Simple Pre-Feasibility of Biogas Projects

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Rural Electrification Authority

Ministry of Energy and Petroleum

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The source of all figures and tables is JICA Expert Team, otherwise specified.

List of Terms and Abbreviations

Abbreviation	Description
AC	Alternating Current
EIA	Environmental Impact Assessment
ERC	Energy Regulatory Commission
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Society for International Cooperation)
GoK	Government of Kenya
HH	Household
Hivos	Humanist Institute for Development Cooperation
IEE	Initial Environmental Examination
JICA	Japan International Cooperation Agency
KPLC	Kenya Power and Lighting Company Ltd.
KSh	Kenya Shilling (1US$ = 82.76 KSh, as of 1 September 2012)
LED	Light Emitting Diode
LPG	Liquefied Petroleum Gas
MoE&P	Ministry of Energy and Petroleum
NEMA	National Environment Management Authority
NGO	Non-Governmental Organization
O&M	Operation and Maintenance
PPR	Polypropylene
PSDA	Promotion of Private Sector Development in Agriculture
PVC	Polyvinyl Chloride
RE	Renewable Energy
REA	Rural Electrification Authority
RT	Retention Time
SNV	Stichting Nederlandse Vrijwilligers (Netherlands Development Organization)
ToR	Terms of Reference
USD	US Dollar
WB	World Bank

List of Electrical Terminology

A (Ampere)	Unit of current
V (Volt)	Unit of voltage
kV (kilovolt)	1,000 volts
W (Watt)	Unit of active power
kW (kilowatt)	1,000 watts
MW (Megawatt)	1,000kW
Wh (Watt-hour)	Unit of energy
kWh (kilowatt-hour)	1,000Wh
MWh (Megawatt-hour)	1,000kWh

CHAPTER 1 OBJECTIVE OF PRE-F/S

1.1 Introduction

Biogas is a combustible gas produced by the fermentation of organic material in the absence of oxygen. It is composed of approx. 60 percent of methane (CH_4) and 40 percent carbon dioxide (CO_2). It has a faint, unpleasant smell. It burns with a hot blue flame and can be used in gas lamps, cooking stoves, to generate electricity and to power diesel and petrol engines, among other applications (Hankins, 1987). The production of biogas requires the use of carbohydrates, proteins and/or fats. The actual reactants, however, are soluble organic matter, volatile fatty acids (mainly acetic acid), amino acid, long chain fatty acids, organic sulfur and ammonium compounds. These are found in food processing effluents, weeds, leaves, non-edible starch and in sewage, municipal and other waste (Dutt and Ravindranath, 1993).

The biogas production process occurs in the digester, which can be divided into two main groups; batch digesters and continuous flow digesters. Batch digestion is the simplest method to adopt for biogas systems. The plant is filled with substrate material and suitably inoculated to enable appropriate bacterial population to predominate. At the completion of the digestion (when gas falls to low levels) the material is removed and replaced with a new batch. After biogas is obtained, slurry (digested material) remains and can be used as compost manure (Ellegard, 1990).

As with other combustible gases, the dangers of explosion exist. When replacement of worn biogas installations is not carried out promptly, gas pipe might burst. Hydrogen sulfide (H_2S) produced has a foul smell, poisonous and corrosive. Biogas slurry that is not properly handled can be environmentally harmful.

Although those issues should be noted for actual implementation, biogas can substitute fuel wood and facilitate decentralized electricity generation in areas with no access to the power grid. Biogas enables energy supply at low cost and waste utilization as fertilizer in rural areas

1.2 Biogas Project and Pre-F/S

Japan International Cooperation Agency (JICA) implemented the "Project for Establishment of Rural Electrification Model using Renewable Energy in Kenya" in 2012-2015. The project has two main components; (i) pilot projects for solar PV systems, and (ii) technical assistance for wind, small hydro, and biomass/biogas. This Guideline for Biogas Generation is prepared within the scope of the project by a Working Group (WG) of JICA Expert Team of Nippon Koei Co., Ltd /KRI in cooperation with Rural Electrification Authority (REA) in Kenya.

A biogas generation system is a method of electricity generation utilizing biogas produced by methane bacteria as the energy source. Similar to natural gas or propane gas, biogas has heat value, and can therefore be utilized as energy. Although the unit heat value of biogas is smaller than that of fossil fuels, biogas can be used as a cooking fuel in the same way as LPG with some modification of cooking stoves. When it is connected to a gas engine or modified diesel engine, it provides rotative force for the generator, producing electricity.

Since waste materials are used as feedstock for biogas systems and no fossil fuel is required, biogas is considered a renewable energy source.

Strategic Master Plan 2013/2014-2017/2018 of Rural Electrification Authority (REA), Third Draft, stipulates that promotion of the use of renewable energy sources including biomass is one of REA's roles. In the strategic objective to develop and promote renewable energy sources, the strategic plan includes a target to develop and promote biogas and biomass systems for institutions and households.

Pre-Feasibility Study for Biogas Projects is therefore prepared to assess the technical and economic feasibility of biogas projects in six schools in Kenya by the Working Group REA and JICA Expert Team.

It is important to evaluate the project feasibility for the project. There are many renewable energy projects that were conducted without sufficient survey and study of economic and financial feasibility. The general project flow is as shown in the figure below.

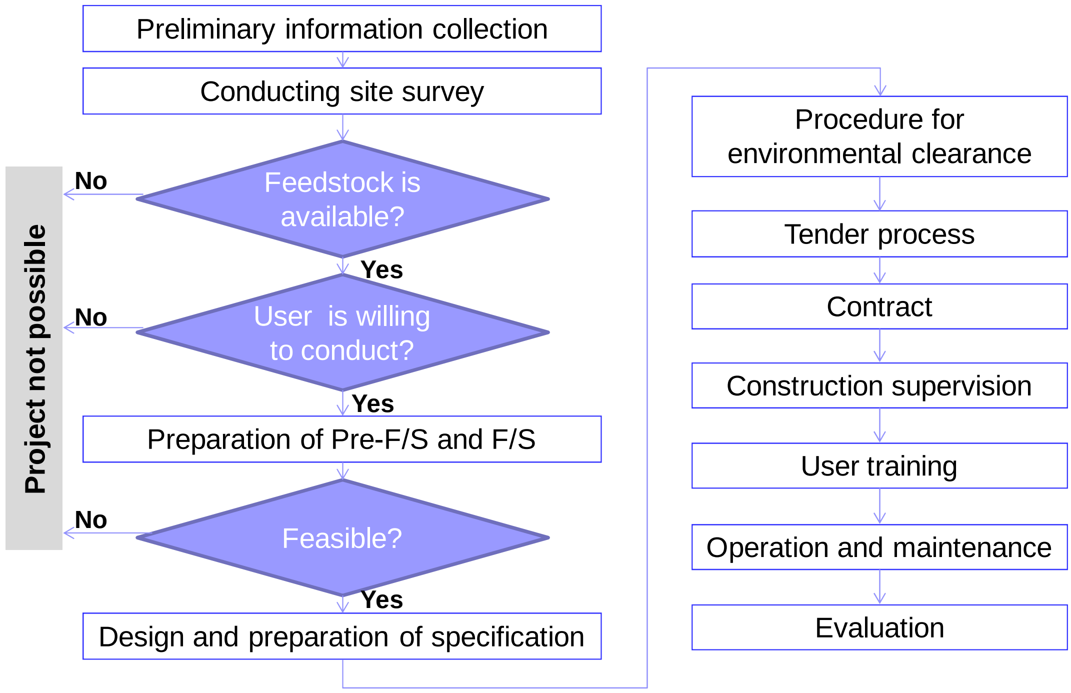

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Figure 1.1 Project Flow

Simple Pre-feasibility study (Pre-F/S) was conducted for six REA biogas candidate project sites. The simple pre-F/S covers following items.

1) Outline and Purpose
2) Particular Features
3) Preliminary Design
4) Energy Production and Demand Assessment
5) Benefit Assessment
6) Cost Estimation
7) Economic/Financial Evaluation
8) Optional Study for the selected Project

For the selected project (Nyeri High School), optional study was conducted to select optimal biogas system component.

Above items are required in the proposal of REA management for project implementation.

CHAPTER 2 METHODOLOGY OF PRE-F/S

2.1 System Model

Biogas system in public facility such as school with dormitory or prisons has advantages in terms of the following:

- Human waste is collective with sewer system and septic tank
- Generally schools have dormitory and own cows for milk supply. Cow dung is the best source of biogas in terms of organic composition and inherent methane producing bacteria.

The biogas system model in facilities such as schools is proposed as in Figure 1.

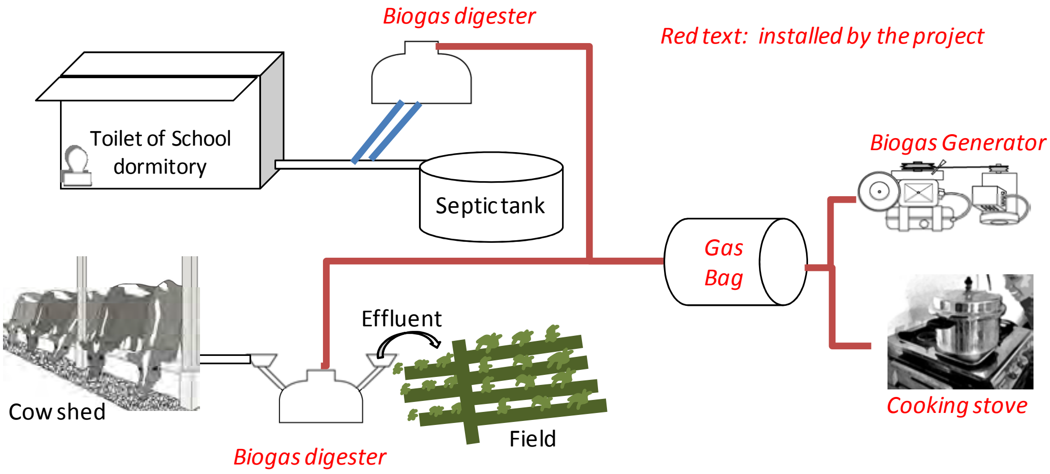

Figure 2.1 Basic Concept of Biogas System

The outline of the system is as follows:

1) Human waste is collected in septic tank. Biogas digester is installed between toilet and septic tank. Effluent from digester will enter existing septic tank. After methane production, solid waste, BOD, and pathogens will be reduced in the digester, and organic load to septic tank is reduced by the digester.

2) Cow dung from cow shed is collected in a digester through a trench. After degradation and methane production in a digester, effluent can be used as fertilizer to increase yield of garden vegetables and feed. The feed will be supplied to cows. This enables material cycle while producing biogas energy.

3) Biogas produced in digesters are collected once in gas bag, and can be used either/both generation by biogas generator or/and cooking stove.

Using above system model, simple pre-feasibility study (pre-F/S) was conducted for six biogas candidate project sites found by Rural Electrification Authority (REA). An optional study was conducted to select optimal biogas system components for the selected project (Nyeri High School) out of six target schools.

2.2 Methodology of Pre-F/S

The simple pre-F/S clarified the following: 1) Outline and Purpose, 2) Particular Features, 3) Preliminary Design, 4) Energy Production and Demand Assessment, 5) Benefit Assessment, 6) Cost Estimation, 7) Economic/Financial Evaluation , and 8) Optional Study for the selected Project for selected site. The work flow of the pre-F/S is shown in the figure below.

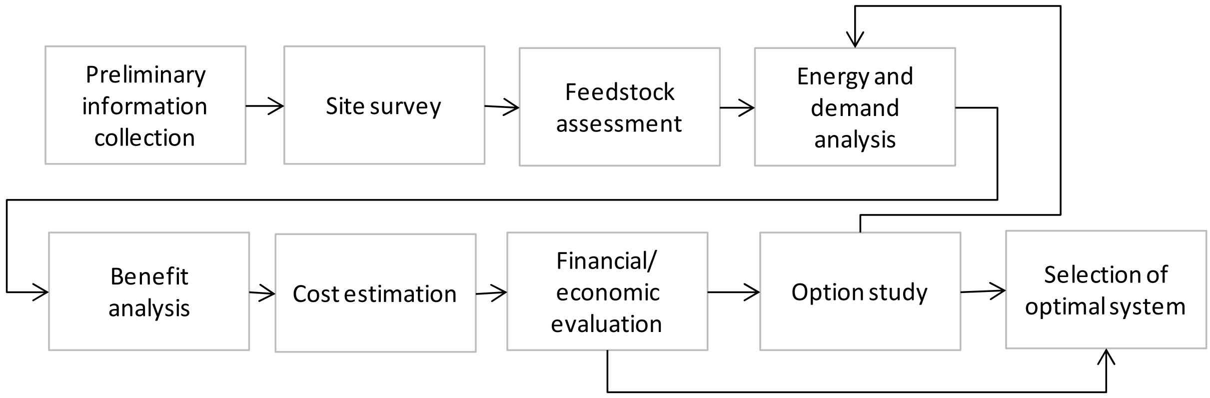

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Figure 2.2 Flow of Pre-Feasibility Study

The method of works in the pre-F/S shown in the above figure is as follows:

- Preliminary information collection: Necessary information for site survey was collected, such as willingness for project implementation of facility, location, existence and type of feedstock, etc.
- Site survey: Six project sites were surveyed and confirmation of building layout, preparation of sketches to determine facility plan, information collection for available number of cows and other livestock, human, possible raw waste, and energy usage status were conducted according to a check list.
- Feedstock assessment: Cow dung and human waste is the main feedstock for school biogas system. The amount of feedstock available in the facility was assessed. The amount of biogas production per kg of cow dung was measured 0.023-0.04 m^3/kg (Gunter U, 2011). With application of the average of this experimental value, the biogas production volume per cow was estimated with the following formula:

$$V_c = 0.033N_c \times W_d \times 365$$

Where, V_c: Volume of biogas production from cow dung (m^3/year)
N_c: Number of cows in facility
W_d: Average cow dung production in kg per cow

The value W_d is variable depending on cow conditions such as age, weight, nutrient status, etc. Here, 20 kg/cow is applied.

The volume of biogas production per person was reported to be 0.02-0.028 m^3/person/day in the experiment in Uganda (E.Menya and Y. Alokore, 2013). With application of average value of this, the amount of biogas production from human waste was estimated with the following formula:

$$V_h = 0.024N_h \times O \times D \times R$$

Where, V_h: Volume of biogas production from human waste (m^3/year)
N_h: Number of persons utilizing a toilet connected to a digester in facility
O: Body weight ratio, average weight of persons/average weight of adults
D: Number of regular days (= 365 – number of long holidays))
R: Toilet usage ratio (percentage of toilet use connected to the digester)

The value O depends on the student age. For high schools, 0.8 was applied. The value D was estimated with school holidays when students and teachers are absent. In this study, 0.75 was applied. The value R was estimated with assumption of how often the toilet connected with digester is used, when different types of toilets, which are not connected to a digester, are installed in a facility. This value was determined by interviews on situation of respective school (0.3-0.75).

- Energy and demand analysis: Energy usage and energy demand in the target facility was assessed by collecting data of monthly electricity bills and amount of actual usage of fuel wood.
- Benefit analysis: The benefit of biogas system consists of fuel wood saving and electricity saving, and can be calculated by the amount of saved fuel wood and/or electricity. The benefit of fuel wood saving was calculated with the following formula:

$$S_f = \frac{(V_{cw}+V_{hw})\times C_{gas}}{C_{wood}/E_{stove}} \quad , \qquad B_f = S_f \times P_{wood}$$

Where, S_f: Saved amount of fuel wood by biogas (tons/year)
V_{cw} and V_{hw} : Biogas volume V_c and V_h allocated for cooking fuel saving (m^3)
C_{gas}: Calorific value of produced biogas (MJ/m^3)
C_{wood}: Calorific value of fuel wood (MJ/ton)
E_{stove}: Efficiency of cooking stove
B_f: Benefit of fuel wood saving (Ksh)
P_{wood}: Price of fuel wood (Ksh/ton)

Here, calorific value of produced biogas 20 MJ/m^3 (M. Kaltschmittm, 2003) was applied for C_{gas}. The calorific value of fuel wood, C_{wood}, is variable depending on moisture percentage and condition of wood. For dry wood, the value is indicated to be 0.019-0.0225 MJ/ton (Hubbard W., et al., 2007). The value of 0.02 is applied in this study. E_{stove} value depends on the actual cooking stove type that the facility uses, and 10% (N.Shrestha, 2001) is applied for E_{stove} here. Fuel wood price, P_{wood}, is also variable depending on local condition, and was set to be 3,300 kSh/ton from local interviews.

The benefit of electricity saving is calculated with the following formula.

$$E_g = G_e \times (V_{ce} + V_{he}), \qquad B_e = T \times E_g$$

Where, E_g: Saved amount of electric energy (kWh)
V_{ce} and V_{he} : Volume of biogas V_c and V_h allocated for electricity saving (m^3)
G_e: Efficiency of biogas generator (kWh/m^3)
B_e: Benefit of electricity saving (Ksh.)
T: Power tariff rate (Ksh./kWh)

The efficiency of biogas generator, G_e depends on specification of biogas engine generator. Here, 1.0 kWh/m^3 was applied according to manufactures' specification in the past project. T, tariff rate is determined with actual monthly bills of the respective facilities, which was 8.7-19.9 Ksh/kWh.

i) System design: System design layout was prepared according to sketches in the survey. The size of digester was determined with the following formula (Gunter U et al., 2011 and Martin G et al, 2012)

$$V_{dc} = 1.89 \times N_c \quad , \qquad V_{dh} = 0.1 \times N_h$$

Where, V_{dc}: Volume of cow dung digester (m^3)
V_{dh}: Volume of human waste digester (m^3)

The size of generator was determined according to required specific load demands such as water pump or lighting.

ii) Cost estimation: The cost of biogas system was estimated by unit cost estimation with quantity or capacity in the past result of REA biogas projects.

iii) Financial and Economic Evaluation: The financial benefit is the same as what was estimated in the benefit assessment. The total economic benefit B_{teb} is calculated with the following formula.

$$B_{teb} = B_{ed} + B_{cr} + B_f + B_{fab} + B_{fco} + B_{fev}$$

The meanings of respective benefit items are explained in the table below.

Table 2.1 Economic Benefit

B	Type of Economic Benefit	Explanation
B_{eb}	Benefit as electricity saving from diesel oil	When electricity is generated using biogas, the electric energy can be considered to save electricity from grid-connected diesel generation system in grid, since diesel generation is the most expensive method. The cost of electricity from diesel generation can be considered as economic benefit in place of grid electricity tariff, different from financial benefit. Diesel Oil Price 110.00 KSh/L and Diesel efficiency 2.40 kWh/L was applied.
B_{cr}	Benefit of carbon reduction by biogas generation	CO_2 emission reduction is expected from biogas generation since it replaces energy from diesel generation. Emission factor of diesel oil can be applied to calculate economic benefit. Emission factor of electricity 0.81805 ton-CO_2/MWh and 1,294 KSh/ton-CO_2 was applied (with exchange rate 86.28 KSh/US$).
B_f	Benefit from fuelwood saving	The benefit is the same as financial benefit of fuel wood saving.
B_{fab}	Fuelwood carbon absorption benefit	Saved fuel wood by biogas can absorb CO_2 in a forest. The carbon credit with the absorption of CO_2 amount is considered to be economic benefit.
B_{fco}	Fuelwood carbon off-set benefit	As well as electricity, saved amount of fuelwood is considered to replace coal, and corresponding amount of CO_2 from the replaced coal. This is considered to be economic benefit of carbon reduction.
B_{fev}	Fuel wood economic value to prevent deforestation	Saving of losses in economic sectors resulting from deforestation is counted as economic benefit. The components of this economic value are: growing of crops and horticulture, fishing, water supply, public administration and defense, deforestation effects on carbon sequestration, and deforestation effects on health, which was quantified as much as 921,165 KSh/ha (Jackie C, 2012).

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CHAPTER 3 SUMMARY RESULT OF SURVEY OF SIX CANDIDATE SITES

The result of site survey jointly prepared with REA staff is summarized in the following tables.

Table 3.1 Summary Result of Site Survey of Six Biogas Project Sites

Confirmation Item	Unit	Nyeri High School	Rware High School	Litein High School
Date of site survey		23 May 2013	23 May 2013	18 June 2013
Location (County, sublocation, location, village)		Nyeri County	Nyeri County	Rift Valley, Kericho
Coordinate (Latitude, longitude, elevation)		N° 24.499', E36° 55.159', EL1844m	N° 24.793', E36° 57.323', EL1786m	N 0° 35' 21.8", E35° 11'11.5", EL1944m
Distance from Nairobi		168 km (paved, except last 1 km)	158 km (paved)	264 km
Grid connected?, Nearest grid connection in km		Yes	Yes	Yes
Financed by		Missionary, government, PTA	Government	Missionary, Government
Establishment year		1924	1985	1964
Nos of cows	nos	5 cows, 1 medium, 4 small, total 10. 2 cows in different cow shed. Possible to increase.	9 cows	12 cows, zero-grazing, possible 5 more cows
Nos of pigs or nos of poultry	nos	NA	NA	none
Nos of students (total)	nos	950 students (all boarding)	400 boys, 200 girls, total 600 students	1015
Nos of students (boarding, period of boarding)	nos	950 students, 13 weeks leave/yr	none (all daily students)	1015, 9 months/yr
Nos of teacher and staff	nos	40 teaches and 30 non-teaching staff	25 teachers and 15 non-teaching staffs	53 teachers and 80 staffs
Nos of teacher (living)	nos	40 teaches and 30 non-teaching staff	None	
Water usage for toilet cleaning	L/day, t/day	30 t/day		
Garden or cultivation near the site		Napier(5acre), sweet potato(0.5acre), Maize(0.25acre), glass(2acre), Tilapia fish pond Feeding 2 t/day	bean, banana, grass land, total 2 acres	Sukuma, egg plant, 1.5 acre
Electricity usage	kWh/mon	TBA	Approx. 1000 kWh/mo	Water pump: 2,089 kWh (Feb-13) School: 663 kWh (Feb-13)
Electricity tariff payment record (invoice for several months)	Ksh/mon	Ave. 130,000 Ksh/mo, 5000 kWh/mo 149,931 KSh with 7,605 kWh (Mar 13)	8974 KSh with 1028 kWh (Feb 13)	Water pump: 37,819 Ksh/m, 18.1 KSh/kWh School: 12,094 kWh/m, 18.2 KSh/kWh
Current use of electric/heat appliance (type, hours) Light, PC, mobile charge, TV, radio, cooking heater, other		General electric appliance, lighting Total 59 nos of 36W FL bulb in dorm.	General administration, lighting, cooking. PC is planned to be installed.	Light, PC, copier, Posho mill
Diesel generator and oil for generation, if any, cost	L/day, L/mon	38.5 kVA, 480L/year	None	20 kVA, temporary use
Type of fuel for cooking (Fuel wood, LPG, etc)		Fuel wood, LPG (45kg/term)	Fire wood.	7 fuel wood stoves
Current usage of fuel wood, cost	kg/day, t/mon	300 t/year, 792,857 KSh/year	42 t/term, 3300 Ksh/t -> 415,800Ksh/yr	300 kg/d, 88.2 t/yr
Current usage of LPG, cost	cylinder/mon	TBA	None	Occasional for lab
Current usage of other fuel		Boiler by firewood	None	None
Source of water supply (pump, etc.)		Municipal water, gravity from river 12 away	Municipal water	Water pump installed 700m away
Type of lighting		Electricity	Electricity	CFL
Priority usage of gas (electricity, fuel, etc)		1) cooking fuel, 2) lighting for dormitory and night class	1) cooking fuel	Fuel wood saving
Proposed digester size		32 m3 for cow dung, 60m3 for toilet	24 m3 x 1	32 m3 for cow dung, 60m3 for toilet
Proposed generation system		5 kW (7kVA) biogas generator	NA (cooking fuel supply only)	15 kW (20 kVA) biogas generator
Other Remarks		Japanese assistance for Math and Science was taken in 2004 through Min of Education. 22 buildings of Teacher Quarter.		- Cow is zero-grazing. Cow shed with no trench is located too far a way (300-400m). Move or long pipeline is necessary. - Toilet is pit latrine. Improvement to septic tank is necessary. - Capacity of pump needs to be confirmed

Confirmation Item	Unit	Kipsigis Girls High School	Mukumu Girls High School	Cardinal Otunga High School
Date of site survey		18 June 2013	19 June 2013	19 June 2013
Name of the facility		Kipsigis Girls High School	Mukumu Girls High School	Cardinal Otunga High School
Location (County, sublocation, location, village)		Rift Valley, Kericho	Western, Kakamega	Nyanza, Kisii
Coordinate (Latitude, longitude, elevation)		N 0° 22' 49.2", E35° 14'58.8", EL1971m	N 0° 12' 56.9", E34° 46'05.9", EL1533m	N 0° 12' 56.6", E34° 46'05.3", EL1523m
Distance from Nairobi		265 km	430 km	385 km
Grid connected?, Nearest grid connection in km		Yes	Yes	Yes
Financed by		Government	Mission school	Catholic sponsored mission school
Establishment year		1955	1959	
Nos of cows	nos	4 cows, possible to increase, not zero-grazed	9 cows, not zero-grazed. 5-14:00 grazing.	8 cows, not zero-grazed (2-4pm grazing), 50 pigs
Nos of pigs or nos of poultry	nos			
Nos of students (total)	nos	900	1248	1000
Nos of students (boarding, period of boarding)	nos	900	1248	1000
Nos of teacher and staff	nos		45 teachers and 42 staffs	63 teachers and 55 staffs
Nos of teacher (living)	nos		18 teachers	
Type of toilet		Two septic tanks (2.5x6m, 3x9m)	Septic tanks 4x10m	Pit latrine, new toilet with septic tank to be installed
Raw waste material (food, vegetable waste, etc)		Kitchen vegetable waste	Kitchen vegetable waste	
Electricity usage	kWh/mon	4,472 kWh (May-13)	School:2,791 kWh (May-13) Pump: 2,954 kWh (May-13)	School:1519 kWh (Apr-13) Pump: 598 kWh (Apr-13)
Electricity tariff payment record (invoice for several months)	Ksh/mon	86,968 KSh (May-13), 19.5 KSh/kWh	School: 49,983 Ksh(May-13), 17.9 KSh/kWh Pump:52,894 KSh (May-13), 17.9 KSh/kWh	School: 30,212 Ksh(Apr-13), 19.9 KSh/kWh Pump:11,746kSh (Apr-13), 19.6 KSh/kWh
Current use of electric/heat appliance (type, hours) Light, PC, mobile charge, TV, radio, cooking heater, other		Light, 11 PCs , copier, kettle	Light, PC, copier, Printer, 2 fridges, water pump	Light, PC, copier, Posho mill
Diesel generator and oil for generation, if any, cost	L/day, L/mon	Available in the past. Power house available.	DG installed. 13.5 kVA	52 kW, automatic changeover for blackout
Type of fuel for cooking (Fuel wood, LPG, etc)		6 fuel wood stoves, 1 middle stove	13 fuelwood stoves, 2 charcoal stoves	6 firewood stoves
Current usage of fuel wood, cost	kg/day, t/mon	2 tractors/d	50 tons/yr, 225,000 KSh/year	1 mil Ksh/yr in 2011. Now self supply
Current usage of LPG, cost	cylinder/mon	Lab use only	Labs and home science, 26,000 KSh/term	Lab
Current usage of other fuel		None	Charcoal 20x50kg/term, Dec 15x50/m, 1000Ksh/50kg	None
Source of water supply (pump, etc.)		Municipal water (no pump)	Water pump installed in 1999. 20hp or 20 kW	Water pump. Water tank tower installed.
Type of lighting		CFL	CFL	CFL
Priority usage of gas (electricity, fuel, etc)		Fuel wood and electricity	Fuel wood and electricity	Fuel wood and electricity
Proposed digester size		16 m3 for cow dung, 50m3 for toilet	28 m3 for cow dung, 60m3 for toilet	32 m3 for cow dung, 60m3 for toilet
Proposed generation system				
Other Remarks		-Strategic Plan 2010-14 includes introduction of biogas. - Willingness is high and ready for project - Dormitory lighting: 13 dorms buildings (13x40W FL+ 2x8W FL/dorm). 21:30-4:00 - 20nos classroom, 3 labs, 1 PC room - All toilets are collected to same septic tank	- Discharge pipe for Bath room and Toilet are same. It needs separation. - Outside pit latrine is used for daytime - Cows possible to increase up to 15. - Pump manager available for O&M.	- Toilet roof need replacement every 7 months due to gas. Toilet 6 times/year drainage required, 15,000 KSh each time. - Lighting required in 14 dorms - New dorm toilet will be installed in Dec 2013. - Land area 50 acres - Every Tuesday 2-9 pm blackout.

Prepared by JET

According to the survey result, the following works were conducted in the basic planning with transferring methodology to the counterpart staff.

- Determination of biogas digester size
- Assumption of feedstock input amount
- Preparation of draft layout of the system
- Estimation of possible biogas production
- Determination of capacity of generator and possible amount of electric energy generation
- Estimation of possible firewood amount saving by biogas
- Calculation of financial benefit
- Cost estimation
- Financial analysis and economic analysis

CHAPTER 4 SITE SURVEY RESULT

4.1 Site Survey of Nyeri High School

4.1.1 Purpose of the Project of Nyeri High School

The School consumes large amount of both electricity and fuel wood to support life of children in boarding. Electricity is consumed especially for lighting of night class and boarding of students. Fuel wood is consumed at 300ton/year for daily meals for students and teachers. The financial burden of electricity is about 1.5 mil KSh/year and that of fuel wood is 0.8mil KSh/Year Electricity supply by biogas can contribute the mitigation of electricity and fuel wood usage in the school.

Nyeri High School has students from all over the country. Students can learn the effectiveness of biogas system. They can be a human resource for the promotion of renewable energy in Kenya.

The school has shown willingness to implement the project, including commitment to participate construction supervising and operation and maintenance.

4.1.2 Particular Features of Nyeri High School

The outline other than above table is as follows.

- The school was established as a missionary school in 1924, and reformed as high school in 1950’s.
- The school received Japanese ODA activity for mathematics and science in 2004 through Ministry of Education.
- All the 950 student stays in the school.
- Diesel generator was installed as a back up, it is however not used frequently.
- The school started fishpond project a few months ago rearing tilapia fingerlings. The school garden utilizes raw manure from the cowshed and grey water from the kitchen to grow nappier grass, maize and sweet potatoes

Organization structure is shown below.

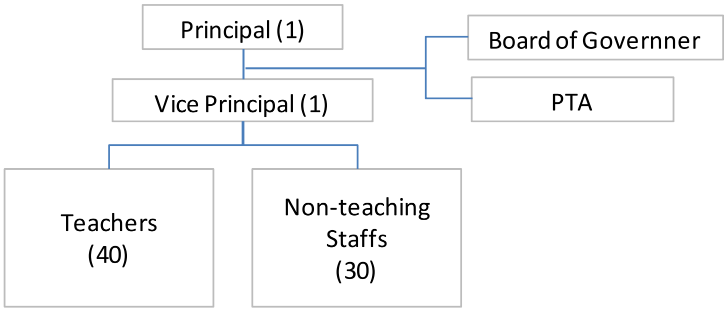

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Figure 4.1 Structure of Nyeri High School

4.1.3 Preliminary Design

The demand for biogas is (i) cooking fuel and (ii) electricity for nighttime lighting in boarding buildings. The proposed system is as follows:

- Digester: 32 m^3 for cow dung, 60m^3 for toilet of boarding
- Generator : 5 kW (7 kVA), exclusive load for nighttime lighting in boarding (59 nos of 36W)
- Gas bag: 40 m^3
- Total gas production: 12 m^3 + 15 m^3 = 27 m^3/day

Table 4.1 Estimation of Cow Dung Digester for Nyeri High School

Description	Qty	Unit	Remarks
Nos of cows	17		to be increased from 10 nos
Digester size	32	m3	
Assumed feedstock input	400	kg/day	
Possible gas production	12	m3/day	
Generated energy	12	kWh	1kWh/m3
Electric energy demand	8.5	kWh	Light, 59 nos of 36W, 4hrs

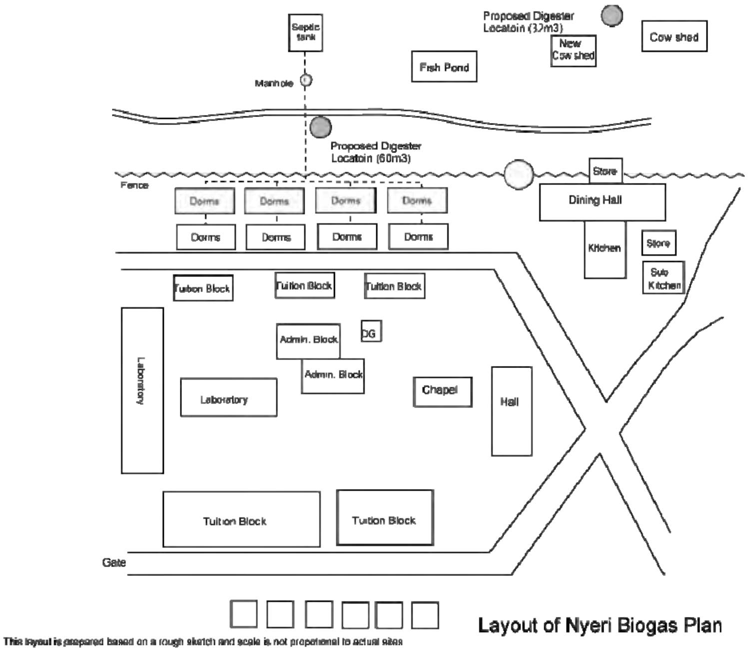
Prepared by JET

Table 4.2 Estimation of Human Waste Digester for Nyeri High School

Description	Value	Unit
Utilization ratio	**0.54**	
Boarding toilet usage ratio	0.67	
Student/adult weight	0.80	
Nos of student utilizing dorm toilet	950	nos
Converted nos of person for biogas	509	nos
Digester volume	**60**	**m3**
Gasproduction amount	**15.3**	**m3/day**

Prepared by JET

- Digester for cow dung can be located at garden area below cow shed. It can utilize gravity flow to transport cow dung and urine. Supply of effluent to garden is also possible by gravity.
- Two digesters can be connected to one gasbag. The bag will supply the biogas to (i) cooking stove and (ii) biogas generator.



Prepared by JET

Figure 4.2 Layout of Nyeri Biogas Plan

4.1.4 Energy Production and Demand Assessment of Nyeri High School

The aspects of energy production and demand assessment are as follows.

- Firewood is purchased locally through tender. Consumption is about 300 ton/year which cost is approximately 0.8 mil KSh/year.
- The electricity consumption is about 5000 kWh/month and 130,000 KSh/month.
- It is planned to install digesters both for cooking fuel supply and electricity supply. lighting for class room is a stable load, which can be supplied by biogas generator.
- Total expected amount of gas production is 8,568 m^3/year, of which 2,321 m3 is used for generation and 6,428m^3 is used for cooking stove.
- Amount of electricity saving will be 2,321 kWh and amount of fuel saving will be 36.3 ton/year. This corresponds to 4% of total electricity usage and 12% of fuel wood.

Table 4.3 Estimation of Biogas Usage for Electricity and Fuel Wood Saving

Item	Value	Unit	Note
Annual biogas production from cow dung	4,380	m3/yr	365 days, 12m3/day
Annual biogas production from toilet	4,188	m3/yr	273 days, 15.3 m3/day
Total amount of gas production	8,568	m3/yr	
Biogas used for generation energy	**2,321**	**kWh/yr**	273 days, 8.5 kWh
Biogas used for cooking fuel	6,248	m3/yr	
Calorific value of biogas for cooking fuel	20	MJ	
Efficiency of biogas stove	45	%	
Efficiency of fuelwood stove	10	%	
Calorific value of fuelwood	15.5	MJ /kg	
Amount of fuelwood reduction	**36.3**	**ton/yr**	

Prepared by JET

4.1.5 Benefit Assessment of Nyeri High School

The aspects of benefit assessment are as follows.

- When unit cost of electricity is 26 KSh/kWh, the annual saving will be 60,333 KSh/year for electricity.
- When unit cost of fuel wood is 3,300 KSh/ton, annual saving for fuel wood will be 119,717 KSh.
- In total, the annual benefit of biogas system will be 180,050 KSh/year.

Table 4.4 Estimation of Benefit for Biogas System Installation

Item	Value	Unit
Unit cost of kWh electricity	26	KSh/kWh
Cost benefit of electricity saving	60,333	Ksh/yr
Unit cost of ton fuelwood	3300	KSh/ton
Cost benefit of fuelwood saving	119,717	KSh
Total benefit of biogas system	**180,050**	**Ksh/yr**
Unit benefit per m3 for electricity	26.0	KSh/m3
Unit benefit per m3 of fuelwood	19.2	KSh/m3

Prepared by JET

4.2 Rware High School

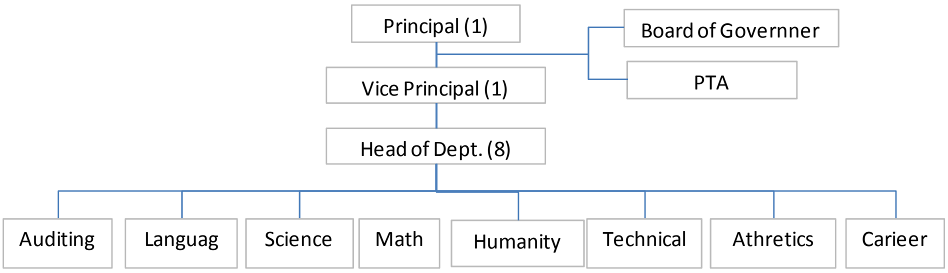
4.2.1 Purpose of the Project of Rware High School

Rware High School is a day school. Large amount of fuel wood is consumed to offer meals for students and teachers. The school has shown interest in install biogas system to reduce the usage of fuel wood. They have a proposed design. Although it is located in town area, the size of the school is typical for rural area.

4.2.2 Particular Features of the School of Rware High School

The outline other than above table is as follows.

- The school is day school and there is no boarding student. The nos of student is 600.
- Primary school is located behind the school.
- There is need to hire a operator from outside for biogas system operation.
- The structure of the school is shown below.
- Toilets are all pit latrine and there is no septic tank.



Prepared by JET

Figure 4.3 Structure of Rware High School

4.2.3 Preliminary Design of Rware High School

The demand for biogas is (i) cooking fuel and (ii) electricity. The consumption of the electricity in the school is about 1000 kWh and the unit cost of electricity is about 9 KSh/kWh. Since the tariff value for electricity is low, it is considered that benefit from electricity saving is small. Accordingly, the system will apply the biogas for cooking fuel only.

Girl's toilet is located near the cow shed. Utilization of girl's toilet is one option to increase amount of gas. However, if the effluent is directly used as the fertilizer of the garden, connection from the toilet is not recommended.

- Digester: 24 m^3 for cow dung (gas bag type digester can also be considered)
- Gas bag: 20 m^3
- Recommended application: biogas burner

Table 4.5 Estimation of Cow Dung Digester for Rware School

Description	Qty	Unit	Remarks
Nos of cows	13		to be increased from 9 nos
Digester size	24	m3	
Assumed feedstock input	300	kg/day	
Possible gas production	9	m3/day	

Prepared by JET

4.2.4 Energy Production and Demand Assessment of Rware High School

The aspects for energy production and demand assessment are as follows:

- Fuelwood is locally procured by tender at 3,300 KSh/ton.
- The annual biogas production is 3,285 m3. This corresponds to 19.1 ton of fuelwood when the efficiency of the current fuelwood stove is 10%.

Table 4.6 Estimation of Fuelwood Saving for Rware High School

Item	Value	Unit	Note
Annual biogas production from cow dung	3,285	m3/yr	365 days, 9m3/day
Biogas used for cooking fuel	3,285	m3/yr	
Calorific value of biogas for cooking fuel	20	MJ	
Efficiency of biogas stove	45	%	
Efficiency of fuelwood stove	10	%	
Calorific value of fuelwood	15.5	MJ /kg	
Amount of fuelwood reduction	**19.1**	**ton/yr**	

Prepared by JET

4.2.5 Benefit Assessment of Rware High School

When unit cost of fuel wood is 3,300 KSh/ton, annual saving for fuel wood will be about 62,900 KSh.

Table 4.7 Estimation of Benefit for Biogas System Installation

Item	Value	Unit
Unit cost of ton fuelwood	3300	KSh/ton
Cost benefit of fuelwood saving	62,945	KSh
Unit benefit per m3 of fuelwood	19.2	KSh/m3

Prepared by JET

4.3 Litein High School

4.3.1 Purpose of the Project and Justification of Selection of Litein High School

The school consumes large amount of fuel wood 300 kg/day or 88.2 ton/year and electricity as much as 12,000 kWh/month. The main load of electricity is water pump. The biogas system will be possible to reduce the consumption of fuel wood and electricity. Diesel engine is installed to supply electricity in the night time power cut, and biogas system could provide electricity during power cut.

4.3.2 Particular Features of the School of Litein High School

The particular features other than above table are as follows.

- The toilet are pit latrine and requires trench toilets to be re-constructed to obtain human waste as feed stock. Installation of septic tank will also be required, unless effluent is managed for supplying garden fertilizer.
- Cows are zero-grazed. The shed is located far away from load center. Shifting of cow shed near load center or 300-400m pipe or cable to transport gas or electricity is necessary. Cow shed has with no trench and its construction is required.
- 20 kVA Diesel generator is used occasionally. Fuel consumption per month is approximately 40litre.
- Water pump is installed 700 m away from the school. Voltage drop for this distance is a major concerned to supply from biogas system. Capacity of the pump is 5.5 hp
- Additional cost for toilet construction, long gas line pipes, and distribution line will be done. This will increase implementation cost.

4.3.3 Preliminary Design of Litein High School

The demand for biogas is (i) cooking fuel, (ii) electricity for nighttime lighting in boarding building, and (iii) water pump. The proposed system is as follows:

- Digester: 32 m^3 for cow dung to supply electricity, 60m^3 for boarding toilet to supply cooking fuel
- Generator : 20 kVA for pump (700 m away)
- Gas bag: 20 m^3 + 20 m^3
- Total gas production: 12 m^3 (from cow) + 16 m^3 (from toilet) = 28 m^3/day

Table 4.8 Estimation of Cow Dung Digester for Litein High School

Description	Qty	Unit	Remarks
Nos of cows	17	nos	12cows, 5 to be added, zero-grazing
Digester size	32	m3	
Assumed feedstock input	400	kg/day	
Possible gas production	12	m3/day	
Generated energy	12	kWh	1kWh/m3
Electric energy demand	40	kWh	20 kW x 2 hours

Prepared by JET

- Trench construction is necessary for connecting cowshed to digester.
- The digester is proposed to connect to biogas generator, which will provide to the water pump 700 m away from the school.

Table 4.9 Estimation of Human Waste Digester for Litein High School

Description	Value	Unit
Utilization ratio	**0.54**	
Boarding toilet usage ratio	0.67	
Student/adult weight	0.80	
Nos of student utilizing dorm toilet	1015	nos
Converted nos of person for biogas	544	nos
Digester volume	**60**	**m3**
Gasproduction amount	**16.3**	**m3/day**

Prepared by JET

New construction of septic tank and trench toilet is necessary. Effluent from human waste digester requires to connect to new septic tank, for easy management.

4.3.4 Energy Production and Demand Assessment of Litein High School

The energy and demand assessment of Litein HS is as follows:

- The electricity consumption for water pump is 2,089 kWh/month and for school is 663 kWh/month as of February 2013.
- Due to the proximity to the water pump, the digester using cowdung should generate electricity to pump water, while the one using the human waste should be constructed near the kitchen to supply for cooking fuel.
- Total expected amount of gas production is 8,846 m^3/year, of which 4,380 m^3 would be used for generation and 4,466 m^3 for cooking stove.
- Amount of electricity saving will be 4.380 kWh/year and 25.9 ton/year fuel wood. This corresponds to 17% of total electricity usage and 29% of fuel wood saving in the school.

Table 4.10 Estimation of Biogas Usage for Electricity and Fuel Wood Saving

Item	Value	Unit	Note
Annual biogas production from cow dung	4,380	m3/yr	365 days, 12m3/day
Annual biogas production from toilet	4,466	m3/yr	274 days, 16.3 m3/day
Total amount of gas production	8,846	m3/yr	
Biogas used for generation energy	**4,380**	**kWh/yr**	from electricity bill Feb-13
Biogas used for cooking fuel	4,466	m3/yr	
Calorific value of biogas for cooking fuel	20	MJ	
Efficiency of biogas stove	45	%	
Efficiency of fuelwood stove	10	%	
Calorific value of fuelwood	15.5	MJ /kg	
Amount of fuelwood reduction	**25.9**	**ton/yr**	

Prepared by JET

4.3.5 Benefit Assessment of Litein High School

The aspects of benefit assessment are as follows:

- When unit cost of electricity is 18.1 KSh/kWh, the annual saving will be 79,278 KSh/year for electricity.
- When unit cost of fuel wood is 3,300 KSh/ton, annual saving for fuel wood will be 85,578 KSh.
- In total, the annual benefit of biogas system will be 164,856 KSh/year.

Table 4.11 Estimation of Benefit for Biogas System Installation

Item	Value	Unit	Note
Unit cost of ton fuelwood	3300	KSh/ton	Not known in this school
Unit cost of unit electricity	18.1	KSh/kWh	from electricity bill Feb-13
Benefit of saving electricity	79,278	KSh/yr	
Benefit of fuel wood saving	85,578	KSh/yr	
Total benefit	164,856	KSh/yr	

Prepared by JET

4.4 Kipsigis Girls High School

4.4.1 Purpose of the Project and Justification of Selection of Kipsigis Girls High School

The school in its 2010-14 strategic plan has proposed installation of biogas system in the school. This indicates a high sense of ownership for the project. The school requires nighttime dormitory lighting and to reduce fuel wood.

4.4.2 Particular Features of the School of Kipsigis Girls High School

The particular features other than above table are as follows.

- The school has 13 blocks of dormitory and requires 13 nos x 40W Fluorescent Light and 2 x 8W Fluorescent Light for each building. This is the major requirement for electricity supply.
- The school has 20 number of classroom, 3 labs, and 1 PC room.
- All toilets are connected to the same septic tank. Utilization of all human waste is possible. However, it is important to understand the sewer network in the school to locate the best location of digester.
- Six fuel wood stoves and one middle size stove is installed for cooking.
- Diesel generator was once used but not in operation anymore. Discussions can be initiated with the school to see possibilities of using the generator house for biogas generation system.
- Water is supplied from municipal water. No pump is installed.

4.4.3 Preliminary Design of Kipsigis Girls High School

The demand for biogas is (i) cooking fuel, (ii) electricity for nighttime lighting in boarding building. The proposed system is as follows:

- Digester: 16 m^3 for cow dung for cooking fuel, 50m^3 for boarding toilet for electricity
- Generator : 12 kVA for night time lighting
- Gas bag: 10 m^3 + 20 m^3
- Total gas production: 4.2 m^3 (from cow) + 18.9 m^3 (from toilet) = 23.1 m^3/day

Table 4.12 Estimation of Cow Dung Digester for Kipsigis Girls High School

Description	Qty	Unit	Remarks
Nos of cows	9		now 4 cows, not zero-grazed.
Digester size	16	m3	
Assumed feedstock input	200	kg/day	
Possible gas production	4.2	m3/day	0.7 utilization ratio is applied.

Prepared by JET

- Since the Cows are not zero-grazed. 0.7 utilization ratio will be applied.
- The digester was proposed to be connected to the kitchen. This, however, is not possible since the number of cows and production amount of biogas is small.

Table 4.13 Estimation of Human Waste Digester for Kipsigis Girls High School

Description	Value	Unit
Utilization ratio	**0.70**	
Boarding toilet usage ratio	1.00	
Student/adult weight	0.70	
Nos of student utilizing dorm toilet	900	nos
Converted nos of person for biogas	630	nos
Digester volume	**70**	**m3**
Gasproduction amount	**18.9**	**m3/day**
Generated energy	18.9	kWh/day
Peak demand	6.9	kW
Electric energy demand	51.75	kWh

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The digester is connected to generator to supply electricity of night time boarding building.

4.4.4 Energy Production and Demand Assessment of Kipsigis Girls High School

The aspects of energy production and demand assessment are as follows:

- The electricity consumption for whole school except teachers quarter is 4,472 kWh/month and the tariff was 86,968 KSh as of May 2013.
- It is planned to install digester using cow dung for cooking fuel saving and digester using human waste to supply electricity for nighttime lighting.
- Total expected amount of gas production is 5,013 m^3/year, of which 3,480 m^3 is used for generation and 1,533 m^3year is used for cooking stove.
- Amount of electricity saving will be 5179 kWh/year and amount of fuel saving will be 8.9 ton/year. This corresponds to 10.3% of total electricity usage, and 11% of fuel wood saving in the school if the school consumes 300 kg/day fuel wood (reportedly, their consumption is 2 tractors/day, and actual amount of usage is unknown) and the number of cows is increased to 9.

Table 4.14 Estimation of Biogas Usage for Electricity and Fuel Wood Saving

Item	Value	Unit	Note
Annual biogas production from cow dung	1,533	m3/yr	365 days, 4.2m3/day
Annual biogas production from toilet	5,179	m3/yr	274 days, 18.9 m3/day
Total amount of gas production	6,712	m3/yr	
Biogas used for generation energy	**5,179**	**kWh/yr**	from electricity bill Feb-13
Biogas used for cooking fuel	1,533	m3/yr	
Calorific value of biogas for cooking fuel	20	MJ	
Efficiency of biogas stove	45	%	
Efficiency of fuelwood stove	10	%	
Calorific value of fuelwood	15.5	MJ /kg	
Amount of fuelwood reduction	**8.9**	**ton/yr**	

Prepared by JET

4.4.5 Benefit Assessment of Kipsigis Girls High School

The aspects of benefit assessment are as follows:

- When unit cost of electricity is 19.5 KSh/kWh, the annual saving will be 100,983 KSh/year for electricity.
- When unit cost of fuel wood is 3,300 KSh/ton, annual saving for fuel wood will be 29,394 KSh.
- In total, the annual benefit of biogas system will be 130,357 KSh/year.

Table 4.15 Estimation of Benefit for Biogas System Installation

Item	Value	Unit	Note
Unit cost of ton fuelwood	3300	KSh/ton	Not known in this school
Unit cost of unit electricity	19.5	KSh/kWh	from electricity bill May-13
Benefit of saving electricity	100,983	KSh/yr	
Benefit of fuel wood saving	29,374	KSh/yr	
Total benefit	130,357	KSh/yr	

Prepared by JET

4.5 Mukumu Girls High School

4.5.1 Purpose of the Project and Justification of Selection of Mukumu Girls High School

The school is utilizing electricity for daily school demand and water pump. It consumes fuel wood and charcoal for energy demand. Biogas system is preferred to reduce electricity and fuel consumption.

4.5.2 Particular Features of the School of Mukumu Girls High School

The particular features other than above table are as follows.

- The school had the project to install water pump of 20 kW or 20 hp. Pump manager available for O&M of the biogas system.
- The school started fish pond and pig farming, and aims for self-supply of food.
- Discharge pipe line for bath room and toilet are same. It needs to obtain pipe line alignment sketch and need separation work. Outside pit latrine is used for daytime.
- Number of cow is currently 9. They are confined between 5:00-14:00, then allowed to graze in the afternoon. the current number is most likely to increase to 15.

4.5.3 Preliminary Design of Mukumu Girls High School

The demand for biogas is (i) cooking fuel, (ii) electricity for nighttime lighting in boarding building., and (iii) Water pump. The proposed system is as follows:

- Digester: 28 m^3 for cow dung for cooking fuel, 60 m^3 for boarding toilet for electricity
- Generator : 20 kW for pump (400 m away)
- Gas bag: 15 m^3 + 35 m^3
- Total gas production: 7.3 m^3 (from cow) + 17.6 m^3 (from toilet) = 24.9 m^3/day

Table 4.16 Estimation of Cow Dung Digester for Mukumu Girls High School

Description	Qty	Unit	Remarks
Nos of cows	15		to be increased from 9 nos
Digester size	28	m3	
Assumed feedstock input	350	kg/day	
Possible gas production	7.35	m3/day	Not zero-grazed. 0.7 utilization is applied.
Generated energy	7.35	kWh	1kWh/m3
Peak demand	20	kW	may be 20 hp
Electric energy demand	40	kWh	

Prepared by JET

Digester for cow dung is connected from cow shed. Cow is not zero-grazed. 0.7 utilization ratio will be applied. Current nos of cows is 9, and 15 cows are considered for planning with scope of increase.

The digester is to be connected to the biogas generator for supply energy of pump. Load of water pump is 300-400m away from cow shed. It needs consideration for voltage drop in the design.

Table 4.17 Estimation of Human Waste Digester for Mukumu Girls High School

Description	Value	Unit
Utilization ratio	**0.47**	
Boarding toilet usage ratio	0.67	
Student/adult weight	0.70	
Nos of student utilizing dorm toilet	1248	nos
Converted nos of person for biogas	585	nos
Digester volume	**60**	**m3**
Gasproduction amount	**17.6**	**m3/day**

Prepared by JET

The digester is connected to the kitchen for saving cooking fuel.

4.5.4 Energy Production and Demand Assessment of Mukumu Girls High School

The aspects of energy production and demand assessment are as follows:

- The electricity consumption for whole school except teachers quarter is 2,791 kWh/month and the tariff was 49,983 KSh and for water pump was 2,954 kWh/month and 52,984 kSh as of May 2013.
- It is planned to install digester of cow dung for electricity supply for water pump and digester of toilet for cooking fuel supply. This is due to proximities to load centre.
- Total expected amount of gas production is 7,505 m^3/year, of which 2,683 m^3 is used for generation and 4,822 m^3year is used for cooking stove.
- Amount of electricity saving will be 2,683 kWh/year and 28 ton/year fuel saving. This corresponds to 7.6% of pump electricity usage, and 35% of fuel wood.

Table 4.18 Estimation of Biogas Usage for Electricity and Fuel Wood Saving

Item	Value	Unit	Note
Annual biogas production from cow dung	2,683	m3/yr	365 days, 7.35m3/day
Annual biogas production from toilet	4,822	m3/yr	274 days, 17.6 m3/day
Total amount of gas production	7,505	m3/yr	
Biogas used for generation energy	**2,683**	**kWh/yr**	from electricity bill Feb-13
Biogas used for cooking fuel	4,822	m3/yr	
Calorific value of biogas for cooking fuel	20	MJ	
Efficiency of biogas stove	45	%	
Efficiency of fuelwood stove	10	%	
Calorific value of fuelwood	15.5	MJ /kg	
Amount of fuelwood reduction	**28.0**	**ton/yr**	

Prepared by JET

4.5.5 Benefit Assessment

The aspects of energy production and demand assessment are as follows:

- When unit cost of electricity is 17.9 KSh/kWh, the annual saving will be 48,021 KSh/year for electricity.
- When unit cost of fuel wood is 4,500 KSh/ton, annual saving for fuel wood will be 126,005 KSh.
- In total, the annual benefit of biogas system will be 174,026 KSh/year.
- The fuel wood purchase in this school is high, as much as 4,500 KSh/ton. This corresponds to 26.1 KSh/m3 of the value of biogas, which is considered to be higher than electricity value. Accordingly, to use all biogas including from cow shed for fuelwood saving will increase the annual benefit. However, since cow shed is located very far a way from kitchen, it would be difficult unless another kitchen is build near cow shed.

Table 4.19 Estimation of Benefit for Biogas System Installation

Item	Value	Unit	Note
Unit cost of ton fuelwood	4500	KSh/ton	Tender result
Unit cost of unit electricity	17.9	KSh/kWh	from electricity bill May-13
Benefit of saving electricity	48,021	KSh/yr	
Benefit of fuel wood saving	126,005	KSh/yr	
Total benefit	174,026	KSh/yr	

Prepared by JET

4.6 Cardinal Otunga High School

4.6.1 Purpose of the Project and Justification of Selection of Cardinal Otunga High School

The school is conscious about environment protection. they have planted trees for fuel wood supply in 2012. However, the amount is not enough to continue and they need biogas system to reduce fuel wood consumption. They also consumes large amount of electricity for school activity and water pump. The consumption of diesel oil is high during power cut hours. The school is eager for project implementation with sufficient experience of construction supervision. The sense of ownership for the project is quite high.

4.6.2 Particular Features of the School of Cardinal Otunga High School

The particular features other than above table are as follows.

- In addition to cow dung, pig dung is also available.
- School farm where cow shed and pig shed are located is approximately 200m from load. this will require more consideration for gasline or cabling for powerline. Considering cost and pressure/voltage drop. Giving-up cow/pig dung might be suggested after the analysis.
- They have day time toilet and dormitory toilet. Dormitory toilet is under re-construction and it will be connected to septic tank by December 2013. Biogas digester can be connected to the new dormitory toilet.
- Toilet roof needs replacement every 7 months due to corrosion suspected to be hydrogen sulphide gas. Toilets are drained 6 times/year. at a cost of 15,000 kSh..
- Consumption of diesel oil is high to supply electricity during power-cut. Automatic change-over switch is installed. Every Tuesday, they experience a black out from 2-9 pm.
- They have just installed posho mill for school needs recently, this will increase electricity consumption. To supply the posho mill from biogas generator, confirmation of posho mill output will be necessary.
- Number of dormitory building is 14. Night time electricity for lighting of dormitory is also demand for biogas generation.

4.6.3 Preliminary Design of Cardinal Otunga High School

The demand for biogas is (i) cooking fuel, (ii) electricity for nighttime lighting in boarding building., and (iii) Water pump. The proposed system is as follows:

- Digester: 32 m^3 for cow/pig dung for cooking fuel, 60 m^3 for boarding toilet for electricity
- Generator : 10 kW (for night time boarding)
- Gas bag: 25 m^3 + 35 m^3
- Total gas production: 12 m^3 (from cow/pig) + 16.1 m^3 (from toilet) = 28.1 m^3/day

Table 4.20 Estimation of Cow Dung Digester for Cardinal Otunga Girls High School

Description	Qty	Unit	Remarks
Nos of cows	17		8 cows to be increased to 10 cows. 50pigs counted (7 pigs=1 cow)
Digester size	32	m3	
Assumed feedstock input	400	kg/day	
Possible gas production	12	m3/day	Not zero-grazed. 0.9 utilization ratio is applied
Generated energy	12	kWh	1kWh/m3
Peak demand	15	kW	Need to adjust according to posho mill hp For dormitory, 14building x535W=7.5 kW
Electric energy demand	67.5	kWh	

Prepared by JET

Digester for cow/pig dung is connected from cow shed and pig shed. It needs to construct long trench to collect cow/pig dung. Cows leave the cowshed between 14:00-16:00 daily. This therefore means that 0.7 utilization ratio is applied. Current nos of cows is 9, and 15 cows are considered for planning with scope of increase.

The digester is to be connected to the biogas generator for supply energy of pump. Load of water pump is 300-400m away from cow shed. It needs consideration for voltage drop in the design.

Table 4.21 Estimation of Human Waste Digester for Cardinal Otunga High School

Description	Value	Unit
Utilization ratio	**0.54**	
Boarding toilet usage ratio	0.67	
Student/adult weight	0.80	
Nos of student utilizing dorm toilet	1000	nos
Converted nos of person for biogas	536	nos
Digester volume	**60**	**m3**
Gasproduction amount	**16.1**	**m3/day**

Prepared by JET

The digester is connected to the kitchen for saving cooking fuel.

4.6.4 Energy Production and Demand Assessment of Cardinal Otunga High School

The aspects of energy production and demand assessment are as follows:

- The electricity consumption for whole school except teachers quarter is 1,519 kWh/month and the tariff was 30,212 KSh, and for water pump was 598 kWh/month and 11,746 kSh as of May 2013.
- It is planned to install digester of cow dung for night time electricity supply for boarding school and digester of toilet for cooking fuel supply.
- Total expected amount of gas production is 8,791 m^3/year, of which 4,380 m^3 is used for generation and 4,411 m^3year is used for cooking stove.
- Amount of electricity saving will be 4,380 kWh/year and amount of fuel saving will be 25.6 ton/year. This corresponds to 17% of total electricity usage, and 8.5% of fuel wood (if cost is 3300 KSh/ton and they spend 1 million KSh/year for fuel wood).

Table 4.22 Estimation of Biogas Usage for Electricity and Fuel Wood Saving

Item	Value	Unit	Note
Annual biogas production from cow dung	4,380	m3/yr	365 days, 12m3/day
Annual biogas production from human waste	4,411	m3/yr	274 days, 16.1 m3/day
Total amount of gas production	8,791	m3/yr	
Biogas used for generation energy	**4,380**	**kWh/yr**	from electricity bill Feb-13
Biogas used for cooking fuel	4,411	m3/yr	
Calorific value of biogas for cooking fuel	20	MJ/m3	
Efficiency of biogas stove	45	%	
Efficiency of fuelwood stove	10	%	
Calorific value of fuelwood	15.5	MJ /kg	
Amount of fuelwood reduction	**25.6**	**ton/yr**	

Prepared by JET

4.6.5 Benefit Assessment of Cardinal Otunga High School

The aspects of benefit assessment are as follows:

- When unit cost of electricity is 17.9 KSh/kWh, the annual saving will be 48,021 KSh/year for electricity.
- When unit cost of fuel wood is 4,500 KSh/ton, annual saving for fuel wood will be 126,005 KSh.
- In total, the annual benefit of biogas system will be 174,026 KSh/year.
- The fuelwood purchase in this school is high, as much as 4,500 KSh/ton. This corresponds to 26.1 KSh/m3 of the value of biogas, which is considered to be higher than electricity value. Accordingly, to use all biogas including from cow shed for fuel wood saving will increase the annual benefit. However, since cowshed is located very far a way from kitchen, it would be difficult unless another kitchen is build near cow shed.

Table 4.23 Estimation of Benefit for Biogas System Installation

Item	Value	Unit	Note
Unit cost of ton fuelwood	3300	KSh/ton	Not known in this school
Unit cost of unit electricity	19.9	KSh/kWh	from electricity bill Apr-13
Benefit of saving electricity	87,162	KSh/yr	
Benefit of fuel wood saving	84,528	KSh/yr	
Total benefit	171,690	KSh/yr	

Prepared by JET

Table 4.24 Estimation of Biogas Usage for Electricity and Fuel Wood Saving

Item	Value	Unit	Note
Annual biogas production from cow dung	2,683	m3/yr	365 days, 7.35m3/day
Annual biogas production from toilet	4,822	m3/yr	274 days, 17.6 m3/day
Total amount of gas production	7,505	m3/yr	
Biogas used for generation energy	**2,683**	**kWh/yr**	from electricity bill Feb-13
Biogas used for cooking fuel	4,822	m3/yr	
Calorific value of biogas for cooking fuel	20	MJ	
Efficiency of biogas stove	45	%	
Efficiency of fuelwood stove	10	%	
Calorific value of fuelwood	15.5	MJ /kg	
Amount of fuelwood reduction	**28.0**	**ton/yr**	

Prepared by JET

4.6.6 Benefit Assessment of Cardinal Otunga High School

The aspects of benefit assessment are as follows:

- When unit cost of electricity is 17.9 KSh/kWh, the annual saving will be 48,021 KSh/year for electricity.
- When unit cost of fuel wood is 4,500 KSh/ton, annual saving for fuel wood will be 126,005 KSh.
- In total, the annual benefit of biogas system will be 174,026 KSh/year.
- The fuel wood purchase in this school is high, as much as 4,500 KSh/ton. This corresponds to 26.1 KSh/m3 of the value of biogas, which is considered to be higher than electricity value. Accordingly, to use all biogas including from cow shed for fuelwood saving will increase the annual benefit. However, since cow shed is located very far a way from kitchen, it would be difficult unless another kitchen is build near cow shed.

Table 4.25 Estimation of Benefit for Biogas System Installation

Item	Value	Unit	Note
Unit cost of ton fuelwood	4500	KSh/ton	Tender result
Unit cost of unit electricity	17.9	KSh/kWh	from electricity bill May-13
Benefit of saving electricity	48,021	KSh/yr	
Benefit of fuel wood saving	126,005	KSh/yr	
Total benefit	174,026	KSh/yr	

Prepared by JET

CHAPTER 5 COST ESTIMATION AND ECONOMIC/FINANCIAL EVALUATION FOR SIX BIOGAS PROJECTS

5.1 Cost Estimation

Site survey for six candidate biogas projects in high schools in Kenya was conducted in May to June 2013. The surveyed schools are namely: Nyeri High School, Rware High School, Litein High School, Kipsigis Girls High School, Mukumu Girls High School, and Cardinal Otunga High

School. “Site Survey Memo of Biogas : 1 Nyeri High School and Rware High School” and “Site Survey Memo of Biogas 2: Rift Valle, Western, and Nyanza Sites” reported the result of the survey with the outline, particular features, basic design, demand assessment, and benefit assessment for six schools. This paper is prepared for cost estimation and economic/financial evaluation for six schools.

Past REA projects at Mangu High School and Moi Girl’s School were referred for the base cost for biogas system component. The reference price is summarized in the table below.

Table 5.1 Reference Values for the Cost Estimation

SN	Item	Mangu HS				Moi Girls			
		Qty	Unit	Unit cost	Amount	Qty	Unit	Unit cost	Amount
0	Sanitation, protection, removal works	1	lot	35,000	35,000	1	lot	35,000	35,000
1-A	Excavation	1	item	376,500	376,500	1	item	375,500	375,500
	Trench toilet 16 cubicles					1	lot	631,000	631,000
2-A	Dome digestor 100m3	2	nos	518,350	1,036,700	2	nos	495,750	991,500
	Dome digester 50m3	1	nos	387,500	387,500				0
3-A	Gas holding steel tank	3	nos	45,700	137,100	2	nos	45,750	91,500
3-B	Gas outlet connection 50mm valve	3	nos	4,700	14,100	2	nos	4,500	9,000
3-C	Biogas flow meters	2	nos	36,500	73,000	2	nos	36,500	73,000
4-A	20m3 PVC gas bag	1	nos	411,000	411,000	1	nos	411,000	411,000
5-A	Biogas generator 20kVA	1	nos	495,500	495,500	1	nos	454,000	454,000
5-B	Energy meters	1	nos	50,000	50,000	1	nos	50,000	50,000
5-C	3-P Distribution board	1	nos	59,500	59,500	1	nos	59,000	59,000
5-D	Switchgear and safety control	1	nos	91,000	91,000	1	nos	91,000	91,000
5-E	Solenoid valves to switch off gas	1	nos	45,500	45,500	1	nos	45,500	45,500
5-F	Biogas purification unit	1	nos	61,000	61,000				
5-G	15hp 12kW existing pump cable work	1	nos	183,000	183,000				
6-A	Plumbing works 50mm dia pipe to gas ba	1	nos	256,000	256,000				
7-A	Chain link fence	1	nos	91,000	91,000				
8-A	Safey, fire extinguisher, alarm, somoke detector,signs	1	nos	27,000	27,000				
9-A	System design	1	Lot	246,000	246,000				
10-A	Testing and commission for 2 eeks	1	Lot	62,000	62,000				
11-A	Technical backstopping in O&M	1	Lot	164,500	164,500				
11-B	Data collection	1	Lot	18,500	18,500				
11-C	Training, manual	1	Lot	73,000	73,000				
11-D	Drawing and video	1	Lot	255,500	255,500				
11-E	6month operation data	1	Lot	45,500	45,500				
	Subtotal				4,695,400				
	VAT 16%				751,264				
	TOTAL				5,446,664				

Prepared by JET

The cost estimation is conducted for the purpose of preliminary financial and economic evaluation to assess the project feasibility. The estimation is based on rough assumption of quantity especially in civil works. The quantity of excavation, cement, concrete works, buildings, etc, needs to be determined with more detailed layout and design in the next stage.

For the estimation of respective quantity and specification, following formulas were applied.

1) Biogas digester: $y = 2,617\ x + 256,700$,
,where y: cost (KSh), x: digester volume (m^3)
2) Excavation works: 2,052 KSh/m^3
3) Biogas bag: 20,550 KSh/m^3
4) Biogas generator: $y=20,000x +100,000$

, where y: cost (KSh), x: capacity of engibne-generator (kVA)

The base cost in table 1 was the value in 2010. Accordingly, inflation rate (4.91%, Kenyan Bureau of Statistics) was applied and price in 2013 was calculated as compounded interest.

For other items, base cost is applied in proportion to the estimated quantity.

The result of cost estimation and recovery year is shown in the table below.

Table 5.2 Result of the Cost Estimation

Item	Nyeri High School			Rware High School			Litein High School			Kipsigis Girls High School			Mukumu Girls High School			Cardinal Otunga High School		
	Qty	unit	KSh	Qty	unit	KSh	Qty	unit	KSh	Qty	unit	KSh	Qty	unit	KSh	Qty	unit	KSh
Biogas Digester for Toilet	60	m3	413,720				60	m3	413,720	50	m3	387,550	60	m3	413,720	60	m3	413,720
Biogas Digeter for Cow Shed	32	m3	340,444	24	m3	319,508	32	m3	340,444	16	m3	298,572	28	m3	329,976	32	m3	340,444
Excavation and civil works	1	lot	188,830	1	lot	49,260	1	lot	804,430	1	lot	135,465	1	lot	180,620	1	lot	188,830
Additional toilet facility with septic tank							1	lot	631,000									
Gas holding steel tank and connection valve	2	nos	100,800	1	nos	50,400	2	nos	100,800	2	nos	100,800	2	nos	100,800	2	nos	100,800
Bigoas flow meter	2	nos	73,000	1	nos	36,500	2	nos	73,000	2	nos	73,000	2	nos	73,000	2	nos	73,000
PVC gas bag	1	nos	411,000	1	nos	411,000	2	nos	822,000	2	nos	513,750	2	nos	616,500	2	nos	616,500
Biogas generator	7	kVA	240,000				20	kVA	500,000	10	kVA	300,000	20	kVA	500,000	20	kVA	500,000
Energy meter	1	nos	50,000				1	nos	50,000	1	nos	50,000	1	nos	50,000	1	nos	50,000
Distribution board, switch gear	1	nos	150,500				1	nos	150,500	1	nos	150,500	1	nos	150,500	1	nos	150,500
Biogas filter and solenoid valve	1	nos	106,500				1	nos	106,500	1	nos	106,500	1	nos	106,500	1	nos	106,500
Cable work	1	lot	200,000				1	lot	600,000	1	lot	175,000	1	lot	200,000	1	lot	300,000
Pipe work	1	lot	250,000	1	lot	150,000	1	lot	500,000	1	lot	150,000	1	lot	250,000	1	lot	250,000
Fence and safety arrangement	1	lot	118,000	1	lot	70,800	1	lot	118,000	1	lot	118,000	1	lot	118,000	1	lot	118,000
Subtotal			2,642,794			1,087,468			5,210,394			2,559,137			3,089,616			3,208,294
Detailed design and drawing	1	lot	246,000	1	lot	147,600	1	lot	369,000	1	lot	246,000	1	lot	246,000	1	lot	501,500
Testing, commissioning, training	1	lot	363,500	1	lot	218,100	1	lot	363,500	1	lot	363,500	1	lot	363,500	1	lot	363,500
Total Cost			3,252,294			1,453,168			5,942,894			3,168,637			3,699,116			4,073,294
Total Cost adjusted with Inflation 2010/13	4.91%/	Ksh	3,755,264	4.91%/yr		1,677,902	4.91%/yr		6,861,967	4.91%/yr		3,658,669	4.91%/yr		4,271,187	4.91%/yr		4,703,232
Annual financial benefit		Ksh	180,050			62,945			164,856			130,357			174,026			171,690
Recovery year		yr	21		yr	27		yr	42		yr	28		yr	25		yr	27
Remarks							300m pipe work & cow shed trench, Pump 700m away			Gas bag: 5m3 + 20 m3			Gas bag: 10m3 + 20 m3			Cable line length 200m Gas bag: 10m3 + 20 m3		

Prepared by JET

Litein high school requires long distance excavation of piping work and additional toilet with septic tank. Because of this, the project cost becomes much higher than other projects (6.86 million KSh) .

Meanwhile, Rware high school does not have much demand for electricity since the school is day school and water supply is depending on municipal water. Accordingly, no electric supply system is planned in the school, which makes project cost smaller than other sites(1.68 million Ksh).

5.2 Financial Evaluation

Financial benefit for biogas system consists of following items:

- Saving of electricity tariff:
- Saving of fuel wood purchase

The electricity tariff rate was set based on actual payment of electricity bill, i.e., amount of the tariff payment in KSh (including fuel surcharge and other adjustment) of the month divided by the amount of electric energy in kWh consumed in the month. The tariff rate is ranged from 17.9 to 19.9KSh/kWh, expect for 8.7 KSh/kWh for Rware High School. The tariff of Rware is low since the consumption of the school is quite small, about 1000 kWh per month.

As for fuel wood price, many of the price per ton that was paid actually by the school was not clear. Accordingly, 3,300 KSh/ton, general price in Nyeri, was applied for all school for the comparison.

The outline of the cost estimation and recovery year (project cost/annual financial benefit) is shown in the table below.

Table 5.3 Summary for Financial Evaluation

Item	Unit	Nyeri High School	Rware High School	Litein High School	Kipsigis Girls High School	Mukumu Girls High School	Cardinal Otunga High School
Project Cost	KSh	3,755,264	1,453,168	6,861,967	3,658,669	4,271,187	4,703,232
Electricity tariff rate	KSh/kWh	19.7	8.7	18.1	19.5	17.9	19.9
Annual planned generated energy	kWh/yr	2,321		4,380	5,179	2,683	4,380
Annual planned fuelwood Saving	ton/yr	36.3	19.1	25.9	8.9	28.0	25.6
Financial benefit	KSh/yr	165,466	62,945	164,856	130,357	174,026	171,690
Recovery year	yr	23	23	42	28	25	27

Prepared by JET

The recovery year ranges from 21 years to 42 years. Since the project life is expected approx. 30 years, Litein High School which requires 42 years for recovery, is not considered to be feasible. For other schools, recovery year is ranged from 23 to 28 years, which can be financially justified.

FIRR will be negative for all six projects, and cannot be calculated.

5.3 Economic Evaluation

For counting economic benefit, it is necessary to quantify indirect value of socioeconomic and environmental benefit. Following table explains the contents of economic benefit which will be borne from the biogas system.

Table 5.4 Economic Benefit

SN	Type of Economic Benefit	Explanation
1	Benefit as electricity saving from diesel oil	When electricity is generated using biogas, the electric energy can be considered to save electricity from diesel generation system in grid, since the cost of diesel generation is higher than that of hydropower. The cost of electricity from diesel generation can be considered as economic benefit, in place of grid electricity tariff.
2	Benefit of carbon reduction by biogas generation	CO_2 emission reduction is expected from biogas generation since it replaces energy from diesel generation. Emission factor of diesel oil can be applied to count economic benefit.
3	Benefit from fuelwood saving	The benefit is the same as financial benefit of fuelwood saving.
4	Fuelwoood carbon absorption benefit	The saved fuel wood by biogas system is considered to absorb CO_2 in forest. The carbon credit with the absorption of CO_2 amount is considered to be economic benefit.
5	Fuelwood carbon off-set benefit	As well as electricity, saved amount of fuelwood is considered to replace coal, and corresponding amount of CO2 from the replaced coal is considered to be economic benefit of carbon reduction.
6	Fuel wood economic value to prevent deforestation	Saving of losses in economic sectors resulting from deforestation is counted as economic benefit. The components of this economic value are: growing of crops and horticulture, fishing, water supply, public administration and defense,

		deforestation effects on carbon sequestration, and deforestation effects on health (malaria). "The Role and Contribution of Montane Forests and Related Ecosystem Services to the Kenyan Economy" of UNEP quantified the economic value as much as 921,165 KSh/ha.

Prepared by JET

To quantify the above economic value, following parameters and formulas were used.

Base condition:

Diesel Oil Price	110.00	KSh/L
Diesel efficiency	2.40	kWh/L
Emission factor of electricity		0.81805 ton-CO2/MWh
Price of fuel wood	3,300	KSh/ton
Exchange rate	86.28	KSh/US$
Carbon credit	1,294	KSh/ton-CO2

Source: The Role and Contribution of Montane Forests and Related Ecosystem Services to the Kenyan Economy", 2012, UNEP

Fuelw1od carbon absorption:

Carbon Absorption A = W x E x (1+R) x C%

ton-CO2 reduction = A x 44/12

Where,

W	Weight of saved tree, ton	
E	Coefficient for tree and branch addition:	1.52
R	Ratio of ground/underground portion:	0.26
C%	Carbon component percentage:	0.5

Source: Forestry and Forest Products Research Institute, Japan

Fuelwood carbon off-set:

ton-CO_2 reduction = W x (1-M/100) x H x EF x BE

Where,

W	Weight of saved tree, ton	
M	Moisture content, %:	10
H	Calorific value GJ/ton:	15.5
EF	Emission coefficient of coal, ton-CO2/GJ:	0.09
BE	Boiler efficiency ratio (fuel wood/fossil fuel):	1

Source: Forestry and Forest Products Research Institute, Japan

Fuelwood economic value to prevent deforestation

Amount of carbon storage	190	C-ton/ha
Weight of wood body	198.4	ton/ha
Economic value per area	921,165	KSh/ha
Economic value per ton fuel wood	4,643	KSh/ton

Source: The Role and Contribution of Montane Forests and Related Ecosystem Services to the Kenyan Economy", 2012, UNEP

According to the above assumption, each economic value was calculated. With the total economic benefit, EIRR for each project was worked out. Generally, EIRR more than 10% is justified in public project.

Since the economic benefit of fuelwood saving is high, Rware high school, which utilize all biogas for fuelwood saving and no electric generation system will be installed, shows highest EIRR value, 16.4%. Meanwhile, Litein High school, of which cost was highest, shows EIRR of 5.85 %

As for Kipsigis Girls High School, the EIRR was only 7.8% which may be considered not being feasible. However, if the school applies all the biogas to replace fuel wood, the EIRR will be increased to be 13.5%. The project will be economically justified depending on the usage of the gas.

Table 5.5 Summary of Economic Evaluation

Item	Unit	Nyeri High School	Rware High School	Litein High School	Kipsigis Girls High School	Mukumu Girls High School	Cardinal Otunga High School
Benefit as diesel generation saving	KSh/yr	106,356	0	200,750	237,353	122,959	200,750
Benefit of electricity carbon reduction	KSh/yr	2,457	0	4,637	5,483	2,840	4,637
Benefit from fuelwood saving	KSh/yr	119,717	62,945	85,578	29,374	126,005	84,528
Fuelwoood carbon absorption benefit	KSh/yr	164,854	86,677	117,844	40,449	127,242	116,398
Fuel wood carbon off-set benefit	KSh/yr	58,947	30,993	42,137	14,463	45,498	41,620
Fuel wood economic value	KSh/yr	168,427	88,555	120,397	41,326	130,000	118,920
Total economic benefit	**KSh/yr**	**620,758**	**269,170**	**571,344**	**368,448**	**554,544**	**566,853**
EIRR		**15.09%**	**16.44%**	**5.85%**	**7.79%**	**11.27%**	**10.26%**

Prepared by JET

CHAPTER 6 OPTION STUDY FOR NYERI HS

6.1 Background

Biogas produced in anaerobic digester can be applied both production of the electricity using engine-generator and cooking fuel for the replacement of fuelwood. Since production of electricity requires installation of high cost generator and larger maintenance cost, it is considered that application of biogas only to cooking fuel would be more economically feasible, as long as demand for fuelwood is high. Accordingly, for the Nyeri High School (HS) biogas system plan of which is ranked first among six sites, the economic feasibility is assessed and compared between the cases (i) biogas supply for both electricity and cooking fuel and (ii) biogas supply for cooking fuel only.

6.2 Cost Estimation

In the original plan with generator of Nyeri HS project, the system will supply electric power for lighting, which use about 1/3 of total produced biogas, and will supply remaining 2/3 of produced biogas for cooking fuel. For the optional system without generator, the system will supply all biogas for cooking fuel.

The cost is assessed with the simple assumption from past tender document of Mangu biogas system conducted in 2010 with applying inflation rate. The cost for system with generator was estimated to be about 3.8 million KSh, while that of without generator was about 2.8 million KSh

Table 6.1 Cost Estimation of Nyeri HS with/Without Generator

Item	Nyeri High School with Generator			Nyeri High School without generator		
	Qty	**unit**	**KSh**	**Qty**	**unit**	**KSh**
Biogas Digester for Toilet	60	m3	413,720	60	m3	413,720
Biogas Digeter for Cow Shed	32	m3	340,444	32	m3	340,444
Excavation and civil works	1	lot	188,830	1	lot	188,830
Additional toilet facility with septic tank						
Gas holding steel tank and connection valve	2	nos	100,800	2	nos	100,800
Bigoas flow meter	2	nos	73,000	2	nos	73,000
PVC gas bag	1	nos	411,000	1	nos	411,000
Biogas generator	7	kVA	240,000		kVA	
Energy meter	1	nos	50,000		nos	
Distribution board, switch gear	1	nos	150,500		nos	
Biogas filter and solenoid valve	1	nos	106,500	1	nos	106,500
Cable work	1	lot	200,000		lot	
Pipe work	1	lot	250,000	1	lot	250,000
Fence and safety arrangement	1	lot	118,000	1	lot	118,000
Subtotal			2,642,794			2,002,294
Detailed design and drawing	1	lot	246,000	1	lot	186,380
Testing, commissioning, training	1	lot	363,500	1	lot	275,403
Total Cost			3,252,294			2,464,077
Total Cost adjusted with Inflation 2010/13	4.91%/y	Ksh	3,755,264	4.91%/y	Ksh	2,845,149

Prepared by JET

6.3 Demand in Nyeri HS

The electricity consumption of Nyeri HS is reported to be about 5,000 kWh/month, about 60,000 kWh/year. The annual fuelwood consumption is about 300 ton/year in Nyeri School. This amount of fuelwood consumption is much higher even if all biogas is used for cooking fuel replacing with fuel wood (49.8 ton/year). If all feedstock is used for reduction of fuelwood, 1/6 of current use will be saved.

6.4 Financial and Economic Benefit

The annual financial benefit is calculated from (i) the amount of electricity tariff saving and (ii) fuel wood saving in the original plan with generator. For alternative plan without generator, only fuel wood saving is counted for financial benefit. The annual economic benefit for generation is calculated from saving of diesel oil assuming that electricity generated from biogas replaces diesel generation in grid. CO_2 emission reduction benefit is also counted. The economic benefit for fuel wood reduction is calculated from fuel wood saving, fuelwood carbon absorption benefit, fuelwood carbon off-set benefit, and fuelwood economic value from forest preservation.

For detailed methodology of calculating economic benefit, see the Progress Report 3 for Project for Establishment of Rural Electrification Model Using Renewable Energy.
The result is shown in the table below.

Table 6.2 Financial and Economic Evaluation with/without Generator

Base condition:

Diesel Oil Price	110.00	KSh/L
Diesel efficiency	2.40	kWh/L
Emission factor of electricity	0.81805	ton-CO_2/MWh
Price of fuel wood	3,300	KSh/ton
Exchange rate	86.28	KSh/US$
Carbon credit	1,294	KSh/ton-CO_2 (15US$/ton)

Item	Unit	Nyeri High School with generator	Nyeri High School without generator
Project Cost	KSh	3,755,264	2,845,149
Planned gas production for fuelwood saving	m^3/yr	6,248	8,568
Planned gas production for electricity saving	m^3/yr	2,321	0
Electricity tariff rate	KSh/kWh	19.7	19.7
Annual planned generated energy	kWh/yr	2,321	0
Annual planned fuelwood Saving	ton/yr	36.3	49.8
Financial benefit	**KSh/yr**	**165,466**	**164,181**
Recovery year	yr	23	17
Benefit of diesel generation saving	KSh/yr	106,356	0
Benefit of CO2 emission reduction by biogas generation	KSh/yr	2,457	0
Benefit from fuelwood saving	KSh/yr	119,717	164,181
Fuelwood carbon absorption benefit	KSh/yr	164,854	226,082
Fuel wood carbon off-set benefit	KSh/yr	58,947	80,840
Fuel wood economic value	KSh/yr	168,427	230,982
Total economic benefit	**KSh/yr**	**620,758**	**702,085**
EIRR		**15.09%**	**24.18%**

Shadow exchange rate is not considered in financial cost.

Prepared by JET

As the result, the financial benefit for system with generator was 165,466 Ksh/yr, higher than without generator (cooking fuel supply only), 164,181 Ksh/yr. However, since investment cost with generator was much higher, recovery year of the system without generator has advantage, 17 years, while that of the system with generator was 23 years.

Meanwhile, economic benefit will be larger in the system without generator (702,086 KSh/yr) than system with generator (620,758 KSh/yr), since economic benefit of forest protection (fuelwood economic value) is considered to be large. The EIRR for the system with generator was 15.1%, while that of without generator was 24.2%.

6.5 Conclusion

The financial return for electricity and cooking fuel from the same amount gas is almost the same at the present electricity tariff rate and fuelwood price. The financial value of unit biogas for fuelwood replacement and electricity generation for the case of Nyeri HS is shown in the table below.

Table 6.3 Value of Biogas for Fuel wood and Electricity Replacement

Fuelwood replacement	Electricity supply
19.2 KSh/m^3	19.7 KSh/m^3

(Condition: 19.7 KSh/kWh for grid electricity, 3,300 KSh/ton for fuelwood purchase)

Prepared by JET

Meanwhile, initial cost of biogas system with generator is 32% higher compared with biogas system for cooking fuel supply only. In addition, generator requires overhaul every 5-7 years and the maintenance cost is also much higher than that of system without generator.

The annual fuelwood requirement in the school (about 300 ton/yr) is larger than the amount possibly replaced by biogas (about 50 ton/yr), it is more financially feasible to utilize all biogas for fuelwood replacement than to supply biogas for electricity generation.

ANNEXES

Annex-1 BoQ and Scope of Works of Nyeri Biogas Project

Annex-2 Scope of Work of Feasibility Study of Nyeri Biogas Project

Annex-3 Drawing of Nyeri Biogas Project

Drawing No. N-01-1 Flow of Biogas System Option-1 Cooking Fuel Supply Only

Drawing No. N-01-2 Flow of Biogas System Option-2 with Generation System

Drawing No. N-02 Excavation Plan for Biogas Digester (32, 60 m^3)

Drawing No. N-03-1 AKUT Fixed Dome Type Biogas Digester (32 m^3) for Cow Dung

Drawing No. N-03-2 AKUT Fixed Dome Type Biogas Digester (60 m^3) for Cow Dung

Drawing No. N-04 Control Chamber and Water Trap

Drawing No. N-05 Reinforcement Plan and Digester Manhole

Annex-1 BoQ and Scope of Works of Nyeri Biogas Project

***Following BoQ was prepared in the stage of Pre-Feasibility Study. The quantity, details and specifications need to be reviewed and revised during Feasibility Study Stage.**

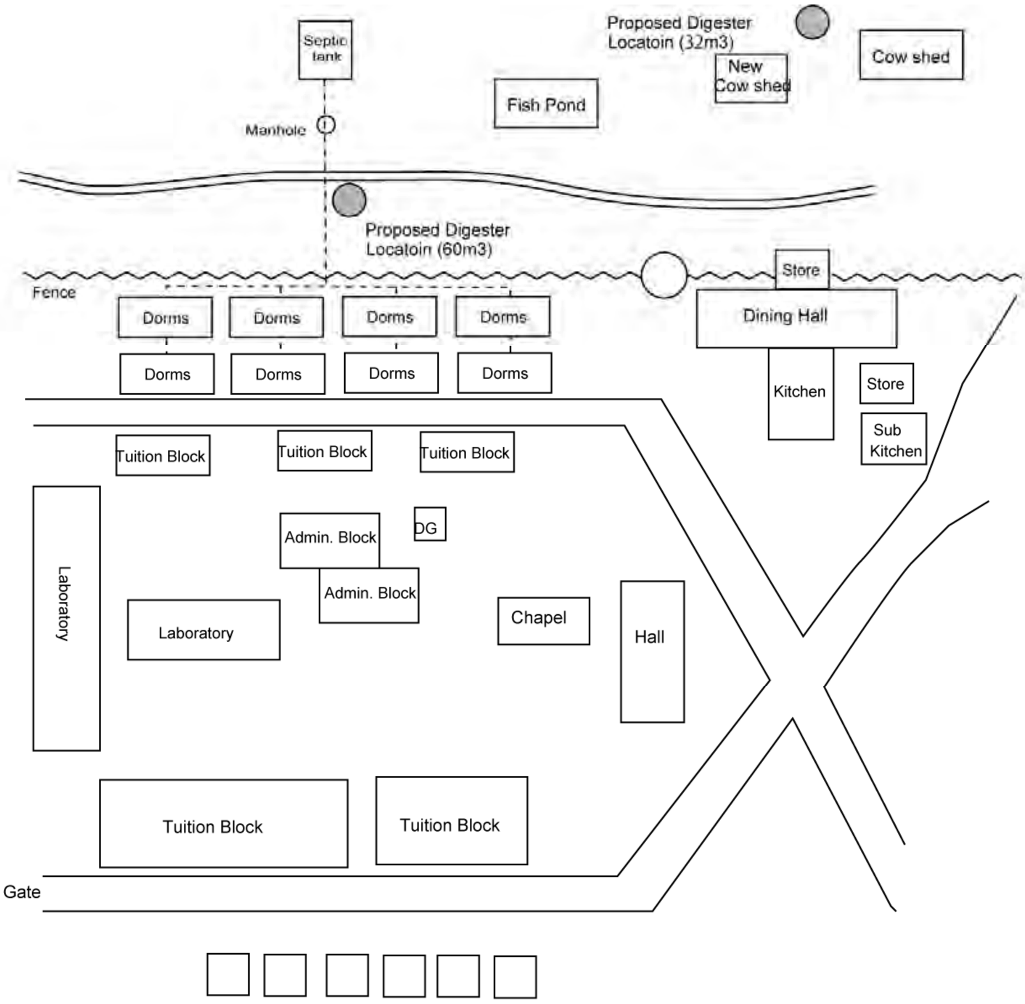
Option-1 Cooking Fuel Supply System (without generator)

SN	Item	Quantity	Unit	Details and Specification
A. Civil, Construction and Installation Works				
A-1	Excavation works and backfilling	1	set	Site cleaning and excavation shall be conducted for biogas digester, trenches, ditches, chambers, pipeline routes, and foundation of gas bag house shall be conducted. Landscaping after backfilling shall be conducted. Water shall be drained or pumped up.
A-2	32m^3 cow dung biogas digester and related works	1	Set	32 m^3 AKUT type fixed dome digester shall be constructed with manhole, feeding chamber, PVC pipe connection, expansion chamber, reinforced concrete beam and slab, and gas outlet, connected from cow shed and to garden. [Drawing No.: N-02, N03-1, N-05]
A-3	60 m^3 human waster biogas digester and related works	1	Set	60 m^3 AKUT type fixed dome digester shall be constructed with manhole, feeding chamber, PVC pipe connection, expansion chamber, reinforced concrete beam and slab, and gas outlet., connected from the pipe of sewer line from toilet and to sewer line to septic tank. [Drawing No.: N-02, N03-1, N-05]
A-4	Two cow sheds modification	40*	m^2	Modification work of cow shed with floor gravel laying and concrete placement to facilitate cow dung gathering shall be conducted for two nos of cow sheds.
A-5	Trench work (from cow shed to digester, from digester to garden)	100*	m	Stone masonry trench shall be constructed for: (i) from the cow shed to the feeding chamber of the digester and (ii) from the expansion chamber to the garden. The trench shall not be smaller than W300xH400*
A-6	Piping work for human waste digester	10**	m	Pipe connection work for slurry shall be done from the existing toilet sewer line to the human waste digester with manholes at the jointing part and joints and valves in the pipe line.
A-7	Gas pipeline from cow dung digester to the kitchen	200	m	Gas pipe line with Φ32 mm PPP gas pipe, with 1-2% slope, shall be installed from cow dung digester to the kitchen. Chambers for water traps shall be constructed and water traps shall be installed very minimum 50 m or any folding point of the gas pipeline. A control chamber with a gas sampling nipple and a manometer shall be installed. [Drawing No.: N-04]
A-8	Gas pipeline from human waste digester to the kitchen	200	m	Gas pipe line of Φ32 mm PPP gas pipe, 1-2% slope, from human waste digester to the kitchen shall in installed. Water traps and water trap chambers every minimum 50 m shall be installed. [Drawing No.: N-04]
A-9	Control Chamber	2	Sets	Control chambers shall be constructed and a gas sampling nipple and a manometer shall be installed in the Control Chamber. One Control Chamber shall be installed in the gas pipe line of human digester and one control chamber in the gas pipe line of cow dung digester.
A-10	Gas holder bag	1	Sets	Minimum 40 m^3 gas bag made of Polyvinyl chloride (PVC) or Isobutylene Isoprene Rubber (IIR) shall be installed and connected from the gas pipe line. The gas bag shall be connected to the kitchen cooking stoves. Leakage test shall be conducted. The material of gas bag

SN	Item	Quantity	Unit	Details and Specification
				shall be resistant to acid and alkali corrosion, resistance to wear and friction. Life span shall be more than 10 years. Suitable temperature at 0-50 ^oC.
A-11 1	Biogas flow meter	3	Sets	The gas flow meter recording in m^3 with one decimal place shall be installed one for the outlet of cow dung digester, one for the outlet of human waste digester, and one for the gas bag. Nominal flow rate shall be up to 2.0 m^3/h. Maximum working pressure shall be more than 10 kPa. Pressure loss shall be ≤200Pa.Air tightness shall have no leakage under 10 kPa. In addition, 3 sets of the same flow meter shall be supplied for the replacement purpose.
A-12	Biogas filtering unit	2	Sets	Activated carbon filter units to remove hydrogen sulfide, more than 99% purifying efficiency shall be installed for the cow dung digester and human waste digester. The unit container material shall be durable for H_2S corrosion.
A-13	Manometer	3	Sets	Manometers of highly resistant to corrosion shall be supplied and installed, one in the control chamber of cow dung digester, one in the control chamber of human waste digester, and one in the kitchen.
A-14	Gas Valve	1	Set	Gas valve shall be installed to stop gas flow from the gas bag.
A-15	Gas holder house	40 x 1	m^2	Stone masonry and zing roof gas holder house shall be constructed. The house shall have ventilation and warning sign of leakage. Door shall be rocked.
A-16	Biogas stove	4	Nos	Biogas stove with double burner, with automatic starter switches and 2 meters of hosepipe. Each burner shall have heat load more than 2.5 kW, gas consumption rate 0.4-0.6 m^3/h, and efficiency more than 57%.
B. Miscellaneous Works				
B-1	Safety arrangement	1	Set	Warning signs at each digester location, fire distinguisher at kitchen, fire alarm at kitchen shall be supplied and installed.
B-2	Sign board	1	Set	Sign boards indicating facility and equipment type shall be installed at digester locations and kitchen.
C. Related Works				
C-1	Testing and commissioning	1	Set	Commissioning shall be done after the observation of gas production. Gas stove test shall be conducted in the commissioning with confirmation of gas pressure and output. Testing record for gas production amount shall be recorded and submitted for initial 2 months after commissioning. Testing format shall be submitted and operation test shall be conducted for initial six months after commissioning. Biogas analysis using gas chromatography shall be conducted and analysis result of percentage CH_4, N_2, CO_2, H_2, H_2S, and O_2 shall be reported.
C-2	Documentation	1	Set	Following documents shall be prepared and submitted 3 copies to the Client and 1 copy to the User. ・ Work Plan including, Detailed work schedule, Contractor's organization chart and personnel list, Consolidated drawings of layout of digester, pipe layout, toilet, and other related facility, Bill of quantity, and safety plan ・ Drawings for approval and drawings for work of detailed drawings of digester, gas pipe, slurry pipes,

SN	Item	Quantity	Unit	Details and Specification
				ditches, houses, and other related facilities that the Contractor will install and/or construct ・ As built drawings ・ Format for testing and commissioning ・ Record of monitoring (record of input, operation record, gas production, energy generation) ・ Program of user training ・ User Manual ・ Record of user training and user's understanding ・ List of consumables and spare parts and supplier's contact list ・ Bills of Quantity and Cost
C-3	User training	1	Set	User training with training program and shall be conducted at least four persons (operators and supervisor) assigned from the user. User manual shall be provided to the Client and the User.
C-4	Technical support	1	Set	Technical supports shall be provided for initial one year for operation and maintenance of the user from the date of commissioning.
C-5	Supply of maintenance tools and spare parts	1	Set	The maintenance tools necessary for operation and maintenance and spare parts including filtering materials shall be provided for 3 years operation.
C-6	Transportation	1	Set	The transportation shall cover all supply of materials and equipment.
C-7	Labor	1	Set	The labor shall cover all construction, civil , electrical, installation works.
C-8	Administration	1	Set	Administration shall cover all administration works including communications and documentations.

*The quantity and size is rough estimate in Pre-FS. Those shall be reviewed and revised according to the result of feasibility study.
**If toilet sewer line is the same as waste water from shower room, additional independent sewer line exclusive for toilet shall be constructed.



This layout is prepared based on a rough sketch and scale is not propotional to actual sites.

Above is a rough layout. Detailed survey drawing with 1/1000 or 1/2000 scale shall be prepared and plan for facilities such as digester, gas bag, power house shall be arranged in the feasibility study

Figure A Sketch Layout of Nyeri Biogas System

***Following BoQ was prepared at the stage of Pre-Feasibility Study. The quantity, details and specifications need to be reviewed and revised during Feasibility Study Stage.**

Option-2 With Biogas Generation System

SN	Item	Quantity	Unit	Details and specification
A. Civil, Construction and Installation Works				
A-1	Excavation works and backfilling	1	set	Site cleaning and excavation for biogas digester excavation shall be conducted, trenches, ditches, chambers, pipeline routes, foundation of gas bag house and powerhouse shall be conducted. Landscaping after backfilling shall be conducted. Water shall be drained or pumped up.
A-2	32m^3 cow dung biogas digester and related works	1	Set	32 m^3 AKUT type fixed dome digester shall be constructed with manhole, feeding chamber, PVC pipe connection, expansion chamber, reinforced concrete beam and slab, and gas outlet, connected from cow shed and to garden. [Drawing No.: N-02, N03-1, N-05]
A-3	60 m^3 human waster biogas digester and related works	1	Set	60 m^3 AKUT type fixed dome digester shall be constructed with manhole, feeding chamber, PVC pipe connection, expansion chamber, reinforced concrete beam and slab, and gas outlet., connected from the pipe of sewer line from toilet and to sewer line to septic tank. [Drawing No.: N-02, N03-1, N-05]
A-4	Two cow sheds modification	40*	m^2	Modification work of cow shed with floor gravel laying and concrete placement to facilitate cow dung gathering shall be conducted for two nos of cow sheds.
A-5	Trench work (from cow shed to digester, from digester to garden)	100*	m	Stone masonry trench shall be constructed for: (i) from the cow shed to the feeding chamber of the digester and (ii) from the expansion chamber to the garden. The trench shall not be smaller than W300xH400*
A-6	Piping work for human waste digester	10**	m	Pipe connection work for slurry shall be done from the existing toilet sewer line to the human waste digester with manholes at the jointing part and joints and valves in the pipe line.
A-7	Gas pipeline from cow dung digester to generation house	200	m	Gas pipe line with Φ32 mm PPP gas pipe, with 1-2% slope, shall be installed from cow dung digester to the power house. Chambers for water traps shall be constructed and water traps shall be installed very minimum 50 m or any folding point of the gas pipeline. A control chamber with a gas sampling nipple and a manometer shall be installed. [Drawing No.: N-04]
A-8	Gas pipeline from human waste digester	200	m	Gas pipe line of Φ32 mm PPP gas pipe, 1-2% slope, from human waste digester to the kitchen shall in installed. Water traps and water trap chambers every minimum 50 m shall be installed. [Drawing No.: N-04]
A-9	Control Chamber	2	Sets	Control chambers shall be constructed and a gas sampling nipple and a manometer shall be installed in the Control Chamber. One Control Chamber shall be installed in the gas pipe line of human digester and one control chamber in the gas pipe line of cow dung digester..

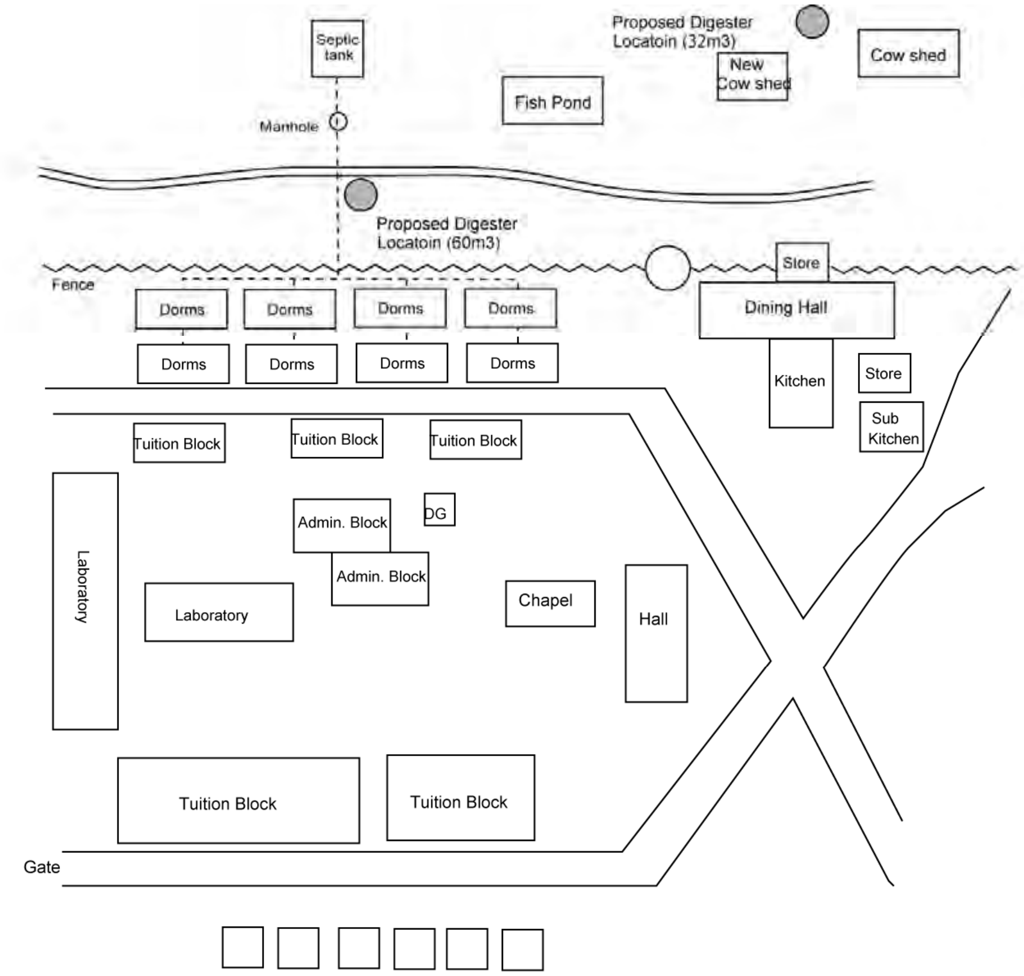
SN	Item	Quantity	Unit	Details and specification
A-10	Gas holder bag	2	Sets	Minimum 20 m^3 gas bags made of Polyvinyl chloride (PVC) or Isobutylene Isoprene Rubber (IIR) shall be installed and connected from the gas pipe line. One gas bag shall be connected to the kitchen cooking stoves and other shall be connected to engine generator. Leakage test shall be conducted. The material of gas bag shall be resistant to acid and alkali corrosion, resistance to wear and friction. Life span shall be more than 10 years. Suitable temperature at 0-50 ^oC.
A-11	Biogas flow meter	4	Sets	The gas flow meter recording in m^3 with one decimal place shall be installed one for the outlet of cow dung digester, one for the outlet of human waste digester, and two for the gas bags. Nominal flow rate shall be up to 2.0 m^3/h. Maximum working pressure shall be more than 10 kPa. Pressure loss shall be ≤200Pa.Air tightness shall have no leakage under 10 kPa. In addition, 3 sets of the same flow meter shall be supplied for the replacement purpose.
A-12	Biogas filtering unit	2	Sets	Activated carbon filter units to remove hydrogen sulfide, more than 99% purifying efficiency shall be installed for the cow dung digester and human waste digester. The unit container material shall be durable for H_2S corrosion.
A-13	Manometer	3	Sets	Manometers of highly resistant to corrosion shall be supplied and installed, one in the control chamber of cow dung digester, one in the control chamber of human waste digester, and one in the kitchen.
A-14	Gas Valve	2	Sets	Gas valves shall be installed to stop gas flow from the gas bags.
A-15	Gas holder house	30 x 2	m^2	Stone masonry and zing roof gas holder house shall be constructed. The house shall have ventilation and warning sign of leakage. Door shall be rocked.
A-16	Biogas stove	4	Nos	Biogas stove with double burner, with automatic starter switches and 2 meters of hosepipe. Each burner shall have heat load more than 2.5 kW, gas consumption rate 0.4-0.6 m^3/h, and efficiency more than 57%.
B. Mechanical and Electrical Works				
B-1	Power house	30	m^2	New power house with a grill fence wall, zinc roofing and door rock shall be constructed to install biogas engine and generator and electrical equipments near the kitchen or appropriate location as the user will assign.
B-2	Energy meter	1	Nos.	An energy kWh meter with one decimal shall be supplied and installed.
B-3	Distribution panel	1	Set	The single phase distribution board with MCB and safety control shall be installed to supply and switch power from biogas generator to the load.
B-4	Change over switch	1	Set	Manual change over switch shall be installed to interchange the power from grid or from biogas generation system.
B-5	Air Inlet Valve	1	Sets	Solenoid air inlet valve shall be installed to switch off gas in the event of generator stoppage.
B-6	Power House wiring	1	Set	Internal wiring shall be done for power house with single-core or multi-core, cross-linked polyethylene (XLPE) insulated, PVC sheathed cables with stranded copper conductors.

SN	Item	Quantity	Unit	Details and specification
B-7	Earthing	1	Set	Appropriate earthing work shall be done with earthing rod or capper tape according to KS requirement.
B-8	Biogas engine-generator set	1	Set	Biogas engine generator set with 10 kW/12.5 kVA or above capacity, single phase, frequency 50 Hz, power factor 0.8 or higher, protection class IP23 or better, generation efficiency more than 80% and 20 MJ/kWh, with electric starter and ignition system, gas mixer, electronic governor, cooling system, silencer, inlet valve, display panel for output kW, A, V, and rpm. Battery for starting shall be supplied and installed. It shall have warranty time more than 1 year and 8000 running hours. Necessary tool kit for maintenance shall be provided.
B-9	Cabling and wiring for load	1	Set	Cabling between the power house lighting load in dormitories shall be conducted. Single-core or multi-core, cross-linked polyethylene (XLPE) insulated, PVC sheathed cables with stranded copper conductors shall be applied.
B-10	Consumer unit with switches	1	Set	Cable from power house shall be connected with switching device with the existing consumer unit of user's dormitories.
C. Miscellaneous Work				
C-1	Safety arrangement	1	Set	Warning signs at each digester location, fire distinguisher at kitchen and power house, fire alarm at kitchen and power house shall be supplied and installed.
C-2	Sign board	1	Set	Sign boards indicating facility and equipment type shall be installed at digester locations, kitchen, and power house.
D. Related Work				
D-1	Testing and commissioning			Commissioning shall be done after the observation of gas production. Gas stove test and generation test shall be conducted in the commissioning with confirmation of gas pressure and output. Testing record for gas production amount and generated energy shall be recorded and submitted for initial 2 months after commissioning. Testing format shall be submitted and operation test shall be conducted for initial six months after commissioning. Biogas analysis using gas chromatography shall be conducted and analysis result of percentage CH_4, N_2, CO_2, H_2, H_2S, and O_2 shall be reported.
D-2	Documentation	1	Set	Following documents shall be prepared and submitted 3 copies to the Client and 1 copy to the User. ・ Work Plan including, Detailed work schedule, Contractor's organization chart and personnel list, Consolidated drawings of layout of digester, pipe layout, toilet, powerhouse, and other related facility, Bill of quantity, and safety plan ・ Drawings for approval and drawings for work of detailed drawings of digester, gas pipe, slurry pipes, ditches, gas houses and the power house, engine and generator, and other related facilities that the Contractor will install and/or construct ・ As built drawings ・ Format for testing and commissioning ・ Record of monitoring (record of input, operation record, gas production, energy generation) ・ Program of user training

SN	Item	Quantity	Unit	Details and specification
				・ User Manual ・ Record of user training and user's understanding ・ List of consumables and spare parts and supplier's contact list ・ Bills of Quantity and Cost
D-3	User training	1	Set	User training with training program and shall be conducted at least four persons (operators and supervisor) assigned from the user. User manual shall be provided to the Client and the User.
D-4	Technical support	1	Set	Technical supports shall be provided for initial one year for operation and maintenance of the user from the date of commissioning.
D-5	Supply of maintenance tools and spare parts	1	Set	The maintenance tools necessary for operation and maintenance and spare parts including filtering materials and engine-generator parts for replacement shall be provided for 3 years operation.
D-6	Transportation	1	Set	The transportation shall cover all supply of materials and equipment.
D-7	Labor	1	Set	The labor shall cover all construction, civil , electrical, installation works.
D-8	Administration	1	Set	Administration shall cover all administration works including communications and documentations.

*The quantity and size is rough estimate in Pre-FS. Those shall be reviewed and revised according to the result of feasibility study.

**If toilet sewer line is the same as waste water from shower room, additional independent sewer line exclusive for toilet shall be constructed.



This layout is prepared based on a rough sketch and scale is not propotional to actual sites.

Above is a rough layout. Detailed survey drawing with 1/1000 or 1/2000 scale shall be prepared and plan for facilities such as digester, gas bag, power house shall be arranged in the feasibility study

Figure A Sketch Layout of Nyeri Biogas System

Scope of Works for Nyeri Biogas Project (for both Option-1 and Option-2)

1 General

The Client conducts construction supervision at all times. The Contractor shall follow Kenyan Standards (KS) and related international and national standards such as the building code and IEEE. All applied standard shall be currently effective.

The Contractor shall assign a manager in charge of the overall project management, and the proposed manager's CV shall be submitted to the Client for approval.

Work Plan shall be prepared and submitted for approval of the User and the Client. It shall include but not be limited to:

- Detailed work schedule
- Contractor's organization chart and personnel list
- Consolidated drawings of layout of digester, pipe layout, power house, toilet, and other related facility
- Bill of quantity
- Drawings of digester, pipe, power house, generator, and other related facilities that the Contractor will install and/or construct
- Safety plan

2 Concrete and Other Works

(1) Cement, sand, and aggregate

The cement shall be obtained from an approved manufacturer. The Portland cement shall be delivered to the site in sealed kraft bags which shall be clearly marked with the name of manufacturer, place of production, the type of cement, the year and month produced and the weight contained. The cement must be fresh, without lumps and stored in a dry place. Bags of cement shall never be stacked directly on the floor or against the walls to protect the cement from absorbing moisture before use.

All aggregates and sands shall be free from earth, clay, chalk, lime, peat, loam, soft clay of shale or decomposed stone, vegetable and organic matter and other impurities. The aggregates shall be hard and dense, and spherical or cubical in shape. Provisions shall be made at the site for the separate storage of fine and coarse aggregates, as well as of each size of coarse aggregates, in such a manner as to avoid contamination of the aggregates by foreign materials. If aggregates are dirty, they should be washed with clean water.

Gravel size shall not be too big or too small. Individual gravel diameter shall not be greater than 25% of the thickness of concrete product where it is used. Gravel should not be larger than 2 cm in size.

The quantity of impurities such as mud shall be tested using a bottle test. Fill a bottle or glass with 1/3 sand and 2/3 water and stir vigorously. Leave the bottle in a stationery position to allow the sand to settle. The particles of sand are heavier than those of mud and will settle down quickly. After 60 minutes, measure the layers of mud and sand inside the bottle and compare the height of mud layer against the height of mud and sand layers as a percentage. A maximum of 3% of mud in the sand shall be permissible. If mud and other impurities are more than 3% of the sand, then the sand shall not be used and shall be discarded.

Water for washing aggregates and sands, and mixing and curing of concrete, shall be taken from an approved source and shall be clean and free from deleterious substances including salt, oil, alkali, organic matter and others that may impair strength, appearance and durability of concrete.

If cobble-sized stones are used, individual stone diameter of 7.5 - 30 cm shall be used for masonry work. The stones shall be clean, solid and of good quality; and shall be washed with clean water if they are dirty.

The concrete shall be arranged according to “KS02-594:1986 Specification of Concrete” or other relevant standard(s) approved by the Client. The compressive strength after 28 days shall be more than 20 N/mm^2 otherwise specified. The concrete mixing property shall be submitted and concrete test shall be conducted.

The same clean containers shall be used and the containers shall not be changed during the work to measure the volumes of concrete.

Concrete bases, slabs, beams, and forms and all the reinforcement shall be prepared and shall be ready before the concrete is mixed. All earth bases and forms shall be wet to prevent absorption of water from the concrete, but excess water content in the mixture shall be avoided. All concrete shall be placed within one hour of mixing the cement with water.

Cement shall be prepared according to “KS EAS 19-1:2001 Composition, Specifications and Conformity Criteria for Common Cement” or other relevant standard(s) approved by the Client.

Waterproof cement mortar shall be applied. The mixing and application of a waterproofing agent shall be in accordance with the manufacturer's instructions. The cement mortar shall be applied carefully using steel trowel. The sand to be used in the cement mortar shall be clean, hard, solid and durable and shall not contain harmful amounts of dust, mud, organic matters or other objectionable matter.

Waterproof cement shall not dissolve in water, but shall float when poured into a bucket of water.

(1) Reinforcement

Concrete reinforcement shall be more than the sufficient amount as indicated in the Drawing, which shall be proposed by the Contractor.

Reinforcement steel used in reinforced concrete shall be deformed steel bars, complying with KS573:2008 High Yield Steel Bars for the Reinforcement of Concrete-Specification.

Reinforcement steel shall be stocked on the site, separated into the various sizes in such a manner that the steel does not get contaminated with deleterious matter. The number, size, form and position of all steel reinforcing bars, ties, links, stirrups and other parts of the reinforcement shall be in accordance with the approved drawings and they shall be kept in the correct position and with the required cover without displacement during the process of compacting the concrete in place.

Cutting, bending and splicing of the reinforcement bars shall be carefully carried out in accordance with the shop drawings submitted to the Client for approval.

The bars shall be bent cold in a manner which will not injure the material. Any ties, links or stirrups connecting the bars shall be tauten so that the bars are properly braced and the inside of hooks and bends shall be in actual contract with the bars around which they are intended to fit. Bars shall be bound together with the best black annealed soft-iron wire and the binding shall be twisted tight with pliers. The free ends of binding wire shall be bent inwards.

Before any steel reinforcement is fabricating, any loose mill scale, loose rust and any oil, grease, mud or other deleterious matter shall be removed.

(2) Concrete placement

Before placing any reinforcement bars on the surfaces of earth, gravel, etc., a layer of concrete shall be worked into the cleaned surface to a thickness of 5 cm. Before placing concrete on foundations, the Contractor shall remove from all such surfaces; soil, objectionable coatings, loose or unsound fragments of rock, earth, mud, debris, and stagnant water, and shall keep such surfaces clean and free from stagnant water during concreting operations.

All concrete and mortar shall be placed and compacted within one hour after being mixed; and no partially set material shall be used in the work. The placing of concrete in individual structural members shall be continuous without stopping up to an approved prearranged construction joint or until the member is completed. Concrete placing shall be carried out rapidly to prevent occurrence of cold joints under hot weather conditions.

The Contractor shall take adequate measures to cure the concrete. These shall include covering the concrete with a moist curing mat or other effective means which shall be kept damp continuously and not exposed to sunlight for a minimum period of seven (7) days after casting.

The finished faces of all concrete works shall be sound, solid and free from honeycombing, protuberances and blemishes. No plastering of imperfect concrete faces shall be allowed and any concrete that is defective in any way shall be cut out and replaced to such depth or be made good.

(3) Bricks and blocks

B ricks shall be prepared according to "KS 02-300:1983 Specification for burnt building bricks", and blocks shall be prepared according to "KS 02-547 Specification for burnt Clay Blocks", or other relevant standard(s) approved by the Client.

If the Contractor applies precast masonry units, the Contractor shall apply "KS 02-625: 1986 Specification for Precast Masonry Units" or other relevant standard(s) approved by the Client.

The bricks shall be of the best quality of their respective kinds. They shall be hard, square, sound, thoroughly well burnt, true to shape, uniform in size, shape and texture, free from lime and hair cracks, uniform in colour, and clean. The porosity shall in no case exceed 20% by weight, though in the case of engineering bricks not more than 5% will be allowed. Before any order for bricks is made by the Contractor, samples must be submitted to the Client for approval. Manual labour shall be employed in unloading and stacking bricks on delivery. No broken, chipped or cracked bricks shall be brought to the Site.

Bricks shall be built in level courses using bricks of the quality or description specified and to the dimensions shown on the approved drawings. Walls are to be built up in a uniform manner and no one portion raised more than 1 m above another at one time, being racked up and not toothed. All bricks shall be perpendicular, kept strictly plumb and square and the whole properly bonded together so that there are no continuous vertical joints through any two courses of brickwork. No broken bricks will be allowed except where necessary to form proper bonds. The mortar for brickwork shall be, unless otherwise specified, cement and sand mixed in the proportion of 1:3 generally.

Immediately before use, bricks are to be immersed in fresh water and thoroughly wetted. Before continuing partly completed work, the exposed bed shall likewise be wetted. All beds and joints are to be completely filled with cement mortar notwithstanding any local or common custom to the contrary. Where the brickwork is specified to be unpainted, the joints on exposed faces are to be ironed in as the work proceeds and special care is to be taken to give the whole of the joints an even colour. Faces of brickwork due to be plastered shall have joints raked out and left open to form a key for plastering.

Concrete bricks can also be made on-site from cement, sand and ballast chipping if fired bricks are not available or are too expensive. The volume ratio of concrete bricks shall be 1:3:4 for cement: sand: gravel respectively.

Concrete bricks shall be strong (good ratio, mixing, and proper compaction when making) and shall uniformly have a regular shape and size. Concrete bricks shall be cured for at least 7 days before they are used.

The concrete bricks shall have a uniform size of:

- 23 x 11 x 9 cm for smaller - radius digesters (up to 32 m^3), and
- 25 x 12 x 10 cm for larger - radius digesters (above 32 m^3).

Bricks with a thickness of less than 9 cm shall not be used.

3 Biogas Digester

The following are the instructions for construction of a general fixed dome type digester.

When the instructions mention “mixing chamber” and “expansion chamber”, the digester utilizes cow dung as feedstock. A toilet connected digester does not have these components and is connected directly with the sewer line.

There are several types in the design of biogas digester. Followings are the general description that the Contractor should follow, referring to AKUT fixed dome biogas digester developed by GIZ. Details may be changed according to specific design of digester.

(1) Finalization of Biogas Location

The finalized location of the digester shall be approved by the User and the Client. The following items shall be considered to determine the finalization location:

- The edge of the foundation of the digester shall be at least two meters away from any other structure to avoid risk of damage during construction.
- The location of digester shall be apart from trees to prevent damage.
- The digester shall be at least 10 meters away from groundwater wells or surface water bodies to prevent water pollution.
- A fixed dome biogas plant shall be constructed as follow: round wall and expansion chamber made of either brick, block or stone, dome made with plain concrete (for small digester less than 10 m3), brick or block, slabs and beam made with reinforced concrete, foundation made with concrete, and feeding chamber made with either stones or bricks.

(2) Marking of Digester Location

After finalization of location, the site layout shall be marked on the ground surface with wooden stakes, rocks, chalk or other materials. The following is an example of a marking method.

1) First, stick a small peg in the ground at the centre spot of the digester.
2) Level the ground and determine the centre line of the digester, feeding chamber, and expansion chamber.
3) Define the reference level. Assume that the ground level is the reference level and indicate this in a drawing. The top of the dome (outer surface) shall be exactly at ground level.
4) Attach a cord to the peg to represent the radius of the digester. Mark the circumference by moving the end of the cord in circular motion.
5) Mark the feeding chamber inlet pipe, feeding chamber, and gas piping.
6) Insert a stick or wooden peg in the leveled ground at the centre of the proposed digester pit. With the help of the stick/peg and cord prepared earlier, mark the circumference of a circle to indicate the area to be dug from the centre point where the central line meets the perimeter line. Draw a tangent to the circle and measure a suitable length.
7) Mark the manhole, ensuring that the inner size.
8) Draw horizontal parallel lines from points on either side of the tangent, which will meet the dome from the centre point where the central line meets the perimeter line. Measure the length of the outlet and the thickness of the wall to define the outer dimension.
9) Check the size diagonally to ensure that the corners are exactly at 90°. Use colored powder to mark the dimensions.

10) After the site layout is marked, the User should review the selected location again to ensure that the best site has been chosen and the digester will not interfere with user's activities.

(3) Excavation of Digester

Excavation of the digester pit shall be started after layout is approved. Tools such as crow-bars, picks, spades, shovels and baskets shall be provided by the Contractor. Digging shall be done as per the dimensions fixed during layout. The following conditions shall be maintained:

- If the water table is high and digging to the required depth is difficult, a deeper pit has to be constructed near the digester pit
- Water accumulated in the digester pit has to be drained from the pit through underground pipes or pumping.
- After the required dimension and depth of digging is attained, the work of leveling and ramming the base shall be done. The pit bottom must be leveled and the earth must be untouched.
- Horizontal poles shall be placed at the ground level, crossing each other at 90 degrees at the centre. It shall be ensured that the poles rest on leveled ground.
- For safety, the pit walls shall be vertical and stepped from the ground surface. For each meter in depth excavated, the stepping shall be shifted one meter away from the center of the excavation. If the soil lacks cohesion and the angle of repose needs more slope cutting, scaffolding may be needed.
- Excavated soil shall be placed at least one meter away from the edge of the pit and steps, so that it does not fall back into the pit during works.
- It is not recommended to construct the digester at or below the groundwater table elevation. The earth base of the excavation shall be compacted to attain at least the same degree of consolidation as undisturbed soil in the site. Compaction shall be done using a rammer or compaction tools.

(4) Construction of Digester

The ring foundation and the conical bottom shall be prepared. A conical shape for the bottom slab is more stable and provides additional volume.

1) Foundation

- The digester foundation shall be laid using cobblestones and/or gravel as aggregate then filled with concrete. The foundation shall not be less than 15 cm in thickness and the mixing ratio shall be 1:3:4 for cement: sand: gravel respectively.
- The foundation concrete shall be cured for at least two days.
- The foundation ring where the brick and concrete work settles shall be shaped horizontally and shall be levelled before filling. For larger sizes of biogas plants (32 m^3 and above) and on weak ground, the foundation ring beam shall be placed with reinforcement bars.
- Horizontal measurements are done with the centre pipe. The 0.5" GI gas pipe shall be placed exactly vertically. The positioning of this center pipe shall be ensured by using a spirit level and adjusting with binding wire fixed at four pegs in the soil on the rim of the excavation. After confirmation of the level, the vertical pipe shall be checked with a plumb to ensure it is still in the exactly vertical position.
- A string or wire shall be attached to the vertical pipe. The length of this wire shall be much longer than the dome diameter.

- The foundation slab shall be placed up to completion at one time, after mixing enough concrete for the whole slab. The slab shall be exactly leveled with the pegs to determine the level of the concrete at every point around the base. If the slab is not leveled, the distribution of weight will not be balanced and the structure may crack.

2) Digester Wall

- Immediately after casting the slab, the first layer of stonework has to be put into the freshly placed concrete to obtain bonding between foundation and walling.
- The first row of bricks shall be placed on a firm, untouched and level foundation. Subsequent rows shall be positioned on their lengths so that the wall thickness is maintained. The wall thickness shall be maintained at not less than 23 cm.
- The cement mortar for joining bricks shall be mixed in the ratio of 1:4 for cement: sand respectively.
- To construct the digester wall, the radius shall be kept constant using a guide square fixed at the centre GI pipe. All blocks shall be laid out properly with the assistance of the radius square. The radius square shall always be leveled, and a spirit level shall be fixed on the square every time blocks are laid. The dimensions shall be checked and corrected at every stage by measuring the vertical distance from the reference line.
- After the round-wall reaches the correct height, both the inside and outside of the wall shall be plastered carefully with a smooth layer of cement mortar with a mixing ratio of 1:4 for cement: sand respectively. Before application of cement mortar, the wall surface shall be cleaned and moistened, after which the plaster shall be applied in one coat of about 2 cm.
- After every three to four layers of blocks, backfilling and compacting should be done so that the completed part is properly reinforced by the soil. The backfilling between wall and pit-side shall be compacted with great care, not sooner than 12 hours after brick course placement to allow the cement mortar to cure. Earth shall be well compacted by adding water and carefully ramming along the digester.
- The feedstock inlet pipe (or toilet pipe in the case of toilet connected digester) shall be placed in position when the round-wall is 30-36 cm high, at a slope of 45°), taking into consideration the location of the inlet mixing chamber.
- At the opposite of the main feedstock inlet pipe, a window must be left for slurry flow to the expansion chamber. After the space for the outlet is dug out, construction of the vertical wall shall proceed, incorporating the outlet steps. In the case of toilet connected digester, outlet pipe shall be connected to a sewer line for septic tank and adequate space for the pipe shall be left.

3) Dome (Gas holder)

- To construct the spherical dome, another square shall be used to create a bowl shape. The square shall be fixed at the central GI pipe, with proper positioning and leveling. The radius square shall be adjusted during the dome construction by fastening and correcting the distance from the guide pipe. For plastering, 2 cm shall be added to the radius.
- A nail at the head of the square is used to mark the exact distance for brickwork construction. Each brick of the dome is laid against the nail of the radius stick, keeping the top of the brick in the same slope as the direction of the radius stick. The inner edge of the brick shall always form a right angle with the radius stick, and the brickwork will automatically rise in spherical shape.
- The mortar mixing ratio for dome brick laying shall be 1:3 for cement: sand respectively.
- The spherical wall ends with the manhole ring beam. Above this ring beam the neck shall

be constructed in masonry work according to the detailed measurements in the drawing. The neck shall be constructed up to completion at one time to avoid any cracks. Flemish bond shall be used, whereby the orientation of stones is changed from row to row. The best stones shall be selected especially for the neck structure and a perfect jointing shall be done for the neck. The dome shall be durable with internal gas pressure on the spherical structure and the neck. The neck shall be able to withstand the internal gas pressure by its own internal structure. A main gas outlet pipe shall be applied at the neck.

- A lid shall be cast inside the neck structure. The lid shall be reinforced concrete. Four (4) steel handles shall be applied for a concrete lid. The thickness shall be 18 to 20 cm. The gap between the neck and lid shall not exceed 2 cm as a large gap will not be gas-tight. Sealing shall be done later with moist clay. After clay sealing, weak mortar with mixing ratio of 1:8 for cement: sand respectively shall be applied on the top of the lid peripherally for top sealing.

- After casting the lid and feeding feedstock, a water jacket covering the lid of the manhole shall be applied to prevent lid sealing from drying up and for leakage detection.

- The outside of the dome shall be covered with a layer of plaster before covering with earth. Cement plaster shall not be applied under sunlight. The mixing ratio of mortar for rendering plastering shall be 1:5 for cement: sand respectively.

- Before mortar application, the surface of the wall shall be cleaned and moistened. Plaster of 2 cm thickness shall be applied all over the surface of the dome. The plaster shall be cured for more than 12 hours before backfilling.

- After above rendering, the inside plaster of the dome and neck shall be done with the most accurate workmanship to secure gas tightness. Special attention shall be given to ensuring that the surface area of the dome and neck forms a unity, and every inside plaster course shall be done up to completion at one time.

- A wooden trowel with smoothened corners shall be used alongside a conventional trowel to execute a smooth and even surface. All mortar that falls down shall not be used for the dome and neck.

- Before application of the first layer, the surface of the wall shall be cleaned well, and excess mortar removed before starting plaster work. The quality of the sand for plastering the dome shall be "best of the best" and no impurities shall be allowed. The sand for plastering shall also be sieved prior to mixing with cement.

- Seven steps shall be taken for plastering of the dome: (i) Cement-water flushing, (ii) preparation of mortar in 1:4 mixing ratio for cement: sand respectively , (iii) Cement-water flushing, (iv) plaster with water proof compound, with mixing ratio of 1:4 for cement: sand respectively, (v) Cement–water flushing with water proof compound, (vi) plaster with water proof compound, with mixing ratio of 1:3 for cement: sand respectively, and (vii) Cement–water finish with water proof compound. Undertaking the seven steps will ensure that the final cement flushing appears as a very smooth and shiny surface.

- Backfilling shall be in layers of less than 30 cm, and then compacted softly. Any damage to the digester wall shall be avoided. The backfill material must be compactable, and clay or black cotton soil shall not be applied.

4 Piping Works and Ditches

Piping works shall be conducted according to the work plan. The layout shall be approved by the User and the Client.

All pipe laying works shall be carried out by experienced personnel. The pipes shall be correctly centered and aligned horizontally and vertically just prior to jointing with the mating socket. Any pipe found to be defective shall be marked, removed and replaced. Any damage to pipe linings or coatings shall be repaired by the Contractor. The pipe shall be corrosion resistant and tolerant of high concentrations of methane gas and hydrogen sulfide.

The pipes and fittings shall be of the same brand. They shall be checked and confirmed not to have any leakages. Pipe manufacturer's specifications and recommendations shall be strictly followed for solvent, welded and electrofusion joints.

After the installation of pipeline, the Contractor shall investigate all the gas lines and pipe joints for any blockages and leaks, and conduct repairs.

The Contractor shall check the pipeline for leakage and secure approval from the User before backfilling. All valves and connections shall be checked to ensure there are no leakages.

The piping for gas shall have a slope of 1/100-2/100 (1-2%) to collect and direct moisture towards water traps. Avoid sagging in the pipe line. A moisture remover shall be installed.

Pressure test on the piping system shall be done after the whole system has been laid and the manometer has been installed. This shall be done before backfilling of the pipe trenches.

Both PVC and PPR pipes shall be laid at least 30 cm below the ground level. Special conditions may require deeper installation. Proper compacting during backfilling shall be done in layers, after every 20 cm to protect pipes.

Manholes shall be installed with metal cover or concrete cover with a steel bar handle at intervals of at least 50 m on the pipe line and at corners along the pipe route. A pressure test unit and gas sampling nipple shall be applied with ball cock.

A manometer shall be provided with a pressure scale so that the User can know the possible amount of gas usage.

For cow shed connected digester, ditch from the cow shed shall be modified so that automatic transportation of cow dung and urine is possible by gravity. A ditch shall be arranged to channel and transport feedstock by gravity. The elevation of ditches between the cow shed and digester shall allow to flow downstream from the cow shed towards the digester. If not, modification work shall be done.

Biogas slurry shall be supplied to the garden by gravity. The location of the garden shall be confirmed to be at lower elevation than expansion chamber of digester. A ditch connecting digester expansion chamber to the garden, with a gate along the channel shall be constructed.

For toilet connected digester, the pipe from sewer line shall be connected to digester inlet pipe. Digester outlet pipe shall be connected with a sewer line to the septic tank. Manholes shall be provided for the connection parts.

For toilet connected digester, a separate pit latrine shall be provided for persons taking antibiotics.

5 Steel and metal works

The Contractor shall furnish and install miscellaneous embedded metal works, such as embedded metal frames for duct cover, anchor bolts with accessories, steel pipes for duct, light gage steel ceiling material with zinc chromate metal finish or hot-dipped galvanized, etc.

The Contractor shall furnish and install miscellaneous non-embedded metal works, such as steel-made chain-link fence with pole, entrance gate, etc. All exposed steel surfaces shall be hot-dip galvanized metal.

Oil paint shall be applied onto two layers of primary anticorrosive paint. Sufficient time shall be allowed for drying between each new coat according to manufacturer's instructions.

Rust on metal surfaces, and oil and dirt on surfaces shall be thoroughly removed before installing.

6 Electrical works (For Option-2 with generation system)

Wiring work shall be conducted in accordance with “KS662: 2002 Kenya Wiring Regulations”.

Insulated cables shall apply “KS 453:2000 Specification for PVC-insulated cables for Electric Power and Lighting”.

All power cables shall be of single-core or multi-core, cross-linked polyethylene (XLPE) insulated, PVC sheathed cables with stranded copper conductors. Power cables shall have ample current carrying capacity and shall duly withstand the maximum prospective fault current for a duration of time.

Each cable shall be fitted with a cable identification label at each end. The cables shall be continuous between terminals, and no junction shall be made in the cable ducts and conduits. The cables shall be laid in the cable ducts or conduits after they have been cleaned. Oil or grease shall not be used as a lubricant for cable laying work, but an approved compound may be used for this purpose.

Where the cables and wires are installed in the conduits, they shall be pulled into a conduit as a bundle to avoid twisting and abrasive actions caused by single conductor pulling.

At least 10% spare terminals shall be provided in the terminal blocks.

Proper earthing shall be done with grounding electrodes. Each electrode shall be complete with approved non-ferrous clamps for the connection of earthing conductors. The measurement of each group of grounding electrodes and earth grid shall be provided and back filling shall only be undertaken after inspection.

The Contractor shall provide detailed guideline for specification, operation and guideline of engine-generator provided from manufacturer.

7 Excavation, soil and waste

Before excavation, the Contractor shall clear and dispose all rubbish and/or any other objectionable matter within the Site. This shall include the removal of existing foundations and other obstructions interfering with the project work, and burning or otherwise disposing of all such materials.

The slope and bottom of all excavation shall be trimmed and cleared of all loose or decomposed material and finished with firm and smooth perpendicular, level, or inclined surfaces as required. The surfaces of the excavation shall be protected from deterioration and be kept clear and uniform. The excavated trench or pit shall be kept well drained of water until and during backfilling operation.

Before all excavation, the contractor shall obtain approval from the user, specifically regarding the location to place excess soil. Avoid accidents while digging near the sides as soil may collapse

If the soil is not suitable for use in embankment and backfilling, the Contractor shall obtain good quality soil for this purpose from borrow pits. The location and areas of borrow pits shall be proposed by the Contractor and approved by the User and the Client.

The soil shall be placed in not more than 30 cm layers evenly spread, and each layer shall be well compacted to attain at least the same degree of consolidation as undisturbed soil in the Site. The soil shall be dried or watered as required to have the optimum moisture content to attain the required consolidation. The surface of embankment and backfill after compaction shall have a slightly cambered surface where required to facilitate drainage.

8 Safety arrangement

The Contractor shall provide insurance for workers. A copy of the certificate of insurance shall be provided to the Client.

Safety equipment shall be provided for all workers and related personnel in the construction site such as helmets and belts. All laborers shall be appropriately dressed for the working conditions to avoid accidents.

The construction site shall be clearly separated from outsiders by a fence or rope. Nobody other than related personnel or laborers shall enter the construction and installation site during works.

The Contractor shall provide maximum warnings to ensure fire hazards are managed. No cigarette smoking shall be allowed on site during works, especially after feedstock has been channeled to the biogas system.

The location of main facilities, such as digester, pipe line, gas bag, and generator shall be apart from traffic line and its extended line of any vehicles to avoid accidental shock.

Fire extinguisher and eye-catching warning sign with shall be attached in power house and other facilities that have possibility of fire.

9 Testing and commissioning

The Contractor shall perform testing and commissioning in the presence of the Client. Testing and commissioning shall be according to the format prepared by the Contractor and submitted for approval by the client before testing.

For biogas digesters connected to toilets, in addition to the feedstock supply from toilets, cow dung at 200 kg per digester shall be applied not less than three times to facilitate initial fermentation at the original stage.

10 User training

The Contractor shall provide user training to not less than three operator assigned by users' representative. The Contractor shall conduct operation and maintenance work during the testing and commissioning period, with participation of users and provision of O&M training. The training period shall not be less than three weeks. The Contractor shall check the users' understanding by using a questionnaire sheet and attach it in the report to the Client. A list of "Do's and Don'ts" shall be provided and presented to users at the working place. The findings and challenges found in the process of user training shall be pointed out.

Proposed user training program shall be submitted to the Client for approval, before conducting the training.

The Contractor shall provide a list of spare parts and consumables, as well as contact addresses for the same, so that user can easily make contact whenever it is necessary.

If the system contains a digester connected to toilets, notification for toilet usage shall be provided and a briefing meeting shall be held with toilet users. The notification of toilet usage shall include but not be limited to:

- Do not flush excessive amounts of water (specify allowable amount)
- Do not use the toilets connected to the digester while taking antibiotics, use a separate toilet instead
- Do not use detergents with disinfecting agents such as chlorine

Visual guidance shall be provided by pasting a laminated instruction paper on the wall of all entrances and exits of toilets.

User manual for operation and maintenance including daily routines, recording sheets, DOs, DON'Ts, trouble shooting, contact list for spare parts and consumables supply shall be provided and submitted for approval of the Client.

Safety instructions to users shall be provided, especially pertaining to the risk of explosion and toxicity of biogas aspiration.

11 Record and Documentation

The Contractor shall present his general work plan for approval by the Client.

The list of documents that the Contractor shall submit is as follows:

- Work Plan
- As built drawings
- Format for testing and commissioning
- Record of monitoring (record of input, operation record, gas production, energy generation)
- Program of user training
- User Manual
- Record of user training and user's understanding
- List of consumables and spare parts and supplier's contact list

Annex 2 Proposed Scope of Work for Feasibility Study of Nyeri Biogas Project

1. Introduction

1.1 Background and Objective

Biogas produced in anaerobic digester can be applied both for the production of the electricity using engine-generator and cooking fuel for the replacement of fuelwood.

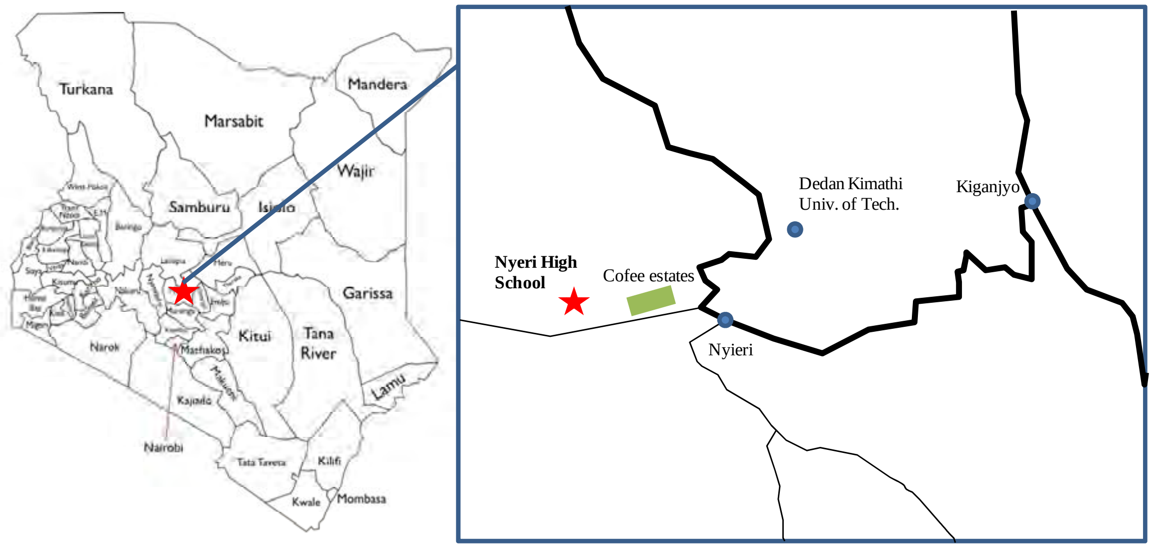
The biogas generation system is a method of electricity generation utilizing biogas produced by methane bacteria as the energy source. Similar to natural gas or propane gas, biogas has heat value, and can therefore be utilized as energy. Although the unit heat value of biogas is smaller than that of fossil fuels, biogas can be used as a cooking fuel in the same way as LPG with some modification of cooking stoves. When it is connected to a gas engine or modified diesel engine, it provides rotative force for the generator, producing electricity. Since waste materials are used as feedstock for biogas systems and no fossil fuel is required, biogas is considered a renewable energy source.

Strategic Master Plan 2013/2014-2017/2018 of Rural Electrification Authority (REA), Third Draft, stipulates that promotion of the use of renewable energy sources including biomass is one of REA's roles. In the strategic objective to develop and promote renewable energy sources, the strategic plan includes a target to develop and promote biogas and biomass systems for institutions.

Pre-Feasibility Study for Biogas Projects was therefore prepared to assess the technical and economic feasibility of biogas projects in six schools in Kenya by the Working Group of REA. In the Pre-F/S, Biogas project in Nyeri High School was evaluated as the most feasible project. Accordingly, REA calls for the consultancy service for the Feasibility Study of Nyeri High School biogas project to formulate the optimal and sustainable biogas system and to prepare the for the procurement and implementation.

1.2 Location

Nyeri High School is located in Nyeri County, around 3 km from Nyeri town. The coordinate of the location is S-0.4078425, N36.9205427. Location map is as shown below.



2. Scope of Work

The work period of the Consultant is four months in total with five Person-Months. The scope of work for the Consultant for the Feasibility Study includes review of Pre-Feasibility Study, survey, energy and demand assessment of the school, optional study and optimal system selection, cost estimation, economic and financial evaluation, design and preparation of specification, construction plan, and environmental assessment.

2.1 Survey and Preparation of Survey Drawing

The Consultant shall conduct site survey in the school. The Consultant shall have sufficient background

information and shall explain to the facility manager and shall ask for the participation in the survey. Necessary information and data shall be updated from those of Pre-Feasibility study data and additional detailed information for energy and demand assessment and design shall be collected for planning of cooking fuel supply and generation using biogas.
Survey drawing of 1/500 or 1/1000 of the school shall be prepared and proposed layout of necessary facility shall be shown in the drawing.

2.2 Assessment of Demand and Energy

The consultant shall assess monthly and yearly energy demand for fuel wood and electricity in the school, and shall estimate the feedstock with realistic amount estimation that can to be utilized in biogas digester. The Consultant shall consider possible amount of the feedstock by type such as cow dung or night soil, with sufficient consideration about geographical condition and feasibility of construction of ditches and pipelines. Cost-minimum and benefit-maximum layout shall be proposed and realistic amount of feedstock shall be assessed.

2.3 Cost Estimation

Cost estimation shall be conducted with recent public work unit price, estimation of construction quantity, and quotation from equipment supplier. The cost estimation items shall have objective base data and shall be the one that can be used as the reference price for the supplier tendering. The cost estimation shall be conducted for all proposed optional system layouts.

2.4 Economic and Financial Evaluation

The economic and financial evaluation shall be conducted with recent prices and estimated cost. Annual cash flow of the system shall be prepared and EIRR, FIRR, B/C shall be calculated. The base of benefit and cost shall be well explained and shall be based on quantitative data. Economic and financial evaluation shall be conducted for all optional system layouts and the comparison of options shall be the base of optimal system selection.

2.5 Study for Optimal System Selection

Based on the assessment of demand and energy, cost estimation, and economic and financial evaluation, the Consultant shall propose optional system size and component and shall propose optimal system. The option shall include variation of biogas amount ratio to be supplied to cooking fuel and generation system. Cost-minimum and benefit-maximum system shall be studied and proposed to REA. The result of optimal study shall be well explained to REA and the facility representative, and shall be agreed.

2.6 Preparation of Specification and Design of Biogas System

For the selected optimal system, the design drawings including but not limited to (i) Overall layout of facility with system and pipeline position, (ii) Digester and feeding chamber and expansion chamber and with reinforcement, (iii) Pipe line, (iv) incidental facility such as control chamber, water trap, valves, (iii) Electrical works with single line diagram, and (vi) Buildings for power house and related facility, shall be proposed. The layout shall consider the elevation difference so that O&M of feedstock and effluent transportation can be minimized.
The specification shall be prepared with updating the one prepared in Pre-Feasibility Study and shall have detailed quantitative information for construction quality management. The specification items shall cover including but not limited to excavation works, digesters, cow shed and toilet modification works, trench works, piping works, gas pipeline works, gas holder bags, flow meters, filtering units, manometers, valves, biogas stoves, power house, energy meters, distribution panel, switches, wiring, earthing, engine and generator sets, safety arrangements, and other requirements.
The specification and design drawing shall be in accordance with related standards of Kenya Bureau of Standards (KBS) with clarifying the code of KBS. The specification and design shall be the one that can be directly utilized as the tender specification and tender drawing in the project implementation stage.
The result of design and specification shall be sufficiently explained to REA and the representative of the School and shall be agreed.

2.7 Construction Plan

The Consultant shall formulate construction plan for construction and installation. Overall construction schedule and plan with detailed work items shall be prepared including excavation, construction of digester and building, installation of equipment, electrical works, piping, steel and metal works, electrical works, testing and commissioning test, and user training. Quality control items, environmental management, and safety measurement to manage contractor shall be proposed.

2.8 O&M Plan

Operation and maintenance plan shall be proposed including work amount, cost, and necessary regular replacement and repair work. The O&M plan shall be well explained to the user in the facility and endorsed from them.

2.9 Environmental Assessment

The Consultant shall support REA to obtain environmental license for the project implementation and shall prepare necessary document for the procedure. Renewable Energy Projects falls under "No. 10 Electrical Infrastructure" in the "Second Schedule" of Environmental Management and Coordination Act (EMCA). Therefore, all Renewable Energy Projects are naturally subject to the Environmental Impact Assessment (EIA) procedures. The Consultant shall prepare Project Report that National Environment Management Authority (NEMA) requires, and support REA for submission of Project Report to NEMA. In case EIA is judged to be necessary by NEMA, the Consultant shall prepare EIA report and support REA for submission of EIA report to NEMA.

3. Input

The feasibility study proposes a total of Five person-months of consulting services. The consultants will include following specialists:

(i) Biogas Specialist and Team Leader (3.5 Person-months),
(ii) Economic and Financial Specialist (1.0 Person-months), and
(iii) Environment Specialist (0.5 Person-months)

The allocation of person-months input shall be proposed in the proposal with the assignment schedule.
In case EIA is judged to be necessary by NEMA, additional person-months can be proposed by the Consultant.

4. Output

The Consultant shall prepare and submit following documents.

(i) Inception Report : 0.5 month after the commencement.
Inception Report shall include work plan, method for each scope of work, task schedule, and personnel assignment.

(ii) Interim Report: 2 month after the commencement.
Interim Report shall include interim result of study including survey result, survey drawing, result of energy and demand assessment, proposed design, and Project Report submitted to NEMA.

(iii) Draft Final Report: 3.5 months after the commencement
The Consultant shall submit draft final report 2 weeks before the final submission, and ask for the comment from REA. The Draft Final Report shall include all the study result including documentation covering all scope of works, drawing, and recommendation for implementation.

(iv) Final Report: 4 months after the commencement
The Consultant shall incorporate REA's comment on Draft Final Report and submit. The Final Report shall include all drawing and documentations prepared in the feasibility study.

5. Qualification

The Consultant shall have following minimum qualifications.

- Minimum five years of working experience in Kenya as consultant for renewable energy projects
- Minimum three years of working experience as biomass/biogas engineer
- Experience in demand and energy assessments for biogas energy
- The team leader shall have MSc. Degree of mechanical, chemical, or electrical engineering or

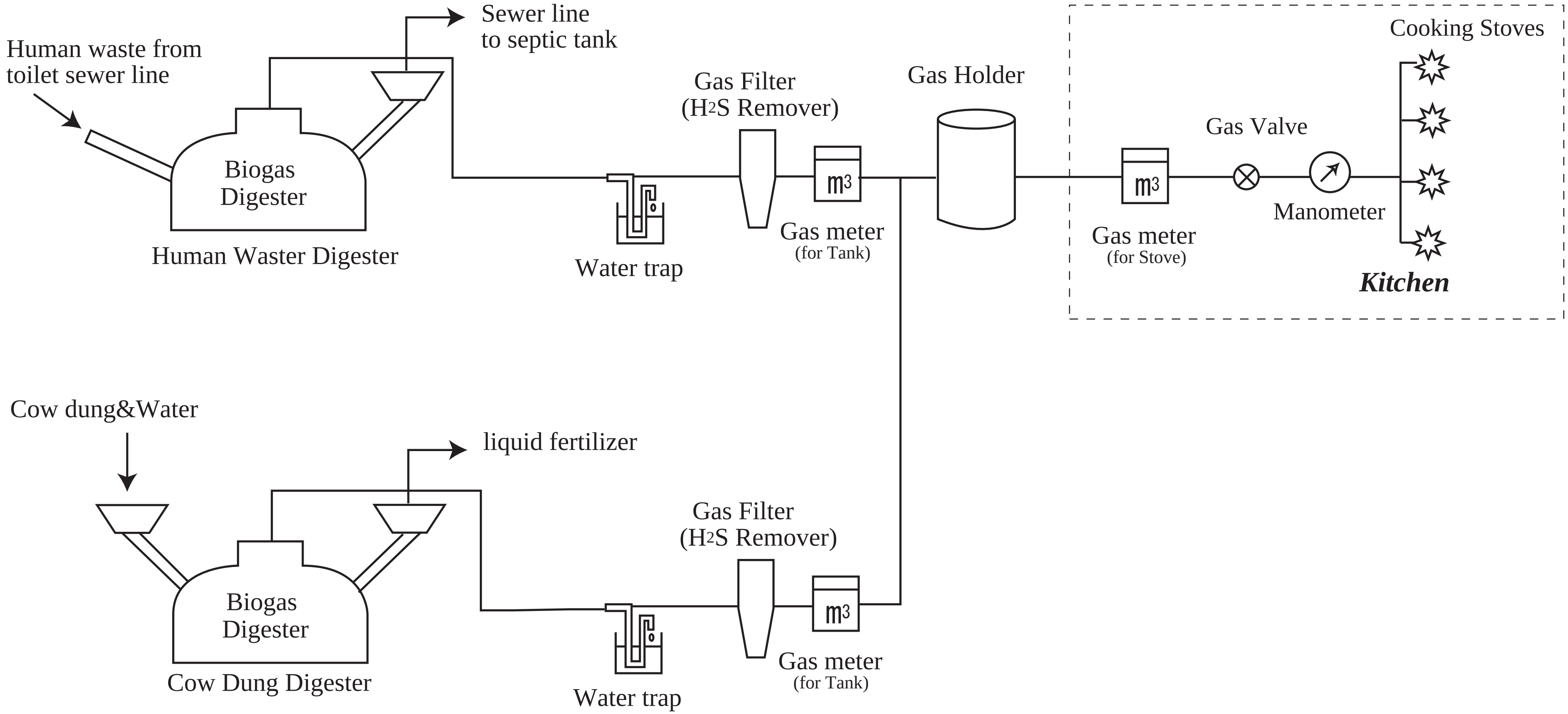
environmental science

- Fluency in oral and written English

* The high-lighten parts need to be revised considering input and conditions.

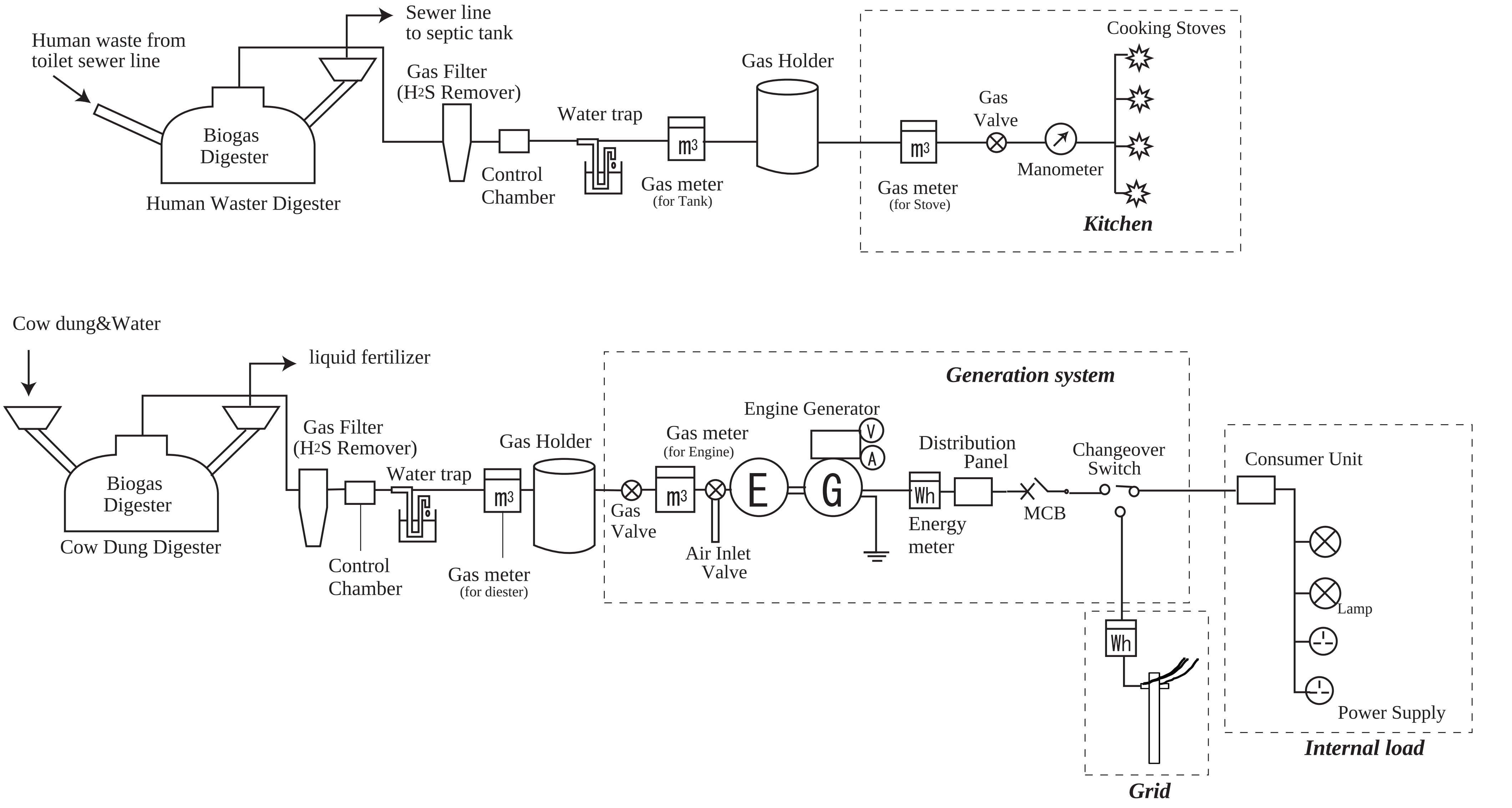
Annex-3 Drawing of Nyeri Biogas Project

Drawing No. N-01-1	Flow of Biogas System Option-1 Cooking Fuel Supply Only
Drawing No. N-01-2	Flow of Biogas System Option-2 with Generation System
Drawing No. N-02	Excavation Plan for Biogas Digester (32, 60 m^3)
Drawing No. N-03-1	AKUT Fixed Dome Type Biogas Digester (32 m^3) for Human Waste
Drawing No. N-03-2	AKUT Fixed Dome Type Biogas Digester (60 m^3) for Cow Dung
Drawing No. N-04	Control Chamber and Water Trap
Drawing No. N-05	Reinforcement Plan and Digester Manhole



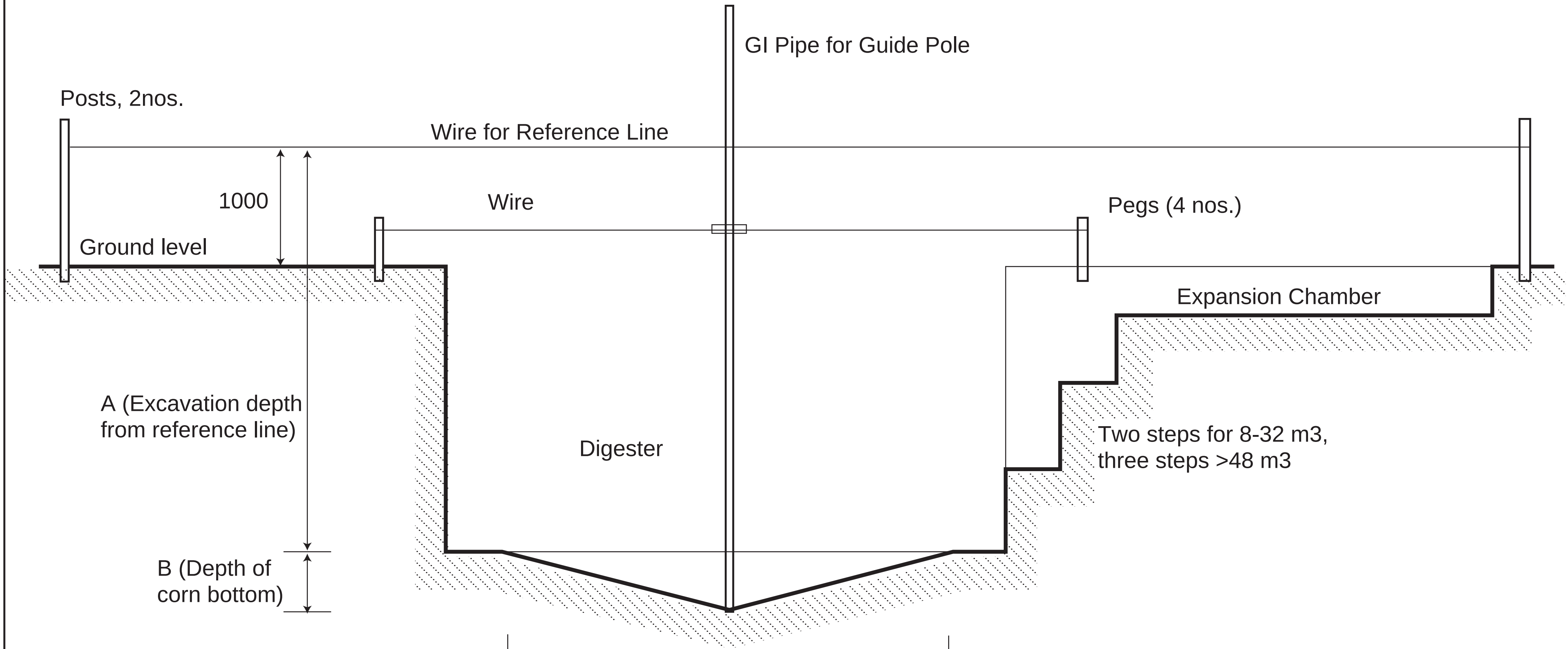
For reference only. Drawing for work shall be prepared by the Contractor.

Flow of Biogas System Option-1 Cooking Fuel Supply Only Pre-feasibility Study of Biogas Project in Nyeri High School	Rural Electrification Authority	Scale: NTS	Drawn by:
		Version: 0.1	Checked by:
		Date: 12/11/14	Drawing No.: N-01-1



For reference only. Drawing for work shall be prepared by the Contractor.

Flow of Biogas System Option-2 with Generation System Pre-feasibility Study of Biogas Project in Nyeri High School	Rural Electrification Authority	Scale: NTS	Drawn by:
		Version: 0.1	Checked by:
		Date: 12/11/14	Drawing No.: N-01-2



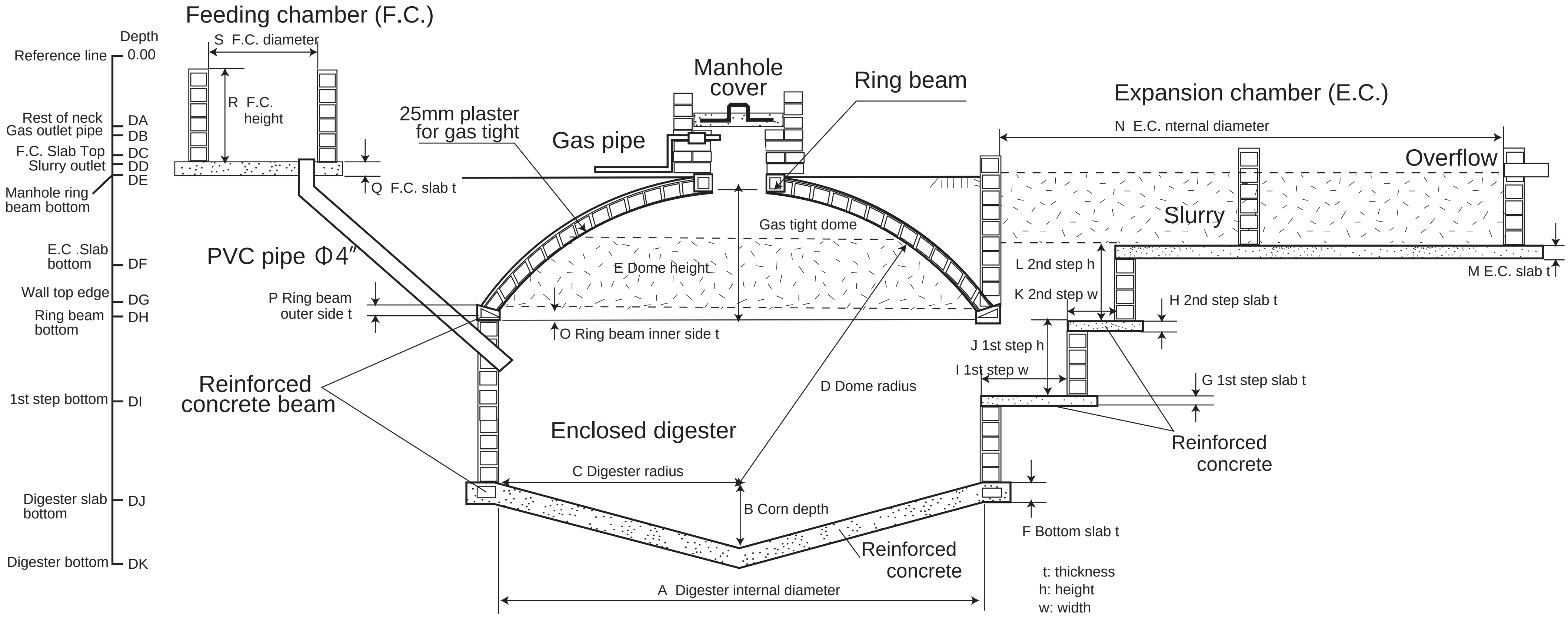
Digestor Size m^3	A Depth from reference line	B Depth of corn botton	C Internal diameter	D Excavation diameter
32	3,900	550	4,160	5,000
60	4,500	600	5,120	5,920

For reference only. Drawing for work shall be prepared by the Contractor.

Excavation Plan for Biogas Digester (32, 60 m3) Pre-feasibility Study of Biogas Project in Nyeri High School	Rural Electrification Authority	Scale: NTS	Drawn by:
		Version: 0.1	Checked by:
		Date: 12/11/14	Drawing No.: N-02

Dimension of Fixed Dome Digester (mm)

Digestor Size m^3	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
	Digester internal diameter	Corn depth	Digester radius	Dome radius	Doem height	Bottom slab thickness	1st step slab thickness	2nd step slab thickness	1st step slab width	1st step slab height	2nd step slab width	2nd step slab height	E.C. slab thickness	E.C. internal diameter	Ring beam inner side thichness	Ring beam outer side thichness	F.C. slab thickness	F.C. height	F.C. diameter
32	4,160	550	R2080	R2600	1,100	150	100	100	750	650	400	650	100	4,360	60	170	100	800	1,000



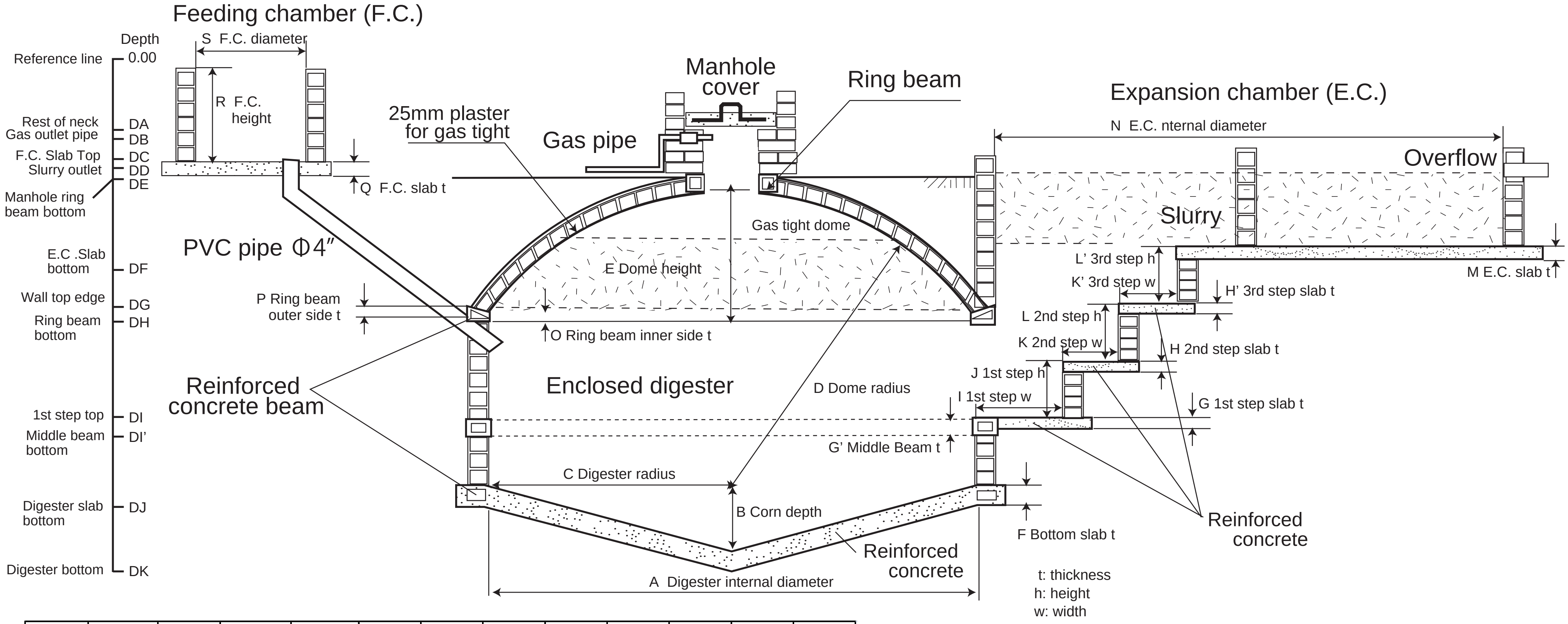
Digestor Size m^3	DA	DB	DC	DD	DE	DF	DG	DH	DI	DJ	DK
	Rest of neck	Gas outlet pipe	F.C. slab top	Slurry outlet	Manhole ring beam bottom	E.C. slab bottom	Wall top edge	Ring beam bottom	1st step slab bottom	Digester slab bottom	Digester bottom
32	550	650	900	1,000	1,150	1,600	2,190	2,250	2,900	3,900	4,550

For reference only. Drawing for work shall be prepared by the Contractor.

AKUT Fixed Dome Type Biogas Digester (32 m^3) for Cow Dung Pre-Feasibility Study of Biogas Project in Nyeri High School	Rural Electrification Authority	Scale: NTS	Drawn by:
		Version: 0.1	Checked by:
		Date: 12/11/14	Drawing No.: N03-1

Dimension of Fixed Dome Digester (mm)

Digestor Size m^3	A Digester internal diameter	B Corn depth	C Digester radius	D Dome radius	E Dome height	F Bottom slab thickness	G 1st step slab thickness	G' Middle beam thickness	H 2nd step slab thickness	H' 3rd step slab thickness	I 1st step slab width	J 1st step slab height	K 2nd step slab width	K' 3rd step slab width	L 2nd step slab height	L' 3rd step slab height	M E.C. slab thickness	N E.C. internal diameter	O Ring beam inner side thichness	P Ring beam outer side thichness	Q F.C. slab thickness	R F.C. height	S F.C. diameter
60	5,120	600	R2560	R3200	1,280	150	120	130	120	100	750	620	400	400	620	620	100	5,260	90	200	100	800	1,100

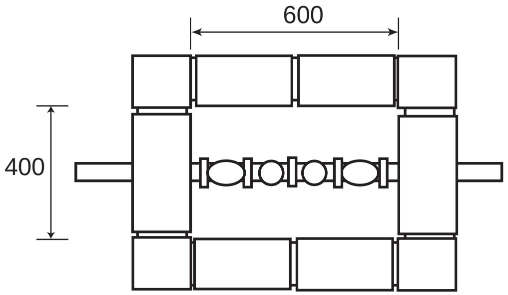


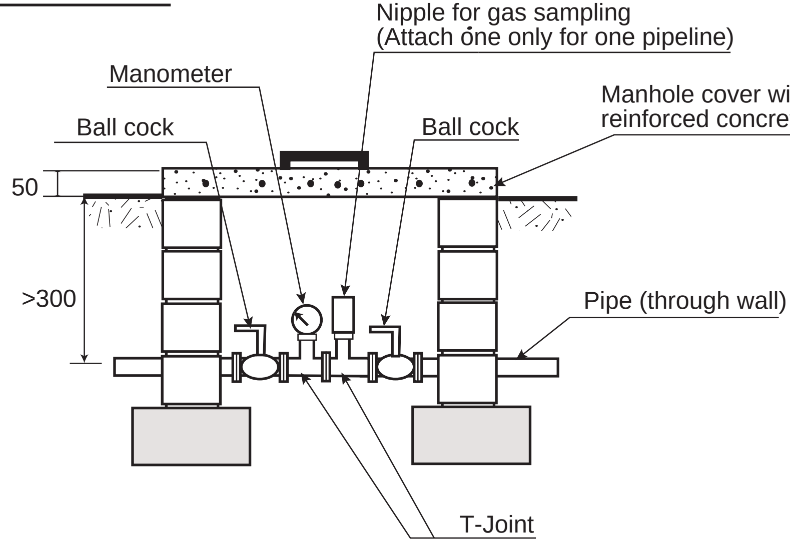
Digestor Size m^3	DA Rest of neck	DB Gas outlet pipe	DC F.C. slab top	DD Slurry outlet	DE Manhole ring beam bottom	DF E.C. slab bottom	DG Wall top edge	DH Ring beam bottom	DI 1st step slab top	DI' Middle beam bottom	DJ Digester slab bottom	DK Digester bottom
60	550	650	900	1,000	1,150	1,600	2,430	2,520	3,360	3,490	4,500	5,250

For reference only. Drawing for work shall be prepared by the Contractor.

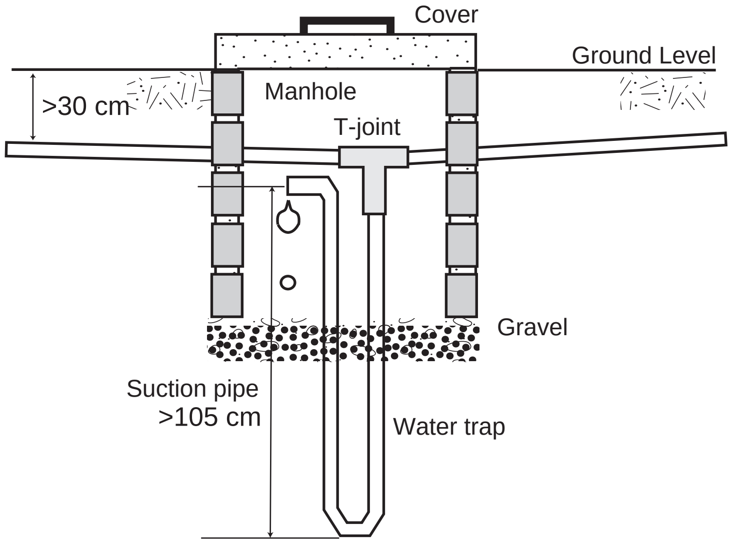
AKUT Fixed Dome Type Biogas Digester (60 m3) for Cow Dung Pre-Feasibility Study of Biogas Project in Nyeri High School	Rural Electrification Authority	Scale: NTS	Drawn by:
		Version: 0.1	Checked by:
		Date: 12/11/14	Drawing No.: N03-2

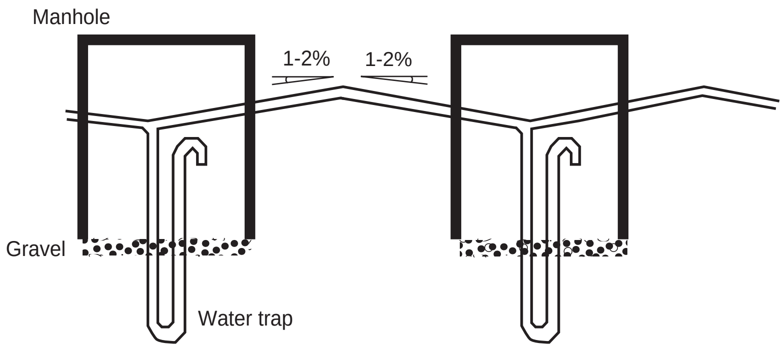
Control Chamber





Water Trap Chamber of Gas Pipeline





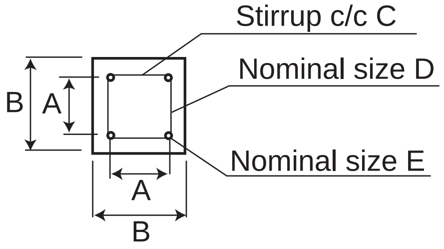
Conceptual figure of slope of water trap and gas pipe

For reference only. Drawing for work shall be prepared by the Contractor.

Fixed Dome Type Biogas Digester (8-124 m^3) Pre-feasibility Study of Biogas Project in Nyeri High School	Rural Electrification Authority	Scale: NTS	Drawn by:
		Version: 0.1	Checked by:
		Date: 12/11/14	Drawing No: N-04

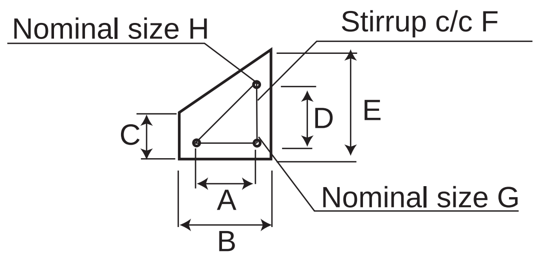
Beam Reinforcements

Manhole



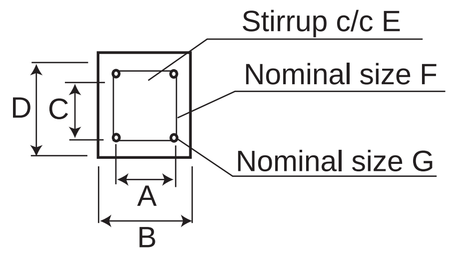
Digestor Size m³	A Steel bar width/ height	B Beam width/ height	C Stirrup C/C mm	D Bar nominal size	E Bar nominal size
32	100	150	c/c 200	R6	R8
60	100	150	c/c 200	R6	R8

Ring beam



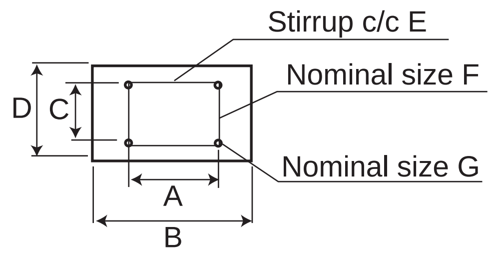
Digestor Size m³	A Steel bar width	B Beam width	C Beam height small	D Steel bar height	E Beam height large	F Stirrup C/C mm	G Bar nominal size	H Bar nominal size
32	100	150	60	100	170	c/c 300	R6	R8
60	100	150	90	100	200	c/c 300	R6	R8

Middle beam



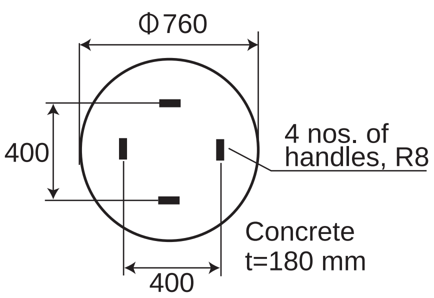
Digestor Size m³	A Steel bar width	B Beam width	C Steel bar height	D Beam height	E Stirrup C/C mm	F Bar nominal size	G Bar nominal size
32	-	-	-	-	-	-	-
60	100	150	100	130	c/c 300	R6	R8

Base beam

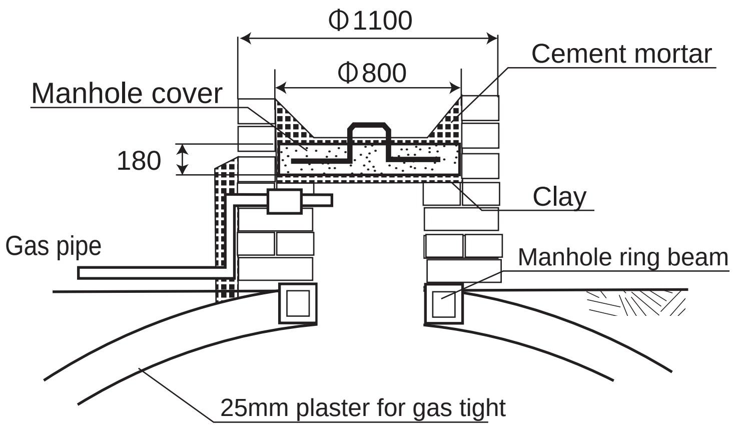


Digestor Size m³	A Steel bar width	B Beam width	C Steel bar height	D Beam height	E Stirrup C/C mm	F Bar nominal size	G Bar nominal size
32	100	250	100	150	c/c 300	R6	R8
60	100	250	100	150	c/c 300	R6	R8

Manhole Cover



Digester Manhole



For reference only. Drawing for work shall be prepared by the Contractor.

Reinforcement Plans for Biogas Digester (32, 60 m3) Pre-feasibility Study of Biogas Project in Nyeri High School	Rural Electrification Authority	Scale: NTS	Drawn by:
		Version: 0.1	Checked by:
		Date: 12/11/14	Drawing No.: N-05

Project for Establishment of Rural Electrification Model using Renewable Energy

Rural Electrification Authority

Seminar on Biogas Planning and Design

by

Caroline Kelly

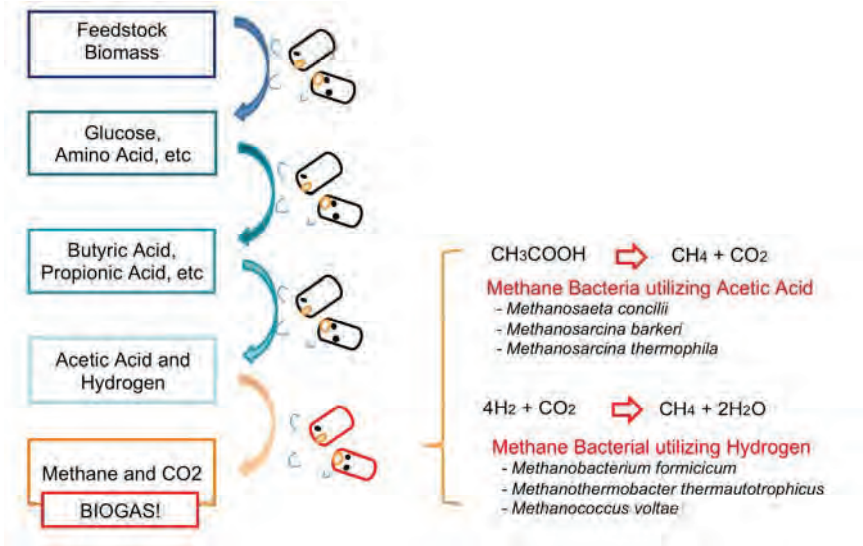
Contents

1. Basics of Biogas: as renewable energy

- Biogas:
  - Fuel gas produced by anaerobic fermentation of organic material by methane producing bacteria
  - Generally, 50-60% methane is contained.
    - Major gas component is methane (CH_4), CO_2, and H_2O,
    - Minor gas component is H_2, N_2, H_2S
  - Biogas can be used as cooking fuel and generation
  - Carbon neutral.

Type	kcal/kg	MJ/m3	Mol-mass
H2	33,886	10.8	2
CO	2,414	10.8	28
CH4	13,267	35.9	16
C3H8	12,034	93.2	44

Basics of Methane Fermentation



Characteristics of Biogas

- Availability of Feedstock is the prerequisite.
  - Plan and design should be done according to availability of feedstock. Collection from other place is not recommended.
  - Cow dung is collective, inherently contains methano bacteria, and the best feedstock.
- Application
  - Design should be conducted so that O&M should be minimized.
  - System should be as simple as possible.

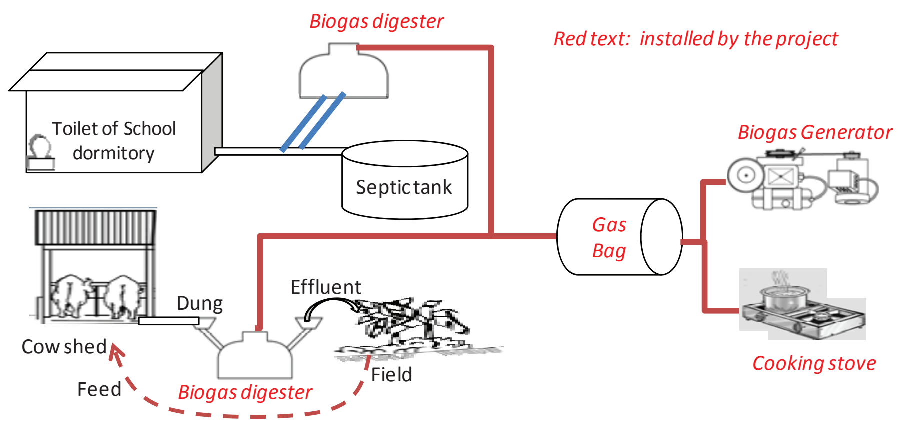
Past Biogas Projects in Kenya

- Over 6,000 biogas installation for cooking fuel in household. 10,000 is planned by 2015.
- Biogas generation projects
  - Kilifi (150 kW) sisal plantation, 2007
  - Nyongara (9 kW) slaughter house by KIRDI and GIZ, 2010
  - Mangu High School by REA (20 kVA), 2011
  - Thika (55 kW) and Insinya (100 kW) flower farm, 2013
  - → Experience of biogas generation is not many

Establishment of Biogas System Model

- Facility such as school with established sewer system or modification of pit latrine
- Advantage
  - Human waste is collective with septic tank
  - Generally owns cows for milk supply. Cow dung is best source of biogas.
- Challenges
  - Proper management of human waste is necessary (prevention of detergent, sanitary waste, water content, etc)

REA Biogas System



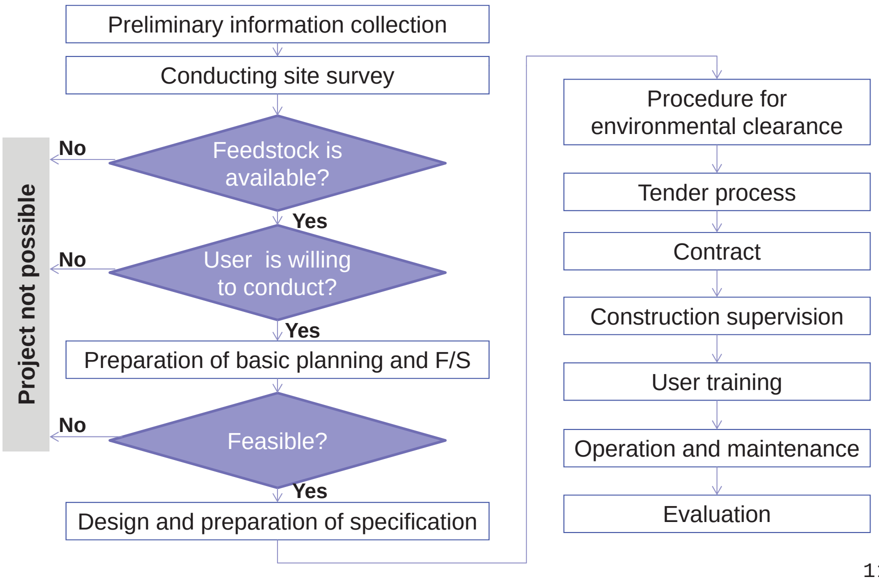
Lessons learned from past biogas projects 1

- Design component
  - The long length of the piping should be avoided, to minimize pressure loss and leakage.
  - Channeling difference of elevation to transport the material by gravity is necessary for cow dung effluent transport.
- Digester connected from toilet
  - The effluent from toilet digesters may contain helminth eggs or coliform. It can be utilized as fertilizer only when adequate care is taken.
  - The quantity of water used to flush the toilets should be limited (about 1L/person). This should be well explained to users.
  - Detergents with Chlorine should not be used for cleaning the toilets. Only biodegradable detergents should be used for cleaning purposes.
  - One toilet which is not connected to the digesters should be assigned to students taking medication to prevent antibiotics from entering the digester.
  - For girls' school, management of disposal of sanitary towels is necessary to prevent such waste from entering the digester.

Lessons learned from past biogas projects 2

- Construction Supervision
  - It is necessary to include provision of user training, manual and drawings, and testing and commissioning in the contract with a contractor.
  - Full-time supervision for approval of construction quality and documentation is necessary. Exclusive staff for supervision should be assigned.
  - It is necessary to check the leakage of gas throughout pipe line and gas bag. Checking of the pipe route is necessary.
- User O&M
  - Prohibition of potential fire hazards should be strictly applied
  - User participation from the stage of planning and construction supervision is necessary as well as training for O&M.
  - Use of cow dung as feedstock in addition to human waste is recommended for favorable bacteria for biogas generation.

Project Flow for Biogas Generation



3.1 Preparation of Site Survey

- Information collection of facility list from Ministries and local government
- Confirmation of location and road condition on the map using
  - Using google map/earth and identifying coordinate (latitude and longitude) makes the survey easier.
- Appointment for facility manager
  - Appointment with technician or staff who manages cows and toilet is preferred.
- Preliminary introduction and interview about the willingness of the project over the phone
- Tools to bring: digital camera, GPS, measuring tape, sketch book, interview sheet, distance meter, booklet about biogas

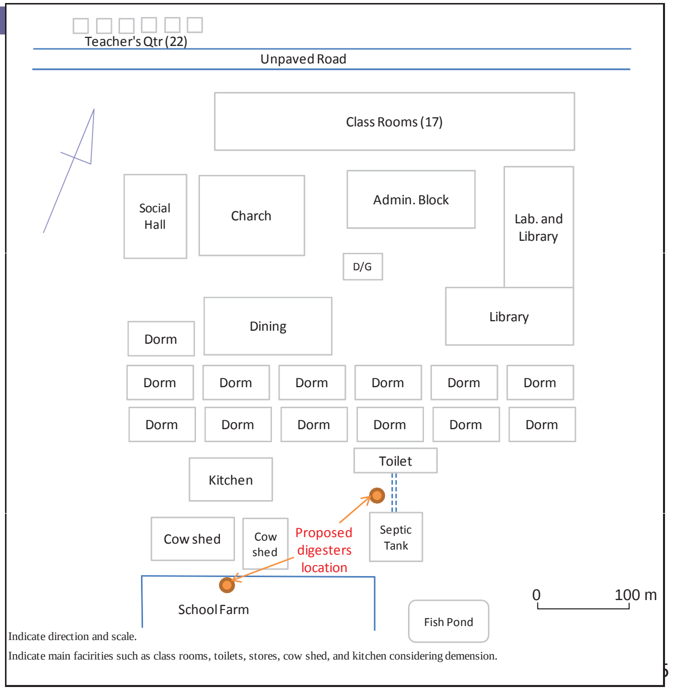
Site Survey Items (1)

- Location
  - Facility name, address, coordinate, elevation, map etc.
- Infrastructure
  - Surrounding road condition, distance from Nairobi, power supply condition, water supply condition
- Facility data
  - Financed by, organization structure, establishment year, name and contact of manager and key staff, geological structure, operation hours, etc.
- Possible amount of feedstock
  - Nos of cows, pigs, poultry, nos of student, qty of raw materials, frequency of toilet use etc.
- Possible location of system
  - Digester, generation system, pipe layout, effluent supply, etc.

Site Survey Items (2)

- Facility layout
  - Layout of facility, sketch or map of buildings inside the facility, location of toilet & septic tank, cow/pig/poultry shed, kitchen, etc.
- Usage of effluent
  - Location of garden, area of garden and type of vegetable
- Current usage of energy (demand analysis)
  - Availability of diesel engine and condition of usage
  - Consumption and cost of fuel wood, electricity, LPG gas, diesel oil, electricity tariff, etc.
  - Current electric appliance, type of lighting
- Priority of biogas usage
  - Electricity, cooking fuel, lamp
- Photos
  - Cow shed, garden, toilet, location for digester, etc.

Example of Sketch



User’s Involvement

- From the time of survey, detailed explanation to school manager and commitment of cooperation for project implementation is necessary for:
  - Assignment of a project manager responsible for overall project implementation
  - Participation in preparation of planning
  - Conducting construction supervision
  - Undertaking of user training from contractor
  - Hiring staff and conducting Operation and maintenance
  - Monitoring, recording, data provision for evaluation

Basic Plan: Items required for project preparation

1. *Outline and Purpose (from site survey)*
2. *Particular Features of site (from site survey)*
3. Energy Production and Demand Assessment
4. Benefit Assessment
5. Basic Design
6. Cost Estimation
7. Economic/Financial Evaluation

Energy Production and Demand Assessment: Amount of biogas production -- Livestock

Type of feedstock	m^3/kg [1)]	kg/nos [2)]
Cattle (cows and bullocks)	0.023-0.04	16-24
Pig	0.04-0.059	1.9-2.5
Poultry	0.065-0.116	0.075-0.1

1) Biogas as an alternative to fuelwood for a household in Uleppi sub-country in Uganda

2) http://ishikawa.lin.gr.jp/kankyo/02.htm

Consideration is necessary for average age and weight of livestock to determine possible amount of gas production. (ex. 16kg/nos for young cattle)

Example:
15 cows: 15 nos x 20 kg/nos x 0.033 m^3/kg= 9.9 m^3
100 pigs: 100 nos x 2.0 kg/nos x 0.05 m^3/kg = 10 m^3

Energy production and demand Amount of biogas production-- Human

Description	Value	Unit
Amount of biogas production	0.02-0.04	m3/person/day
Size of digester	0.1	m3/person/day
Substrate	3.3-4.9	L/person/day
faeces	0.25-0.4	kg/person/day
urine	1-1.5	L/person/day
flushing water	2-3	L/person/day

Availability ratio needs to be considered according to actual condition.

750 students: 750 nos x 0.025 m^3/nos/day x 0.8 x 0.67 = 10.1 m^3 /day
0.8: Body weight ratio, student / adult
0.67: Dormitory toilet usage ratio (evening and morning)

It is recommended to add cow dung to supply methane producing bacteria.
School available days ratio (without holiday) 0.75 needs to be considered for annual estimation.

Calorific Value and Generation Energy

1 J = 1 kg·m²/s² = 1 Ws (Watt-second) = 0.239 Cal

1Wh = 3600 Ws = 3600 J = 860 Cal

	J	Wh	Cal
1 J	1	$= 0.278\times10^{-3}$	= 0.239
1 Wh	= 3600	1	860
1Cal	= 4.1868	$= 1.163\times10^{-3}$	1

1MJ	=0.278 kWh

Benefit: Calculation of Fuel Saving

Fuel Type	Value	Unit
LPG	45-51	MJ/kg
LPG	26	MJ/L
Natural gas	37.3	MJ/kg
Kerosene	36.7	MJ/L
Diesel oil	37.7	MJ/L
Coal	22-26	MJ/kg
Biogas	20-30	MJ/m3
Firewood*	10-20	MJ/kg

Stove Type	Efficiency
Wood stove	10-25%
Three stone stove	8%
Single and two pot mud stove	13%
Charcoal stove	20-35%
Biogas stove	45-55%
LPG stove	60%
Electric stove	70-85%

* Depending on type and moisture content

Energy Output = Calorific Value x Quantity x Efficiency

Example:

- Biogas: 20 MJ/m3 x 10 m3 x 0.45 = 90 MJ

- Fuel wood: 15.5 MJ/kg x 58 kg x 0.1 = 90 MJ

10 m^3/day biogas can save 58-87 kg/day (21-31.5 t/year) of fuel wood

Benefit: Calculation of Fuel Saving—Fuel Wood

Various type of fuel wood is used according to site, and calorific value is different according to moisture content.

Fuelwood Type	Moisture%	Value	Unit
Green wood	50%	9.5	MJ/kg
Seasoned wood	20%	15.5	MJ/kg
Dry sawdust	13%	16.2	MJ/kg
Wood pellets	10%	16.8	MJ/kg
Dry wood (non-resinous)	0%	19	MJ/kg
Dry wood (resinous)	0%	22.5	MJ/kg
Dry steamwood	0%	19.1	MJ/kg
Dry bark	0%	19.6	MJ/kg
Dry branches	0%	20.1	MJ/kg
Dry needles	0%	20.4	MJ/kg

Source: Sustainable Forestry for Bio-based Products, Ashton S, 2007

Calculation of Electricity Saving

Type of Generation and Item	Value	Unit
Diesel oil generation efficiency	3.0-3.7	kWh/L
Diesel generator efficiency	28-35%	
Biogas generation efficiency	1.0-2.0	kWh/m3
Biogas generator efficiency	18-25%	

Saving of electricity by 10m3/day biomass:

10 m3 x 1.5 kWh/m3 = 15 kWh

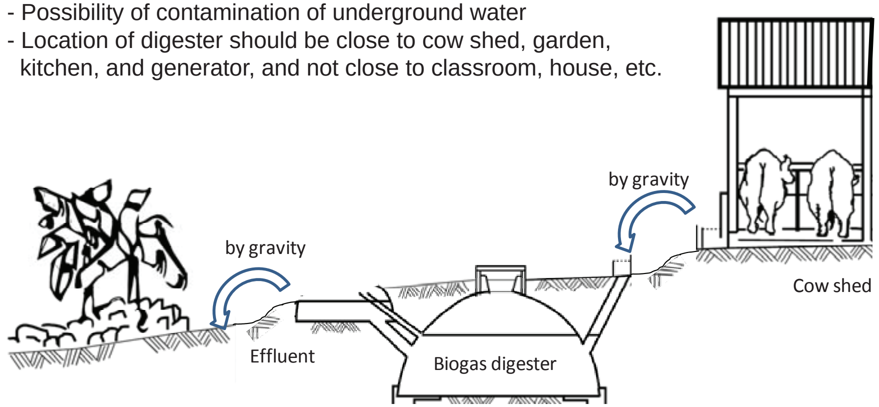
Annual electricity saving is:
15 kWh x 360 days/year = 5400 kWh/year

If electricity tariff is 20 KSh/kWh, annual saving is:
5400 kWh x 20 KSh/kWh = 108,000 KSh
If diesel oil cost for generator is 105 KSh/L, annual saving for oil is:
5400 kWh x 1/3.0 kWh/L = 189,000 KWh

Basic Design: Layout of Biogas Digester

Location of digester should consider:

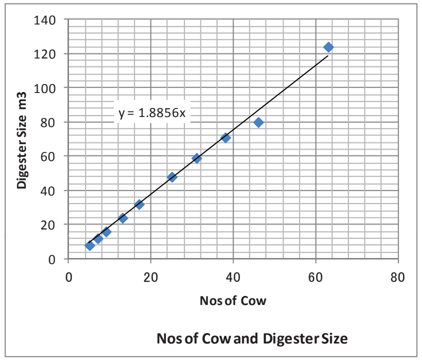
- Elevation arrangement for gravity flow of feedstock to avoid manual transportation
  - Input location of digester should be lower than cow shed
  - Garden for effluent should be lower than outlet of digester
- Possibility of contamination of underground water
- Location of digester should be close to cow shed, garden, kitchen, and generator, and not close to classroom, house, etc.

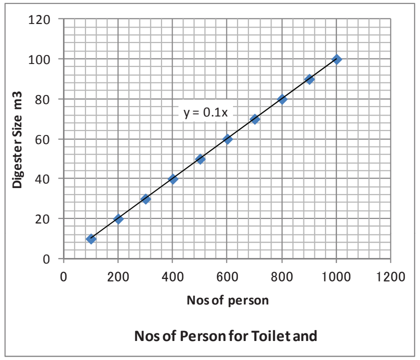


Design of Biogas System

- Determination of digester volume
- Determination of digester type
- Strength of digester
- Selection of pipe (for liquid ,gas)
- Selection of generator

Determination of Digester Size





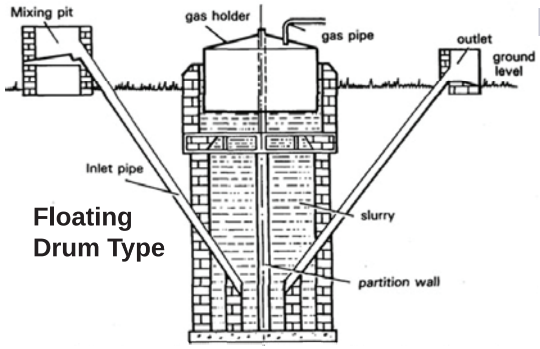
- It is recommended to select one larger size
- Maximum size is 100m^3, considering structural strength

Cow dung: Size (m^3) = 1.89 x nos of Cow
Human waste: Size (m^3) = 0.1 x nos of person utilizing toilet

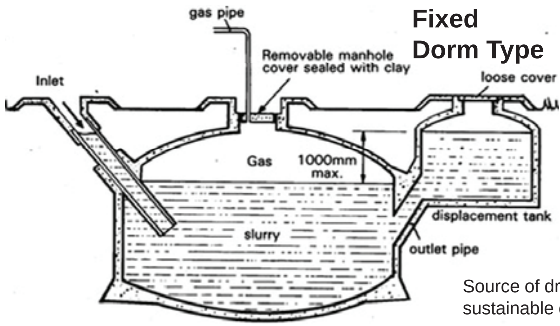
Types of Biogas digester

- Fixed dome type
  - Mainly developed in China, 5-100 m^3
  - Construction requires great care in design and workmanship
  - Long life time (30 years) and life-time cost is cheaper than floating drum type
- Floating drum type
  - Mainly build in India, 5-100 m^3
  - easy to understand and operate
  - gas at a constant pressure, and the stored gas-volume is recognizable by the position of the drum.
  - The steel drum is expensive and maintenance-intensive. Removing rust and painting has to be carried out regularly.
  - The life-time of the drum is short (5-15 years)
- Gas Bag type
  - Small and household type (3-10 m^3)
  - Cheap, short installation time, excavation and construction not required
  - Life time is short (10-15 years), durability depends on material.

L3-7



Gas Bag Type

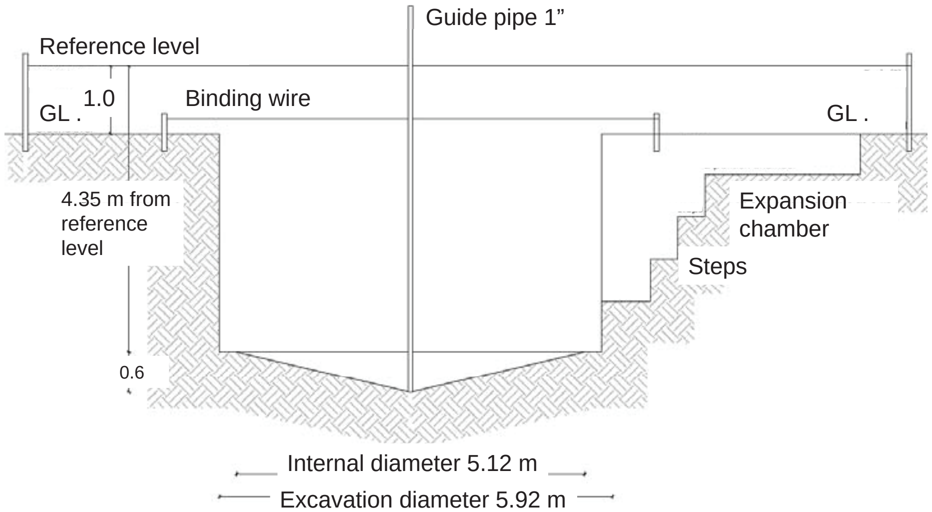


Fixed Dorm Type is selected for institution biogas type

Source of drawing: Biogas processes for sustainable development, FAO, 1992

Attachment L-3

Excavation for 60m^3 Digester



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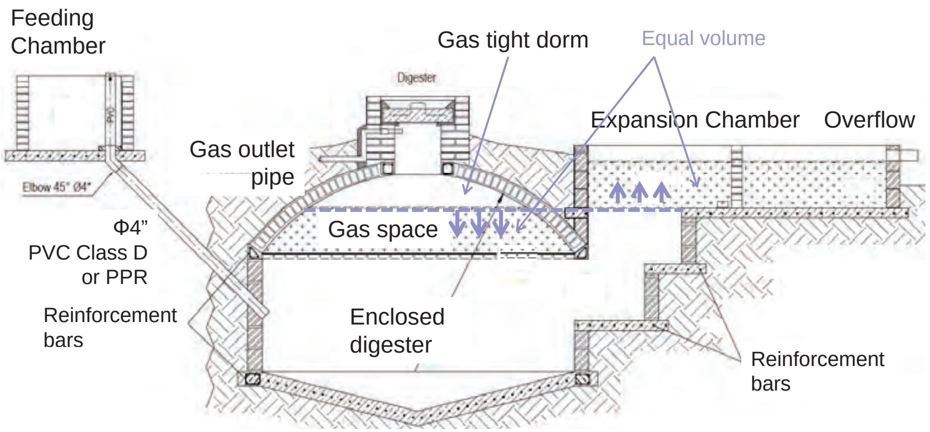
Example of Biogas Digester



Source: AKUT Type Digester, Biogas Construction Manual, PSDA/GIZ

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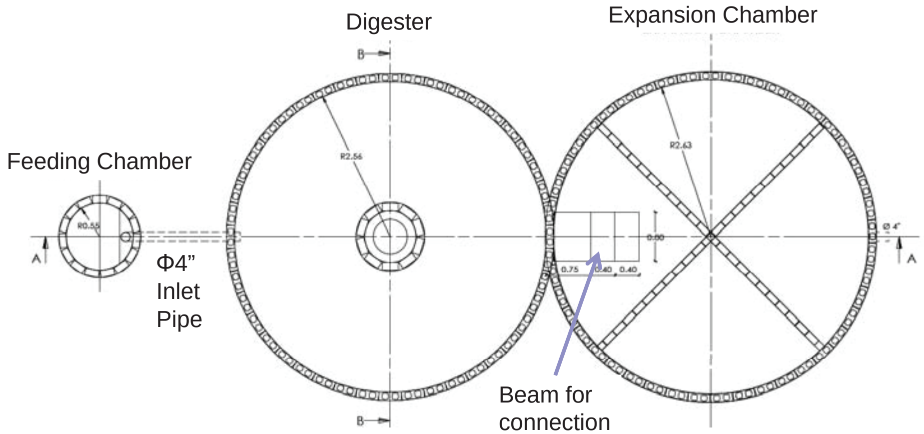
Top View of Digester and chambers



L3-8

Source: AKUT Type Digester, Biogas Construction Manual, PSDA/GIZ

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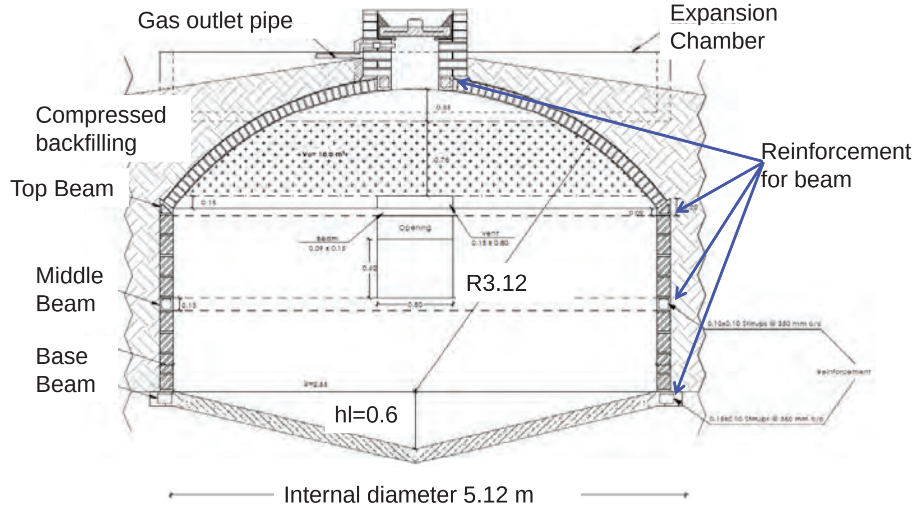
Design of Biogas Digester



Attachment L-3

Source: AKUT Type Digester, Biogas Construction Manual, PSDA/GIZ

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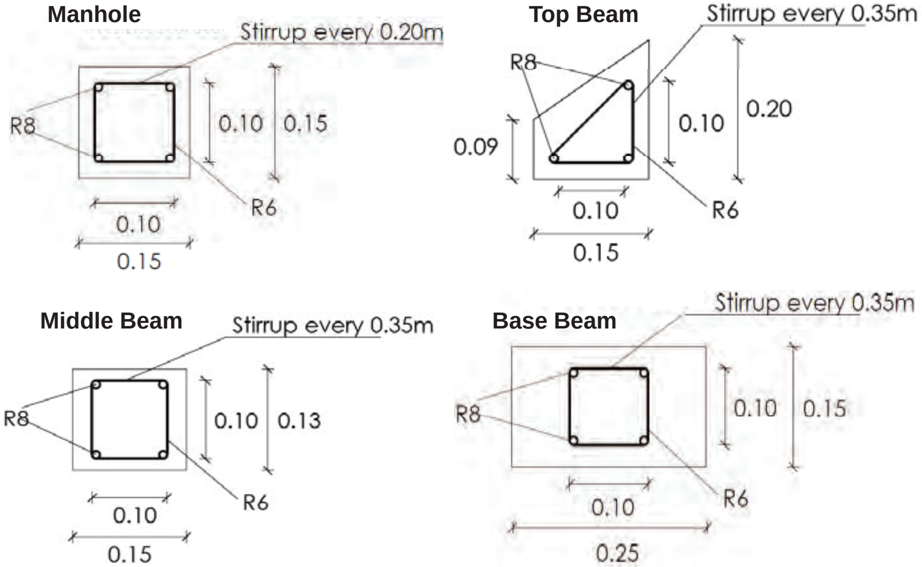
Reinforcement of Beam



Selection of pipe

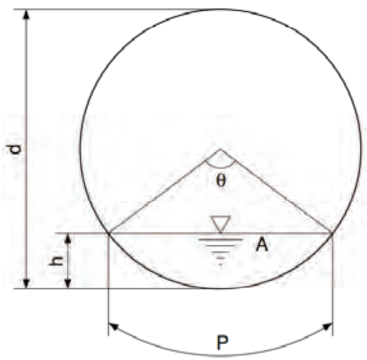
- PVC (Polyvinyl Chloride) Pipe:
  - Good abrasion resistance but poor to sunlight and physical impact
  - Operation temperature 0-60ºC
  - Solvent cement joint
  - Only Class D is acceptable
  - Low cost
- PPR (Polypropylene) Pipe:
  - Good strength and fatigue
  - Operation temperature -20 to +110 ºC
  - Fusion welding (require electricity)
  - For longer distance
  - Higher cost than PVC
- Pipe and fittings are of the same brand

Pipe Flow (Liquid)

Manning's Formula for hydraulics
Velocity and discharge in a pipe

$$Q = V \cdot A$$

$$V = \frac{1}{n} \cdot R^{\frac{2}{3}} \cdot I^{\frac{1}{2}}$$



Q: Discharge (m^3/s)
V: Velocity (m/s)
A: Area of flow (m^2) → $A = 1/8 \times (\theta - \sin\theta)\, d^2$
n: Coarse coefficient = 0.010 (PVC)
R: Hydraulic radius = A/P (m)
P: Wetted perimeter (m) → $P = 1/2 \times \theta \times d$
I: Slope

θ : central angle (rad.)
d: diameter (m)

$$A_{full} = \frac{\pi}{4} d^2$$

$$P_{full} = \pi \cdot d$$

$$R_{full} = \frac{d}{4}$$

$$h_{full} = d$$

Example: Flow in PVC Pipe

- PVC Pipe
  - Φ4" → Diameter 0.1016 m
  - Pipe length 1.5 m
  - Slope 0.5% (1/200)
  - Q = V・A

    $V = 1/n \times R^{2/3} \times I^{1/2}$

    n: Coarse coefficient（=0.010）

    R：Hydraulic radius（=D/4=0.1016/4=0.0254)

    I：slope（=0.005）

    $\therefore V = 1/0.01 \times 0.0254^{2/3} \times 0.005^{1/2}$

    ＝2.800（m/sec)

    $A = \pi \cdot D^2/4 = \pi \cdot 0.04^2/4 = 1.257 \times 10^{-3}$

    $Q = 2.800 \times 1.257 \times 10^{-3} \times 10^3 \times 60 = 211$ L/min

Pipe Diameter Selection for Gas

← PVC Pipe Diameter

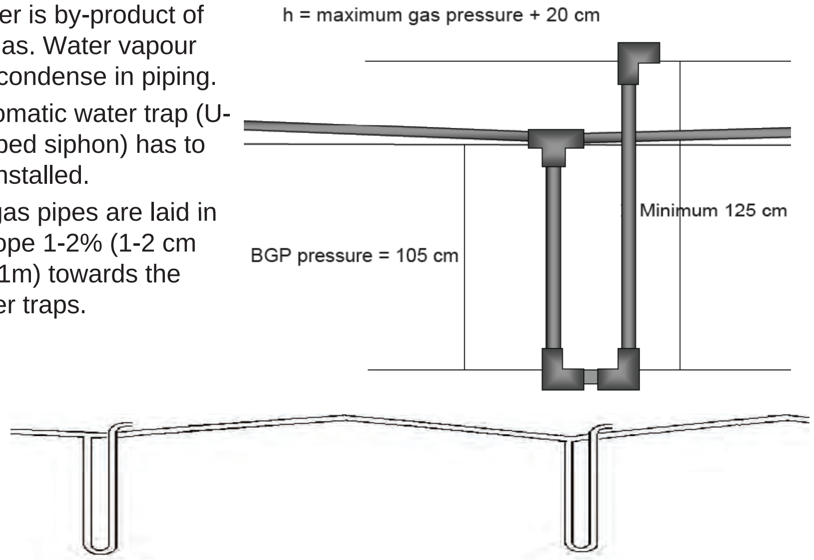
Flow rate (m3/h)	Length (m)			
	20	60	100	150
0.5	0.5"	0.5"	0.5"	1"
1	0.5"	0.5"	0.5"	1"
1.5	0.5"	0.5"	0.5"	1"
2	0.75"	0.75"	0.75"	1"
2.5	1"	1"	1"	1.5"
3	1.5"	1.5"	1.5"	1.5"
4	1.5"	1.5"	1.5"	2.0"

↓ PPR Pipe Diameter

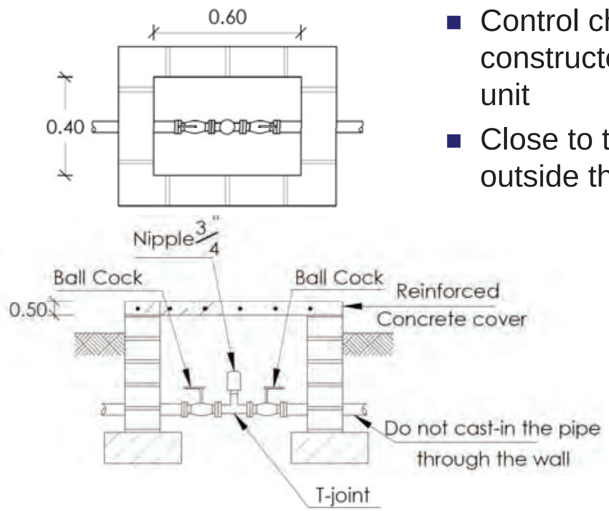
Flow rate (m3/h)	Length (m)							
	20	100	150	200	250	300	400	500
0.5	25	25	25	25	25	25	32	32
1	25	25	25	32	32	32	32	40
1.5	25	25	32	32	32	32	40	40
2	32	32	40	40	50	50	50	50
2.5	32	32	40	50	50	50	50	60
3	32	32	50	50	50	50	60	60
4	32	40	50	50	50	60	60	60

Water trap for gas

- Water is by-product of biogas. Water vapour will condense in piping.
- Automatic water trap (U-shaped siphon) has to be installed.
- All gas pipes are laid in a slope 1-2% (1-2 cm per 1m) towards the water traps.



Pressure test unit



- Control chamber has to be constructed as pressure test unit
- Close to the digester but outside the dome radius area.

Biogas engine/generator

- Gasoline engine generator
  - 0.5-3 kW
- Diesel engine generator
  - Larger size > 10s kW
  - Available in market
  - Modification is required for plug
- Biogas generator
  - Specially arranged generator for biogas characteristics
  - Filtering unit is equipped
  - Special order/import required

Cost Estimation

- The estimated price is used for budgeting and reference price for tender evaluation
- Cost components
  - Equipment, construction, labor, design, admin., operation and maintenance, renewal, etc.
- Refer to past tender price (Pre-F/S level)
  - Need to reflect inflation rate
- Quantify material and multiplying unit price (F/S level)
- Requesting estimation to supplier
  - Estimation from each component
  - Obtaining from possible contractor need to be careful since it nay against fairness of tendering

Estimation from past example (Experimental)

1) Biogas digester (30-100m^3):

y = 2,617 x + 256,700,

,where y: cost (KSh), x: digester volume (m^3)

2) Excavation works: 2,052 KSh/m^3

3) Biogas bag: 20,550 KSh/m^3

4) Biogas generator: y=20,000x +100,000

, where y: cost (KSh), x: capacity of engine-generator (kVA)

Cost Estimation (Example, past tender was referred)

Item	Nyeri High School		
	Qty	unit	KSh
Biogas Digester for Toilet	60	m3	413,720
Biogas Digeter for Cow Shed	32	m3	340,444
Excavation and civil works	1	lot	188,830
Additional toilet facility with septic tank			
Gas holding steel tank and connection valve	2	nos	100,800
Bigoas flow meter	2	nos	73,000
PVC gas bag	1	nos	411,000
Biogas generator	7	kVA	240,000
Energy meter	1	nos	50,000
Distribution board, switch gear	1	nos	150,500
Biogas filter and solenoid valve	1	nos	106,500
Cable work	1	lot	200,000
Pipe work	1	lot	250,000
Fence and safety arrangement	1	lot	118,000
Subtotal			2,642,794
Detailed design and drawing	1	lot	246,000
Testing, commissioning, training	1	lot	363,500
Transportation and installation	1	lot	264,279
Total Cost			3,516,573
Total Cost adjusted with Inflation 2010/13	4.91%/yr	Ksh	4,060,414

Financial/Economic Evaluation

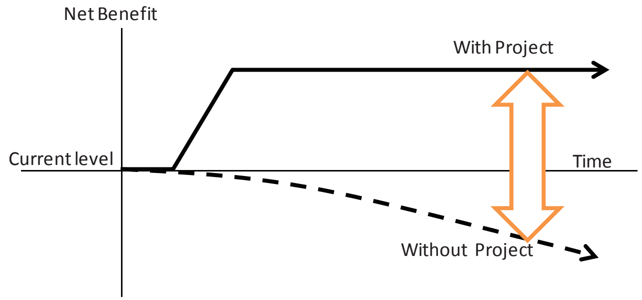
- Evaluation by monetary cash flow
- General objective:
  - To assess future profit of the project for investors
  - To avoid risks of dead loan of the borrower (project owner)
- Objective as development project
  - To confirm financial feasibility in O&M
  - To assess if the project is "worth while" to implement
  - Feasibility of general development project is evaluated by economic evaluation
- Conducted by: Business manager, planner, bank, investor, etc.

Discount Rate and Net Present Value

- "Time is money": Value of money in the future is less than that of now
- Ex. Save 1000$ with compound Interest rate 10%
  - 1 yr later: 1000$x(1+0.1)=$1100, 2yr: 1000x(1+0.1)^2$=$1210
  - n yr later: 1000x(1+0.1)^n$
  - →1000$ is no more 1000$ in years later
- "Net Present Value": Converted future value into present value
- Ex. Net Present Value of $1000
  - 1yr later: 1000$x1/(1+0.1)=$909, 2yr: 1000$x1/$(1+0.1)^2$=$826
  - n yr later: 1000$x1/$(1+0.1)^n$
- The rate10%: "Discount Rate"

Project Benefit

- Incremental Analysis: With/Without project
  - Production of energy, saving, service, etc.
- Tangible benefit
  - kWh, tons of fuel wood, saved cash, CO2 reduction
- Intangible benefit
  - Health, education, environment



IRR (Internal Rate of Return)

- Measurement index to assess efficiency of capital investment
- Quantitative evaluation for governmental public expenditure, also used in appraisal of development banks for loan provision
- IRR: Discount Rate that makes total net benefit generated during project period zero
- Cash Flow = B-C (Benefit – Cost)
- IRR(r) = Σ [$(B-C)_t$ / $(1+r)^t$] = 0, where t = 1, 2, …, n (year)

  IRR(r) = (B-C)/(1+r) + $(B-C)_2/(1+r)^2$ + $(B-C)_3/(1+r)^3$ + …. $(B-C)_n/(1+r)^n$

  B: benefit, C: Cost, n: Project Year
- NPV = Σ [$(B-C)_t$ / $(1+i)^t$], where t=1, 2,…,n,

  i:discount rate, needs to be determined by evaluator

FIRR and EIRR

- Financial Internal Rate of Return (FIRR)
  - Financial profit for implementing organization using market price
  - To assess financial sustainability
  - Opportunity Cost of Capital (OCC) is the index. Interest rate of Treasury bill (short-time government bond) is referred, obtained from national bank or statistics of Ministry of Finance, IMF, etc.
- Economic Internal Rate of Return (EIRR)
  - Efficiency of resource distribution in nation's economy
  - Both tangible and intangible value are counted
  - SDR (Social Discount Rate) is referred. Generally, 10-12% is the cut-off value to be evaluated being feasible
  - Shadow exchange rate needs to be applied for conversion from financial price

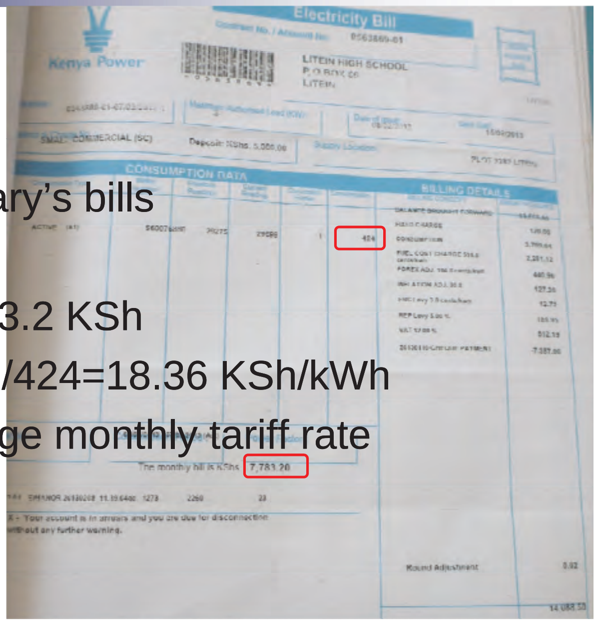
Cash Flow (B-C)

- B(Benefit)=Income, C(Cost)=Expenditure
- Remarks for analysis
  - Construction and equipment, labor, environment, land, design, operation and maintenance, etc.
  - Estimate real resource costs.
  - Present value is used. Inflation is not considered.
  - Price contingency is not included. Physical contingency should be included.
  - Sunk cost (indirect cost before project) is not considered.
  - Interest rate and depreciation is not considered.
  - Accounts payable, accounts receivable is not considered.

Financial Benefit of Biogas

- Financial benefit for FIRR
- Calculate savings of electricity in kWh by biogas generator and savings of fuel wood in ton
- Calculate benefit value in Ksh
  - Electricity saving: kWh x tariff rate (KSh/kWh) in KSh, based on actual payment of electricity bill
    - Collect actual electricity bill of the recipient every month
    - 18-20 Ksh/kWh
  - Fuel wood saving:
    fuel wood saving (ton) x unit fuelwood price (KSh/ton)
    - Confirm fuel wood purchase price in the area (Ksh/ton)
    - 3000-4500 Ksh/ton

Electricity tariff



- Obtain beneficiary's bills
- 424 kWh/month
- Monthly bill 7783.2 KSh

→ Tariff rate: 7783/424=18.36 KSh/kWh

→ Calculate average monthly tariff rate

Base conditions for evaluation

- Diesel Oil Price 110.00 KSh/L
- Diesel efficiency 2.40 kWh/L
- Emission factor of electricity 0.81805 ton-CO2/MWh
- Price of fuel wood 3,300 KSh/ton
- Exchange rate 86.28 KSh/US$
- Carbon credit 1,294 KSh/ton-CO2

Benefit of Economic Analysis

- Benefit of diesel generation saving
  - Diesel price: 105-110 KSh/L, efficiency: 2-3 kWh/L
- Benefit of CO_2 emission reduction by biogas electricity generation
  - Emission Factor of diesel oil: 0.81805 ton-CO2/kWh
  - Carbon credit 5-20 US$/ton-$CO_2$ (depends on international trend)
- Benefit from fuelwood saving
- Fuelwood carbon absorption benefit
- Fuel wood carbon off-set benefit
- Fuel wood economic value: protection of forest

Benefit of fuel wood saving

Carbon absorption

Carbon Absorption A = W x E x (1+R) x C%

ton-CO2 reduction = A x 44/12

Where,

W	Weight of saved tree, ton	1
E	Coefficient for tree and branch addition	1.52
R	Ratio of ground/underground portion	0.26
C%	Carbon component percentage	0.5
ton-CO2		**3.51**

Carbon off-set

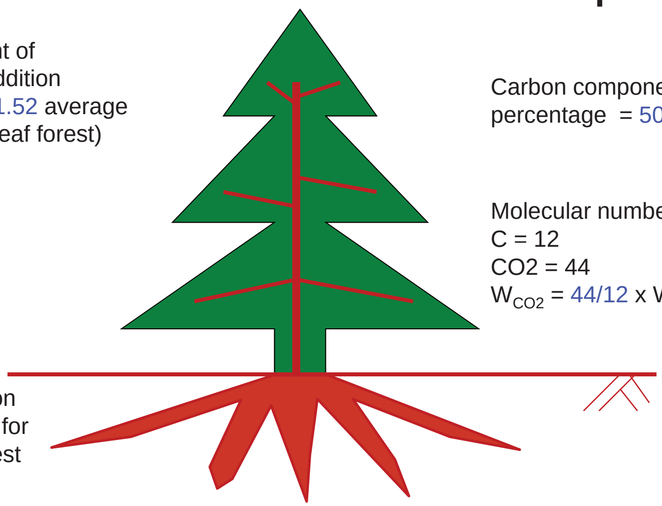
ton-CO2 reduction = W x (1-M/100) x H x EF x BE

Where,

W	Weight of saved tree, ton	1
M	Moisture content, %	10
H	Calorific value GJ/ton	15.5
EF	Emission coefficient of coal, ton-CO2/GJ	0.09
BE	Boiler efficiency ratio (fuel wood/fossil fuel)	1
ton-CO2		**1.26**

Source: Forestry and Forest Products Research Institute, Japan

Calculation of Carbon Absorption



CO_2 absorption of 1 ton fuel wood
= 1 ton x 1.52 x (1+0.26) x 0.5 x 44/12 = 3.51 ton-CO_2
If 10US$/ton-$CO_2$, 1 ton fuel wood = 35.1 US$ carbon credit value

Economic Value of Forest Preservation

Amount of carbon storage	190	C-ton/ha
Weight of wood body	198.4	ton/ha
Economic value per area	921,165	KSh/ha
Economic value per ton fuel wood	4,643	KSh/ton

- The economic value is much depending on condition, assumption, and location of forest. It requires another project to assess actual economic value of forest. Here, the estimation of other project in Kenya was referred.

Source: The Role and Contribution of Montane Forests and Related Ecosystem Services to the Kenyan Economy", 2012, UNEP

Economic Analysis of Nyeri HS

Annual benefit	620,758	KSh
Project investment cost	3,755,264	KSh
Discount rate	10%	
Project year	30	Years
Tax	0%	(Exempted)

Cash Flow (CF)= Benefit – total Cost

No.	Year	Revenue %	Benefit	Cost					Cash Flow
				Initial Investment	TAX	Rehabilitation	O&M	Total Cost	
			KSh	KSh	KSh	KSh	KSh	KSh	KSh
1	2012	0%	0	3,755,264	0	0	0	3,755,264	-3,755,264
2	2013	100%	620,758		0	0	17,000	17,000	603,758
3	2014	100%	620,758		0	0	17,000	17,000	603,758
4	2015	100%	620,758		0	0	17,000	17,000	603,758
5	2016	100%	620,758		0	0	17,000	17,000	603,758
6	2017	100%	620,758		0	187,763	17,000	204,763	415,995
	.								
	.								
29	2040	100%	620,758		0	0	17,000	17,000	603,758
30	2041	100%	620,758		0	0	17,000	17,000	603,758
		Total	18,001,991	3,755,264	0	938,816	493,000	5,187,080	12,814,911
	NPV(Benefit)=		5,287,510			NPV(Cost)=		3,812,466	

=IRR(CF_1+CF_2+...)

EIRR=	15.09%
NPV=	1,475,043
B/C=	1.3869

=NPV(DR, (CF_1+CF_2+...))

=NPV(Benefit)/NPV(Cost)

Result of Financial/Economic Evaluation

Item	Unit	Nyeri High School	Rware High School	Litein High School	Kipsigis Girls High School	Mukumu Girls High School	Cardinal Otunga High School
Project Cost	KSh	3,755,264	1,453,168	6,861,967	3,658,669	4,271,187	4,703,232
Planned gas production for fuelwood saving	m^3/yr	6,248	3,285	4,466	1,533	4,822	4,411
Planned gas production for electricity saving	m^3/yr	2,321	0	4,380	5,179	2,683	4,380
Electricity tariff rate	KSh/kWh	19.7	8.7	18.1	19.5	17.9	19.9
Annual planned generated energy	kWh/yr	2,321		4,380	5,179	2,683	4,380
Annual planned fuelwood Saving	ton/yr	36.3	19.1	25.9	8.9	28.0	25.6
Financial benefit	**KSh/yr**	**165,466**	**62,945**	**164,856**	**130,357**	**174,026**	**171,690**
Recovery year	yr	23	23	42	28	25	27
Benefit of diesel generation saving	KSh/yr	106,356	0	200,750	237,353	122,959	200,750
Benefit of CO2 emission reduction by biogas generation	KSh/yr	2,457	0	4,637	5,483	2,840	4,637
Benefit from fuelwood saving	KSh/yr	119,717	62,945	85,578	29,374	126,005	84,528
Fuelwood carbon absorption benefit	KSh/yr	164,854	86,677	117,844	40,449	127,242	116,398
Fuel wood carbon off-set benefit	KSh/yr	58,947	30,993	42,137	14,463	45,498	41,620
Fuel wood economic value	KSh/yr	168,427	88,555	120,397	41,326	130,000	118,920
Total economic benefit	**KSh/yr**	**620,758**	**269,170**	**571,344**	**368,448**	**554,544**	**566,853**
EIRR		**15.09%**	**16.44%**	**5.85%**	**7.79%**	**11.27%**	**10.26%**
Ranking		**1**	**5**	**6**	**4**	**2**	**3**

Shadow exchange rate is not considered in financial cost.

THANK YOU

PRE FEASIBILITY STUDY ON BIOGAS SYSTEMS FOR SCHOOLS IN KENYA

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Abstract
Simple Pre-feasibility studies for biogas systems in six schools were conducted in Nyeri, Western and Nyanza regions. The objective was to plan optimum biogas system for the public school and clarify economic feasibility. In the study, survey was conducted in six schools. Information of available feed stock (cow dung and human waste) was collected and possible amount of gas production and energy generation were estimated. Basic design of the bio-digester and generator was prepared. In this study, benefit and cost was estimated and financial evaluation was conducted considering tariffs and fuel price. Economic benefit was also assessed considering carbon absorption and forest preservation values. Financial efficiency of systems was compared with/without generator for Nyeri High School (HS) as a case study.

The result of the study shows the financial return for electricity and cooking fuel from the same amount of gas is almost the same at the present electricity tariff rate and fuel wood price (economic value of biogas for fuelwood replacement was 19.2 KSh/m^3 while that of electricity replacement was 19.7 KSh/m^3) in case of Nyeri HS. Meanwhile, initial cost of biogas system with generator was 32% higher compared with biogas system without generator (i.e., cooking fuel supply only). In addition, generators require overhauling every 5-7 years, and the maintenance cost is much higher than that of systems without generator. Annual fuel wood requirement in the school (about 300 tons/yr) is larger than the amount possibly replaced by biogas (about 50 tons/yr). Thus, it was concluded that to utilize all biogas for fuel wood replacement is more financially feasible than to supply biogas for electricity generation in the case study.

Key words: biogas, pre-feasibility study, fuel wood, financial evaluation

1.0 Introduction:

Biogas is a combustible gas produced by the fermentation of organic material in the absence of oxygen. It is composed of approx. 60 percent of methane (CH_4) and 40 percent carbon dioxide (CO_2). It has a faint, unpleasant smell. It burns with a hot blue flame and can be used in gas lamps, cooking stoves, to generate electricity and to power diesel and petrol engines, among other applications (Hankins, 1987). The production of biogas requires the use of carbohydrates, proteins and/or fats. The actual reactants, however, are soluble organic matter, volatile fatty acids (mainly acetic acid), amino acid, long chain fatty acids, organic sulfur and ammonium compounds. These are found in food processing effluents, weeds, leaves, non-edible starch and in sewage, municipal and other waste (Dutt and Ravindranath, 1993).

The biogas production process occurs in the digester, which can be divided into two main groups; batch digesters and continuous flow digesters. Batch digestion is the simplest method to adopt for biogas systems. The plant is filled with substrate material and suitably inoculated to enable appropriate bacterial population to predominate. At the completion of the digestion (when gas falls to low levels) the material is removed and replaced with a new batch. After biogas is obtained, slurry (digested material) remains and can be used as compost manure (Ellegard, 1990).

As with other combustible gases, the dangers of explosion exist. When replacement of worn biogas installations is not carried out promptly, gas pipe might burst. Hydrogen sulfide (H_2S) produced has a foul smell, poisonous and corrosive. Biogas slurry that is not properly handled can be environmentally harmful.

Although those issues should be noted for actual implementation, biogas can substitute fuel wood and facilitate decentralized electricity generation in areas with no access to the power grid. Biogas enables energy supply at low cost and waste utilization as fertilizer in rural areas

2.0 Materials and Methods

2.1 Methods for Simple Pre-feasibility Study

Biogas system in public facility such as school with dormitory or prisons has advantages in terms of the following:

- Human waste is collective with sewer system and septic tank
- Generally schools have dormitory and own cows for milk supply. Cow dung is the best source of biogas in terms of organic composition and inherent methane producing bacteria.

The biogas system model in facilities such as schools is proposed as in Figure 1.

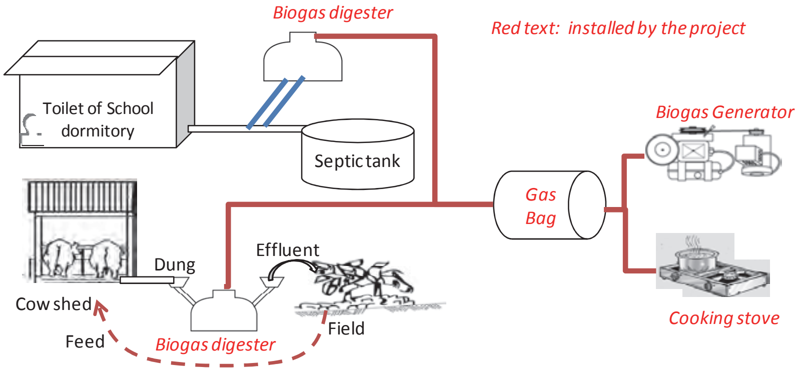

Figure 1: Basic Concept of Biogas System

The outline of the system is as follows:

- Human waste is collected in septic tank. Biogas digester is installed between toilet and septic tank. Effluent from digester will enter existing septic tank. After methane production, solid waste, BOD, and pathogens will be reduced in the digester, and organic load to septic tank is reduced by the digester.
- Cow dung from cow shed is collected in a digester through a trench. After degradation and methane production in a digester, effluent can be used as fertilizer to increase yield of garden vegetables and feed. The feed will be supplied to cows. This enables material cycle while producing biogas energy.
- Biogas produced in digesters are collected once in gas bag, and can be used either/both generation by biogas generator or/and cooking stove.

Using above system model, simple pre-feasibility study (pre-F/S) was conducted for six biogas candidate project sites found by Rural Electrification Authority (REA). An optional study was conducted to select optimal biogas system components for the selected project (Nyeri High School) out of six target schools.

The simple pre-F/S clarified the following: 1) Outline and Purpose, 2) Particular Features, 3) Preliminary Design, 4) Energy Production and Demand Assessment, 5) Benefit Assessment, 6) Cost Estimation, 7) Economic/Financial Evaluation , and 8) Optional Study for the selected Project for selected site. The work flow of the pre-F/S is shown in the figure below.

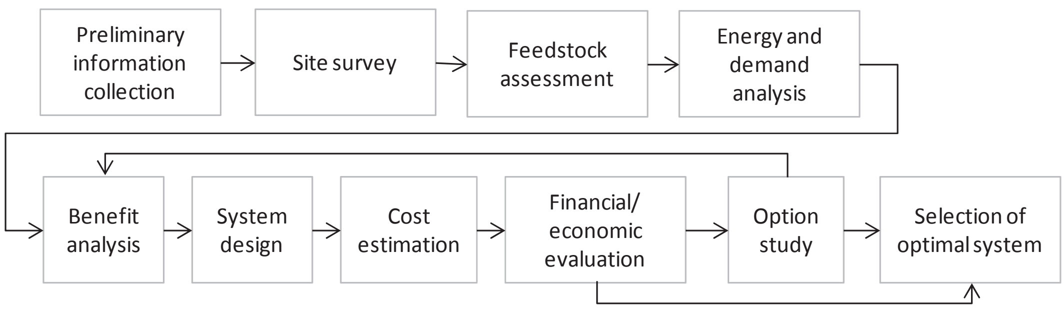

Figure 2: Flow of Pre-feasibility Study

The method of works in the pre-F/S shown in Figure 2 is as follows:

i) Preliminary information collection: Necessary information for site survey was collected, such as willingness for project implementation of facility, location, existence and type of feedstock, etc.

ii) Site survey: Six project sites were surveyed and confirmation of building layout, preparation of sketches to determine facility plan, information collection for available number of cows and other livestock, human, possible raw waste, and energy usage status were conducted according to a check list.

iii) Feedstock assessment: Cow dung and human waste is the main feedstock for school biogas system. The amount of feedstock available in the facility was assessed. The amount of biogas production per kg of cow dung was measured 0.023-0.04 m^3/kg (Gunter U, 2011). With application of the average of this experimental value, the biogas production volume per cow was estimated with the following formula:

$$V_c = 0.033N_c \times W_d \times 365$$

Where, V_c: Volume of biogas production from cow dung (m^3/year)
N_c: Number of cows in facility
W_d: Average cow dung production in kg per cow

The value W_d is variable depending on cow conditions such as age, weight, nutrient status, etc. Here, 20 kg/cow is applied.

The volume of biogas production per person was reported to be 0.02-0.028 m^3/person/day in the experiment in Uganda (E.Menya and Y. Alokore, 2013). With application of average value of this, the amount of biogas production from human waste was estimated with the following formula:

$$V_h = 0.024N_h \times O \times D \times R$$

Where, V_h: Volume of biogas production from human waste (m^3/year)
N_h: Number of persons utilizing the toilet connected to a digester in facility
O: Body weight ratio, average weight of persons/average weight of adults
D: Number of regular days (= 365 – number of long holidays))
R: Toilet usage ratio (percentage of toilet use connected to the digester)

The value O depends on the student age. For high schools, 0.8 was applied. The value D was estimated with school holidays when students and teachers are absent. In this study, 0.75 was applied. The value R was estimated with assumption of how often the toilet connected with digester is used, when different types of toilets, which are not connected to a digester, are installed in a facility. This value was determined by interviews on situation of respective school (0.3-0.95).

iv) Energy and demand analysis: Energy usage and energy demand in the target facility was assessed by collecting data of monthly electricity bills and amount of actual usage of fuel wood.

v) Benefit analysis: The benefit of biogas system consists of fuel wood saving and electricity saving, and can be calculated by the amount of saved fuel wood and/or electricity. The benefit of fuel wood saving was calculated with the following formula:

$$S_f = \frac{(V_{cw}+V_{hw})\times C_{gas}}{C_{wood}/E_{stove}} , \qquad B_f = S_f \times P_{wood}$$

Where, S_f: Saved amount of fuel wood by biogas (tons/year)
V_{cw} and V_{hw} : Volume of biogas V_c and V_h allocated for cooking fuel saving (m^3)
C_{gas}: Calorific value of produced biogas (MJ/m^3)
C_{wood}: Calorific value of fuel wood (MJ/ton)
E_{stove}: Efficiency of cooking stove
B_f: Benefit of fuel wood saving (Ksh)
P_{wood}: Price of fuel wood (Ksh/ton)

Here, calorific value of produced biogas 20 MJ/m^3 (M. Kaltschmittm, 2003) was applied for C_{gas}. The calorific value of fuel wood, C_{wood}, is variable depending on moisture percentage and condition of wood. For dry wood, the value is indicated to be 0.019-0.0225 MJ/ton (Hubbard W., et al., 2007). The value of 0.02 is applied in this study. E_{stove} value depends on the actual cooking stove type that the facility uses, and 10% (N.Shrestha, 2001) is applied for E_{stove} here. Fuel wood price, P_{wood}, is also variable depending on local condition, and was set to be 3,300 kSh/ton from local interviews.

The benefit of electricity saving is calculated with the following formula.

$$E_g = G_e \times (V_{ce} + V_{he}), \qquad B_e = T \times E_g$$

Where, E_g: Saved amount of electric energy (kWh)

V_{ce} and V_{he} : Volume of biogas V_c and V_h allocated for electricity saving (m^3)
G_e: Efficiency of biogas generator (kWh/m^3)
B_e: Benefit of electricity saving (Ksh.)
T: Power tariff rate (Ksh./kWh)

The efficiency of biogas generator, G_e depends on specification of biogas engine generator. Here, 1.0 kWh/m^3 was applied according to manufactures' specification in the past project. T, tariff rate is determined with actual monthly bills of the respective facilities, which was 8.7-19.9 Ksh/kWh.

vi) System design: System design layout was prepared according to sketches in the survey. The size of digester was determined with the following formula (Gunter U et al., 2011 and Martin G et al, 2012)

$$V_{dc} = 1.89 \times N_c \ , \quad V_{dh} = 0.1 \times N_h$$

Where, V_{dc}: Volume of cow dung digester (m^3)
V_{dh}: Volume of human waste digester (m^3)

The size of generator was determined according to required specific load demands such as water pump or lighting.

vii) Cost estimation: The cost of biogas system was estimated by unit cost estimation with quantity or capacity in the past result of REA biogas projects.

viii) Financial and Economic Evaluation: The financial benefit is the same as what was estimated in the benefit assessment. The total economic benefit B_{teb} is calculated with the following formula.

$$B_{teb} = B_{ed} + B_{cr} + B_f + B_{fab} + B_{fco} + B_{fev}$$

The meanings of respective benefit items are explained in Table 1.

Table 1: Economic Benefit

B	Type of Economic Benefit	Explanation
B_{eb}	Benefit as electricity saving from diesel oil	When electricity is generated using biogas, the electric energy can be considered to save electricity from grid-connected diesel generation system in grid, since diesel generation is the most expensive method. The cost of electricity from diesel generation can be considered as economic benefit in place of grid electricity tariff, different from financial benefit. Diesel Oil Price 110.00 KSh/L and Diesel efficiency 2.40 kWh/L was applied.
B_{cr}	Benefit of carbon reduction by biogas generation	CO_2 emission reduction is expected from biogas generation since it replaces energy from diesel generation. Emission factor of diesel oil can be applied to calculate economic benefit. Emission factor of electricity 0.81805 ton-CO_2/MWh and 1,294 KSh/ton-CO_2 was applied (with exchange rate 86.28 KSh/US$).
B_f	Benefit from fuelwood saving	The benefit is the same as financial benefit of fuel wood saving.
B_{fab}	Fuelwood carbon absorption benefit	Saved fuel wood by biogas can absorb CO_2 in a forest. The carbon credit with the absorption of CO_2 amount is considered to be economic benefit.
B_{fco}	Fuelwood carbon off-set benefit	As well as electricity, saved amount of fuelwood is considered to replace coal, and corresponding amount of CO_2 from the replaced coal. This is considered to be economic benefit of carbon reduction.
B_{fev}	Fuel wood economic value to prevent deforestation	Saving of losses in economic sectors resulting from deforestation is counted as economic benefit. The components of this economic value are: growing of crops and horticulture, fishing, water supply, public administration and defense, deforestation effects on carbon sequestration, and deforestation effects on health, which was quantified as much as 921,165 KSh/ha (Jackie C, 2012).

3.0 Results

3.1 Overall Pre-F/S

Pre-F/S was conducted for six sites in Kenya. The institutions were visited to assess the availability of feedstock, their current energy demand and economic benefit of the biogas system. In addition to the work flow up to economic evaluation, Nyeri HS was selected for optional study. Summary results from those other than Nyeri HS are indicated in Table 2. The result for Nyeri HS is described in detail later.

Table 2: Summary of the Result and Plan of Other Institutions

Description	**Name of institution**				
	Litein HS	**Rware HS**	**Kipsigis Girls HS**	**Mukumu Girls HS**	**Cardinal Otunga HS**
Estimated feedstock	17 cows and 1015 students	9 cows and 600 students	13 cows 1000 students	14 cows 1300students	10 cows 1000students
Possible gas production per day	Cowdung:12m^3 Humanwaste:16m^3	Cowdung:9m^3 Humanwaste:- (no septic tank)	Cowdung:4.2m^3 Humanwaste:23m^3	Cowdung:7.3m^3 Humanwaste: 17m^3	Cowdung:12m^3 Humanwaste: 16.1m^3
Digester volume	Cowdung: 32m^3 Human waste:60m^3	Cowdung: 24m^3	Cowdung:16m^3 Humanwaste:50m^3	Cowdung:28m^3 Humanwaste:60m^3	Cowdung: 32m^3 Humanwaste:6om^3
Total gas production	28m^3/day	9m^3/day	18.9m^3/day	24.9m^3/day	28.1m^3/day
Amount of fuel wood reduction	25.9 tons/yr	19.1 tons/yr	8.9 tons/yr	28.0 tons/yr	25.6 tons/yr
Benefit of saving electricity	Ksh. 79,278/yr	No plan for electricity	Ksh. 100,983/yr	Ksh. 48,021/yr	Ksh. 87,162/yr
Benefit of fuel wood saving	Ksh. 85,578/yr	62,945 Ksh/yr	Ksh. 29,374/yr	Ksh. 126,005/yr	Ksh. 84,528/yr
Cost	6.9 million Ksh	1.7 million Ksh	3.8 million Ksh	4.3 million Ksh	4.7 million Ksh

As a result, the project recovery year was within 30 years, ranged from 23 years (Rware HS) to 28 years (Kipsigis Girls HS), and considered to be feasible, except for 42 years in Litein HS. Since facilities are isolated and civil cost was high, the project in Litein HS is not considered to be feasible. Economic internal rate of return was calculated to be from 5.8% (Litein HS) to 16.4% (Rware HS).

3.2 Overview of Nyeri High School

Nyeri high school was established in 1924 as a missionary school, which was later on reformed into a high school in 1950. The current population in the school is approximately 1000 persons including teaching and non-teaching staff. At the time of visit, there were 10 cows and 15 pigs. The agricultural activities in the school include; nappier grass, sweet potato, sukuma wiki, and recently fishpond for rearing tilapia fingerlings, all these activities would utilize the bio slurry.

3.3 Purpose of the Project in Nyeri HS and Energy and Demand Assessment

The School consumes large amounts of both electricity and fuel wood to support the activities within the school. Electricity is consumed mainly for lighting. A diesel generator (38.5 kVA) is on standby incase of blackout, and it consumes diesel oil approximately 480 L/yr. Fuel wood is consumed at 300 tons/year for daily meals for students and teachers. The financial burden of electricity is about 1.5 mil KSh/year and that of fuel wood is 0.8mil Ksh/Yr. Electricity supply by biogas is expected to contribute toward mitigation of electricity and fuel wood usage in the school.

3.4 Preliminary Design in Nyeri HS

The demand for biogas is for (i) cooking fuel and (ii) electricity lighting in boarding buildings. The proposed systems are (i) digester connected with cow shed for electricity generation system and (ii) digester connected from toilet for cooking fuel use. The system components are shown in the table below.

Table 3: Cow Dung Digester for Electricity

Description	Qty	Unit	Remarks
Nos of cows	17		to be increased from 10 nos
Digester size	32	m3	
Assumed feedstock input	400	kg/day	
Possible gas production	12	m3/day	
Generated energy	12	kWh	1kWh/m3
Electric energy demand	8.5	kWh	Light, 59 nos of 36W, 4hrs

Table 4: Human Waste Digesterfor Cooking fuel

Description	Value	Unit
Utilization ratio	**0.54**	
Boarding toilet usage ratio	0.67	
Student/adult weight	0.80	
Nos of student utilizing dorm toilet	950	nos
Converted nos of person for biogas	509	nos
Digester volume	**60**	**m3**
Gasproduction amount	**15.3**	**m3/day**

The digester for cow dung will be located at a garden area below a cow shed. The layout was considered in a way that it would utilize gravity to transport cow dung . Effluent supply as fertilizer for a garden is also by gravity.

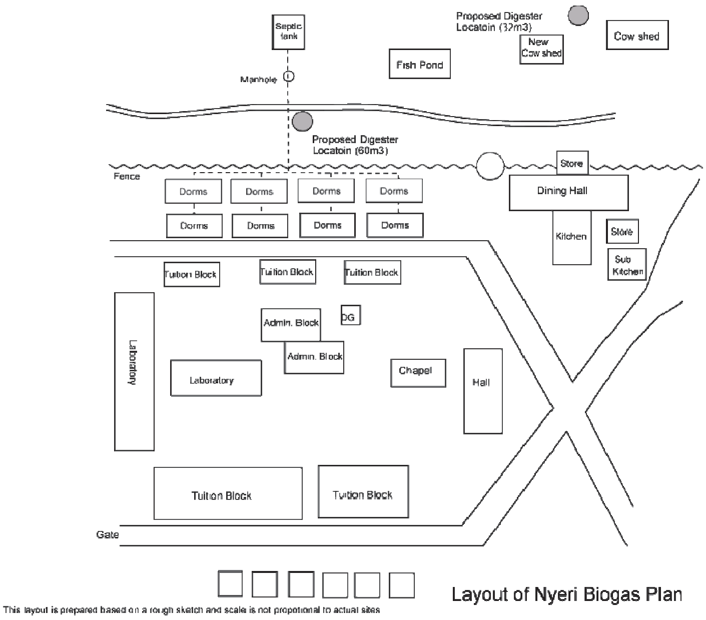

Figure 3: Layout of Nyeri School Biogas System

3.5 Benefit Assessment

Total expected amount of gas production is approximately 8,568 m^3/year, of which 2,321 m^3 is planned to be used for generation and 6,248m^3 for cooking stove. Amount of electricity saving will be 2,321 kWh and amount of fuel saving will be 36.3 tons/year. This corresponds to 4% of total electricity usage and 12% of fuel wood use in the school. The unit cost of electricity at the school is 19.7 KSh/kWh, therefore the annual saving will be 45,748 KSh/year for electricity. The unit cost of fuel wood is 3,300 KSh/ton, therefore the annual saving for fuel wood will be 119,717 KSh. In total, the annual benefit of biogas system will be 165,466 KSh/year.

3.5 Cost Estimation

The cost for the system was estimated as in Table 5. As the optional study, system without electricity generation was also studied. This is because usage of fuel wood by the school is more than the replacing amount of biogas even if all biogas is used for cooking fuel supply only. The cost with generator was estimated to be about 3.8 million KSh, while that of without generator was about 2.8 million KSh. The installation cost of biogas system with generator is 32% higher that that of without generation system. The details are shown in Table 5. In addition, generators require overhauling every 5-7 years, and the maintenance cost is high, which was considered in the cash flow.

Table 5: Cost Estimation with/without Generation

Item	Nyeri High School with Generator			Nyeri High School without generator		
	Qty	unit	KSh	Qty	unit	KSh
Biogas Digester for Toilet	60	m3	413,720	60	m3	413,720
Biogas Digeter for Cow Shed	32	m3	340,444	32	m3	340,444
Excavation and civil works	1	lot	188,830	1	lot	188,830
Additional toilet facility with septic tank						
Gas holding steel tank and connection valve	2	nos	100,800	2	nos	100,800
Bigoas flow meter	2	nos	73,000	2	nos	73,000
PVC gas bag	1	nos	411,000	1	nos	411,000
Biogas generator	7	kVA	240,000		kVA	
Energy meter	1	nos	50,000		nos	
Distribution board, switch gear	1	nos	150,500		nos	
Biogas filter and solenoid valve	1	nos	106,500	1	nos	106,500
Cable work	1	lot	200,000		lot	
Pipe work	1	lot	250,000	1	lot	250,000
Fence and safety arrangement	1	lot	118,000	1	lot	118,000
Subtotal			2,642,794			2,002,294
Detailed design and drawing	1	lot	246,000	1	lot	186,380
Testing, commissioning, training	1	lot	363,500	1	lot	275,403
Total Cost			3,252,294			2,464,077
Total Cost adjusted with Inflation 2010/13	4.91%/	Ksh	3,755,264	4.91%/	Ksh	2,845,149

3.6 Results of Financial and Economic Evaluation

As the result shown in Table 6, the financial benefit for the system with generator was 165,466 Ksh/yr, higher than without generator (cooking fuel supply only), 164,181 Ksh/yr. However, since investment cost with generator will be much higher, recovery year of the system without generator has advantage, 17 years, while that of the system with generator was 23 years.

Meanwhile, economic benefit will be larger in the system without generator (702,086 KSh/yr) than system with generator (620,758 KSh/yr), since economic benefit of forest protection

Table 6: Cost Estimation with/without Generation

Item	Unit	Nyeri High School with generator	Nyeri High School without generator
Project Cost	KSh	3,755,264	2,845,149
Planned gas production for fuelwood saving	m^3/yr	6,248	8,568
Planned gas production for electricity saving	m^3/yr	2,321	0
Electricity tariff rate	KSh/kWh	19.7	19.7
Annual planned generated energy	kWh/yr	2,321	0
Annual planned fuelwood Saving	ton/yr	36.3	49.8
Financial benefit	**KSh/yr**	**165,466**	**164,181**
Recovery year	yr	23	17
Benefit of diesel generation saving	KSh/yr	106,356	0
Benefit of CO2 emission reduction by biogas generation	KSh/yr	2,457	0
Benefit from fuelwood saving	KSh/yr	119,717	164,181
Fuelwood carbon absorption benefit	KSh/yr	164,854	226,082
Fuel wood carbon off-set benefit	KSh/yr	58,947	80,840
Fuel wood economic value	KSh/yr	168,427	230,982
Total economic benefit	**KSh/yr**	**620,758**	**702,085**
EIRR		**15.09%**	**24.18%**

Shadow exchange rate is not considered in financial cost.

(fuelwood economic value) is considered to be large. The economic internal rate of return (EIRR) for the system with generator was 15.1%, while that of without generator was 24.2%.

The financial return for electricity and cooking fuel from the same amount of biogas was calculated to be 19.2 KSh/m^3 for fuel wood replacement and 19.7 KSh/m^3 for electricity supply. Those were almost the same at the present electricity tariff rate (19.7 KSh/kWh) and fuel wood price (3,300 KSh/ton). For generation system, engine maintenance is challanging expecially in rural areas, and O&M requrement becomes a hurdle for sustainable operatoin for users. Considering higher installation and O&M cost necessary for the generation system, simple fuel wood replacement system is considered to be more efficient and sustainable.

4.0 Conclusions

All the six schools visited have potential for generating biogas from the available waste. Except one school, all biogas systems are considered to be economically feasible. This biogas can be used to reduce the amount of fuel wood and electricity that the institutions are currently using. Biogas used for thermal application, i.e., cooking fuel replacement, is more economically feasible than the one used for generating electricity, considering installation and O&M cost for generation system.

Although biogas system is applicable both for fuel wood replacement and electric energy saving, simple system only for fuel wood replacement is the most sustainable especially in rural areas, where it is difficult to find and train skilled operators. Optimal system components should be selected in view of economic efficiency and feasibility in biogas projects, considering demand and possible energy supply.

5.0 Acknowledgements

The authors wish to acknowledge Japan International Cooperation Agency (JICA) for providing assistance for this study.

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Rural Electrification Authority

Lighting up rural Kenya

PRE-FEASIBILITY STUDY ON BIOGAS SYSTEMS FOR SCHOOLS IN KENYA

Authors: Caroline Kelly(Kelly@rea.co.ke), **Gilbert Gichunge** (ggichunge@rea.co.ke) , Renewable Energy Dept., *Rural Electrification Authority*

Objective: Biogas is combustible gas produced by anaerobic fermentation of organic material. Biogas has approx. 60% methane (CH_4) , 20 MJ/m^3 calorific value. Biogas can substitute fuel wood and electricity. Slurry after fermentation becomes fertilizer. **Pre-Feasibility Study** to install 6 schools biogas system was conducted to assess benefit and conduct economic evaluation.

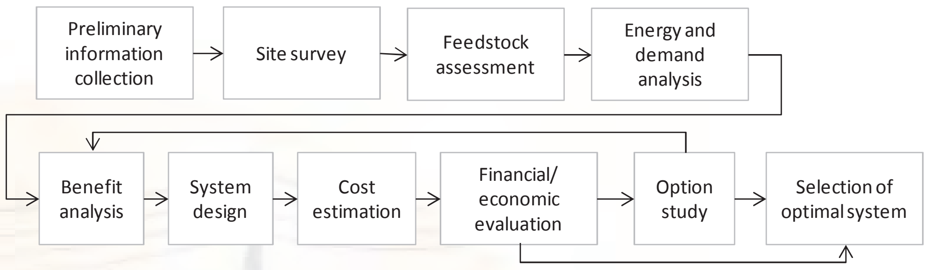

Figure 1 Work Flow of Pre-Feasibility Study

(1) Feedstock Assessment : Cow dung

$$V_c = 0.033 N_c \times W_d \times 365$$

V_c: Biogas volume from cow dung (m^3/year)
N_c: Number of cows in facility
W_d: Average cow dung production (kg/cow)

(2) Feedstock Assessment : Human Waste

$$V_h = 0.024 N_h \times O \times D \times R$$

V_h: Biogas volume from human waste (m^3/year)
N_h: Number of persons utilizing toilets for digester
O: Body weight ratio (% of adult)
D: Number of operation days
R: Utilization ratio (%of toilet for digester use)

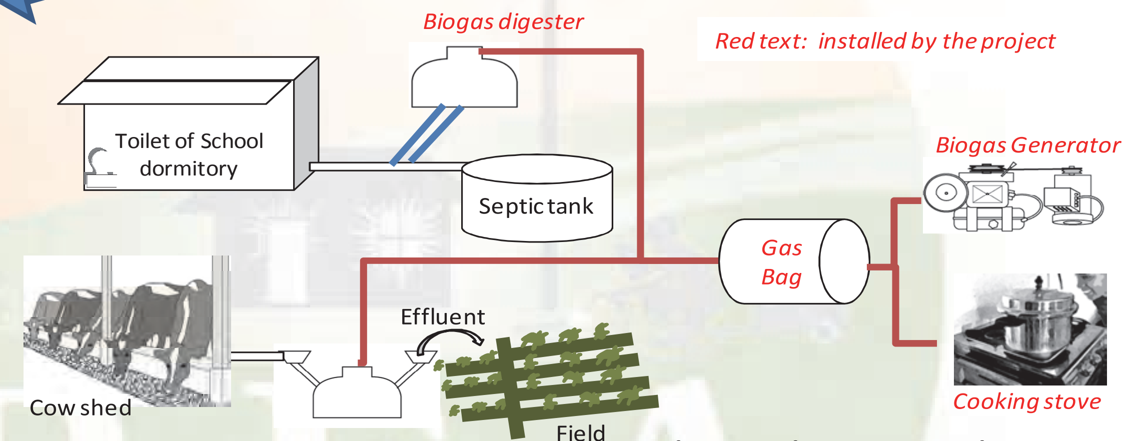

Figure 2 Biogas Generation System Model

(3) Benefit: Electricity Saving

$$E_g = G_e \times (V_{ce} + V_{he}) \quad B_e = T \times E_g$$

E_g: Saved amount of electric energy (kWh)
V_{ce} and V_{he} : Volume of biogas
V_c and V_h :allocated for electricity saving (m^3)
G_e: Efficiency of biogas generator (kWh/m^3)
B_e: Benefit of electricity saving (KSh.)
T: Power tariff rate (KSh./kWh)

(4) Benefit: Fuelwood Saving

$$S_f = \frac{(V_{cw} + V_{hw}) \times C_{gas}}{C_{wood} / E_{stove}} \quad B_f = S_f \times P_{wood}$$

S_f: Saved amount of fuel wood by biogas (tons/year)
V_{cw} &V_{hw} : Biogas volume for cooking fuel saving (m^3)
C_{gas}: Calorific value of produced biogas (MJ/m^3)
C_{wood}: Calorific value of fuel wood (MJ/ton)
E_{stove}: Efficiency of cooking stove
B_f: Benefit of fuel wood saving (KSh)
P_{wood}: Price of fuel wood (KSh/ton)

(5) Design and Cost Estimation

Cow dung: Digester Size (m^3) = 1.89 x nos of cow
Human waste: Size (m^3) = 0.1 x nos of person
Gen-set, Pipeline, Civil/Electrical Works, etc

(6) Financial/Economic Evaluation

$$B_{teb} = B_{ed} + B_{cr} + B_f + B_{fab} + B_{fco} + B_{fev}$$

Table 1 Biogas Economic Benefits

B	Type of Economic Benefit	Value*
B_{teb}	Total economic benefit	Summation of values velow.
B_{ed}	Benefit as electricity saving from diesel oil	From diesel oil price and diesel generation efficiency
B_{cr}	Benefit of carbon reduction by biogas generation	when 0.81805 ton-CO_2/MWh and 1,294 KSh/ton-CO_2, 1059 KSh/MWh
B_f	Benefit from fuelwood saving	From fuel wood price and saved amount of wood
B_{fab}	Fuelwood carbon absorption benefit	1 ton fuel wood saving corresponds to 3.51 ton-CO_2
B_{fco}	Fuelwood carbon off-set benefit	1 ton fuel wood saving corresponds to 1.26 ton-CO_2
B_{fev}	Fuel wood economic value to prevent deforestation	Economic value per ton fuelwood 4,643 KSh/ton

* All values here are subject to be changed according to carbon credit, emission coefficient, exchange rate, and method of socio-economic calculation. For detail, refer to the guideline.

Agricultural benefit by bio-slurry can be added as benefit in the above when experimental value of yield increase is available.

(7) Result of Pre-Feasibility

Table 2 Summary of Pre-Feasibility Study for Six Schools in Kenya

Description	School Name				
	Litein HS	Rware HS	Kipsigis Girls HS	Mukumu Girls HS	Cardinal Otunga HS
Estimated feedstock	17 cows and 1015 students	9 cows and 600 students	13 cows 1000 students	14 cows 1300students	10 cows 1000students
Possible gas production per day	Cowdung:12m^3 Humanwaste:16m^3	Cowdung:9m^3 Humanwaste:- (no septic tank)	Cowdung:4.2m^3 Humanwaste:23m^3	Cowdung:7.3m^3 Humanwaste: 17m^3	Cowdung:12m^3 Humanwaste: 16.1m^3
Digester volume	Cowdung: 32m^3 Human waste:60m^3	Cowdung: 24m^3	Cowdung:16m^3 Humanwaste:50m^3	Cowdung:28m^3 Humanwaste:60m^3	Cowdung: 32m^3 Humanwaste:60m^3
Total gas production	28m^3/day	9m^3/day	18.9m^3/day	24.9m^3/day	28.1m^3/day
Fuel wood reduction	25.9 tons/yr	19.1 tons/yr	8.9 tons/yr	28.0 tons/yr	25.6 tons/yr
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Fuel wood saving benefit	Ksh. 85,578/yr	62,945 Ksh/yr	Ksh. 29,374/yr	Ksh. 126,005/yr	Ksh. 84,528/yr
Cost	6.9 million Ksh	1.7 million Ksh	3.8 million Ksh	4.3 million Ksh	4.7 million Ksh

(8) Option Studies for Nyeri High School

Table 3 Design of Cow Dung Digester for Generation

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Nos of cows	17		to be increased from 10 nos
Digester size	32	m3	
Assumed feedstock input	400	kg/day	
Possible gas production	12	m3/day	
Generated energy	12	kWh	1kWh/m3
Electric energy demand	8.5	kWh	Light, 59 nos of 36W, 4hrs

Table 4 Design of Human Waste Digester for Cooking

Description	Value	Unit
Utilization ratio	**0.54**	
Boarding toilet usage ratio	0.67	
Student/adult weight	0.80	
Nos of student utilizing dorm toilet	950	nos
Converted nos of person for biogas	509	nos
Digester volume	**60**	**m3**
Gasproduction amount	**15.3**	**m3/day**

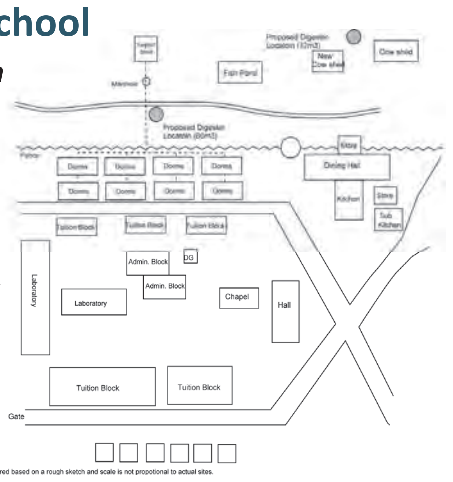

Figure 3 System Layout in Nyeri HS

Table 5 Case Study Result of System With/Without Generator

Item	Unit	Nyeri High School with generator	Nyeri High School without generator
Project Cost	KSh	3,755,264	2,845,149
Planned gas production for fuelwood saving	m^3/yr	6,248	8,568
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Annual planned generated energy	kWh/yr	2,321	0
Annual planned fuelwood Saving	ton/yr	36.3	49.8
Financial benefit	**KSh/yr**	**165,466**	**164,181**
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Total economic benefit	**KSh/yr**	**620,758**	**702,085**
EIRR		**15.09%**	**24.18%**

Shadow exchange rate is not considered in financial cost.

(9) Conclusions

All the six schools have potential for generating biogas from the available waste. Except one school, **all biogas systems are economically feasible.**

Biogas used for saving cooking fuel is more economically feasible than the one used for generating electricity, considering installation and O&M cost for generation system.

Simple system only for fuel wood saving is the most sustainable especially in rural areas.

Optimal system components should be selected in view of economic efficiency in feasibility studies, considering demand and possible energy supply.

Project for Establishment of Rural Electrification Model Using Renewable Energy
Sector: Biogas
Date: 30th May 2012
Organization: Siongiroi Milk Cooling Facility

Meeting Called By	JICA Project Team
Type Of Meeting	Project Preparation Meeting- Preliminary Research
List Of Attendees	1. Ferdinand Okinyi- Manager, Siongiroi Cooling Facility 2. Hillary Pacho- Kenya Dairy Board (KDB) Branch Manager (Bomet/Kericho) 3. Tsutomu Dei- Project Team 4. Ken Shimomukai- Project Team 5. Aisha Abdulaziz- Project Team
Agenda	1. Project Overview 2. Dairy Production Industry 3. Industry Situational Analysis 4. Community Situational Analysis 5. Dairy Management Groups 6. Project Candidate Sites 7. Conclusion

SUMMARY OF DISCUSSION

1. Project Overview- The project team introduced the biogas energy project, introducing the agenda for the meeting which was to gain better understanding of the dairy production industry in the area and the systems in place between the farmers and market. In turn, the information was provided by Siongiroi cooling facility on its history, functions and ongoing activities.
2. Dairy Production Industry- Dairy production in the area is of high quality and quantity (noted as one of the best in the country). Dairy farming is not a subsistence activity in the area, as most of the produce is delivered by the farmers to the cooling facility for sale to private milk processing companies. The facility has a capacity of 50,000 liters per day and has been able to handle up to 80,000 liters a day during peak seasons. The current handling is at about 47,000 liters a day. Majority of the farmers deliver milk in plastic containers/jerikans transported mostly by donkeys, bicycles and motorcycles while a few use private vehicles.
3. Industry Situational Analysis- The community has progressed considerably through their own initiative, having contributed money to set up the facility and secured additional donor support. The farmers' society established a company with the aim of protecting their investments in reaction to the collapse of cooperative societies in Kenya. The industry potential is very high; though challenges include poor road infrastructure, lack of electricity and its limiting cost where there is grid connection. The cooling facility considered installation of alternative energy sources such as generators, solar and wind but costs and energy potential were limiting factors respectively. The facility intends to establish up to 4 extension/satellite facilities in the course of the year. However, site selection is determined by electricity availability first rather than areas of greatest dairy production; and are therefore proposed in trading centres/markets. The facility indicated a willingness to consider the biogas installation site as a satellite cooling facility should the project be implemented for their members who are off-grid. The potential to increase the quality and quantity of milk to the main facility was welcome. The KDB indicated that the benefits of such a site would include health due to improved quality. Currently, the local hospital treats numerous milk-borne diseases majority of which are attributed to handling.

4. Community Situational Analysis- The community has a number of initiatives in conjunction with the facility. These include model farms where members provide demonstrations in best agricultural practices such as feeding and breeding. Case studies were shared by the facility, indicating the proactive nature of its members and the community structures. The facility has a check off system in place that allows farmers to procure necessary materials and equipment. In terms of sanitation, farmers are encouraged to use aluminum cans but are not able to adhere to the regulation because of the distances and state of roads to the facility. It was also noted that the industry is women-centered in provision of labour and the project would alleviate the work load on this group.
5. Dairy Management Groups- The community has dairy management groups (DMGs) as a structure for the farmers and cooperative society to engage with each other, through activities that include training, loan facilities and production quality assurance. Each DMG is comprised of about 15 farmers and the recommendation was for the project to have at least 3 or 4 such groups come together for the project implementation. There has also been a community farm model, which has been tried though with minimal increase in production quantity/quality.
6. Project Candidate Sites- Based on the discussion, the facility was keen to recommend candidate sites for the project. The recommendation was to reconsider the distance criteria to be at least 8 Km rather than 15. Justification provided was that the nature of the terrain was challenging and the hardship faced by the community in transporting their produce was quite high. As a case in point, the Siongiroi Facility was 18 Km from the main road but took us considerable amount of time and paused a difficulty. Additionally, based on the national grid extension lines already in place; distances between already existing grid lines would probably not exceed 25 Km.
7. It was concluded that the facility would identify candidate sites and/or dairy management groups within their catchment area radius (varying from 15-30 Km). The sites would meet the basic criteria of being at least 8 Km from the national grid, be in an area with considerable potential to maximize benefits from such a biogas system installation and target group(s) showing initiative in industry activity. KDB also indicated support for the project and keenness to collaborate in conjunction with the Ministry of Livestock local office.

Action Items	Person Responsible
Provide list of candidate sites and/or dairy management groups	Siongiroi Cooling Facility
Provide overview of the energy project	Project Team
Introduction to District Livestock and/or Dairy officers	KDB

Project for Establishment of Rural Electrification Model Using Renewable Energy

Sector: Biogas

Date: 22 June 2012

Organization: Biogas International and Nyongara Slaughter House

Meeting Called By	JICA Project Team
Type Of Meeting	Site Visit
List Of Attendees	1. Mr. Otake – JKUAT Team 2. Mr. Yumoto – JKUAT Team 3. Mr. Kikuchi - JKUAT Team 4. Yuka Nakagawa- Project Team 5. Aisha Abdulaziz- Project Team 6. Evans Gitahi- JKUAT Team 7. Caroline Kelly- REA 8. Kennedy Ababu- Nyongara Slaughter House 9. Dominic Wanjihia- Biogas International
Agenda	1. Visit to Biogas International 2. Visit to Nyongara Slaughter House

SUMMARY OF FINDINGS

1. Biogas International
   1) Owner: Mr. Dominic Wanjihia, 072-2700-530, info@biogas.co.ke
   2) Product list

Model	Capacity	Cost in Ksh	Remarks
BG4	6m3	58,500	15% discount for schools and children home for 2 units
BG6	9m3	71,500	

   3) Installation period required : 1-2 days
   4) Gas generation starting: in 4-7 days if starting with cow dung and 7-14 days if starting with slaughterhouse waste.
   5) Food drier is under testing with a wooden box like a smoker.
   6) Material is PVC, 1.5 psi pressure durable. Sealed with a zip made of plastic hose.
   7) Small damage such as pin hole can be repaired by super glue.
   8) Life time needs confirmation and is still under testing. Local bag is not durable with exposure to sun light for a long time. Cost is low and is possible to replace at 1000 Ksh/bag.
   9) Bag color needs to be selected according to site condition. Black and green bags become too hot and sterilize the bacteria if installed in a hot place.
   10) UV treated Green-house cover is applied to increase temperature.
   11) Petro engine alternator 5 hp can be applied.
   12) 20 kg cow dung can produce $1m^3$/day. 50-60 kg cow dung produces 3.5-5 m^3 gas.
   13) The company started in 2010. Up to now, 200 systems have been installed.
   14) Application of animal wastes derived from the stomach (tatha) is effective to accelerate starting gas production, since it has methane bacteria inherently.
   15) Human waste can be applied and a small model has been developed, but cow dung is necessary to input to grow preferable bacteria consortium. There is no indication however of the relationship between microbes found in the two wastes separately.
   16) Gas concentration is 80-85%, reportedly. (This needs confirmation.)
   17) Parallel application is possible. They have experience up to 4-bags parallel
   18) For application of biogas for cooking, the air jets of the cooker need modification.
   19) Gas distribution up to 30m is possible without compressor. Estimated pressure is 0.1-0.5 psi
   20) For Hydrogen Sulfide removal, steel wool (steel fiber scrubber) is applied, replacing

once/month.

21) Tax (VAT) exemption preference is being applied.

2. Nyongara Slaughter House
    1) Assistant Administrator- Kennedy Ababu, 0722795902
    2) Founded by UNDP, UNEP, and KIRDI, PPP Green Energy Project.
    3) Process is: (1) Feeding, (2) Anaerobic treatment (Hydrolysis, Digester ($60m^3$ bag), and Overflow), (3) Aerobic Treatment, and (4) Biogas Use (Gas holder bag $40m^3$, 10kva generator, and biogas stove)
    4) Hydrolysis is conducted before entering digester for decomposition of carbohydrates, proteins, fats, and organic material into amino acid, fatty acid, and sugar.
    5) For (3) Aerobic Treatment, through adding oxygen, the effluent is treated to reduce BOD and fecal coliform bacteria and to release the effluent to the environment.
    6) Solar thermal heating system is applied to keep digester at optimum temperature 37^oC. In practice, average temperature obtained is $24\text{-}27^0C$ with a maximum of 34^0C
    7) Out of 4 ton/day waste, 300 kg/day solid waste and 3.5 m^3/day liquid waste is utilized for biogas. Remaining waste is utilized for compost.
    8) Expansion is considered and distribution of biogas to the neighboring community is an idea, however it has not yet materialized due to lack of funds.
    9) Slurry fertilizer is not utilized. There are plans for mineral content analysis currently under consideration in partnership with University of Nairobi.
    10) Equipped with 7kW (9kW max) modified petrol engine, consuming $40m^3$ of gas in 6hrs. It has gas inlet valve and filter.
    11) Their electricity bill since installation of the system has reduced from about 25,000 KSH/month to 15,000 KSH/month.

Digester with Greenhouse Cover

Slurry Outlet

H_2S Removing Filter

Steel Wool for H_2S Removal

PVC Gas Bag and Zip

Food Drier with Biogas

Biogas Toilet

Petro Engine Generator

Water Heating for Gas Digester

Liquid Waste

Gas Holder (40m3)

Slurry Outlet

Inlet Gas/Air Valve

Petro Engine Generator

Project for Establishment of Rural Electrification Model Using Renewable Energy

Sector: Biogas

Date: 28th June 2012

Organization: Biopower Systems Ltd.

Meeting Called By	JICA Project Team
Type Of Meeting	Information collection
List Of Attendees	1. Peter Gichohi – Biopower Systems 2. Yuka Nakagawa - Project Team 3. Aisha Abdulaziz- Project Team
Agenda	1. Company Information 2. Project Information 3. Technical Advices

SUMMARY OF DISCUSSION

1. Company Information
   (1) Biopower Systems Ltd.: Mr. Peter Gichohi, 0722 620 234 biogassystems@yahoo.com
   (2) Started in 2007, as a change-over from another company name. Biogas installation experience is abundant. For generation, experiences are:2kW (Petro engine) for milking machine and chaff cutter, 4.5kW for domestic application, 16kVA for water pump, 2kW under construction for pig facility, 20 kW for a secondary school (Mang'u) and 20 kW planned for 1000 Cows farm
   (3) PVC bag is durable more than 10 years. It was initially imported from Germany, and is currently imported from China. Up to 120m^3 is possible. Red Mud Bag contains aluminum sludge which makes it durable against pressure.
   (4) For civil work, they hire outside civil engineers and workers.
   (5) Permanent employees are4
   (6) The company provides EIA consulting service.

2. Project Information:
   (1) <u>Murang'a Biogas Project:</u> 80 Km from Nairobi. Funded by UNIDO. Not being successful due to feed stock, which is banana waste and requires hydrolysis process. 150 kg/day. 20m^3 tank is installed. 12 kVA modified diesel engine is installed, utilizing 20% diesel and 80% biogas. The grid was also extended when the project was underway and electricity is now being used.
   (2) <u>Mang'u high school</u> (40 km from Nairobi): REA project. 20 kW generator is installed. Feedstock is cow dung and human waste. Tender document of REA only specified the size (2 x 100m^3 and 1 x 50m^3), and detailed design was conducted by the manufacturer.
   (3) <u>Flower Biogas:</u> Currently it is on-going under MoEn, with 400 m^3 tank, 100 kW biogas-engine generator, expected to include CHP. EIA was conducted and license was issued.
   (4) <u>Thika:</u> 115 m^3 digester is planned with a 55 kW generator, also expected to include CHP.

3. Technical Advises
   (1) Generally, gas-generation efficiency is reported to be 0.5 m^3/kWh. Their system achieves more. Recommendation to use natural gas generators rather than modify.
   (2) Masonry/concrete tank and gas holder PVC bag is provided. SSB (1:10 cement: soil) is traditionally applied for masonry. Recommendation to use padding as insulation in the plastic bag pit.
   (3) H_2S is required to be removed completely for application of biogas to generation system. They are planning to procure methane and H_2S sensor to measure concentration.
   (4) Utilization of modified petro-generator is possible up to 10kW. Limitation of use at

maximum 6 hours per day. At present, China manufacturer produces biogas engine generator with spark igniter, possible up to 1MW.

(5) For power production, gas holder is a must as well as H_2S purification .
(6) Masonry tank is possible up to 200m^3. Bag digester is recommended up to 9m^3. Explore possibility of using steel tanks (experience of use over 10 years).
(7) CHP is advised to circulate hot water from engine and keep the digester warm.
(8) For fridge, solar heat pump is recommended for effective cooling.
(9) EIA must be conducted and submitted to National Environmental Management Authority, for any system that treats waste water. The company prepared EIA report for FS of Power Generation from Flower Waste at P.J. DAVE Flowers Ltd. The report soft copy was requested to provide to the Team.

Action Items	Person Responsible
Example of EIA report for Biogas generation	Mr. Peter, follow-up by Ms.Aisha
Tender document for Mang'u high school.	Ms. Aisha (obtain from REA)

Attachment: Specification of gas holder bag.

Project for Establishment of Rural Electrification Model Using Renewable Energy

Sector: Biogas

Date: 12 July 2012

Organization: REA

Meeting Called By	JICA Project Team and REA
Type Of Meeting	Site Visit
List Of Attendees	1. Caroline Kelly- REA 2. Samson Ondiek 3. Kenji Igarashi – Project Team 4. Yuka Nakagawa - Project Team 5. Geofrey Ochieng - Project Team
Agenda	1. Moi Girl's High School, Isihya 2. Mangu High School

The Team visited two schools with biogas generation system. Those schools were funded by REA as the first demonstration case for biogas.

1. Moi Girls School, Isihya
   - (1) The system is not in operation. Biogas has not been generated, except at the time of commissioning test.
   - (2) Feedstock is human waste only. 16 Cubicle-toilet was constructed in the Project. Nos of user is 700 in dormitory.
   - (3) 2 nos of 100m^3 dome digester were installed. Total capacity is 200m^3. Two digesters are connected.
   - (4) Slurry is not utilized, sent to soak pit after the second digester.
   - (5) Gas leakage is found at the pipe above the metal dome, probably due to corrosion of H_2S.
   - (6) Gas meter is installed only at the 1st 100m^3 digester. The meter shows 354 m^3.
   - (7) Gas genset was installed, CAMDA Generator Work Co., Ltd, made in China. 13kVA, 10 kW, PH0.8, 415/240V (3phase), 1500 rpm. 3 Phase distribution board and Wh meter was installed. The generated energy shown in the meter was 1 kWh only.
   - (8) 20 m^3 PVC gas bag is installed to store gas.
   - (9) Gas measured at the engine inlet was only 15.7 m^3. Gas at 330 m^3 is missing, probably leaked.
   - (10) To re-start fermentation, the Team advised to check pH value if it is above 6.0 (if it is acid condition, it needs to neutralize), and use cow dung and cow stomach to obtain methano-bacteria consortium, not only using human waste.

2. Mangu High School
   - (1) The system was commenced in August 2011.
   - (2) About 1000 students live in dormitory.
   - (3) 2 nos of 100m^3 (human waste) + 1 nos of 50 m3 (cow dung) digesters are installed. Total capacity is 250m^3. All are in operation and generate gas.
   - (4) Human waste is a feedstock for 2 x 100m^3 digester. The waste is collected from a septic tank by gravity to the digester. The pipe is PVC pipe, ϕ 6". No garbage from a kitchen is used.
   - (5) Gas meter was installed only one of 100m^3 digester, which shows gas generation at 2947m^3.
   - (6) Water jacket is put surrounding metal dome of the digester. Used black engine oil was poured to the surface of water to prevent mosquito.

(7) No leakage was found at the digester and pipe.
(8) 40-50 nos of cows in collective cowshed supply dung to 50m^3 digester. This amount is too much and half of the amount is not utilized due to limitation of digester size. The school wants to increase number of digester for this.
(9) Electricity is supplied to 13-14kW water pump, used for the water supply 1.5 hr/day.
(10) Gas genset was installed, CAMDA Generator Work Co., Ltd, made in China. 25 kVA, 20 kW, PH0.8, 415/240V(3phase), 1500 rpm. 3 Phase distribution board and Wh meter were installed. The generated energy up to now is 1,704 kWh.
(11) 20 m^3 PVC gas bag is installed to store gas.
(12) Gas purification unit with hydrogen sulfate remover is installed.
(13) Gas measured at the engine inlet was 3,898 m3. Considering one 100m^3 digester produced 2,947m^3 at its outlet point of digester, the amount seems small. There may be possibility of leakage along the pipeline. In addition, required gas consumption for unit energy, 3,898/1704 = 2.35 m^3/kWh, seems large (usually, 0.5-1.0 m^3/kWh expected). Considering 10months operation, the average daily energy is 1,704/10/30=5.7 kWh/day. This seems small considering size of digester. It is advised to confirm to the manufacture about this aspect.

Action Items	Person Responsible
Provision of submitted document and drawing from the manufacturer	Ms. Caroline

< Moi Girl'a High School>

Toilet to supply human waste to digester

2 nos of digester (100m^3 x 2)

Gas meter at outlet of the digester

Starring handle for digester

Power House for Genset and Gas Holder

Biogas Engine

<Mangu High School>

Water Pump

100m^3 Digester

Used engine oil to prevent mosquito

Collective cow shed

Ditch for cow dung and waste connected to digester

Gas purification unit

$20m^3$ Gas holder

Project for Establishment of Rural Electrification Model Using Renewable Energy

Sector: Biogas

Date: 10 August 2012

Organization: Biogas Plant in Kilifi Sisal Plantation

Meeting Called By	JICA Project Team
Type Of Meeting	Information collection and meeting with community/school
List Of Attendees	1. Christopher Wilson- Director (Biogas Power Holdings (EA) Ltd. 2. Robert- Biogas Project Technician 3. Yuka Nakagawa-Project Team 4. Aisha Abdulaziz- Project Team 5. Evans Gitahi - JKUAT
Agenda	1. Site memo

SUMMARY OF DISCUSSION

(1) The biogas generation plant using sisal waste and cow dung was installed in 2007 by the Kilifi Sisal Plantations Ltd. as a private facility. It is operated by a company; the Biogas Power Holdings (EA) Ltd. The company is a joint venture between Kilifi Sisal Plantations Ltd (KE) and German companies, agri Komp GmbH and Schnell Zündstrahlmotoren AG & Co. KG. The project was established through a tripartite Public Private Partnership (PPP) with the support of GTZ.

(2) The facility sells livestock at following prices:

In calf heifers	120,000 Ksh
In calf cows	110,000 Ksh
Bull calves	5,000 Ksh
Breeding bulls	120,000 Ksh
Pregnant nanny goat	12,500 Ksh

(3) The system is grid connected, which was necessary as the installation included induction motors. However, a PPA (Power Purchase Agreement) has not yet been concluded. The initial tariff rate that KPLC offered (2007) was 2-3 USc/kWh, which was too low and was turned down by the company. At present, all the generated electricity is used for internal consumption. They are applying banking system (total energy generated in the company is deducted 7from total usage of electricity in the bill of KPLC) for electricity metering without PPA .

(4) PF (Power Factor) requirement for connection with KPLC is 0.9. The company has to pay penalties for phase-wise mismatching PF. As an example, where the PF was not matching to grid, the electricity consumption bill was 120,000 Ksh, and the additional penalty was 200,000 Ksh bringing the billing to 320,000 for the month. FIT (Feed-in-tariff) has been drafted and is awaiting approval and gazettement by government. It is hoped that this will be doneby the end of August 2012. The rate proposed by stakeholders is 12 USc/kWh.

(5) The average electricity tariff rate that the company paid to KPLC is: 10.9 Ksh/kWh in 2007, 16.2 Ksh/kWh in 2010, 23.71 Ksh/kWh in 2011, and 22.8 Ksh/kWh in 2012. 5.75 Ksh/kWh is the standard tariff (cost per Kwh exluding other billing charges such as RE) for their 3 phase category.

(6) Digester size: 750 m^3, on-ground fixed dome type. Hot water from the heat exchanger at engine is circulated to maintain the temperature of digester.

(7) Installed capacity: Engine is 150 kW (75 kW x 2 units), manufactured by Brook Crompton, 2003, three phase, PF=0.87. Actual output is 90 kW. The generator is inductive type, which needs power supply from grid.

(8) Installation cost was 3,500 US$ per kW of actual output, i.e., 315,000 US$.

(9) Generator: modified diesel (modification of combustion chamber, injection, and plug)

(10) Annual generation amount: 200,000 kWh/year; with capacity/plans to increase to 1,200,000 kWh/year if tariffs are suitable.

(11) Operation hours match the amount of gas available. The generators are operated for 36 hours continuously to exhaust available gas. A 12 hour rest period is then required for maximum gas build-up in the digester.

(12) 2 Litres per day of engine oil is consumed.

(13) Capacity of motor for Sisal cutting: 100 kW.

(14) 250 cows are bred in a cow shed. Cow dung is collected by a scraper with a tractor and transported through a ditch to collection basin. Feedstock is 4 ton per day (cow dung 40% and sisal waste 60%).

(15) For removing hydrogen sulfide, filter with sieve trap and sponge is applied. The sponge is cleaned with petrol every two weeks.

Action Items	Person Responsible

Sisal Material

Sisal Cutting

Sisal waste used for Biogas

Cow shed with 250 cows

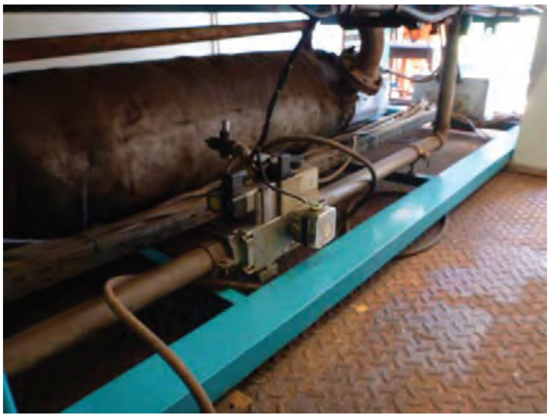
Cow shed, collection chamber, and biogas dome

Cow dung collection chamber and mixer

Biogas dome

Slurry outlet for fertilizer

Diesel generator 75 kW x 2



Desulfurizing Filter

Project for Establishment of Rural Electrification Model Using Renewable Energy

Sector: Biogas

Date: 4th December 2012

Organization: JICA Project Team and Chemamit Community

Meeting Called By	JICA Project Team
Type Of Meeting	Meeting to inform the community of the project status (cancellation)
List Of Attendees	1. Yuka Nakagawa- Project Team 2. Aisha Abdulaziz- Project Team 3. Community members including representatives of Kiletien secondary school and Siongiroi milk cooling facility
Agenda	1. Project Decision and Inclusion of Chemamit/Kiletien in REA's grid extension list. 2. Project Design 3. Community Feedback

SUMMARY OF DISCUSSION

Meeting with Chemamit Community

1. Project Decision and Inclusion of Chemamit/Kiletien in REA REMP

The project team informed the community of the decision to cancel the project due to REA/MoEn's targets to electrify secondary and primary schools by 2013 and 2015 respectively. The community was also informed that Kiletien secondary school and trading center had already been included in REA's grid extension list, and rural electrification projects in the area were expected to be implemented in the short term. The project team explained that taking this into consideration, JICA decided to cancel the biogas project, despite the continuous efforts by the project team to justify the project. The community was also made aware that the decision to cancel the project was because that various other off-grid renewable energy projects in the country were not in operation as a result of grid extension, which are regarded to have failed.

2. Project Design

The project team explained that the community could consider going ahead with the milk cooling business model once the village becomes electrified by grid. The community was informed of the extensive work that had been done and a synopsis of the planning report and socio-economic survey conducted was shared. It was noted that should the community decide to go ahead with developing the milk refrigeration business, the design and operations will be much simpler than indicated in the document. The project design document was handed over to the community, with the chief as custodian.

3. Community Feedback

The community was disappointed by the project's cancellation as a lot of work and discussion had been underway in preparation for project implementation. They however also appreciated the time and consideration of the team, the team's selection of Chemamit and the follow up meetings and surveys conducted. The community also noted in reference to the project design document the amount of work that had already been completed.

They requested for :

- Recommendation/consideration of Chemamit for other community development projects that may come up
- Assistance in procuring a milk cooler should the project team be in a position to communicate such a request to any development partners.

The project team also provided clarification on the fact that since the project had been cancelled, it would not be possible to provide any technical or financial assistance in regards to the proposed milk cooling business.

4. Conclusion from Community Meeting

The requests by the community were noted, and the project team commended them on their positive consideration and support during the project development phase. It was noted that the Chemamit community is remarkable and would be recommended should the team have any other opportunity.

The meeting was concluded by the project team presenting a small token of appreciation (solar lantern) to Chief. Phillip Kirui for his consistent support and mobilization of the community.

5. Meeting with Singiroi Milk Cooling Facility

The project team paid a courtesy call to Mr. Ferdinand Okinyi (Manager, Siongiroi milk cooling facility) to inform him of the project cancellation and community discussion. The facility was disappointed in the project cancellation due to the high level of interest in establishing an extension office for Chemamit dairy farmers.

The project team provided an overview of the project plans and highlighted information which may be useful for the cooling facility; specifically the financial analysis and dairy potential.

The project team communicated the community's interest in the milk cooling services despite the project's cancellation. Mr. Ferdinand stated that they have a plan to install satellite cooling facility.

The project team closed the meeting with a word of appreciation for the support and consideration extended by the members of the cooling facility and encouragement to continue its good work in extension of dairy services in rural Kenya.

Project for Establishment of Rural Electrification Model Using Renewable Energy

Sector: Biogas

Date: 29 October 2013

Organization: Biogas Plant in Kilifi Sisal Plantation

Type Of Meeting	Site Memo
List Of Attendees	1. Mr. John K. Mania, MoE&P 2. Mr. Edwin I. Nateminya, UNDP 3. Ms. Caroline Kelly, REA 4. Ms. Yuka Nakagawa, JET

SUMMARY OF DISCUSSION

(1) The flower farm has 24 ha for green house for rose cultivation and coffee plantation. The farm is owned by Eureka Holdings.

(2) The biogas plant started gas production in 21 April 2013. Design and implementation of two pilot biogas plants were conducted using flower waste as feedstock (another pilot plant is 100 kW by Insinya Roses with 400 m^3 digester). Cow dung seeding for anaerobic bacteria was conducted at the initial stage.

(3) The farm consumes electricity at 10,000-18,000 kWh/month in 2012. Tariff rate is 20.6 Ksh/kWh in average. Thus, 200,000-370,000 KSh/month was paid to Kenya Power.

(4) Flower leafs are the feed stock. The feedstock input is 300-400 kg/day. The material is homogeneously cut by a 7 kW shredder (About 2 kWh is consumed to process 300 kg feedstock).

(5) A 200 m^3 anaerobic digester with concrete base and plastic gas dome is installed. It has a 5.5 hp pump for mixing.

(6) Two 8 m^3 hydrolysis tanks are also installed for pre-treatment before anaerobic process. It has the same 5.5 hp pump for effluent transportation for each tank.

(7) The digester is covered by a shade to avoid rain.

(8) A 55 kW biogas engine generator is installed (1500 rpm, six-cylinder 5.88 L engine, ϕ =0.8) with a hydrogen sulfide removal unit and heat exchanger for digester heating.

(9) The project cost is 206,859 US$ (3,761 US$/kW). MoE&P invested 25% and while Eureka Holdings invested 75%.

(10) Hydrolysis tank has solar water heating system. Digester is equipped with hot water circulation system utilizing waste heat of biogas engine. Temperature of the hydrolysis tanks and the digester is monitored by thermocouples. The temperature of the digester was 27 °C

(11) Exhaust CO_2 gas from engine is introduced to greenhouses to enhance plant growth.

(12) Gas pipe from anaerobic digester is cooled down in a pool surrounding the digester to trap water content in the gas. This is a good device to trap water efficiently.

(13) The report says that 357 kg/day average feedstock input produces biogas of 600 m^3/month gas in June 2013. This means average gas production is 20 m^3/day and gas generation amount per weight of feedstock is 17.8 kg/m^3.

(14) According to the log book in the power plant, the output in October 2013 is as follows:
Average gas production: 16.6 m^3/day
Average electric energy production: 17.1 kWh/day
Average gas efficiency: 1.03 kWh/m^3.

Date	Time	Flow m3	Export kWh	Operation Time h:m	Gas Production	Energy kWh	Efficiency kWh/m3
1/10/13	11:40	2,195.4	1,903.0	0:55	5.75	21.4	3.72
	12:35	2,201.1	1,924.4				
4/10/13	11:30	2,208.6	1,926.3	1:30	7.81	33	4.23
	13:00	2,216.4	1,959.3				
(10/7, 10, 11, 15 operated)							
?/10/13	9:25	2,259.1	1,959.3	0:55	40.66	36.3	0.89
	10:20	2,299.8	1,995.6				
16/10/13	9:15	2,429.1	2,120.4	2:45	56.11	63.3	1.13
	12:00	2,485.2	2,183.7				
(2 days in operation, date not sure)							
21/10/13	10:04	2,527.7	2,225.7	1:46	33.15	37.4	1.13
	11:50	2,560.8	2,263.1				
23/10/13	10:10	2,560.8	2,263.9	1:50	46.28	54.9	1.19
	12:00	2,607.1	2,318.8				
28/10/13	8:50	2,560.8	2,314.2	2:20	99.48	66.8	0.67
	11:10	2,660.3	2,381.0				
Average		**16.60**	**17.07**				**1.03**

(15) Compared to the initial plan of 48.6 kW operation at 8 hours/day, the current production amount is considered to be small (48.6kW x 8h/d x PF0.4 /1.03kWh/m^3=151 m^3). Flower waste may require long retention time for digestion since it contains fibers which are difficult to decompose. Since the project is still at the initial stage at present, the circumstance in digester may still require a lead time for bacteria acclimation. Gas production may be increased in the later stage after the bacteria is optimized for decomposition of feedstock at optimum temperature.

Action Items	Person Responsible

Feedstock rose leaves and shredder.

Plastic gas dome and PVC pipe in a pool for gas cooling

Project for Establishment of Rural Electrification Model Using Renewable Energy
Sector: Biogas
Date: 31 October 2013
Organization: Univ. of Eastern Africa, Baraton

Type Of Meeting	Site Memo
List Of Attendees	1. Mr. Helekiah Moracha, Univ. of Eastern Africa, Baraton 2. Ms. Caroline Kelly, REA 3. Ms. Yuka Nakagawa, JET

SUMMARY OF DISCUSSION

(1) The university is planning to install biogas system for reduction of fuel wood and electricity usage. The university has the intention to utilize the biogas system as the model for surrounding community.

(2) Summary of information is as follows:

Confirmation Item	Unit	Description
Basic Information		
Date of site survey		31 Oct 2013
Name of the facility		Univ. of Eastern Africa, Baraton
Location (County, sublocation, location, village)		Eldoret
Coordinate (Latitude, longitude, elevation)		N00.25563°, E035.08368°
Distance from Nairobi		about 350 km
Grid connected?, Nearest grid connection in km		Grid connected
Financed by		Church
Contact address and number		Mr. Helekiah Moracha, Auxiliary Enterprises Manage, ohmoracha@yahoo.com Cell: +254-722 742375
Possible feedstock input		
Nos of cows	nos	25 nos x 4 cow shed = 100 nos 70 cows grazed
Nos of pigs or nos of pultry	nos	-
Nos of students (total)	nos	1000
Nos of students (boarding)	nos	1000
Nos of teacher and staff	nos	400
Nos of teacher (living)	nos	
Type of toilet		Flush, connected to sedimentation pond
Raw waste material (food, vegetable waste, etc)		kitchen waste
Garden or caltivation near the site		Potetoes, sukuma, tomato, etc.
Current energy usage		
Electricity usage	kWh/mon	2 million KSh/mo (if 20 KSh/kWh, 100,000 kWh/month is consumed)
Electricity tariff payment record (invoice for several months)	Ksh/mon	need to confirm bill
Current use of electric/heat appliance (type, hours) Light, PC, mobile charge, TV, radio, cooking heater, other		Most of appriances in urban area used.
Type of fuel for cooking (Fuel wood, LPG, etc)		Fuel wood and LPG
Current usage of fuel wood, cost	kg/day, t/mon	2-3 trailers/month (about 3 tons/trailer)
Current usage of LPG, cost	cylinder/mon	50 kg tank installed. Purchased at 6000 KSh/60kg. Amount needs to be confirmed.

(3) The school has 1000 students and 40 faculty members. In total, human waste for 1,400 persons are connected to sedimentation ponds for purification. The distance from buildings and sedimentation pond is about 1.5 km.

(4)	It is considered that human waste in this school is not preferable to biogas digester since (i) the toilets in the school is urban type and utilize too much water, and (ii) distance from sedimentation pond is too far a way to demand center and it needs long piping and distribution lines.
(5)	School cafeteria is supplied by LPG with 50 kg fuel tank. LPG is purchased at 6000 KSh per 60 kg. The amount of LPG usage needs to be confirmed in energy audit of the school. Cooking fuel supply to the cafeteria is the priority for biogas use. The cafeteria is located about 1km from cow shed.
(6)	There are teacher's quarter buildings about 300-400m from cow shed.
(7)	The school has four number of cow sheds. Each has 50 nos of cows. In total, 200 cows are zero-grazed. This can be considered as the source of cow dung feedstock. It needs floor cement placement and construction of ditch for collection of cow dung to the digester. In addition, there are 70 grazed cows but this is not considered as feedstock source since collection of cow dung is necessary.
(8)	Milk is processed at plant to pasteurize milk and fuelwood is consumed about 4-6 tons/month for the boiler in the plant.
(9)	The available budget of the school is 600,000 KSh only. This will cover only one digester, and not sufficient for whole system. It will require additional finance source for whole system.
(10)	It is not much recommended to install generator due to budget limitation and low economic feasibility electricity compared to replacement of fuel wood.
(11)	The most feasible system is considered as follows: - 4 nos of 50 m^3 digesters for each cow shed (or 2 nos of 100 m^3 digesters for two cow sheds respectively with connecting trench construction) - 2.4 ton/day cow dung will be available as feedstock, then 72 m^3/day gas production and 12.5 ton/month fuel wood saving is expected. - Boiler in milk processing plant near cow shed is the best demand in terms of distance and cost. Short pipe connection is necessary. - It is proposed about 40-50% of the gas is consumed in milk processing plant, and remaining gas is consumed in teacher's quarter if 4 x 50 m^3 (or 2 x 100m^3) digester is constructed. Connection with school cafeteria needs consideration for pressure drop and cost in terms of long distance. - It is recommended to construct 1 or 2 nos of 50 m^3 digester and connect with milk processing plant at the first stage, monitor the feasibility, and then, determine to whether expand the system with another digester and piping to other demand or not.

Action Items	Person Responsible
- Mr. Moracha will send energy audit report, electricity bill, amount of LPG consumption, and price of fuel wood to REA	

Cow shed, need floor cement placement

Sedimentation pond