduction of prisons due to the release of genocide suspects, the institutional biogas system should focus on the more than 640 secondary schools scattered around the country[4] which host 416 students on average for each school. These institutes are potential clients for medium biogas systems of 40 m^3 on average.

[4] Number of Rwanda public and private secondary schools in 2007; Provided by MINEDUC Statistics

V. CONCLUSIONS

The survey in September 2008 found a total of 28 institutional biogas systems were installed in the county while another 8 are under construction. 13 are in secondary schools, 11 in prisons, 7 in community households, 2 in military camps and 2 in training centers. Much needs to be improved on the operation aspects as only 11 of 28 institutional biogas systems operate very well, 5 operate with major defects while, 6 have never operated (either abandoned or wrongly designed).

The size of the digesters varies from 16 to over 1000 mtr^3. Digesters of 16m^3 to 40 m^3 were installed and operate very well in community households of 15 people (Religious Missions, etc) and are fed by 5 to 10 cows' dung. Secondary schools opted for digesters with the capacity of 60, 76 and 100 m^3 but 3 biogas systems of 100m^3 have never operated because they were wrong designed (not built in series) and too big compared to the number students living full time in the school. Other biogas systems installed in secondary schools do not perform well due to the lack of sufficient gas to operate stove of at least 200 liters. The lack of follow-up and technical support is also the hindrance of the success of secondary school biogas systems. Most community households visited have changed their source of cooking energy from fuel wood to biogas.

Prison biogas systems are by far the biggest in use in the country and vary in size from 200 to 1250 m^3. These have experienced success in the reduction of fuel wood used for cooking (estimated at an average of 19% but with a much higher potential) and the improvement of the environment around prisons both in smell and health aspects. Nevertheless, lack of follow-up and technical support affects significantly the efficiency of prisons biogas system; 4 of 8 prison systems are operating with major defects.

The costs savings of institutional biogas systems can vary from 3 to 16 million annual. This can allow prison to pay back the biogas investment costs within a period of 4 to 17 years. This period can be reduced if technical problems are solved and maintenance is assured properly.

The performance of institutional biogas system is highly related on one hand to the commitment and support of the institution managers and on another hand to the skills of internal operators and the technical and maintenance support availed for each institution. For all institution visited, there is a strong need of permanent technical support.

VI. RECOMMENDATIONS

In the short term

1. Building Contractors (especially KIST/CITT) have to complete constructions/installation of biogas systems which construction has started 2 years ago. This will allow all prison institutions not only to use gas but also to solve environment and waste management;
2. To help biogas users to solve or avoid minor technical problems, Biogas User's manuals should be produced and given to the institution.
3. Short term training sessions should be conducted in order to equip internal technicians to solve minor technical problems which can damage the whole biogas system;
4. There should be a training and regulation for the companies that want to specialize in biogas installation to ensure quality and the success of the technology as a whole.
5. All the companies specialized in biogas installation should be registered and recognized to avoid disorder in the area of biogas technology.
6. The technicians and masons who were trained on small/domestic biogas plants construction should not contract for bigger/institutional biogas plants until they are trained for bigger plants construction

In the long term

To assure the sustainability of the institutional biogas program in Rwanda;

1. Mobilization and sensitization should be done in all institutions especially prisons and schools on the advantage of the usage in terms of money and environment conservation; reduction of firewood and waste management;
2. Training of large biogas system builder because only small biogas system builders are trained up to now;
3. Training of at least 30 local technicians (at least 1 per district) who will assure permanent support to institutions technical support;
4. Help establishment of more institutional Biogas installations; at least for each prison, school.
5. Schools and other institutions should be made aware of the potential benefits of biogas systems especially in environmental and costs savings.

VII. APPENDIXES

Appendix 1: Terms of Reference

SURVEY INSTITUTIONAL BIOGAS SYSTEMS In RWANDA

Terms of Reference

Background

Over the past decades a number of biogas systems have been constructed in Rwanda and in particular the Government program with the prisons has attracted international attention and recognition. In addition, there are also some schools which have installed biogas systems to reduce the consumption of fuel wood while at the same time reducing the environmental burden on the surrounding communities. Also few large dairy farms have installed digesters using cow dung to produce gas for cooking and heating purposes. KIST/CITT has played an important role as an innovator of the biogas systems but also as a contracting agency and as such has constructed many of the larger units in the country. More recently, private companies have adapted the technology, often starting as sub-contractor to KIST but are now working for different clients.

There are at least 25 large digesters which have been constructed over the last 10 years and the table in annex 2 provides an overview based on data provided by various biogas experts in the country. However, this list is not complete and it is likely that other units will be “discovered” during the data collection process.

There is an interest among Government agencies and development partners in a program to support institutional biogas in Rwanda to help reduce both expenses for fuel wood as well as the burden on the natural environment including the hygienic aspects. This survey will provide baseline information that will contribute towards the development of a more detailed plan for dissemination of biogas systems for schools, hospitals and other public institutions.

Objective

The objective of the assignment is to collect baseline data and set up a data base providing an overview of the institutional biogas systems in Rwanda and to make a first assessment of the operation and maintenance practices which will provide lessons for a possible future program.

Scope of Work

The contractors will the following activities under this assignment including:

1. Verification and updating of the list of institutional biogas systems as provided in the annex. It is of particular importance to include sites which have not been mentioned in the annex.
2. Prepare and agree a questionnaire for the collection of data covering the requirements set out in annex 1.
3. Visits to all the listed institutional biogas systems (above 30 mtr3) to collect the required data as indicated in the draft survey questionnaire

4. Setting up of a data base (excel or other suitable format) with overview of all the data collected
5. Brief summary report of the work undertaken

Profile of contractor

The contractor will have the required human and other resources to carry out this assignment. This includes a sufficient number of qualified remunerators, a supervisor to ensure that the work is quality assured and the necessary administrative capacity to implement the contract including the provision of appropriate transport arrangements for the field activities. The contractor is also responsible for the provision of office and computer facilities to process the data.

The contractor should be able to provide evidence of previous survey activities undertaken for other organizations.

Schedule of work

The survey is expected to be carried out over a period of one month including the data collection in the field, data entry and processing and report preparation.

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Deliverables

The contractor will deliver the data base listing all the biogas systems which have been surveyed and a brief final report covering the methodology of the work and the main findings of the survey data.

Appendix 2: Questionnaire

QUESTIONNAIRE FOR PERFORMANCE AND IMPACT ASSESSMENT OF BIOGAS INSTALLATIONS IN PUBLIC INSTITUTIONS – RWANDA

Code of the sample	
Names of data collector	
Date of interview	***……/09/2008***
Names of data entry agent:	
Date of data entry:	***……/09/2008***

1. Institution – basic data

1. Interviewee Name			
2. Interviewee title/position			
3. Institution name			
4. Institution Type (Please Select):		1. Secondary school 2. Prison 3. Hospital 4. Community household (religious Convent) 5. Individual household 6. Farm 7. Other (Specify/write it down)	
5. Location	GPS data (coordinates)	Latitude	……..° …….. , ……..’
		Longitude	……..° …….. , ……..’
		Altitude	……
	Province		
	District		
	Sector		
	Cell		
6. Address	P.O Box		
	E-mail		
	Website		
	Telephone:		
	Fax:		
7. Contact person	Names		
	Position at the institution:		
	Telephone:		
	Email Address:		
8. Date of Establishment			
9. Main activity			
10. Number people living in the institution		a)Full time	b) Part time

11. Number of cows		12. Number of Pigs	

2. Bio-digester- Construction, technical, feeding and maintenance data

1. Size				……..m^3
2. Completion Date of construction works; ready for use); month and year				
3. Estimated construction cost in Rwfr				……Rwfr
4. Who pay for these costs	Institution itself (1) GoR (2) Loan from the Bank *(write it down)* (2) NGO*(write it down)* (3) External donor *(write it down)* (4)			
5. The contribution of institution	*a) …… Rwfr*		*b) ……..%*	
6. The builder contractor	a) Name: b) Address: c) Contact Name:			
7. Feeding material	Human (1) Cow (2) Pigs (3) Others *(write them down)* (4)			
8. Feeding liquid	Urine (1) water (2)			
9. Water supply to feed digester	a) Quantity per day (in litre)			
	b) Source: At the place (1) Fetched (2) Rain water (3)			
	c) If it is fetched, what is the distance to the source			.....min
	d) The cost per month in (Rwfr)			.....Rwfr)
10. Who is in charge of digester	*(Position)*			
11. Is there anyone who is in charge of feeding?	Yes (1) No (2)	If yes a) How many?		
		b) Is digester feeding his/her/their only task	Yes (1) He/she/They combine it with other activities (2)	
		d) Is the feeding activity paid?	Yes (1) No (2)	
		e) What are Incentive/ salary for the person(s) in charge of feeding in term of money (Rwfr) per month?		……..Rwfr
		d) Are Incentive/ salary for the person(s) in charge of feeding calculated in term gas or slurry	Yes (1) No (2)	
12. Who does repair /maintenance gas control?	a)Internal(1) External (2) technician	b)Name: c)Level of education: d)Phone:		
	e) Is the technician trained on Biogas installation repair/maintenance?	f) Trained by whom? ……		

	Yes (1) No (2)	

13. What Type of technical problems did digester account and their frequencies? ***(quarterly)***

	Technical problem	**Frequency**
	a)	
	b)	
	c)	
	d)	
	e)	
	f)	
	g)	
	h)	

3. Energy supply and use; gas and other sources of energy

1. Gas is used for	Cooking (1) Lights (2) Others (3)
2. How many hours of use per day for cooking?	
3. How many hours of use per day for lighting?	
4. How many people are served for cooking?	
5. How many people are served for lighting?	
6. How many lights do you use	
7. How many stoves do you use	

Source of energy consumed per month before and after the use of gas

Source of energy	**Before/After**	**Quantity in tons/kHw/pieces**	**Unity cost (in Rwfr)**	**Total Cost (in Rwfr)**
8. **Firewood**	a) Before			
	b) After			
9. **Charcoal**	a) Before			
	b) After			
10. **Plant residues**	a) Before			
	b) After			
11. **Electricity**	a) Before			
	b) After			
12. **Kerosene**/candles/batteries for lighting consumed per month	a) Before			
	b) After			

4. Use of slurry

1. Is the slurry used as a fertiliser?	Yes (1) No (2)
2. If no, why?	
3. If so, who are the users?	Institution itself (1) Others (2)
4. Do they pay for the product?	Yes (1) No (2)
5. If so, how much per ton? (*In Rwfr)*	

6. How does the slurry compare with dung/previously used fertiliser?	Better (1) Good (2) Bad (3) worst (4) The same (5) Unknown(6)

5. Impact in general

1. Are there any changes in terms of time needed for cooking per day since you started using biogas?	a)Increased (1) decreased (2) No change (3)	b) If increased, for how many minutes?	
		C) If decreased, for hoe many minutes?	
2. Are there any changes in terms of number of meals cooked per day since you started using biogas?	a)Increased (1) Decreased (2) No change (3)		
3. Are there any changes in terms of Cleanliness?	a)Increased (1) decreased (2) No change (3)		
4. Do you think there has been a change in the number of eye infections and coughs for the people in charge of cooking since the introduction of the system?	a)Increased (1) decreased (2) No change (3) *Comments*		
5. How has biogas change life generally in your institution?			
6. Would you recommend biogas to other institutions?	Yes (1) No (2) I don't know (3) *Comments*		
7. Are other institutions interested in similar digesters?	a) Yes (1) No (2) I don't know (3) b) If yes which ones:		
8. Remarks from owners and users			

Appendix 3: Length of operations

Completion date of construction	Institutions	Number of institutions	%
2001	Cyangugu Prison, Nsenga Farm	2	5.6
2002	Gako organic Farm Training Center	1	2.8
2003	Air Force Camp	1	2.8
2004	Groupe Scolaire Rwaza, APENA Secondary School and Nyagatare Prison	3	8.3
2005	ETO Gitarama, Gitarama Prison, Kabutare Prison I, Petit Seminaire de Kabgayi, Rilima Prison	5	13.9
2006	College Saint Jean Nyarusange, Ecole Technique de Kabgayi, Kibuye Hospital, Mpanga Prison, Remera Prison, Shyira Hospital,	7	19.4
2007	Gikongoro Prison,	1	2.8
Up to sept.2008	Soeurs de l'Assomption, Institut Don Bosco Kabarondo, Carmelites Sisters, Groupe Scolaire Notre Dame du Bon Conseil Byumba	4	11.1
Under construction	Kabutare Prison II, Monastry of Benectine Sisters, Nyamirama High School, Nyarutovu High School, Rukira Secondary School, Zirambe Diary farm, Nsinda Prison, Miyove Prison	8	22.2
Unknown	Ecole Saint Bernadette, Lycee de Kigali, Masaka Miltary Camp, Ruyumba Farm and Demonstration and Training Center	4	11.1
Total		**36**	**100.0**

Appendix 4: List of biogas institution per district and province

Province	District	Institution Type						Total
		Secondary school	***Prison***	***Hospital***	***Community & Individual household/ Farm***	***Military Camp***	***Training Center***	
Eastern	Bugesera	0	1					1
	Kayonza	2	0					2
	Kirehe	1	0					1
	Ngoma	1	0					1
	Nyagatare	0	1					1
	Rwamagana	0	1					1
	Total	**4**	**3**					**7**
Kigali City	Gasabo	0	1		2	0	0	3
	Kicukiro	0	0		1	2	1	4
	Nyarugenge	1	0		1	0	0	2
	Total	**1**	**1**		**4**	**2**	**1**	**9**
Northern	Gakenke	1	0					1
	Gicumbi	1	1					2
	Musanze	1	0					1
	Total	**3**	**1**					**4**
Southern	Huye	0	2		1		0	3
	Kamonyi	1	0		0		1	2
	Muhanga	2	1		0		0	3
	Musanze	1	0		0		0	1
	Nyamagabe	0	1		0		0	1
	Nyanza	1	1		0		0	2
	Total	**5**	**5**		**1**		**1**	**12**
Western	Karongi		0	1	0			1
	Nyabihu		0	0	1			1
	Rusizi		1	0	1			2
	Total		**1**	**1**	**2**			**4**
Total		**13**	**11**	**2**	**7**	**2**	**2**	**36**

Appendix 5: List of for the needed materials to install a biogas system

SN	Construction materials	SN	TOOLS
1	Cement	1	Spirit level
2	bricks	2	Plastic sheeting
3	Coarse aggregates	3	hack saw
4	Stones	4	Tape measure (5m)
5	Fine sand	5	hammer 4 kg
6	Big sand	6	hammer 5 kg
7	Water proof Cement	7	craw hammer
8	Lime	8	hammer 2kg
9	Steel bars 12 mm	9	Building trowels
10	Steel bars 6 mm	10	Timber Hacksaw
11	Binding wire	11	Ropes
12	Chicken wire (2m wide)	12	Horse pipe (50 m)
13	Welded mesh		
14	Manilla rope		
15	Nails 12 cm		
16	Nails 10 cm		
17	Nails 8 cm		
18	Nails 5 cm		
19	Madriers		
20	Timber		
21	Galvinised pipes 3/4"		
22	PVC 125 mm		
23	Water		
24	Plywood		

Appendix 6: Biogas system management versus performance

Digester performance		Responsible for Management														
	Institution Name	**A prisoner**	**Director**	**Director/ a prisoner in charge of Biogas**	**Head Master**	**Head master/ Intendante**	**Intendant Manager**	**Internal Technician**	**Never operate**	**None**	**Not yet started**	**One of the household member**	**Responsible of social affaires**	**The manager**	**Veterinary**	**Total**
Good; Operating with defects	Gitarama Prison	1				0										**1**
	Groupe Scolaire Notre Dame du Bon Conseil Byuma	0				1										**1**
	Remera Prison	0		1		0										**1**
	Cyangugu Prison	1														**1**
	Total	**2**		**1**		**1**										**4**
Poor; Stop operating	APENA Secondary School				0		1			0	0					**1**
	Carmelites Sisters				0		0			0	1					**1**
	Ecole Saint Bernadette				1		0			0	0					**1**
	Institut Don Bosco Kabarondo				0		0			1	0					**1**
	Kibuye Hospital				0		0			1	0					**1**
	Petit Seminaire de Kabgayi				0		1			0	0					**1**
	Total				**1**		**2**			**2**	**1**					**6**
Fair; Operate with major defects	Gikongoro Prison									1			0			**1**
	Groupe Scolaire Rwaza				1					0			0			**1**
	Kabutare Prison I									0			1			**1**
	Nyagatare Prison									1			0			**1**
	Rilima Prison									1			0			**1**
	Total				**1**					**3**			**1**			**5**
Never operate	Air Force Camp				0			0	1							**1**
	College Saint Jean Nyarusange				0			0	1							**1**
	Ecole Technique de Kabgayi				1			0	0							**1**
	ETO Gitarama				0			1	0							**1**
	Lycee de Kigali				0			0	1							**1**
	Masaka Miltary Camp				0			0	1							**1**
	Total				**1**			**1**	**4**							**6**

		Responsible for Management														
Excellent; Operate without any defect	Frere de Saint Gabriel		0	0			1					0		0	0	**1**
	Gako organic Farm Training Center		1	0								0		0	0	**1**
	Mpanga Prison		0	1								0		0	0	**1**
	Nsenga Farm		0	0								1		0	0	**1**
	Ruyumba Farm and Demonstration and Training Center		0	0								0		0	1	**1**
	Shyira Hospital		1	0								0		0	0	**1**
	Soeurs de l'Assomption		0	0								0		1	0	**1**
	Total		**2**	**1**			**1**					**1**		**1**	**1**	**7**
Under construction	Kabutare Prison II										1					**1**
	Miyove Prison										1					**1**
	Monastry of Benectine Sisters										1					**1**
	Nsinda Prison										1					**1**
	Nyamirama High School										1					**1**
	Nyarutovu High School										1					**1**
	Rukira Secondary School										1					**1**
	Zirambe Diary farm										1					**1**
	Total										**8**					**8**

Appendix 7: Biogas system performance indicators

Biogas plants performance	Indicators	Institution
Excellent; Operate without any defect	• All the plant-components are constructed with good workmanship complying with the basic minimum quality standards; • All the plant-components are operational without any technical problem • Location and relative orientation of plant components meet the basic minimum standards of site lay-out; • Location of plant is managed in such a way that it is at reasonable distances from kitchen (point of gas application), water source, cattle shed and main access way.	1. Frère Saint Gabriel 2. Soeur de l'Assomption 3. Nsenga farm 4. Gako organic farming training centre 5. Ruyumba Demonstration and Training Center 6. Mpanga Prison 7. Shyra Hospital
Good; Operating with minor defects	• All the plant-components are constructed with good workmanship complying with the basic minimum quality standards • Most of the plant-components are operational without any technical problem; • Location and relative orientation of plant components meet the most of the basic minimum standards of site lay-out; • Location of plant is managed in such a way that it is at reasonable distances from kitchen (point of gas application), water source, cattle shed and main access way.	1. Gitarama Prison 2. Groupe Scolaire Notre Dame du Bon Conseil Byumba 3. Remera Prison 4. Cyangugu Prison
Fair; Operate with major defects	• Plant-components are constructed with moderate workmanship. Plants are constructed without giving due attentions to the quality norms and standards; • Plant-components are operational with one or more technical problems; • Location and relative orientation of plant components do not meet the basic minimum standard of site lay-out, however, the non-compliance does not affect gas production seriously; • Location of plant is either very near or reasonably far from kitchen (point of gas application), water source, cattle shed and main access way.	1. Gikongoro Prison 2. Groupe Scolaire Rwaza 3. Kabutare Prison I 4. Nyagatare Prison 5. Rilima Prison
Stopped operating	• Some plant-components are constructed with good workmanship but due to poor management and maintenance are no longer operating. • Plants are constructed without giving due attentions to the quality norms and	1. APENA Secondary School 2. Carmelites Sisters 3. Ecole Saint Bernadette

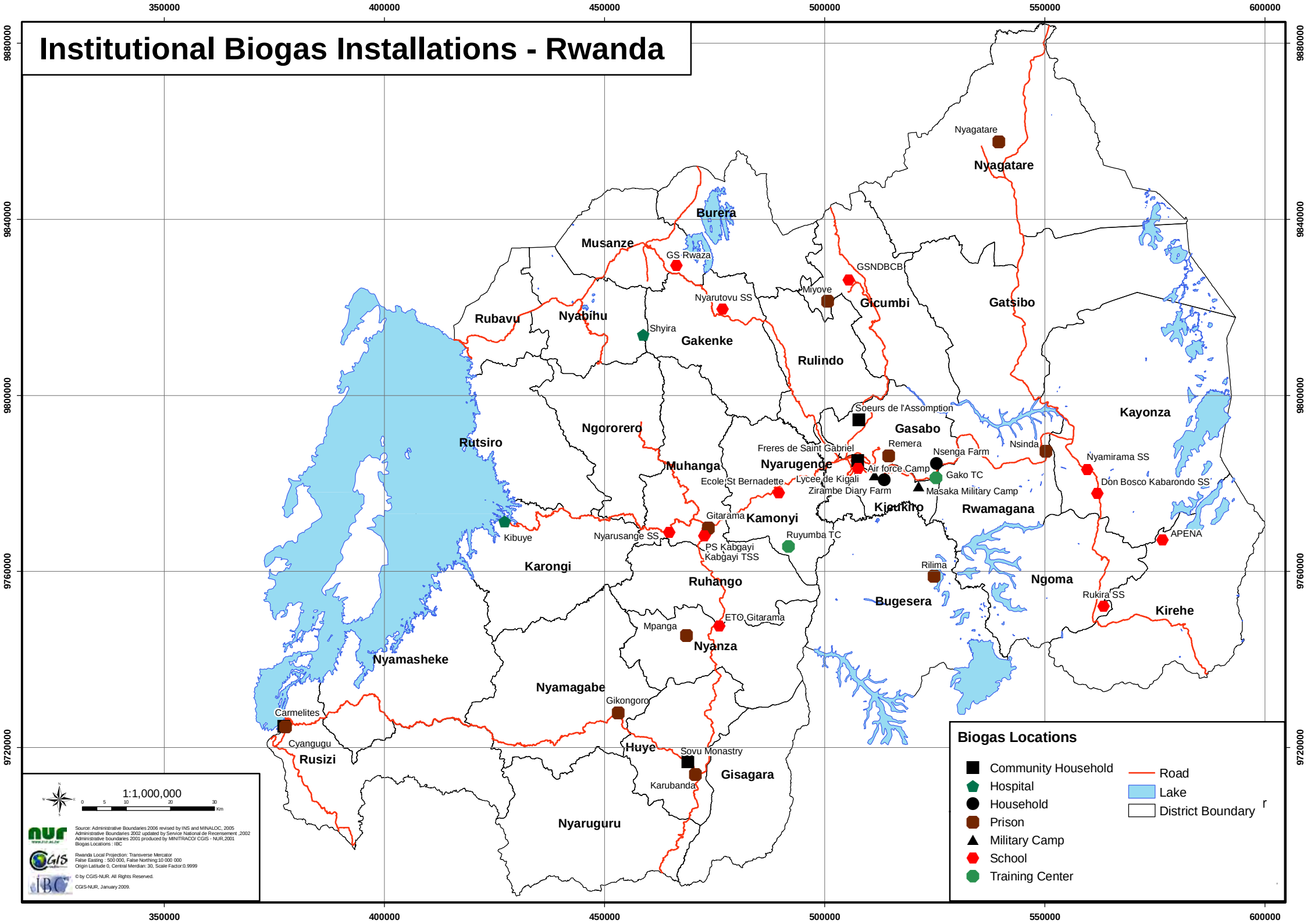
Biogas plants performance	Indicators	Institution
	standards • Plant-components are not operational due to major technical problems • Location and relative orientation of plant components do not meet at all the basic minimum standard of site lay-out and the non-compliance affects gas production significantly	4. Institut Don Bosco Kabarondo 5. Kibuye Hospital 6. Petit Seminaire de Kabgayi
Never operate	• Plant-components are constructed with poor workmanship. Plants are constructed without giving due attentions to the quality norms and standards and in many cases it violets basic minimum standards • Plant-components are not operational and there are one or more technical problems • Location and relative orientation of plant components do not meet the basic minimum standard of site lay-out, and the non-compliance affect gas production seriously • Location of plant is quite far from kitchen (point of gas application), water source and cattle shed and vary near to main access way. • Plant abandoned due to various reasons	1. Air Force Camp 2. College Saint Jean Nyarusange 3. Ecole Technique de Kabgayi 4. ETO Gitarama 5. Lycee de Kigali 6. Masaka Miltary Camp
Under construction **(8)**	• Construction/installation works are not yet finished	1. Kabutare Prison 2. Miyove Prison 3. Monastry of Benectine Sisters 4. Nsinda Prison 5. Nyamirama High School 6. Nyarutovu High School 7. Rukira Secondary School 8. Zirambe Diary farm

Appendix 8: Operating Hours for cooking/ day for each type of institution

		Institution Type						Total
	Hours	Secondary school	Prison	Hospital	Community& Individual household/Farm	Military Camp	Training Center	
Operating Hours for cooking/ day	0	11	3	1	3	2	0	**20**
	1	1	0	0	0	0	0	1
	2	0	0	0	0	0	0	1
	3	1	1	0	0	0	0	3
	5	0	1	0	0	0	1	2
	6	0	2	0	0	0	0	2
	8	0	0	0	2	0	0	3
	10	0	1	0	1	0	1	2
	12	0	2	0	0	0	0	1
	14	0	0	0	1	0	0	1
	20	0	1	0	0	0	0	1
	Total	**13**	**11**	**1**	**7**	**2**	**2**	**36**

Appendix 9: Map of institutional biogas installations

To be added


Institutional Biogas Installations - Rwanda
350000
400000
450000
500000
550000
600000
9880000
9840000
9800000
9760000
9720000
Nyagatare
Nyagatare
Burera
Musanze
GS Rwaza
GSNDBCB
Miyove
Nyarutovu SS
Gicumbi
Gatsibo
Rubavu
Nyabihu
Shyira
Gakenke
Rulindo
Soeurs de l'Assomption
Gasabo
Kayonza
Ngororero
Rutsiro
Freres de Saint Gabriel
Remera
Nsenga Farm
Nsinda
Nyamirama SS
Muhanga
Nyarugenge
Air force Camp
Gako TC
Ecole St Bernadette
Lycee de Kigali
Zirambe Diary Farm
Masaka Military Camp
Don Bosco Kabarondo SS
Kicukiro
Rwamagana
Gitarama
Kamonyi
Kibuye
Nyarusange SS
Ruyumba TC
APENA
PS Kabgayi
Kabgayi TSS
Karongi
Rilima
Ngoma
Ruhango
Bugesera
Rukira SS
Kirehe
ETO Gitarama
Mpanga
Nyanza
Nyamasheke
Nyamagabe
Gikongoro
Carmelites
Cyangugu
Rusizi
Huye
Sovu Monastry
Gisagara
Karubanda
Nyaruguru
Biogas Locations
Community Household
Hospital
Household
Prison
Military Camp
School
Training Center
Road
Lake
District Boundary
1:1,000,000
0 5 10 20 30 Km
Source: Administrative Boundaries 2006 revised by INS and MINALOC, 2005
Administrative Boundaries 2002 updated by Service National de Recensement ,2002
Administrative boundaries 2001 produced by MINITRACO/ CGIS - NUR,2001
Biogas Locations : IBC
Rwanda Local Projection: Transverse Mercator
False Easting : 500 000, False Northing:10 000 000
Origin Latitude 0, Central Meridian: 30, Scale Factor:0.9999
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