Life Cycle Thinking Assessment Applied to Three Biogas Projects in Central Uganda

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This report "Life Cycle Thinking Assessment Applied to Three Biogas Projects in Central Uganda" is hereby approved in partial fulfillment of the requirements for the Degree of MASTER OF SCIENCE IN ENVIRONMENTAL ENGINEERING.

Civil and Environmental Engineering

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Preface

This research was completed during my time in Uganda serving as a Peace Corps Volunteer from August 2007 to October 2009. I was a general health (water and sanitation) volunteer placed in the central region of Uganda with a local Community Based Organization (CBO), Kyetume Community Based Health Care Program. I worked on a variety of projects including; health clubs at secondary schools, water and sanitation education at primary schools, fuel efficient stoves, income generating activities for a women's group, keyhole gardens for food security, and a water system supplying water to the resource center and health center of the community and protected springs.

This report is submitted to complete the requirements for my master's degree in Environmental Engineering from the Master's International Program in Civil and Environmental Engineering from Michigan Technological University (MTU). This paper applies the Life Cycle Matrix Methodology developed by Jennifer McConville for her master's degree in Environmental Engineering from MTU. The three case studies used for this report are not a part of my general work mentioned above but, came to my attention through other Peace Corps volunteers and Ugandan friends I had met.

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Acknowledgements

I would like to take this opportunity to first thank my family and friends, who have done a wonderful job supporting me during these past two years. Through their emails and calls they have helped me adjust and gave me the opportunity to completely enjoy my time in Uganda.

James Mihelcic’s excitement for this research gave me the confidence that I would be able to compile enough information for this report and that it would be information worth sharing. The help from him and the rest my committee, Blair Orr and Kurt Patterson, has been amazing as I finished the report. All this while I was adjusting back to life in America.

The community of Kyetume and the Kyetume Community Based Health Care Programme welcomed me with open hearts and arms. Without their support and friendship this report and my Peace Corps service would not have been possible. They enabled me to work within the community for my Peace Corps service but also supported me while I did my additional research for this report.

Mwebale obuyambi bwe mwampa. Njakubajukiranga emirembe nemirembe.

Abstract

This report applies the life cycle thinking assessment to three biogas projects in central Uganda. Previously the life cycle thinking assessment has been applied only to a rainwater harvesting project and a small drip irrigation project by evaluation after the completion of the projects. For these case studies the assessment was done after completion of the project but the case studies are compared using the life cycle thinking assessment to help determine best practice methods for future biogas projects in Uganda.

The three biogas projects are Jim's Education Center (case study 1), Katosi (case study 2), and James Mugerwa (case study 3). The case studies are of the same fixed dome design but vary in the community set up as well as the source of the material to be used in the digester. Only one of the three case studies is currently in operation. The overall scores for Jim's Education Center, Katosi and James Mugerwa biogas projects are 61/100, 20/100 and 67/100 respectively. These scores indicate how well a project did in the different sustainability factors as well as the five different life stages.

Conclusions include recommendations for future biogas projects such as; making sure the community has a manual to provide a guide as how to operate and maintain the system. It was also observed that the life cycle assessment tool can also be made more specialized, having a different matrix for water projects and sanitation projects.

1.0 Introduction and Objective

2.4 billion people have no access to any form of improved sanitation (United Nations, 2005). Funding and projects keep on increasing to meet this demand, but not every project succeeds. There are many factors that can cause a sanitation project to fail and currently it is estimated that about 50% of water and sanitation projects assessed by the World Bank in the developing world are not sustainable (World Bank, 2003).

By looking at all the life stages of a project a development worker is able to identify problem areas before the project is complete. For example, in many communities a sanitation system is never cleaned, opened or repaired. Many issues cause these problems; for example, no sense of ownership of the project by the community, lack of knowledge by the community, lack of funds, and no plan for operation.

To determine best practice methods in the developed world an existing assessment tool that uses a life cycle thinking approach is the Streamlined Life Cycle Assessment (LCA). It provides users the ability to measure the environmental impact a product or service has during each stage of its life. The assessment tool allows the individual to compile the environmental impact associated with raw material acquisition, the manufacturing process, transportation and packaging, the use phase, and end of life disposal of a product or service. For example, the environmental stressors to collect and process raw materials are taken into consideration based on the percentage of the raw material that shows up in the final product. This concept could not be directly applied to development projects because the required detailed information on how products and materials are produced in developing countries has not been collected. Also, development projects have some different factors such as community participation and appropriate technology that are not considered for industrial processes in the developed world.

To adopt the LCA to conditions in developing countries, a life cycle assessment tool that is similar in principle to a Streamlined LCA was developed by Jennifer McConville (McConville, 2006) from her experience as a Peace Corps Volunteer. This matrix takes into account five sustainability factors: (1) socio cultural respect, (2) community participation, (3) political cohesion, (4) economic sustainability and (5) environmental sustainability. These sustainability factors are considered in each life stage of the project. The five life stages of a development project are: (1) needs assessment, (2) conceptual designs and feasibility, (3) design and action planning, (4) implementation and (5) operation and maintenance. The life cycle matrix provides a tool for development workers to approach a project in a different way, looking at the sustainability of each life stage.

This report applies this method to three different biogas projects located in the central region of Uganda. Each case study was scored based on interviews and information gathered during site visits. By applying this method to a group of similar projects, in this case three biogas case studies, similarities about biogas projects can been seen, as well as lessons learned for future biogas projects in Uganda. Preliminary results have been published in Ocwieja, S.M. & J.R. Mihelcic, (2009). Life Cycle Approach for Evaluating Sanitation Projects- Case Study: Biogas Latrine. *Proceedings of 34th WEDC International Conference, Water, Sanitation and Hygiene: Sustainable Development and Multisectoral Approaches*, Addis Ababa, Ethiopia, May 18-22.

1.1 Introduction to Biogas Projects in Africa

Biogas projects are on the rise through out the world. They provide a method to produce methane used for cooking and lighting from the waste of animals and humans. In countries such as Nepal there is a large push to increase the number of biogas plants in the country. These projects usually use cow manure to produce the gas, but by making a small adjustment, a household latrine can be connected to a digester increasing gas production and providing an easy way to manage the human waste.

In 2002, there were 2.6 billion people in the world without access to basic sanitation facilities. In Sub-Saharan Africa only 36% of the population is served with improved sanitation facilities, and only 58% are served with a safe and clean water supply

(WHO/UNICEF, 2005). Biogas projects can help meet the sanitation needs of many of the world's poor. They can also help meet many of the United Nation's Millennium Goals (MDGs). The first goal of the MDGs is to eradicate extreme poverty and hunger. By using the slurry (the digested waste) that is produced from the biogas systems a community can fertilize its crops and also improve the composition of its soil. Goal Three of the MDGs is to promote gender equality and empower women. Most families count on firewood to cook their meals; it is the women and the girl child that assume the burden of cooking and gathering firewood. By using biogas women and the girl child would have more time for other activities such as attending school (related to Goal Two: Achieve universal primary education), income generating activities and more social time. Also, the exposure to smoke produced from the cooking fire would be reduced, improving the health of women and children (related to Goal Four: Reduce child mortality). In addition, Goal Seven of the MDGs, ensuring environmental sustainability is assisted by biogas technology by providing sanitation for both urban and rural communities, reducing deforestation, and reducing the amount of CO_2 released into the atmosphere (United Nations, 2005).

Table 1 shows that as of 1993 the number of biogas plants in Africa was small with only a few countries making an effort to increase access to biogas technology. There is a new African initiative to increase the number of biogas plants that was launched in 2007. The goal of this initiative is to provide 2 million households by 2020 with biogas digesters (Ukpabi, 2008). However, the number of biogas plants currently in Africa is unknown with most units installed in Tanzania (around 4,000).

It has also been estimated that only 60% of these plants have remained in operation (van Nes, & Nhete, 2007). The reasons for failure or unsatisfactory performance of these biogas systems can often be found in the mistakes made during the planning stages (GTZ, 2009). Other reasons for failures include lack of interest and understanding by the community, construction faults, insufficient maintenance on the system, misconception of benefits of the system, lack of training new owners on the system, and budgeting errors.

Country	Number of small/medium digesters (100 m^3)	Number of large digesters (>100 m^3)	Region
Botswana	Several	1	Southern Africa
Burkina Faso	>20	–	West Africa
Burundi	>136	–	East Africa
Egypt	Several	>1	North Africa
Ethiopia	Several	–	East Africa
Ghana	Several	–	West Africa
Cote D'Ivoire	Several	1	West Africa
Kenya	>140	–	East Africa
Lesotho	Few	–	Southern Africa
Malawi	–	1	Southern Africa
Morocco	Several	–	North Africa
Rwanda	Several	–	East Africa
Senegal	Several	–	West Africa
Sudan	Several	–	North Africa
South Africa	Several	Several	Southern Africa
Swaziland	Several	–	Southern Africa
Tanzania	>600	–	East Africa
Tunisia	>40	–	North Africa
Uganda	Few	–	East Africa
Zimbabwe	>100	–	Southern Africa

Table 1: Countries with biogas producing plants in Africa as of 1993
Source: (Akinbami et al, 2001)

A biogas plant or latrine when successful is an appropriate and sustainable method to deal with human or animal waste. This system produces two extremely useful products from the waste: biogas and slurry. Using biogas for cooking and lighting reduces the strain on the environment by decreasing the use of biomass and the production of green house gases (as methane that is produced normally from manure is now captured and used). The biogas system also provides a barrier protecting ground water from contamination from untreated waste.

The three biogas projects that will be examined in this study are all located in the central region of Uganda (location shown by the arrow in Figure 1). Uganda is a land-locked country in East Africa, with an area slightly smaller than Oregon. The population is 32,369,558, with only 13% living in urban areas. The central region has a tropical climate which is generally rainy with two dry seasons, usually from December to February and June to August (but these dry seasons are no longer consistent).

Approximately 82% of the labor force is employed in the agriculture services. Some of the current environmental issues include draining wetlands for agricultural use, deforestation, overgrazing, soil erosion, water hyacinth infestation of Lake Victoria and widespread poaching (Central Intelligence Agency, 2009).

Figure 1: Map of Uganda
(Source: Central Intelligence Agency, 2009)

1.2 Objectives

The objective of this research is to apply life cycle thinking assessment to three biogas projects located in Uganda. Using this assessment tool to evaluate this project should provide information to improve future biogas projects, especially in this region. Failed projects create a stigma about existing biogas projects and prevent other beneficiaries from wanting to become involved despite the many advantages. It is hoped that by applying the life cycle thinking assessment to a wide range of sanitation projects in different regions of the world such as in this research, different insights about best practices for implementation can then be developed.

1.3 Energy in Uganda

Uganda has many different energy sources including hydro, geothermal, biomass, wind, solar and fossil fuels. As of 2002, the total annual energy consumption was estimated to be provided by 20 million tons of wood, 430,000 tons of oil products, a hydropower capacity of 300 MW and 3 MW of thermal power. The reported annual population growth rate is 3.7% but the annual growth in energy is 7-8% (Walekhwa et al, 2009). Figure 2 provides a more detailed breakdown of the energy consumption of Uganda.

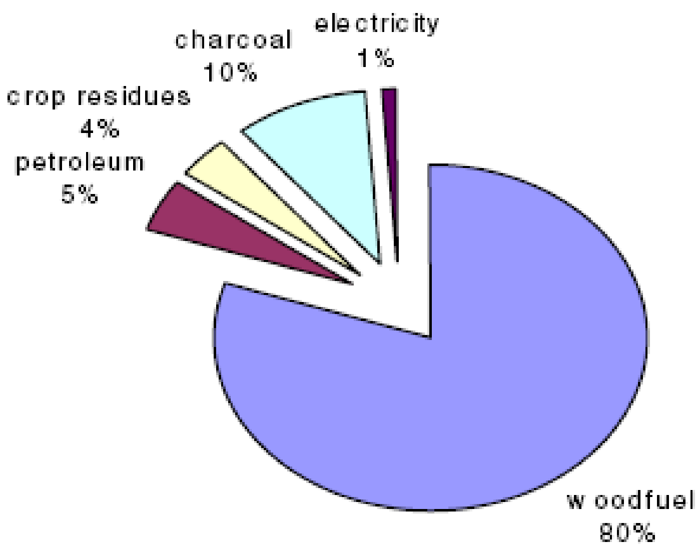


Figure 2: Uganda's energy consumption in 2000
(Source: Energy Sector Profile, 2000)

1.4 Biogas Projects in Uganda

By talking with Christopher Kato (a biogas engineer) the author was able to learn the current status of biogas projects in Uganda (from his point of view). Biogas projects were introduced in Uganda in the early 1950's by the Christian Missionary Society. From 1980 to 1985 under the African Energy Program, the Common Wealth Science Council constructed demonstration plants and fuel efficient stoves. In 1985 the first Chinese design (fixed dome) plant was constructed and was successful (Mr. Kato had worked on this project). This plant was one of seven constructed in the Eastern Region. Other studies and projects mentioned by Mr. Kato included a capacity building project in Mitiana (8 fixed dome plants) that was constructed in 2005 by Makerere University and a feasibility study performed by Winrock International in 2007 (Kato, 2009).

Approximately 84% of energy used in Uganda is biomass fuel, with 94% at the household level. The household biogas plants typically use only agricultural waste and the biogas plants built at institutions (e.g., schools, health centers) have used a latrine design. Usually the gas that is produced is used for cooking stoves and lighting; however, in some cases the gas is now used to generate electricity and some plants are trying to package the gas for commercial use. Some of the problems include high up front cost, no renewable energy policy in Uganda and lack of research and development in Uganda (Kato, 2009).

The most common type of biogas system seen in Africa is the design modified by the Centre for Agricultural Mechanisation and Rural Technology (CAMERATEC), Tanzania. It is estimated that around 600 family-sized biogas digesters have been installed in Uganda (Walekhwa et al, 2009).

According to a study on adaptation of biogas plants in Uganda; the following nine factors were investigated to see their impact on the adoption of biogas technology;

1. age of household head
2. formal education of household head
3. household size
4. number of cattle owned
5. costs of fuel wood and kerosene
6. area of land owned
7. gender of household head
8. location of the household
9. income of household

Increasing household income, number of cattle, fuel wood costs and kerosene costs were found to have a positive correlation to the adoption of biogas technology. In contrast, increasing age of household head, household size, location of household and formal education had a negative correlation (Walekhwa et al, 2009).

Most biogas systems that are built in Uganda use cow manure as the main source of substrate for the system. This could be expanded to include manure from pigs, chickens, and goats, crop residue and human waste. Since so many families use wood as their source of cooking fuel and kerosene as the source of lighting, a dramatic impact on health and environment could be made by a large increase in adoption of biogas technology. This would reduce the health risks associated with exposure to smoke for women and children and would reduce the need for wood resources used for firewood and charcoal supplies.

2.0 Biogas Systems

A biogas plant converts biodegradable waste to a useable gas under anaerobic conditions. This gas consists mainly of methane and carbon dioxide. Material is added to the digester where under anaerobic conditions bacteria convert the material to two products, biogas and slurry. The system consists of a digester, which provides an area for the material to be digested by bacteria in an environment devoid of oxygen. Material is added to the system via an inlet tube and the digested material is then removed from a separate opening.

"Domestically, biogas can be used for cooking, lighting, heating water, running refrigerators, water pumps and electric generators. Agriculturally, it can be used on farms for drying crops, pumping water for irrigation and other purposes. In industry, it can be used in small-scale industrial operations for direct heating applications such as scalding tanks, drying rooms and in the running of internal combustion engines for shaft power needs" (Akinbami et al, 2001). The slurry is used as a fertilizer and soil composition improver. By treating the material in such a way it not only reduces the pollution of the surrounding area by animal waste but also reduces the need for chemical fertilizers. "Biogas is a service that is broader than just energy supply and a latrine. It uplifts the dignity of women and improves the health and hygienic conditions of families" (van Nes, & Nhete, 2007). The women are uplifted because their time can be better used for income generating activities, education, and managing the household instead of spending hours collecting firewood.

2.1 Anaerobic Process

An anaerobic process occurs in an environment that lacks oxygen; the organic material (such as carbohydrates, lipids and proteins but not lignins and other hydrocarbons) is broken down in three stages: hydrolysis, acidification and methanization. Hydrolysis is the rate limiting step; it turns the insoluble materials into liquids. Hydrolysis is followed by acidification where the now soluble organic matter is converted into carbon dioxide and short chain organic acids. The final step is methanization, where methane is produced by methanogens. The final gaseous product is composed of 55-75% methane, 25-45% carbon dioxide, and trace amounts of hydrogen sulfide, nitrogen, hydrogen, carbon monoxide, water vapor and oxygen gases (Igoni, 2007, Burke, 2001, Miron, 2000, FAO, 1996).

There are three main designs of biogas projects that are used in the developing world; Fixed Dome, Floating Drum and Tubular. Each design will be described in more detail below. Table 2 provides information on issues that arise for the three biogas systems. Some of the issues are advantages for one system while a disadvantage for another.

Table 2: Issues arising for the three different biogas systems

		Biogas System	
	Fixed Dome	**Floating Drum**	**Tubular**
Issues			
Materials	Easily accessible in Uganda, no moving or rusting parts	A quality drum may be hard to obtain and this can lead to increased cost	Easily accessible and low cost, some materials can also be scavenged from the biogas plant after lifespan is over.
Construction	Type of masonry work required is difficult and requires special sealants and skilled laborers, need exact planning of levels and excavation in rock can be difficult	Since the digester can be of masonry work or steel or reinforced plastic, the amount of skilled labor depends on the material used	Two day construction, with a lot of the work completed by the household
Simplicity	Plant operation not easily understandable by household	Because the household can visually see the gas pressure rise and fall the operation is easier to understand	Because the household can visually see inside the digester and gas storage container the operation is easier to understand, a household can also make their own repairs
Gas Pressure	Pressure is not maintained, and leaks are common	Constant gas pressure	Pressure can be regulated by adding weights to the polyethylene storage container
Maintenance	Daily stirring of the system, managing inflow and outflow, complicated maintenance if a gas leak presents itself	Regular removal of rust and paint from the drum, managing inflow and outflow of system	Repairs can be done by the household, managing inflow and outflow of system
Damage Possibilities	A scum layer can build up reducing gas pressure, but system is protected as it is built underground	Drum will rust, drum can become misaligned.	Can be damaged by sun, animals, debris and people.
Cost (approximate)	For a 16 cubic meter plant costs in Uganda range from 4,500 to 6,000 USD	For a 16 cubic meter plant the approximate cost in Uganda is 5,000 to 6,500 USD	For a small household plant costs in Uganda range from 350 to 500 USD

2.2 Fixed Dome Design

Figure 3 shows the basic diagram of a fixed dome plant with labels indicating the following parts: 1) Mixing tank with inlet pipe and sand trap. 2) Digester. 3) Compensation and removal tank. 4) Gasholder. 5) Gas pipe. 6) Entry hatch, with gastight seal. 7) Accumulation of thick sludge. 8) Outlet pipe. 9) Reference level. 10) Supernatant scum, broken up by varying level.

The construction cost of a fixed dome plant is relatively low. However, the costs are almost double in Africa compared to Asia due to cost of materials and transportation. The fixed dome is a simple design with no moving parts creating a long life of the plant (upwards of 20 years). The digester is usually masonry construction underground to protect it from physical damage and saving space. The construction of these plants is labor-intensive, creating local employment but should only be built where construction can be supervised by experienced biogas technicians. If construction is poor the digester may not be gas-tight or water proof. The waste enters from the mixing area or latrine house into the material in the digester, as the gas is produced the gas pressure builds up in the dome pushing the material into the expansion chamber where it can be removed. Stirring of the system occurs through the pipe that allows the slurry to exit. The importance of stirring is to limit the formation of a scum layer on top of the slurry that reduces the production of gas (GTZ, 2009).

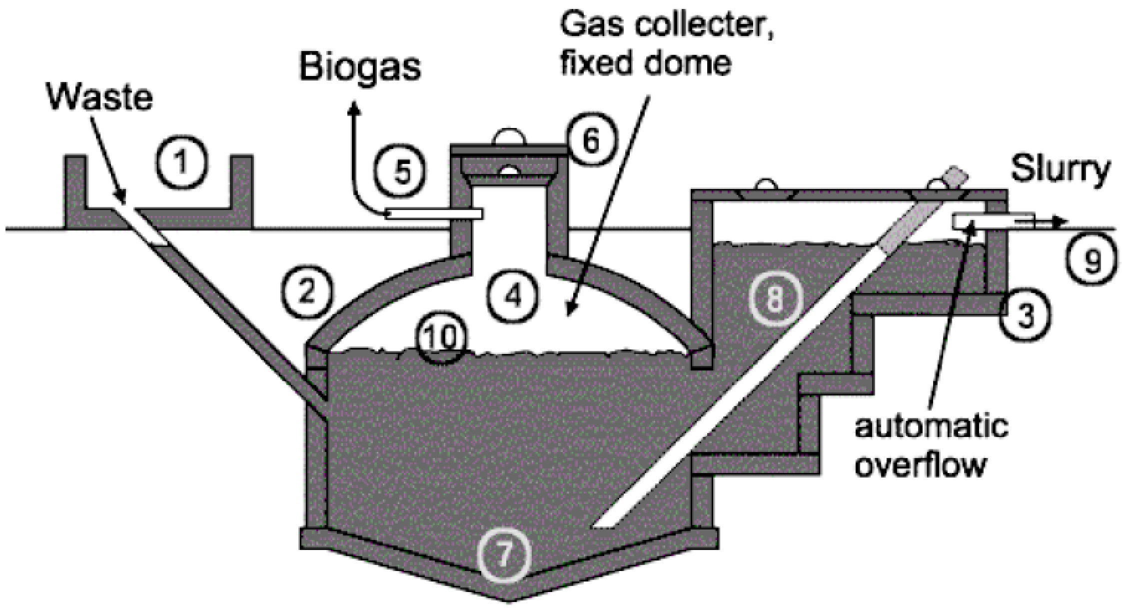


Figure 3: Fixed dome biogas plant (Nicarao design)
(Source: GTZ, 2009)

2.3 Floating Drum Design

Figure 4 shows a plant with a water jacket with labels indicating the following: 1) Mixing area 2) Digester. 3) Gas-holder. 4) Slurry store 5) Gas pipe. And 11) Fill pipe (GTZ, 2009).

A floating-drum plant consists of a cylindrical or dome-shaped digester with a moving or floating gas-holder or drum located on top. The drum can float directly in the slurry or be located in a separate water jacket. This drum collects the gas for storage and moves up as gas is produced and down as gas is used; this provides a more regulated gas pressure. The digester can by of masonry work, steel or reinforced plastic. A guided frame is used to provide support for the gas-holder, but the floating drum must not touch the outer walls or tilt, because it can then be damaged or get stuck.

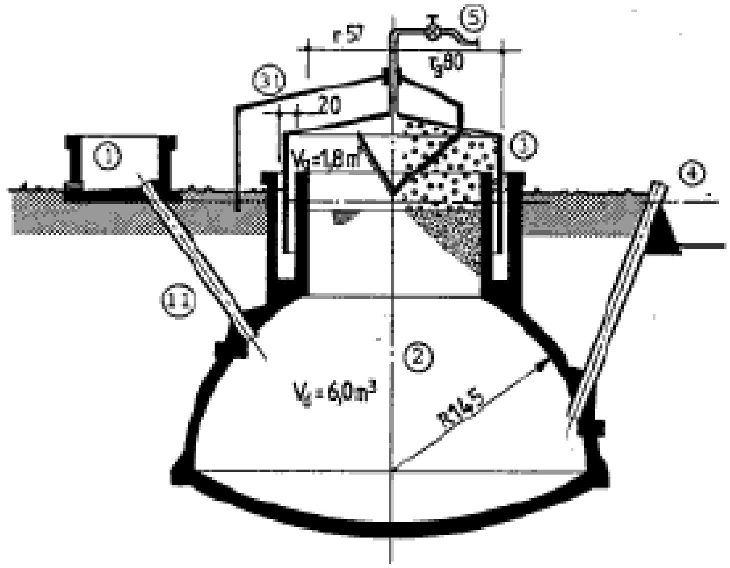


Figure 4: Floating drum biogas system with a water-jacket and external guide frame
(Source: GTZ, 2009)

2.4 Tubular Design

A tubular system usually consists of two large polyethylene bags and is commonly used on the household level for small-scale dairy farmers. As shown in Figure 5, one bag acts as a digester, which lies in a trench to provide protection. Some type of structure should be built above this digester to protect it from UV rays, falling debris, children and animals. The other bag provides storage for the gas before its use. The system is easily constructed and maintained, with a lifespan of about 3 years.

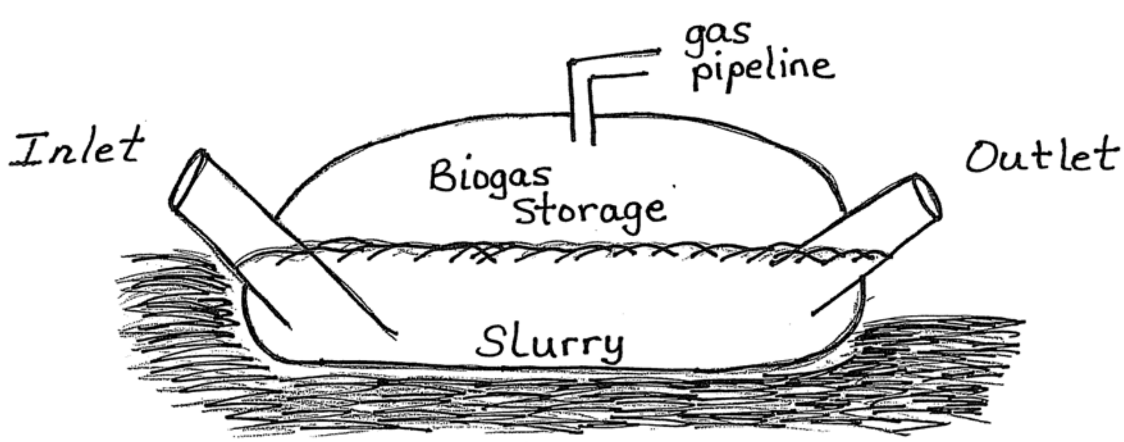


Figure 5: Diagram of tubular system

3.0 Methods

3.1 Introduction of Life Cycle Matrix Methodology

The life cycle assessment matrix used in this study (McConville, 2006; McConville & Mihelcic, 2007) provides a tool for development workers to approach a project in a different way, looking at the sustainability of the project over each life stage. Currently it is difficult for a development worker to identify the problem areas in a project and a complete evaluation of a project. Some organizations or individuals tend to concentrate on one of the life stages or to encourage community participation to ensure sustainability, but while doing this many other stages and factors are neglected. For example, in many communities a sanitation system is never cleaned, opened or repaired. Many issues cause these problems such as: no sense of ownership of the project by the community, lack of knowledge by the community, lack of funds, and no operation plan. There have been different methods developed to increase the sustainability of a project, but few try to address all of these issues at once.

A less resource intensive method to apply a life cycle thinking approach to assess a problem is the Life Cycle Assessment (LCA) tool; it provides engineers and companies a method to measure the impact a product or service has on the environment during each stage of its life from "cradle to grave". In this process, the individual would compile the raw materials, process, and end of life issues of a product or service, taking into account the environmental impact of each life stage. For example, the requirements to collect and process the raw materials used in a product are taken into consideration based on the percentage of the raw material that shows up in the final product. "By including the impacts throughout the product life cycle, LCA provide a comprehensive view of the environmental aspects of a product or process and a more accurate picture of the true trade-offs in product and process selection" (SAIC, 2006). This process is time consuming and costly, making it necessary to define the goals and the scope of the assessment.

The concept of LCA as it is currently being used in the developed world could not be directly applied to development projects due to costs, goals and scope of the current tools. Accordingly, a life cycle assessment tool that could be applied to water and sanitation projects in a developing world setting was developed by McConville (McConville 2006, McConville & Mihelcic, 2007) from her experience as a Peace Corps Volunteer in Mali.

In the method developed by McConville, instead of the traditional three pillars of sustainability, economy, environment, society, this matrix takes into account five sustainability factors: (1) socio cultural respect, (2) community participation, (3) political cohesion, (4) economic sustainability and (5) environmental sustainability. These factors are discussed in more detail in Table 3.

The five sustainability factors are assessed in each of the life stages of the project. The five life stages are: (1) needs assessment, (2) conceptual designs and feasibility, (3) design and action planning, (4) implementation and (5) operation and maintenance. In Figure 6 the solid arrows indicate the flow of the life cycle process. The dotted arrow indicates the potential for iteration between stages 2 and 3 (McConville & Mihelcic, 2007). Table 4 shows the actual matrix with the five life stages of a water/sanitation project listed in the left column and the five sustainability factors listed across the top.

Table 3: Five factors identified in the study of sustainable development of water and sanitation projects

Social Sustainability	Socio-Cultural Respect	A socially acceptable project is built on an understanding of local traditions and core values.
	Community Participation	A process which fosters empowerment and ownership in community members through direct participation in development decision-making affecting the community.
	Political Cohesion	Involves increasing the alignment of development projects with host country priorities and coordinating aid efforts at all levels (local, national, and international) to increase ownership and efficient delivery of services.
Economic Sustainability		Implies that sufficient local resources and capacity exist to continue the project in the absence of outside resources.
Environmental Sustainability		Implies that non-renewable and other natural resources are not depleted nor destroyed for short-term improvements.

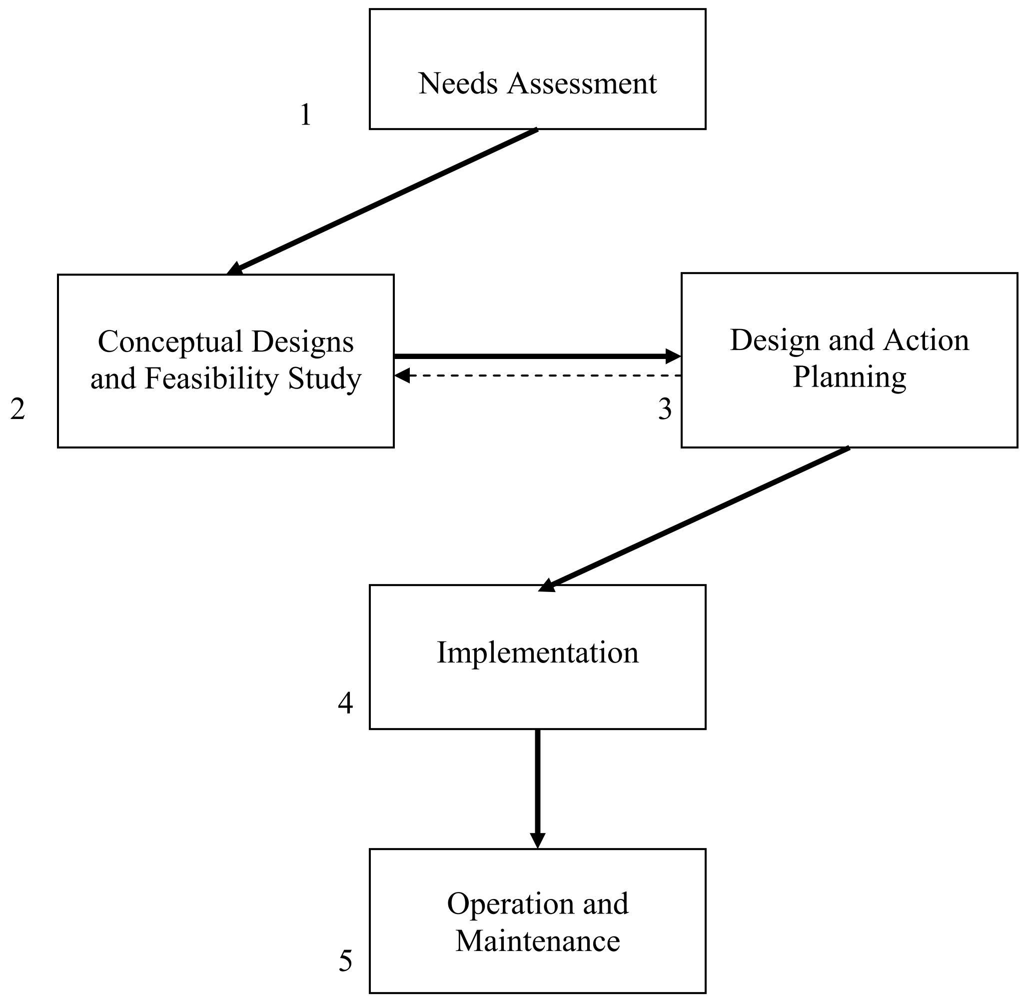


Figure 6: Flow chart of the five life cycle stages of water and sanitation development projects located in the developing world.

Table 4: Sustainability assessment matrix

	Sustainability Factor					
Life Stage	Socio-cultural Respect	Community Participation	Political Cohesion	Economic Sustainability	Environmental Sustainability	Total
Needs Assessment	1,1	1,2	1,3	1,4	1,5	20
Conceptual Designs and Feasibility	2,1	2,2	2,3	2,4	2,5	20
Design and Action Planning	3,1	3,2	3,3	3,4	3,5	20
Implementation	4,1	4,2	4,3	4,4	4,5	20
Operation and Maintenance	5,1	5,2	5,3	5,4	5,5	20
Total	20	20	20	20	20	100

3.2 Application of Life Cycle Matrix

One goal of this report is to gain more knowledge of the life cycle matrix by applying it to a new project area, new geographic location, and in a new capacity. To date, the life cycle thinking approach has been applied to two projects in Mali (McConville, 2006) and a small scale drip irrigation system in Benin (Castro, 2009). In the Mali projects, a top-well repair and wash area were constructed to protect a traditional well and provide an area for clothes to be washed near the well and reduce contamination from runoff and animal waste. The other project was the construction of a rainwater harvesting pond to collect and provide water for animals and small gardens during the dry season. In these cases the matrix was used to evaluate the projects after completion, here it is being used to compare three case studies after completion.

For this report the author applies this matrix on a different technology, in a new location and in a different context. The biogas systems would be classified as sanitation projects, as the first two projects in Mali that used this matrix would be classified as water projects. The location of these case studies is in East Africa while previous case studies had been located in West Africa. The previous case studies used this matrix as an evaluation tool after construction was completed, here we will use this matrix as a way to compare three different projects in hopes to determine best practice methods for biogas projects in Uganda and demonstrate a new way to use the life cycle matrix.

By using easy to evaluate questions and considerations developed by McConville, one is able to score each element of the matrix (from 0 to 4); this gives the overall project a possible score of 100 (as shown in Table 4). Each box of the matrix is given a value, giving the overall project a score. Answering the questions and evaluating each element provides a systematic way to explore the project's different life stages which is just as important as the score that is obtained at the end. A full set of the assessment questions used to develop the matrix can be found in Jennifer McConville's report (McConville, 2006).

If none of the recommendations are met then the element is provided a score of 0, while if all recommendations are met the element will have a score of 4. For example, looking at Element 1, 1 in Table 4, the recommendations are to; (1) generate a yearly calendar of work and social life in the community, (2) identify social preferences and traditional beliefs associated with water supply and sanitation practices, (3) determine the level of health education in the community, and (4) recognize differences in gender roles in water and sanitation. To provide an idea of how involved the process is, to address these four recommendations, (please refer to 8.1 Scoring for Element 1,1 on page 54) questions/issues need to be addressed. For Element 5, 5 the recommendations are to; (1) minimize, treat, and dispose of waste properly, (2) explore alternate plans for reducing the use of consumables, (3) monitor and evaluate environmental impacts, and (4) continue environmental and hygiene education efforts (McConville, 2006).

When applying this method the different life stages can not be planned separately; considering a project is a continuous process with each life stage interacting with the other. One sustainability factor can not be put above another; an environmentally sustainable project may not always be an economically sustainable project.

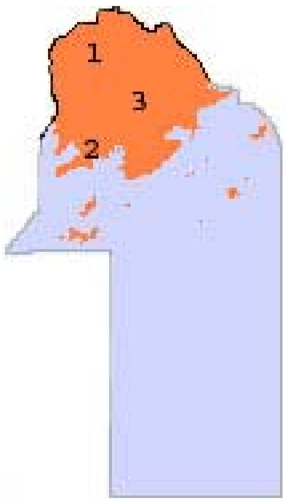
4.0 Case Studies used for this Research

The information gathered for the following three case studies was conducted over a year and a half while the author was a Peace Corps volunteer serving in Uganda. The information was collected mostly from informal interviews with stakeholders of the project and site visits. Some information is lacking due to information lost over the years, or the inability to attain certain information from stakeholders. Due to lack of easy access to a computer at all times the information was compiled in written notes. These notes were then summarized into descriptions of the case studies (which provided the starting point for the following case studies). The copies of the notes can be obtained by a request to the author.

The three projects for the case studies were chosen for this research because they are located close to where the author was placed as a Peace Corps Volunteer. Two of the cases studies (Jim's Education Center, and Katosi) were developed because fellow Peace Corps Volunteers were located at those sites, giving the author an introduction into the community. The third case study (James Mugerwa) was introduced to the author by the water and sanitation officer for the district. All three projects are located within 30 km of the author's site. These three case studies also give a representation of the biogas projects that are being implemented in Uganda. The government has been building biogas projects at schools, prison and large farms, which would be represented by the biogas project at the boarding school (Jim's Education Center). Smaller biogas projects are being implemented by NGO's for small scale farmers, which is represented by the project built at the household of James Mugerwa. The Katosi project was constructed for the community and to be used as a public latrine, this type is not common in Uganda but is used in Kenya and India to provide public sanitation.

Lessons are learned from each individual case study, but by comparing all three together best practice methods can be developed for future biogas projects.

Figure 7 indicates the different location of the three case studies in Mukono District. Table 5 lists some of the basic information about the case studies so they can be easily referred to during the comparison of the scores that will take place.



1: Jim's Education Center
2: Katosi
3: James Mugerwa

Figure 7: Location of three case studies assessed in this research
(Source: Wikimedia, 2005)

Table 5: Brief comparison of case studies

Case Study	Jim's Education Center	Katosi	James Mugerwa
Community	Boarding School	Village	Household
Design	Fixed dome biogas latrine	Fixed dome biogas latrine	Fixed dome biogas project
Material Source	Children and teachers	Villagers	Dairy cows
Size of system	18 m^3	40 m^3	18 m^3
Funding source	Friends of PCV	Outside NGO and District	District and household
Intended gas usage	Lighting and Cooking	Lighting	Cooking and Lighting
Fuel to be replaced	Electricity and firewood	Electricity	Firewood/charcoal and electricity
Year of construction	2006	1997	2003

4.1 Case Study 1: Jim’s Education Center

Jim's Education Center is a co-education day and boarding school for 370 students, with 10 teachers. It is a primary school that serves children from primary 1 to primary 7 (ages 5 to 14). The school is located in Kiyunga Trading Center, a small community about 8 km north of Mukono, in the Mukono District in the central region of Uganda. Kiyunga has a population of about 3,000 people. Most of the children that attend this school are orphans and vulnerable children. The new latrine was initially needed to serve the population of girls (as there was a latrine for the boy population near the upper primary dorms about 250 m from the bio-gas latrine), but as the plan moved forward it grew to serve the entire population. The gas was to be used for lighting in the classrooms and cooking.

The project was started in August of 2006 with the mobilization of funds by the Center’s director, Musisi Josephus, and the local Peace Corps Volunteer (PCV), Michelle. The overall budget for the system was 10 million Ugandan shillings ($US 6,200). The size of the digester was to be approximately 18 cubic meters (the height of the dome shaped digester is 266 cm and the diameter of the floor is 543 cm). The funders are identified as friends of the PCV's from the United States. Construction was completed in March of 2007.

This project started when Musisi Josephus met Christopher Kato at Kireka Hill constructing a Biogas latrine. Kato informed Musisi that he was a Biogas latrine consultant in Uganda. The school had been planning a new latrine, but with the idea that the biogas system could meet the need for the latrine, as well as cooking and lighting, this project was quickly initiated. After the bill of materials was submitted, construction was started.

Josephus only informed the required government offices of the project: the Community Development Officer, the Local Council and a local Community Based Organization. The neighbors of a household or a school (for this situation) are usually not informed of latrine construction for privacy reasons. The surrounding community was able to supply some of the labor for the unskilled construction jobs.

The type, model and size of the biogas system were developed by the engineer with no communication with the school or community. There was no formal training of the school staff on how the process of anaerobic digestion works, how the latrine needed to be maintained and operated, or the dangers of burning and storing methane gas. No manual on the system or trouble shooting information was provided to the school. Consequently, the school staff was unable to ask questions to gain pertinent information from the engineer.

When asked questions about the system, Musisi Josephus did not know about the gas seal on the manhole, how flammable methane is, the temperatures this gas can reach while burning, the dangers of breathing methane, or how to light the cooking stove or lights to minimize safety risks. According to Musisi no agreement was made between the school and Christopher Kato. The PC volunteer gave Kato the job. The school was not told about the cost of the cow dung that was needed to fill the digester initially (the digester needed to be filled half way), which is another reason why the project stalled. Christopher Kato also indicated that there was a lack of transparency of funding and expectations by all parties (Kato, 2009).

Figure 8: Latrine house at Jim's Education Center

Figure 9: Opening for expansion chamber at Jim's Education Center

The latrine house depicted in Figure 8 is situated almost completely above the first chamber, which has a radius of 255 cm with the weak ring 175 cm from the floor of the chamber. There are three chambers, each an approximate semi-sphere. The first is the anaerobic stage. The second chamber is exposed to the atmosphere by a pipe with a diameter of 50 cm (the pipe provides means to mix the slurry in the digester), and the third chamber is for the removal of the material. The pipe connecting the latrine to the first chamber is 40 cm in diameter and the pipe connecting the first chamber to the second is 50 cm in diameter. The second and third chambers both have a radius of 139 cm. These two chambers can be seen in front of the latrine house in Figure 9. The manhole lid (gas seal) is above the first chamber. There is no barrel (which could regulate the pressure of the gas, as this is a fixed dome system). The connection of the tank to the out going pipes is under water.

Figure 10 provides a detailed drawing for design of the system.

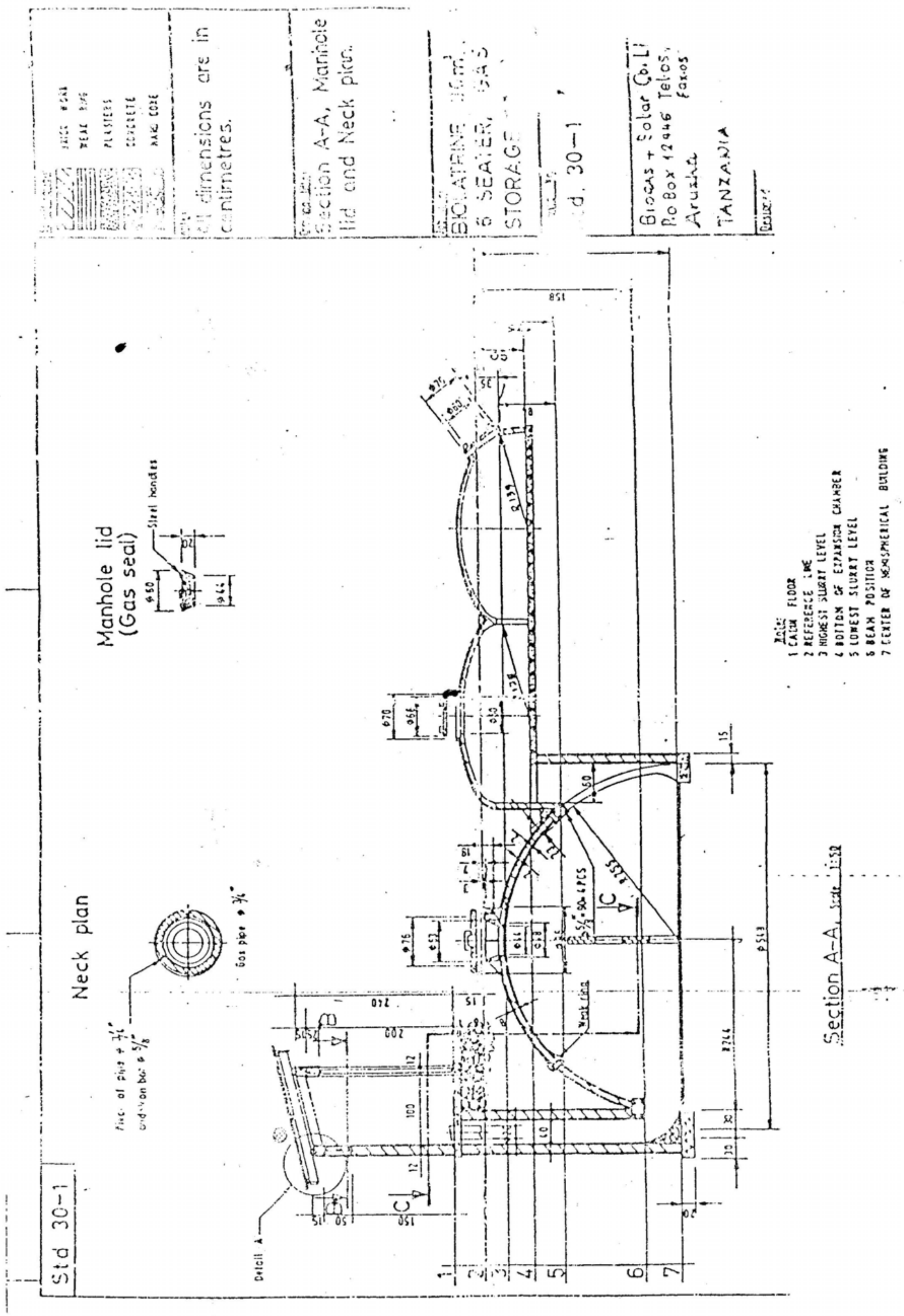


Figure 10: Detailed diagram for built system at Jim's Education Center

The school is outfitted with one lamp that is connected to the first chamber to reduce the dependency on electricity. There is one other pipe that is not connected but can be redirected to the kitchen (see Figure 11) and used to cook. The classroom with the lamp is approximately 20 meters from the digester and the kitchen area is 50 meters away.

Figure 11: Kitchen at Jim's Education Center

There were no plans implemented for how the system was to be operated and maintained after construction. This lack of information and planning caused the system never to become operational. The initial seed material needed for the system was not included in the bill of materials resulting in a lack of funds which limited the amount of manure initially purchased. The seed material that was subsequently placed in the digester was insufficient, and failure to seal the digester from the atmosphere resulted in the system never reaching an anaerobic state.

On August 4, 2008, George Makumbi, a biogas engineer from National Research Organization (NARO), was asked to visit the site to diagnose the system's problems. He explained that the built system can be very different from the planned design. He needed to see if the initial feeding was enough for the system. For the system to be effective, the expansion chamber needs to be filled with manure. The manure sits until it starts to produce gas. Only after gas production starts, is the system sealed. It is at this point that the gas can be utilized.

With George Makumbi's help the manhole on the digester was removed (which is seen in Figure 12). A small amount of gas was visually observed by the presence of small bubbles (shown in Figure 13). If the system was operating correctly, the slurry would bubble like it was boiling. The gas production was only on the top layer of the slurry, because the slurry contained too much water. The source of the excess water could have been a crack in the digester or from stormwater. The expansion chambers, outlet pipe, and the inlet pipe from the mixing station were also all blocked with a variety of debris.

Figure 12: Manhole Cover with Gas Outlet

Figure 13: Inside View of Digester

To make the system operational, the first steps will be to clear the blocked systems and add more cow dung, mixing it properly. George Makumbi planned on training the staff at the school on the proper mixing of the manure, continue to check the gas pipeline for blocks and bends; and re-seal the digester to see if gas is produced. Since this is a biogas latrine, the last option is to empty the system and have someone go inside the digester to check for cracks and leaks, all other issues should be checked first. At the time that this report was written none of the previous steps have been taken.

4.1.1 Assessment

The scoring of a project can be done by those directly involved in the implementation, but in this case the author had scored this project after collecting information from stakeholders involved in the project: Musisi Josephus (school founder), Christopher Kato (engineer), Sharlene Shortt (replacement PCV for Michelle).

Table 6 provides the scores for each of the assessment elements of the matrix. The project scores the highest in the first life stage, in the needs assessment (17/20), and in the sustainability factor of socio cultural respect (17/20). This can be attributed to having the founder of the school identify the need for the project. As the project life increases there is a decreasing trend in the scores from 17/20 to 12/20 to 11/20 to 9/20. This is because the engineering team did not transfer sufficient knowledge to the community members and a lack of communication among all parties involved (engineers, community, builders and funders).

A lack of communication about the budget and financial requirements is evident in the scoring of the economic sustainability (score 8/20). Instead of having the engineers design the system alone, obtaining input from the community, in this case the Headmaster of the school would have provided the teachers and eventually the students with information about how the system worked and what was needed to maintain it. A clear operation and maintenance manual is necessary in the case of a biogas latrine; it provides a place for reference for troubleshooting and to remind those in charge of what needs to be done. In terms of the financial issues, a rough budget is not enough to cover all the costs during construction. A detailed budget needs to be used along with explanations which detail what the money will be used for. If this had occurred the cow manure that was needed to fill and seed the digester initially would have been budgeted for and explained to the community. The low score for the political cohesion (score 9/20) is a result of the engineer only including the local leaders in the beginning, the lack of seeking outside support and advice, and not having a clear action plan or clearly defined roles.

By using this method of assessing the project, the future work to enable this biogas latrine to operate effectively has been laid out to the school but no action has yet been taken. A manual explaining how the system operates and what maintenance is needed has been developed and provided to the community. The community is being encouraged to ask questions and while funding is not yet secure, a detailed budget has already been developed. This budget has been formulated by a different engineer (George Makumbi) but was explained during a site visit to the community.

Table 6: Assessment of Jim's Education Center latrine (Case Study 1)

	Sustainability Factor					
Life Stage	Socio-cultural Respect	Community Participation	Political Cohesion	Economic Sustainability	Environmental Sustainability	Total
Needs Assessment	4	4	2	4	3	17/20
Conceptual Designs and Feasibility	3	3	2	1	3	12/20
Design and Action Planning	4	2	2	1	3	12/20
Implementation	3	2	2	1	3	11/20
Operation and Maintenance	3	2	1	1	2	9/20
Total	17/20	13/20	9/20	8/20	14/20	61/100

4.1.2 Conclusion

In case study 1, a life cycle thinking assessment was applied to the construction of a biogas latrine project located in Kiyunga Trading Center, Uganda. From this case study, it is seen that knowledge transfer was the largest obstacle to overcome for the success of this project. Without the needed knowledge, the community, in this case the school was unable to properly prepare for the system. When construction was complete, there was no plan to manage and operate the latrine and deal with problems that might arise. So even though the initial problem was small, (lack of enough manure to start the system producing biogas) it spiraled down into a mess of miscommunication and lack of understanding. This created the current situation of no maintenance or repair of the system, students blocking inlets and outlets with debris, and a year between construction and action).

The overall score of 61/100 is relatively high, but yet the project is not operational. The project was just missing a couple of things that created the current situation. The lack of knowledge transfer and the budgeting error that are discussed above caused a relatively well planned project to fail. Since the Headmaster was in charge of implementation the needs assessment life stage and social cultural sustainability factor received high scores. This demonstrates that no matter what a project scores there can be small issues or external factors that might determine if a project will fail or succeed.

4.2 Case Study 2: Katosi

Katosi is a small landing site on the Northern shore of Lake Victoria in the Central region of Uganda. The population is approximately 7,000 people, and is always changing because it is a fishing village that accommodates many fishing islands. The fishermen and boat builders are often on the move because of financial interests such as looking for work and fish. The land is right on the lake which causes problems with digging latrines. Currently there are some public latrines; one is an unused eco-san latrine. It was the hope of the district offices to build a bio-gas latrine to provide a public toilet for fishermen and some of the population near the police station. The project was started by the sub-county government with help from the government of Mukono District.

The project's construction started in 1997. Because of the extended time line some of the details have been hard to come by. The project was organized from the top down and was developed and implemented by the district office. The district officers brought the project to the sub-county offices which then introduced this project to the local leaders. Most people in the community were not informed of this project, introduced to the concept of biogas, or trained on how the system operates.

The construction was never completed (the collapsing latrine house can be seen in Figure 14 and Figure 15), it has been estimated that about 7.8 million ushs (Ugandan Shillings) approximately 4,656 USD had been spent during the 6 month construction period.

Figure 14: Latrine house at Katosi

Figure 15: View of expansion chamber, top of digester and latrine house at Katosi

According to the project engineer (Christopher Kato) construction usually takes one month, but with this project there were problems with funding and construction was uncoordinated (Kato, 2009). During my discussions with the local leaders it was hinted that the money ran out and that the construction and management was inconsistent and unreliable. The digester was supposed to have a 40,000 L capacity as shown in the system diagram provided in Figure 16.

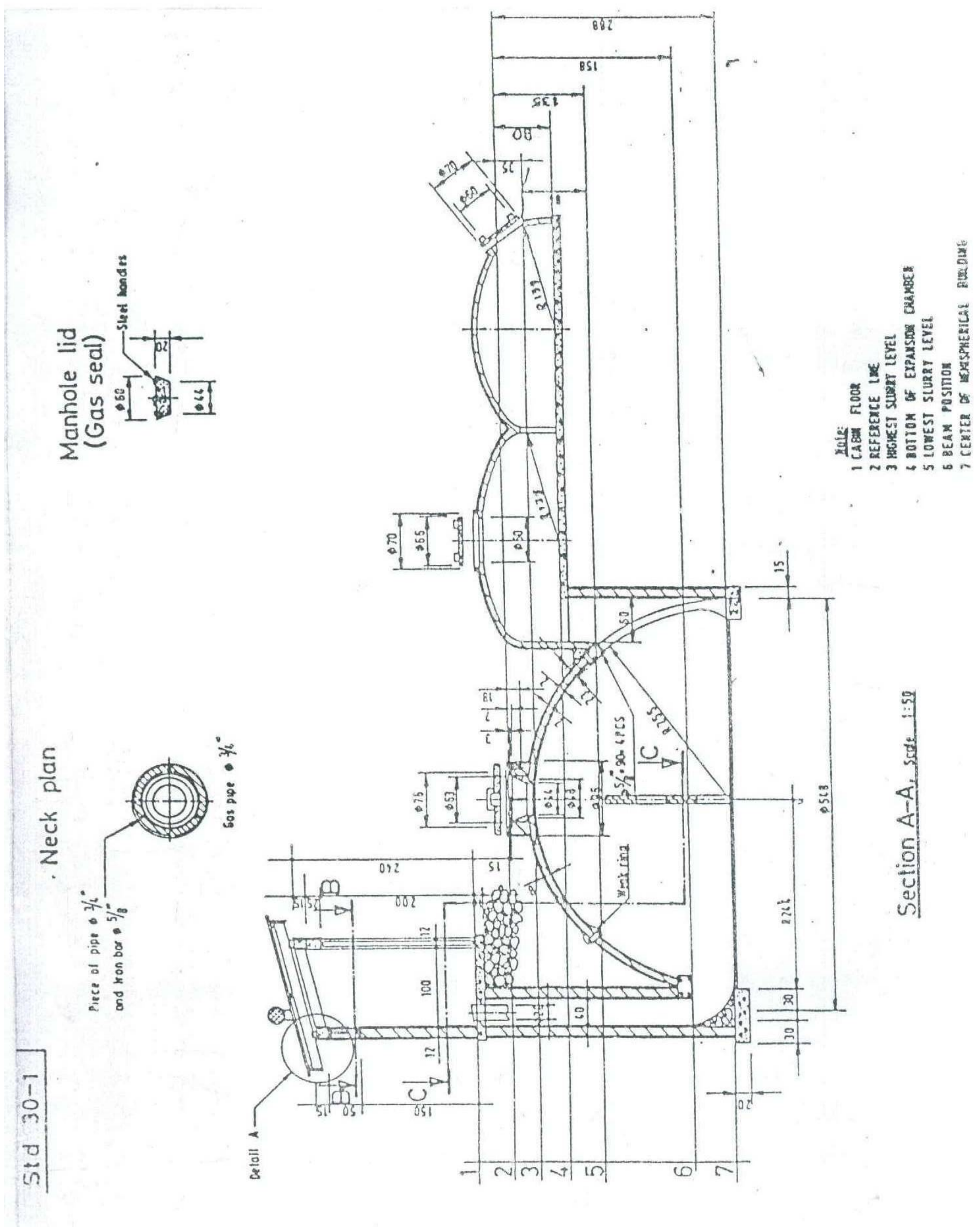


Figure 16: Diagram of biogas latrine at Katosi

The community leaders informed the author that the community's estimated contribution was recorded as 10% of the total cost. When the construction was completed a local committee was to be elected to be in charge of the project. The foreign contribution was from the Danish organization Aseden Trust. The system was to be maintained by the community with the gas being used for lighting the area around the latrine and the police station. The solid material would be used as fertilizer. While the project engineer informed the author the funding was from NARO, joint and engineering international in Mackerere University and some help from the District. The latrine was to be used by the fisherman for improved sanitation with a user fee of 200 ushs per visit, and the gas was to be used by the police.

While discussing the case study with Mr. Kato some of the more important issues that he commented on included; the lack of manure to initially fill (seed) the digester, there was no contribution by the community towards construction and basic development of the overall project (such as figuring out the location for the system), the community was not sensitized on the benefits and uses of the project, and finally the project was behind schedule causing the belief that the project would never get finished.

Currently the latrine is being used by the community, even though construction was never completed and parts of the chambers have collapsed (see Figure 15). The community seems unconcerned about the failure of the project. Few projects in Katosi have been implemented by the village to improve the sanitation condition of the surrounding area, which is why a project from the District was implemented. There is a small NGO working in this area that helps improve sanitation at the household level, focusing on working with women. But the overall community currently has two failed latrine projects on hand (the biogas latrine, the eco-san latrine). There are some public toilets for the community to use, but they are un-kept and almost full.

4.2.1 Assessment

From the description of the case study provided above, the overall low score of 20/100 in Table 7 is not surprising. The case study scored the highest in Political Cohesion, because this was a political project; the District and Sub-county offices organized the project. This high level of political involvement also caused problems. The project was implemented from the top down and between the government offices, the engineer and community coordination was limited. This meant certain tasks were not done because it was unclear whose job it was. Also the score for implementation was one of the highest but still incredibly low. This is mostly due to the design of biogas project, a process that requires a thorough understanding of the general environment and local cultural issues.

The score of 1/20 for community participation reflects that the government and engineering team did not involve the community, except when hiring unskilled labor during construction. Without involving the community in the planning, design and implementation of a project there is no community ownership and little chance for success. In this case very few people in the community even knew this project was being built. The plan was for the police to use the gas that would be produced from the system, a decision determined by the government and not the community. It was shared by Christopher Kato that a community does not readily trust the police and would not want to give the benefits of a project to them. The score of 4/20 for Economic Sustainability reflects problems with funding. Funding was not available during key stages of construction drawing out a one month project into six months.

The two other lowest scores were received by the Design and Action Planning (3/20) stage and the Operation and Maintenance (2/20) stage. For the Design and Action planning the low score indicates that no designing or action planning took place. The only plans that were hinted at by the different interviewees was having the design reflect some cultural aspects, having government involved in the creating of the idea and informing the engineer what they wanted and having a budget for the entire project.

Table 7: Assessment of Katosi biogas latrine (Case Study 2)

	Sustainability Factor					
Life Stage	Socio-cultural Respect	Community Participation	Political Cohesion	Economic Sustainability	Environmental Sustainability	Total
Needs Assessment	1	0	2	1	0	4/20
Conceptual Designs and Feasibility	1	0	2	1	1	5/20
Design and Action Planning	1	0	1	1	0	3/20
Implementation	2	1	1	0	2	6/20
Operation and Maintenance	0	0	0	1	1	2/20
Total	5/20	1/20	6/20	4/20	4/20	20/100

4.2.2 Conclusion

By looking at the overall and individual scores of the project, it is not surprising that the project failed. However, by analyzing the scores one could be prevented from making similar mistakes. This project shows the possible results of implementing a project completely from the top down, without conferring with the community on their views of the new technology and how it will be used. The importance of having the management of the money as a more open issue is another lesson learned from this project.

Some information was hard to obtain for this project based on the long time between start and the time of research. Based on the information available there are many conflicting statements. This is common in Uganda, few people will fix a problem because then it is assumed that they are the one responsible for creating the problem. This cultural practice could be why no one stepped up during the implementation of the project and tried to put it on the right track. Information such as this is not easily obtained but is learned after working in a community for a period of time, but the matrix offers some useful questions and recommendations on a starting place to understand some of the cultural practices that will affect a project.

4.3 Case Study 3: James Mugerwa

James Mugerwa lives just outside Mukono Town Council (about 5 km off of Kampala-Jinja Road) in Mukono County in Mukono District of Uganda. He helps run a cooperative of dairy farmers, where the farmers bring milk to his house and then he transports the milk to Mukono Town Council to sell. He originally had constructed a tubular biogas system with private funding in 2001. The system was 28 feet long and was used for 3 years. A double layer polythene balloon is used as the digester which is placed in a trench (shown in Figure 17) with a slope of 5% enabling the new material to push out the old slurry each day. The digester is protected from the sun and animals by either covering with planks or with a slanted roof above (this is better as it enables air flow and a more consistent temperature for the digester). James paid 700,000 ushs (US $400) for this system (but this price did not include the bricks and the digging labor, which he himself provided). The tubular system had a low volume and the produced some gas used for cooking (storage for the gas was provided by the polyethylene bag shown in Figure 18).

Figure 17: Trench for tubular system for James Mugerwa

Figure 18: Gas storage for tubular system for James Mugerwa

In 2003 the district wanted to build a model biogas plant and James was a viable option that showed interest. An 18 cubic meter fixed dome digester was built, which was partially funded by the District Plan for Modernization of Agriculture (PMA). This is one of four parts of Poverty Eradication Action Plan (PEAP). The biogas projects falls under the Natural Resource Management division (NRM) of PMA; of which there are seven. The other six divisions under PMA include; NAADS, Research (NARO), Agro Processing, Primary Education, Micro Finance and Infrastructure development. The construction took 3 weeks, and then the digester was filled during a 1-month period. After the digester was filled with substrate the lid was sealed. The project cost 2.4 million ushs (US $1500) with the District contributing 1.8 million ushs and James (who can be seen in Figure 19) covering the balance of 0.6 million ushs. The plant was built by George Makumbi from NARO. Currently it is difficult to gain more information about this project (in terms of a clear design and project from the view point of the engineer or district officials).

Currently there are three cows which supply the manure for the system. The urine is added to the manure before it is added to the digester (just enough urine to have it flow). The slurry that it produced at the end is used as a fertilizer (which is transported via jerry cans, shown in the front of Figure 20), with elephant grass having the first priority. The elephant grass is the main food supply for the cows. James advises that the elephant grass must be cut into small pellets as it is easier for the cows to digest and it is better for the biogas system as it reduces clogs and floaters in the system. The system is fed twice a week and the digester is stirred twice a week. The burner has a diameter of 3 inches with the stand 1 foot in width and length. The gas is used for both cooking and lighting (which is the second priority), but there is a fear in his household that the food will not be cooked on time when using the gas. To light either the burner or the lamp, one must light first and then release the gas which then catches fire.

Figure 19: James near the manhole of the digester

Figure 20: Expansion chamber with jerry cans to transport slurry to field

4.3.1 Assessment

Scoring for this project has been a bit difficult as it has been difficult to obtain interviews with the district officials and even with George Makumbi. The project can be termed a success as it is currently in operation and producing gas. The family is able to maintain the system and is modeling the system for their community and also at the district level. The project scores high in the needs assessment as it was initiated by the family with help from the district. Since James Mugerwa already had experience with a biogas system he and his family understood how the system operates and what is needed to maintain it. Some of the information that would have been useful during scoring includes who in the district initiated the project, a detailed budget, a diagram that used to build the system, and different view points of the project.

The individual element scores can be seen in Table 8. The project scored the highest in both the needs assessment life stage (16/20) and in the community participation sustainability (16/20) factor this can be attributed to having the household initiate the project and having the household understand the system which enabled them to participate at the different life stages of the project. When looking at the project certain steps (or recommendations considered for scoring an element) were overlooked by the household, engineer and district especially during the conceptual designs and feasibility (12/20) and design and action planning (12/20) life stages. For example, different designs were not considered nor was the design selected by the household, a site impact analysis was not completed (partially accounting for the low score for environmental sustainability (12/20)), a work timeline was not set and considerations to increase the involvement of women was not taken.

Table 8: Assessment of James Mugerwa biogas plant (Case Study 3)

	Sustainability Factor					
Life Stage	Socio-cultural Respect	Community Participation	Political Cohesion	Economic Sustainability	Environmental Sustainability	Total
Needs Assessment	3	4	4	3	2	16/20
Conceptual Designs and Feasibility	3	3	2	2	2	12/20
Design and Action Planning	2	2	3	2	3	12/20
Implementation	2	3	3	3	2	13/20
Operation and Maintenance	3	4	2	2	3	14/20
Total	13/20	16/20	14/20	12/20	12/20	67/100

4.3.2 Conclusion

The lesson learned from taking this approach is that even when the project is considered a success, improvements can be made. A community can be more involved in the process; more consideration can be taken for the economic and environmental sustainability of the project. This can be done by looking at the impact of the construction and operation on the site, figuring out where raw materials will be procured from and disposed of, and actually looking into and estimating the long term costs of running the system. From the information gained for this project it is clear that these steps were not taken for this project.

5.0 Comparing Case Studies

5.1 Life Stage Comparison

Figure 21 provides a visual comparison of the scores for each of the five life stages for the three case studies. The score for the Katosi project (Case Study 2) (Figure 21 b) is the lowest in all life stages, which can be attributed to the failure of that project. There was little to no community involvement, the project was implemented from the top down and construction was never completed. By comparing the scores for Jim's Education Center (Case Study 1) (Figure 21 a) and James Mugerwa (Case Study 3) (Figure 21 c), all life stage scores are very similar except for Operation and Maintenance. While this is the last life stage it is one that is often over looked, partially because the NGO or funders will have left the project area when this life stage begins. But without the education of the community on how the system works, how are they to operate and maintain it? This life stage must be planned from the beginning. There is also a small difference in the score for the implementation life stage, as in Jim's Education Center the community was not involved in this process and little communication took place.

The overall scores for Jim's Education Center (Case Study 1) and James Mugerwa (Case Study 3) are similar. Case study 3 is currently being used to produce gas for the family while the latrine at Case Study 1 is unused. In the life stages of Implementation and Operation and Maintenance Case Study 3 has a higher score than case study 1; 13/20, 11/20 and 14/20, 9/20 respectively.

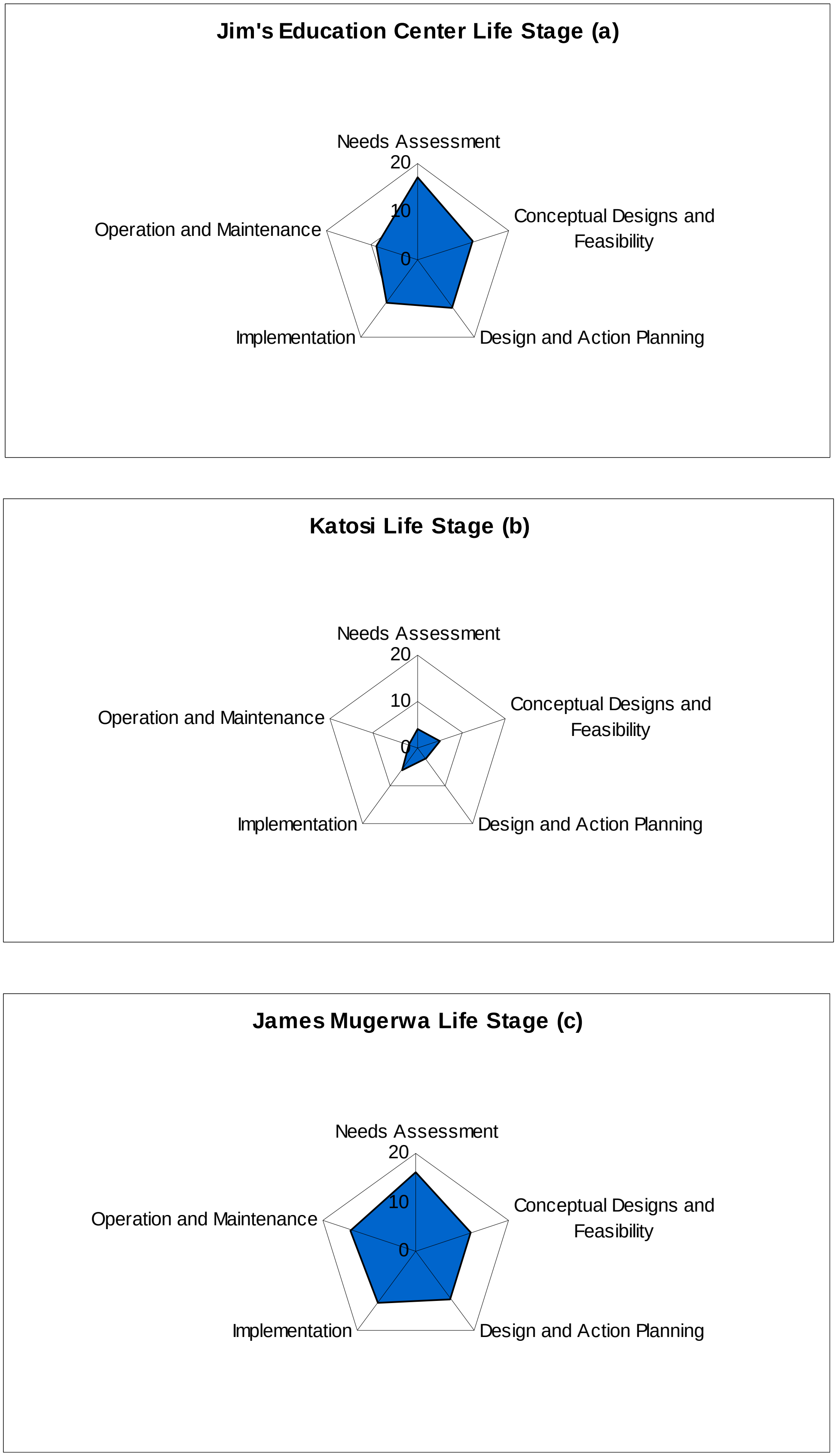
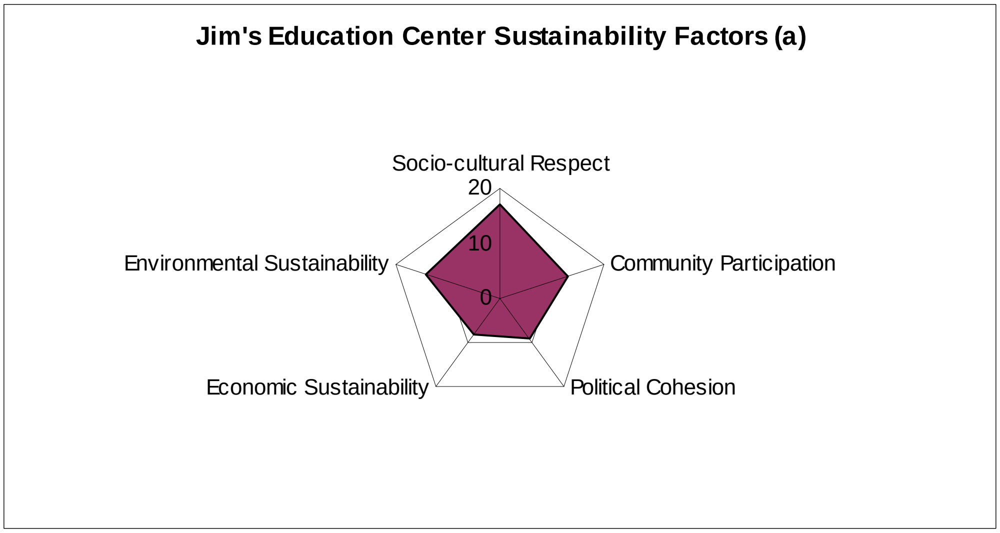
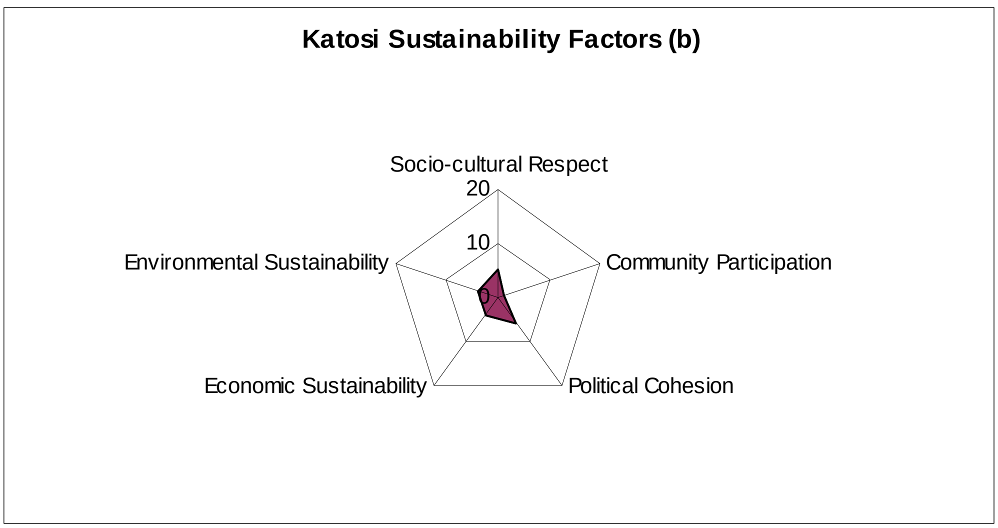


Figure 21 Life Stage comparison for the three case studies

5.2 Sustainability Comparison

Figure 22 provides a comparison of the scoring for the sustainability factors for the three case studies. The scores for the Katosi project (Case Study 2) (Figure 22 b) again are extremely low compared to the other two projects. It seems none of the sustainability factors were seriously taken into consideration during planning or implementation of the project, but instead by nature of trying to complete a project some recommendations were completed, such as involving different political officials in the planning, or having the idea that there will be a fee for usage of the latrine. The sustainability scores for Jim's Education Center (Case Study 1) (Figure 22 a) and James Mugerwa (Case Study 3) (Figure 22 c) are not as similar as those for the Life Stages. This can be attributed to having the community involved at different levels of the project; having the headmaster initiate the project and provide information to deal with Socio-cultural Respect for Case Study 1 compared to James Mugerwa involved more in implementation contributing to the high score for Community Participation for Case Study 3. Another factor with a large difference is Political Cohesion; the project completed at James Mugerwa's house was partially initiated by the district causing political officials to be involved at different levels in Case Study 3 (scoring 14/20), while only a few government officials were even informed of the project at Jim's Education Center in Case Study 1 (scoring 9/20).





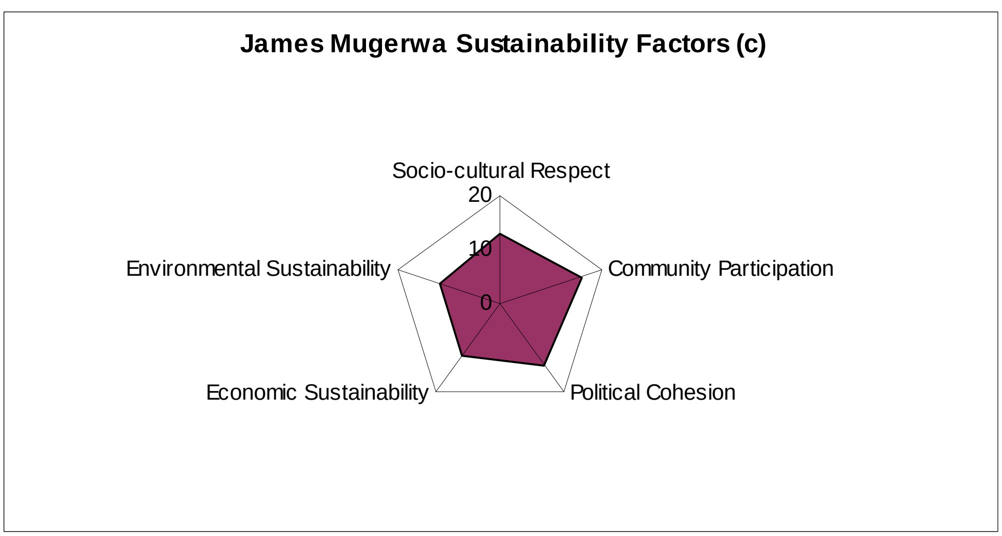


Figure 22: Sustainability comparison for the three case studies

6.0 Conclusions and Recommendations for Future Projects

6.1 Conclusions

For this report the life cycle matrix was applied to three different biogas projects in the central region of Uganda (Mukono district). In this case the LCA matrix tool was used to compare the case studies with each other in hopes to gain insight on how to make biogas projects more successful in this region. The life cycle matrix provides a tool for development workers to approach a project in a different way, looking at the sustainability of each life stage. Recommendations and questions provide a guide to scoring the project. In these cases the scoring was done long after completion of the project, but it can be applied before, during and after implementation.

The numerical score that is reached is not the most important factor, but the knowledge gained during the assessment of the project. It does give insight into how the project might do, and is relative for projects scored by the same person or when comparing one life stage to another. The ability to compare also holds true when looking at the sustainability factors. It would be hard for two separate people to score the same project and have them reach the same score. The scores would be similar but there are experiences and a different knowledge base that affect how a person sees and scores a project.

When looking at the three projects, James Mugerwa's project scored the highest. For this project the community only consists of one individual and their household, creating social simplicity. Social simplicity will not always increase a score for a project. However, in some cases, the assessment tool assumes the project is part of something larger, in terms of the overall development picture of a region and country, including the local and national government. If a project has social simplicity it would score fewer points in the case of the political cohesion sustainability factor. In the case of community participation, the score could be increased by reducing the size of the community. This would create a situation where it is easier and more realistic that the community would be continuously consulted during the different life stages of the project. It is also important to consider simplicity in the technology used. For biogas this would entail using the tubular system to introduce the technology to an area, as it provides a design that the community can see what is going on.

6.2 Recommendations to Improve the Assessment Tool

The life cycle matrix was useful to compare the three case studies; further work could be done on the life cycle matrix creating a matrix for water projects and one for sanitation projects (currently another graduate student is developing a matrix to be used for indoor air projects). The matrix currently can be used at any point in a project, but the questions and recommendations could be geared towards using this tool for comparison purposes (as done here), an evaluation tool for use after construction, or as a tool for monitoring throughout the lifespan of the project. Also a more user friendly interface could be developed, making it easier for the user to refer back to the questions and guidelines as they are scoring their project.

6.3 Recommendations for Future Biogas Projects

For many projects that take place in the developing world, plans, implementation and other logistics are rushed, over looked or not properly considered. Each case study had a factor(s) that could have been improved upon. When looking at biogas projects in the future, the author feels that there is a lot of potential, but communication among all parties and community participation are two extremely important factors. This is not a technology that one can inform others that they need (i.e., can not be a top down approach, but since some have no experience with biogas technology it might not be possible for all projects to be completely grass root projects), education on the system and benefits must precede any project, so only families or communities that are interested and committed take part.

Biogas projects can be an appropriate technology for the urban and rural populations in Uganda. There are three main designs, (with others in development) which have been used in a variety of countries. Each design has its own advantages and disadvantages which need to be looked at before this technology is disseminated in an area. The operation and maintenance of these systems is not overly complicated but an understanding of the requirements and benefits must be clearly communicated before a project begins.

The idea of having a biogas latrine provide sanitation to a community is not a new one, but for the project in Katosi a lot of issues were overlooked. For example little education of the community was done and planning for who would benefit from the slurry and gas was not discussed. This type of project has been a success in the slums surround Narobi. The BioCentres provide toilets and washrooms, water kiosks, and public spaces. The biogas is then used to help with children's feeding projects and to meet other fuel needs (Word Press, 2009). This example is provided so that one does not write off biogas projects in the community setting, but they do need intensive planning since a large community must understand and accept the technology and project as a whole.

Different material sources should also be investigated. Biogas systems can use animal or human waste to produce biogas, but some projects run on plant waste and municipal solid-waste (MSW). Future biogas projects in Uganda could be a mixture of systems using different fuel sources. For example, currently only about a third of the MSW produces in Kampala City Council is collected and removed to a landfill (Womakuyu, 2008). A biogas system using MSW could reduce the amount of waste clogging the streets and drains while producing useful products.

Certain small steps can be taken to help with the success of such a project, providing a manual (in the local language) to the community will give them a reference for trouble shooting. On the same track, a maintenance and repair professional should be trained in order to serve systems built and organized by a larger project. This would prevent the system from falling into disrepair. Another easy step would be to walk through the budget, design, construction and operation of the system with all stake holders.

When implementing a biogas project in Uganda the factors from the “Biogas energy from family-sized digesters in Uganda: Critical factors and policy implications” (Walekhwa et al, 2009) case study that attribute to an increased adoption of biogas technology should be considered. These factors are increasing household income, number of cattle, fuel wood costs and kerosene costs. While increasing age of household head, household size, location of household and formal education had a negative correlation (Walekhwa et al, 2009).

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8.0 Appendix

8.1 Scoring for Element 1,1

To help with understanding how a project can be scored, the author will demonstrate here how each case study was scored for the social cultural respect/needs assessment; Element 1,1. Information for each case study was gathered during multiple visits to the site and with different stakeholders. For scoring, each recommendation was treated as a point for that Element (recommendations could score between 0.5 and 1 point), only questions that related to the projects were considered. In McConville (2006) recommendations could only obtain a score of 0 or 1. During correspondence between the author and McConville, she shared that providing the option of scoring a recommendation with a 0, 0.5, or 1 might improve the scoring method.

The recommendations for Elements 1,1 are as follows, with the questions to help complete or answer that recommendations are listed under their corresponding recommendations these have been taken from McConville (2006).

Below are the questions and recommendations for Element 1,1 and the responses relating to the three case studies. If the overall recommendation was met then that will receive a yes, but if not then the questions that follow will be answered to determine if a half point could be scored for that recommendation. Many of the questions are not yes or no questions but for this scoring they are answered as such to demonstrate if this information was gathered and understood before the project started. If a question does not apply to this project it will be answered as NA.

1. Generate a yearly calendar of work and social life in the community
    a. How is a year defined?
    b. How are the seasons identified?
    c. What are the characteristics of each season?
    d. What is the primary employment in the area?
        i. For men?
        ii. For women?

        iii. For children?
    e. Is this work constant throughout the year or seasonal?
    f. What time of year is the busiest? Are other seasons very slow?
    g. Are there patterns of seasonal migration?
    h. What is the primary religion in the area?
    i. When are the major holidays?
    j. When do weddings, baptisms and other social ceremonies take place?
2. Identify social preferences and traditional beliefs associated with water supply and sanitation practices
    a. Are certain water sources preferred over others?
    b. Is there folklore or old stories associated with water sources or water use?
    c. Are there traditional methods for protection of a water source?
    d. Do people add things to their water? At the source or at home?
    e. Do people consider sanitation issues around the water sources?
    f. Are there social caste issues about the use of water from certain sources?
    g. Is there a history of filtering or screening water sources?
    h. Are there seasonal changes in the quality of the water supply? How are they explained?
    i. What is the preferred sanitation method in the community?
    j. What are the preferred methods of anal cleansing?
    k. How do people feel about handling excreta (even when decomposed)?
        i. Will people transport it?
        ii. Will they reuse it?
        iii. How will this affect maintenance issues?
    l. Are there religious constraints to be considered?
        i. A traditional rule is that Muslims should not defecate facing or with their backs towards Mecca.
    m. Do people believe that excreta are harmful?
        i. Many people believe that children's excreta are less harmful than that of adults
        ii. Others believe that disease is "an act of God", therefore sanitation and hygiene practices are irrelevant.
    n. Are people afraid to use latrines? Why?
        i. Snakes, insects, and other animals
        ii. Black magic
        iii. Smells
        iv. Collection of excreta in a single place is "unsanitary"
        v. Belief that women using a pit latrine will become infertile
    o. Are there taboos associated with washing hands with soap? (In Mali, this practice was believed to wash away a person's wealth)
    p. For further examples refer to Pickford, 1995
3. Determine the level of health education in the community
    a. Have community members been involved in answering questions on community health? In formal and informal settings?
    b. What is their education background?
    c. What health education issues are covered in schools?

d. Who receives education? Men or women? (Note: that there are many discrepancies between who receives education and who performs water/sanitation related tasks)
e. How often do people get sick in the community?
f. Why do people get sick? (According to them)
g. Do people connect water and sanitation issues with disease?
h. What is the community motivation for improved water and sanitation services?
i. Are there health care facilities available?
j. How is the quality of water? How is quality perceived in the community?
k. How do you perceive the cleanliness of the community? How do the community members perceive it?
l. Do they wash their hands with soap?
m. Do they have a latrine?
n. Do they use a latrine? Do the children?

4. Recognize differences in gender roles in water and sanitation
    a. How do men use water? How much?
    b. How do women use water? How much?
    c. How much time do men/women spend per day on water collection?
    d. Do men and women follow separate sanitation practices?
    e. Are there separate latrines for men and women?
    f. Who is in charge of the children's hygiene?

Case Study 1

The headmaster and the previous and current Peace Corps volunteer provided the information to score this element. It was considered since the headmaster, who knows the school (which in this case is the community being considered) had all this information already. As it was a school a yearly calendar for the community had already been developed. The Headmaster knows and practices the social preferences and traditional beliefs for sanitation. He also participated in teaching the community what it had previously known about water and sanitation issues as well as making sure boarding students practiced proper hygiene and sanitation methods. The two Peace Corps volunteers confirmed that the headmaster as well as the senior teachers understood the water and sanitation practices of the community. For these reasons element the case study scored 4/4.

1. Generate a yearly calendar of work and social life in the community **YES**
    g. How is a year defined?
    h. How are the seasons identified?
    i. What are the characteristics of each season?
    j. What is the primary employment in the area?
        i. For men?

        ii. For women?
        iii. For children?
    k. Is this work constant throughout the year or seasonal?
    l. What time of year is the busiest? Are other seasons very slow?
    m. Are there patterns of seasonal migration?
    n. What is the primary religion in the area?
    o. When are the major holidays?
    p. When do weddings, baptisms and other social ceremonies take place?
2. Identify social preferences and traditional beliefs associated with water supply and sanitation practices **YES**
    a. Are certain water sources preferred over others?
    b. Is there folklore or old stories associated with water sources or water use?
    c. Are there traditional methods for protection of a water source?
    d. Do people add things to their water? At the source or at home?
    e. Do people consider sanitation issues around the water sources?
    f. Are there social caste issues about the use of water from certain sources?
    g. Is there a history of filtering or screening water sources?
    h. Are there seasonal changes in the quality of the water supply? How are they explained?
    i. What is the preferred sanitation method in the community?
    j. What are the preferred methods of anal cleansing?
    k. How do people feel about handling excreta (even when decomposed)?
        i. Will people transport it?
        ii. Will they reuse it?
        iii. How will this affect maintenance issues?
    l. Are there religious constraints to be considered?
        i. A traditional rule is that Muslims should not defecate facing or with their backs towards Mecca.
    m. Do people believe that excreta are harmful?
        i. Many people believe that children's excreta are less harmful than that of adults
        ii. Others believe that disease is "an act of God", therefore sanitation and hygiene practices are irrelevant.
    n. Are people afraid to use latrines? Why?
        i. Snakes, insects, and other animals
        ii. Black magic
        iii. Smells
        iv. Collection of excreta in a single place is "unsanitary"
        v. Belief that women using a pit latrine will become infertile
    o. Are there taboos associated with washing hands with soap? (In Mali, this practice was believed to wash away a person's wealth)
    p. For further examples refer to Pickford, 1995
3. Determine the level of health education in the community **YES**
    a. Have community members been involved in answering questions on community health? In formal and informal settings?
    b. What is their education background?
    c. What health education issues are covered in schools?

d. Who receives education? Men or women? (Note: that there are many discrepancies between who receives education and who performs water/sanitation related tasks)
e. How often do people get sick in the community?
f. Why do people get sick? (According to them)
g. Do people connect water and sanitation issues with disease?
h. What is the community motivation for improved water and sanitation services?
i. Are there health care facilities available?
j. How is the quality of water? How is quality perceived in the community?
k. How do you perceive the cleanliness of the community? How do the community members perceive it?
l. Do they wash their hands with soap?
m. Do they have a latrine?
n. Do they use a latrine? Do the children?

4. Recognize differences in gender roles in water and sanitation **YES**
    a. How do men use water? How much?
    b. How do women use water? How much?
    c. How much time do men/women spend per day on water collection?
    d. Do men and women follow separate sanitation practices?
    e. Are there separate latrines for men and women?
    f. Who is in charge of the children's hygiene?

Case Study 2

Gaining information for this case study was more difficult, partly because of the time lapse but also because it was widely viewed as a failed project. I was able to talk to some of the local leaders, the Local Council 1 (LC 1) chairman and treasurer, as well as some women from the Katosi Women's Development Trust. An interview was also arranged with the engineer of the project, Mr. Kato. This project was initiated and managed from the top down. Katosi is a well known fishing village on Lake Victoria; because of this the knowledge of the social life and social preferences for sanitation was known. These two only constitute parts of recommendation 1 and 2, giving each of those recommendations a score of .5 points. Recommendations 3 and 4 where completely ignored by the district, bring the total score for element 1,1 to 1/4.

1. Generate a yearly calendar of work and social life in the community
    a. How is a year defined? **YES**
    b. How are the seasons identified? **YES**
    c. What are the characteristics of each season? **YES**
    d. What is the primary employment in the area?

        i. For men? **YES**
        ii. For women? **YES**
        iii. For children? **NO**
    e. Is this work constant throughout the year or seasonal? **NO**
    f. What time of year is the busiest? Are other seasons very slow? **NO**
    g. Are there patterns of seasonal migration? **NO**
    h. What is the primary religion in the area? **NO**
    i. When are the major holidays? **NO**
    j. When do weddings, baptisms and other social ceremonies take place? **NO**
2. Identify social preferences and traditional beliefs associated with water supply and sanitation practices
    a. Are certain water sources preferred over others? **NO**
    b. Is there folklore or old stories associated with water sources or water use? **YES**
    c. Are there traditional methods for protection of a water source? **YES**
    d. Do people add things to their water? At the source or at home? **NO**
    e. Do people consider sanitation issues around the water sources? **YES**
    f. Are there social caste issues about the use of water from certain sources? **YES**
    g. Is there a history of filtering or screening water sources? **NO**
    h. Are there seasonal changes in the quality of the water supply? How are they explained? **NO**
    i. What is the preferred sanitation method in the community? **NO**
    j. What are the preferred methods of anal cleansing? **NO**
    k. How do people feel about handling excreta (even when decomposed)?
        i. Will people transport it?
        ii. Will they reuse it?
        iii. How will this affect maintenance issues?
    l. Are there religious constraints to be considered? **NO**
        i. A traditional rule is that Muslims should not defecate facing or with their backs towards Mecca.
    m. Do people believe that excreta are harmful? **YES**
        i. Many people believe that children's excreta are less harmful than that of adults
        ii. Others believe that disease is "an act of God", therefore sanitation and hygiene practices are irrelevant.
    n. Are people afraid to use latrines? Why? **YES**
        i. Snakes, insects, and other animals
        ii. Black magic
        iii. Smells
        iv. Collection of excreta in a single place is "unsanitary"
        v. Belief that women using a pit latrine will become infertile
    o. Are there taboos associated with washing hands with soap? (In Mali, this practice was believed to wash away a person's wealth) **NA**
    p. For further examples refer to Pickford, 1995
3. Determine the level of health education in the community

a. Have community members been involved in answering questions on community health? In formal and informal settings? **NO**
b. What is their education background? **NO**
c. What health education issues are covered in schools? **YES**
d. Who receives education? Men or women? (Note: that there are many discrepancies between who receives education and who performs water/sanitation related tasks) **NO**
e. How often do people get sick in the community? **NO**
f. Why do people get sick? (According to them) **NO**
g. Do people connect water and sanitation issues with disease? **NO**
h. What is the community motivation for improved water and sanitation services? **NO**
i. Are there health care facilities available? **YES**
j. How is the quality of water? How is quality perceived in the community? **NO**
k. How do you perceive the cleanliness of the community? How do the community members perceive it? **NO**
l. Do they wash their hands with soap? **NO**
m. Do they have a latrine? **NO**
n. Do they use a latrine? Do the children? **NO**

4. Recognize differences in gender roles in water and sanitation
   a. How do men use water? How much? **NO**
   b. How do women use water? How much? **NO**
   c. How much time do men/women spend per day on water collection? **NO**
   d. Do men and women follow separate sanitation practices? **NO**
   e. Are there separate latrines for men and women? **YES**
   f. Who is in charge of the children's hygiene? **YES**

Case Study 3

From talking to James Mugerwa (the home owner) and George Mukumbi (the engineer for the project) the information for the project description was obtained. James Mugerwa is the head of the household, which in this case is the community. He was able to provide the information on the social cultural/needs assessment. It might seem like Case Study 1 and this case study should have scored the same on this element as both the head of the community was involved in the project. The differences for this case study for the author are that James Mugerwa was not as organized in the understanding of the community as the headmaster of the school. This caused recommendations 3 and 4 to receive a half point, while recommendations 1 and 2 received a full point. Giving the project a score of 3/4 for Element 1,1.

1. Generate a yearly calendar of work and social life in the community **YES**
    a. How is a year defined?
    b. How are the seasons identified?
    c. What are the characteristics of each season?
    d. What is the primary employment in the area?
        i. For men?
        ii. For women?
        iii. For children?
    e. Is this work constant throughout the year or seasonal?
    f. What time of year is the busiest? Are other seasons very slow?
    g. Are there patterns of seasonal migration?
    h. What is the primary religion in the area?
    i. When are the major holidays?
    j. When do weddings, baptisms and other social ceremonies take place?
2. Identify social preferences and traditional beliefs associated with water supply and sanitation practices **YES**
    a. Are certain water sources preferred over others?
    b. Is there folklore or old stories associated with water sources or water use?
    c. Are there traditional methods for protection of a water source?
    d. Do people add things to their water? At the source or at home?
    e. Do people consider sanitation issues around the water sources?
    f. Are there social caste issues about the use of water from certain sources?
    g. Is there a history of filtering or screening water sources?
    h. Are there seasonal changes in the quality of the water supply? How are they explained?
    i. What is the preferred sanitation method in the community?
    j. What are the preferred methods of anal cleansing?
    k. How do people feel about handling excreta (even when decomposed)?
        i. Will people transport it?
        ii. Will they reuse it?
        iii. How will this affect maintenance issues?
    l. Are there religious constraints to be considered?
        i. A traditional rule is that Muslims should not defecate facing or with their backs towards Mecca.
    m. Do people believe that excreta are harmful?
        i. Many people believe that children's excreta are less harmful than that of adults
        ii. Others believe that disease is "an act of God", therefore sanitation and hygiene practices are irrelevant.
    n. Are people afraid to use latrines? Why?
        i. Snakes, insects, and other animals
        ii. Black magic
        iii. Smells
        iv. Collection of excreta in a single place is "unsanitary"
        v. Belief that women using a pit latrine will become infertile
    o. Are there taboos associated with washing hands with soap? (In Mali, this practice was believed to wash away a person's wealth)

p. For further examples refer to Pickford, 1995

3. Determine the level of health education in the community
    a. Have community members been involved in answering questions on community health? In formal and informal settings? **YES**
    b. What is their education background? **YES**
    c. What health education issues are covered in schools? **NO**
    d. Who receives education? Men or women? (Note: that there are many discrepancies between who receives education and who performs water/sanitation related tasks) **NO**
    e. How often do people get sick in the community? **YES**
    f. Why do people get sick? (According to them) **NO**
    g. Do people connect water and sanitation issues with disease? **NO**
    h. What is the community motivation for improved water and sanitation services? **NO**
    i. Are there health care facilities available? **YES**
    j. How is the quality of water? How is quality perceived in the community?
    k. How do you perceive the cleanliness of the community? How do the community members perceive it? **NO**
    l. Do they wash their hands with soap? **YES**
    m. Do they have a latrine? **YES**
    n. Do they use a latrine? Do the children? **YES**
4. Recognize differences in gender roles in water and sanitation
    a. How do men use water? How much? **NO, in this case the information for how much water the farm used was understood**
    b. How do women use water? How much? **NO**
    c. How much time do men/women spend per day on water collection? **NO**
    d. Do men and women follow separate sanitation practices? **NO**
    e. Are there separate latrines for men and women? **YES**
    f. Who is in charge of the children's hygiene? **YES**

8.2 Prices for construction of Biogas Projects by NARO

The projects listed below are of the fixed dome design and can be attached to a latrine creating a biogas latrine, or have a manual input for agricultural uses. Prices are given in Uganda shillings (ushs), currently 1 USD is 1,900 ushs. These price lists were compiled in 2008.

COST ESTIMATE FOR CONSTRUCTION OF BIOGAS PLANT (8 CUBIC)				
Items	**Descriptions**	**Quantity**	**Unit Cost**	**Total Ushs.**
	Local materials			
1	Burnt clay bricks	2000	150.00	300,000.00
2	Hard core stones truck	1	20,000.00	20,000.00
3	Lake Sand truck	1	60,000.00	60,000.00
4	Plaster Sand truck	2	55,000.00	110,000.00
5	Aggregate stones truck 1/4	1	50,000.00	50,000.00
	Sub-total			**540,000.00**
	Manufactured Goods			
6	Cement (bags)	15	25,000.00	375,000.00
7	Lime	2	15,000.00	30,000.00
8	PVC Pipe 6" x 10ft	1	60,000.00	60,000.00
9	PVC Pipe 4" x 20ft	1	25,000.00	25,000.00
10	Chicken mesh (roll)	1	35,000.00	35,000.00
11	Water proof (kgs)	5	3,000.00	15,000.00
12	Betumen	1	45,000.00	45,000.00
13	Weld mesh	1	15,000.00	15,000.00
14	Mold	1	50,000.00	50,000.00
15	Pit excavation	1	160,000.00	160,000.00
	Sub-total			**810,000.00**
	Gas-line			
16	G.I Pipe x 1/2"	2	20,000.00	40,000.00

17	G.I Pipe x 3/4"	5	22,000.00	110,000.00
18	Assorted Fittings	30	1,000.00	30,000.00
19	Gas valves	4	8,000.00	32,000.00
20	Rubber tubes	1	3,000.00	3,000.00
	Sub-total			**215,000.00**
	Labor			
	Skilled, Semi-skilled & Un-skilled	Lump sum	Lamp sum	450,000.00
	Transporting materials	1	60,000	60,000.00
	Sub-total			**510,000.00**
	Grand Total			**2,075,000.00**

COST ESTIMATE FOR CONSTRUCTION OF BIOGAS PLANT (12 CUBIC METERS)				
Items	**Descriptions**	**Quantity**	**Unit Cost**	**Total Ushs.**
	Local materials			
1	Burnt clay bricks	2500	130.00	325,000.00
2	Hard core stones truck	1	40,000.00	40,000.00
3	Lake Sand truck	1	60,000.00	60,000.00
4	Plaster Sand truck	2	40,000.00	80,000.00
5	Aggregate stones truck 1/4	1	70,000.00	70,000.00
	Sub-total			**575,000.00**
	Manufactured Goods			
6	Cement (bags)	28	25,000.00	700,000.00
7	Lime	3	20,000.00	60,000.00
8	PVC Pipe 6" x 10ft	1	70,000.00	70,000.00
9	PVC Pipe 4" x 20ft	1	40,000.00	40,000.00
10	Chicken mesh (roll)	1	40,000.00	40,000.00
11	Water proof (kgs)	20	3,500.00	70,000.00
12	Betumen	1	30,000.00	30,000.00
13	Weld mesh	1	15,000.00	15,000.00
14	Hooks	30	2,000.00	60,000.00
15	Mold	1	80,000.00	80,000.00
16	Pit excavation	1	350,000.00	350,000.00
	Sub-total			**1,515,000.00**
	Gas-line			
17	G.I Pipe x 1/2"	3	20,000.00	60,000.00
18	G.I Pipe x 3/4"	3	25,000.00	75,000.00
19	Assorted Fittings	25	1,500.00	37,500.00
20	Rubber tubes	4	3,000.00	12,000.00
	Sub-total			

	Labor			
21	Transporting materials	5	50,000	250,000.00
22	AEATREC Supervisor	14	35,000	490,000.00
23	AEATREC Mason	14	15,000	210,000.00
	Sub-total			**950,000.00**
	Grand Total			**3,040,000.00**

COST ESTIMATE FOR CONSTRUCTION OF SURFACE RUN-OFF COLLECTION- 16 CUBIC METERS				
Items	**Descriptions**	**Quantity**	**Unit Cost**	**Total Ushs.**
	Tank/reversiour			
1	Burnt clay bricks	3000	150.00	450,000.00
2	Hard core stones truck (2.5mt. load)	1	100,000.00	100,000.00
3	Lake Sand truck	2	50,000.00	100,000.00
4	Plaster Sand truck	2	40,000.00	80,000.00
5	Aggregate stones truck 1/4 (2.5mt. Load)	1	80,000.00	80,000.00
6	Cement (bags)	35	27,000.00	945,000.00
7	Lime	2	20,000.00	40,000.00
11	Water proof (kgs)	15	3,000.00	45,000.00
13	Weld mesh,G10	2	15,000.00	30,000.00
	Water, Jerricans	30	300.00	9,000.00
	Transporting materials	Lamp sum	1	170,000.00
15	Pit excavation	1	350,000.00	350,000.00
	Sub-total			**2,399,000.00**
	WATER CONVEYANCY			
	PVC Pipe 6" x 20ft (Heavy duty)	1	100,000.00	100,000.00
	PVC Pipe 4" x 20ft (Heavy duty)	10	60,000.00	600,000.00
18	Assorted Fittings			150,000.00
	Get-valves	6	30,000.00	180,000.00
20	Transporting materials	Lamp sum		50,000.00
	Sub-total			**1,080,000.00**
	PERIMETER WALL			
	Burnt clay bricks	6000	150	900,000.00
	Lake Sand truck	4	50,000.00	200,000.00
	Plaster Sand truck	4	40,000.00	160,000.00
	Cement (bags)	50		

			27,000.00	1,350,000.00
	Water, Jerry cans	65	300.00	19,500.00
	Sub-total			**2,610,000.00**
	SETTLEMENT/ IN-TAKE TANKS			
	Pit excavation	1	100,000.00	100,000.00
	Burnt clay bricks	1000	150	150,000.00
	Lake Sand truck	0.5	50,000.00	25,000.00
	Plaster Sand truck	0.5	40,000.00	20,000.00
	Cement (bags)	8	27,000.00	216,000.00
	Aggregate stones truck 1/4 (2.5mt. Load)	0.5	80,000.00	40,000.00
	Water, Jerry cans	18	300.00	5,400.00
	Sub-total			**556,400.00**
	WORKING TOOLS			
	Pike axes	4	10,000.00	40,000.00
	Hand hoes	3	5,000.00	15,000.00
	Wheel borrows	1	80,000.00	80,000.00
	Nylon string	3	1,500.00	4,500.00
	Motor pans	4	3,000.00	12,000.00
	Sledge hummer	2	45,000.00	90,000.00
	Trowels	4	3,000.00	12,000.00
	Gum-boots (pair)	3	20,000.00	60,000.00
	Spades	2	6,500.00	13,000.00
	Sub-total			**326,500.00**
	Semi-skilled labor			
	Masons:4 x 20 days @ 7,000	80	7,000.00	560,000.00
	Helpers: 4 x 25 days @ 3,000	100	3,000.00	300,000.00
	Sub-total			**860,000.00**
	Administrative costs			
	Communication, Airtime	4	10,000.00	40,000.00
	Production of sketches:			

	assorted			110,000.00
	Sub-total			**150,000.00**
	Grand Total			**7,981,900.00**

COST ESTIMATE FOR CONSTRUCTION OF A 30 CUBIC METER INSTITUTIONAL BIOGAS DIGESTER

Descriptions	Unit	Quantity	Unit Cost	Total Ushs.
Local materials				
Burnt clay bricks	number	3000	150	450,000
Hard core stones(truck)	trucks	2	30,000	60,000
Lake Sand (truck)	trucks	2	60,000	120,000
Clay for sealing the neck	kgs	50	600	30,000
Plaster Sand (truck)	trucks	3	40,000	120,000
Aggregate stones truck 1/4	trucks	2	45,000	90,000
Sub-total				**870,000**
Manufactured Goods				
Cement (bags)	bags	30	25,000	750,000
Lime	bags	2	15,000	30,000
PVC Pipe 6" x 20ft	pieces	1	50,000	50,000
PVC Pipe 4" x 20ft	pieces	1	40,000	40,000
Chicken mesh (roll)	roll	1	35,000	35,000
Water proof (kgs)	kgs	15	3,000	45,000
Betumen	tins	2	30,000	60,000
Weld mesh	pieces	2	17,000	34,000
Hooks	pieces	30	2,000	60,000
Mold	pieces	1	50,000	50,000
Pit excavation		1	360,000	360,000
Sub-total				**1,514,000**
Gas-line				
G.I Pipe x 1/2"	pieces	3	25,000	75,000
G.I Pipe x 3/4"	pieces	3	27,000	81,000
Gas Valves	pieces	7		

			10,000	70,000
Assorted Fittings Unions, Tees, Shellac, clips etc)	pieces	30	1,000	30,000
Rubber tubes	meters	4	3,000	12,000
Installation of gas line		L/SUM	L/SUM	200,000
Biogas stoves	pieces	2	90,000	180,000
Transporting materials to site	trips	7	50,000	350,000
Sub-total				**998,000**
Labor				
Skilled and semi-skilled and unskilled labor		L/SUM	L/SUM	2,250,000
Sub-total				**2,250,000**
Grand Total				**5,632,000**

COST ESTIMATE FOR CONSTRUCTION OF A 50 CUBIC METER INSTITUTIONAL BIOGAS DIGESTER

Descriptions	Unit	Quantity	Unit Cost	Total Ushs.
Local materials				
Burnt clay bricks	number	4500	150	675,000
Hard core stones(truck)	trucks	3	50,000	150,000
Lake Sand (truck)	trucks	2	120,000	240,000
Clay for sealing the neck	kgs	50	600	30,000
Plaster Sand (truck)	trucks	3	45,000	135,000
Aggregate stones truck 1/4	trucks	2	80,000	160,000
Sub-total				**1,390,000**
Manufactured Goods				
Cement (bags)	bags	50	27,000	1,350,000
Lime	bags	3	20,000	60,000
PVC Pipe 6" x 20ft	pieces	1	70,000	70,000
PVC Pipe 4" x 20ft	pieces	1	50,000	50,000
Chicken mesh (roll)	roll	1	40,000	40,000
Water proof (kgs)	kgs	20	3,000	60,000
Betumen	tins	2	35,000	70,000
Weld mesh	pieces	2	15,000	30,000
Hooks	pieces	30	2,000	60,000
Mold	pieces	1	80,000	80,000
Pit excavation		1	480,000	480,000
Sub-total				**2,350,000**
Gas-line				
G.I Pipe x 1/2"	pieces	3	25,000	75,000
G.I Pipe x 3/4"	pieces	3	27,000	81,000
Gas Valves	pieces	8	10,000	80,000

Assorted Fittings Unions, Tees, Shellac, clips etc)	pieces	25	1,500	37,500
Rubber tubes	meters	4	3,000	12,000
Installation of gas line		L/SUM	L/SUM	200,000
Biogas stoves	pieces	2	90,000	180,000
Transporting materials to site	trips	6	50,000	300,000
Sub-total				**965,500**
Labor				
Construction of digester, expansion chamber and mixing box (Skilled and semi-skilled labor)		L/SUM	L/SUM	2,670,000
Sub-total				**2,670,000**
Grand Total				**7,375,500**