EVALUATION OF THE ACCEPTABILITY, IMPACT AND FEASIBILITY OF BIOGAS DIGESTERS IN RURAL MAPHEPHETHENI, KWAZULU-NATAL.

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ABSTRACT

Biogas has the potential to provide energy to communities, especially those where grid electrification will not be installed for a long time and who experience problems in accessing energy resources. The purpose of this study was to investigate whether biogas technology could provide households and a school with an acceptable, affordable, efficient, and sustainable alternative energy resource, thereby providing opportunities for cost savings, reduction of the labour burden and income generation. Three case studies were selected, two households and Myeka High School in rural Maphephetheni. Maphephetheni is situated approximately 80 km west of Durban and is characterised by the lack of grid electrification. The two households selected as case studies were both using firewood and paraffin for thermal energy. Collection of firewood was a tiresome burden to women and paraffin was expensive to purchase. The third case study, Myeka High School was using solar energy and LP gas to support its energy needs. Biogas digesters were donated to the two households and the school. Data before and after installation of biogas was collected through questionnaires, informal interviews and observations. Monitoring and evaluation of the case studies was carried out.

Results collected revealed that biogas was an acceptable source of energy because the household and school equipped with the floating dome biogas digesters accepted cooking on biogas while the household used the fertiliser from biogas on their crops. However it was not affordable both to the household and the school because in the household income did not allow for its purchase while savings on energy expenditure from both the school and household could not offset the cost in the six years estimated by the engineer but it would take 11 years.

Biogas was found to be efficient and sustainable provided proper management was available. Although income generation opportunities were not fully utilised, there was an opportunity for income generation through the biogas provided there was encouragement, support and markets available.

Recommendations are that government policy should provide for training of stakeholders on proper management techniques. Government or organisations involved with biogas energy could do this, as well as provide an extension service for the dissemination of biogas and other renewable energy information. However, government policy should as in other countries provide for subsidies, risk underwritten bank loans or tax incentives to manufacturers.

DECLARATION

I hereby declare that this research is of my own investigation, and has not been submitted for any other degree. Where other sources have been used, these are duly acknowledged in the text.

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As the study supervisor, I agree/~~disagree~~ to submission of this thesis for examination.

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TABLE OF CONTENTS

APPENDICES

APPENDIX A: Pre-biogas installation questionnaires household questionnaires

APPENDIX B: Post biogas installation household questionnaires

APPENDIX C: Myeka High School students's pre installation survey questionnaire

APPENDIX D: Myeka High School students's impact assessment survey questionnaire

APPENDIX E: Myeka High School secretary's questionnaire on energy resources and expenditure

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1
THE PROBLEM AND ITS SETTING

1.1 Introduction to the research problem

The South African government's vision outlined in the Department of Minerals and Energy (DME) policy concerning renewable energy has two objectives: making renewable energy accessible and affordable to the people and ensuring that it contributes to sustainable development in a manner that conserves the environment (White Paper 2002). This vision is important for people who experience difficulties in accessing and using both modern and traditional energy resources but have abundant potential resources of renewable energy. In the policy the government envisages reducing the dependence of people on wood and dung as their main sources of fuel as this has potentially a negative effect on the environment. The government has committed itself to creating an enabling environment for renewable energy, as renewable energy has now been acknowledged as having the potential to supply energy to people. In the policy, biomass is mentioned as one type of renewable energy to be focused on. Biogas, which is generated from cow dung, a biomass source is the focus of this study (White Paper 2002).

Grid electrification is by far the most common method of providing energy for urban and rural people to promote economic development and an improved standard of living for the people (Seeling-Hochmuth 2002). Electricity is also the most preferred type of fuel because of its multiple uses like cooking, lighting, and refrigeration. However, grid rural electrification seems to be a far-fetched dream as electricity is expensive to both the supplier and the consumer. One reason for this is that rural incomes are very low and large numbers of people live below subsistence levels with much reliance on the informal sector, seasonal agricultural produce and livestock, making affordability of electricity difficult (Mapako 1997).

A report suggests that rural households in KwaZulu Natal have an income around R811.82 a month, with a national study quoted in the same report saying that an average monthly income for households is R796.15 (May 1995). In Kotze (2003) it is said that rural incomes in South Africa vary from less than R200 for the elderly and the poor to over R2000 per month for the well off people. The median of rural income is around R500 a month. Rural people also tend to reserve electricity for home lighting and use other sources of fuel for cooking such as wood and paraffin because of the expense. This prevents the supplier from receiving a return on investment (Foley 1990). Rural communities are dispersed and far from main roads, which means that electrification costs are higher as there will be fewer consumers per unit length of powerline. For the supplier, the heavy investment required for rural electrification makes the supplier place greater priority on areas which do not demand such high investments. These are urban areas where households are closer together (Seeling-Hochmuth 2002).

Another problem with rural energy is the potential of wood scarcity in these areas. Wood has been and still is the main source of thermal energy (Kgathi and Mlotshwa 1997). Besides the scarcity, there are problems attached to using wood for energy requirements (Keyun 2001). Indoor wood fires cause a number of health problems such as eye diseases and respiratory infections (Keyun 2001). It also has negative effects on the environment such as soil degradation because of trees being cut down and not replaced and also the depletion of soil because fallen wood is not permitted to rot and return nutrients to the soil. Another problem is the burden of wood collection placed on women. Women have to travel long distances, sometimes taking more than four hours each trip, meaning that most of their day has been spent on wood collection (Lawbuary 2001). In Sweetman (1998) it is said that in Tanzania, women had to travel at least 30km a day to find wood during certain times of the year when wood was scarce Therefore it is essential that a solution to the provision of clean, inexpensive fuel which does not make physical demands on people be found.

With the support of the DME and other institutions, the vision of the government was put to the test by implementing a biogas pilot project to assess the social and economic benefits that biogas energy could bring to rural people. The pilot project was implemented in two households and at Myeka High School, Maphephetheni, rural KwaZulu Natal. The area was chosen because of the lack of modern energy resources and the community's major request for a thermal energy source other than wood in a survey (Green and Erskine 1998)

This study reviews the pilot project mentioned above in terms of its feasibility, impact and sustainability in the area. Biogas technology is rare in South Africa, with a few small farm-based digesters working but none have been properly monitored and evaluated nor proper records kept (Solar Engineering Services 2002). The DME has also been involved in a pilot project which installed four biogas digesters around South Africa in which only three were found to be in working order but not enough monitoring was done (Solar Engineering Services 2002). Therefore this study is unique in that it envisages doing what other projects have not done, that is to monitor and evaluate a biogas project from the beginning. There is also little local literature available to support what was done in Maphephetheni.

1.2 Statement of the problem

Can biogas technology provide households and a school in Maphephetheni with an acceptable, affordable, efficient and sustainable alternative energy resource, thereby providing opportunities for cost savings, reduction of the labour burden and income generation?

1.3 Measurement parameters

Acceptability means acceptance of cooking with the gas, using it to run appliances and using the fertiliser in crops. Both cow dung and human excreta generate the biogas and may carry a stigma about their use.

Affordability means whether people will be able to purchase the system and pay for maintenance if needed. This was measured by looking at the total income of the household and expenditure incurred on the system and by comparing energy expenditure before and after biogas installation.

Efficiency means whether sufficient gas was generated whenever it was needed.

Sustainability means whether the biogas system was able to be maintained in the long term. Sustainability was measured by looking at maintenance, the commitment to continuous feeding of the biogas system, manpower and time spent in feeding. Availability of the resources needed to generate biogas was also assessed.

Income generation was assessed by looking at the use of biogas and its byproducts to generate income. Cooked food sales, fertiliser sales, crop sales and other income generating activities were identified. Reduction of the labour burden was also looked at by comparing the time women spent cooking and collecting energy resources before and after biogas installation, with the view that released time could be used for income generating activities.

1.4 Hypothesis

Biogas technology has the potential to provide households and a school in Maphephetheni with energy that is acceptable, affordable, efficient and sustainable and creates opportunities for income generation.

1.5 Subproblems

Subproblem 1

Does the inexpensive fixed volume tubular plastic biogas digester have the potential to provide a household with energy that is an acceptable, affordable, efficient and sustainable alternative to existing forms of energy and also increase opportunities for income generation?

Subproblem 2

Does the domestic floating dome biogas digester have the potential to provide a household with energy that is an acceptable, affordable, efficient and sustainable alternative to existing forms of energy and also increase opportunities for income generation?

Subproblem 3

Does a large capacity floating dome biogas digester have the potential to provide a school with energy that is an acceptable, affordable, efficient and sustainable alternative to existing forms of energy and also increase opportunities for income generation?

1.6 Study limits

The results of this study cannot be generalised to other communities in other areas because the study was specific to Maphephetheni. Only cow dung and human excreta were investigated as feeder for biogas but biomass could be another source of methane, which was not investigated because the project was specifically investigating cow dung and human excreta. Accurate quantification of measurements was difficult to obtain from non-numerate households dealt with in the research. Therefore the study concentrates on the qualitative aspects of impacts of biogas technology.

1.7 Assumptions

One assumption made in the study was that even if rural households and schools were connected to grid electricity, they would still use the biogas system because of its benefits. Another assumption was that non-payment for the biogas digesters will not influence the attitudes of beneficiaries towards its use. The biogas digesters were donated. The last assumption made was that the school will continue to use other sources of energy to supplement biogas because biogas would not replace all current energy sources used at the school.

1.8 Outline of the thesis

Chapter one deals with the introduction of the thesis, the problem statement and the subproblems. The hypothesis, limits and assumptions have been outlined. The literature review will form chapter two whereby previous literature will be looked at to find out what has been done before in relation to the study, to justify the methodology of the study and to support the findings. Chapter three will provide the description of the study area. Chapter four will discuss the Dube household as a case study of the inexpensive fixed volume plastic biogas digester while chapters five and six will discuss the Gwala household system of the floating dome biogas digester and the Myeka High School floating dome biogas digester system as case studies respectively. In chapters four, five and six, the description of the cases, methodology, results, discussions and conclusions will be reported for each case study. Chapter seven will look at the policy on renewable energy and this will be linked to the findings of the study. General conclusions and recommendations will be outlined in chapter eight.

CHAPTER 2
REVIEW OF RELATED LITERATURE

The availability of sufficient thermal energy is an important factor for improving people's living standards and also developing the economy (Sokona 2002). Large businesses, shops, hospitals, schools, farmers, households and other institutions are dependent on energy to run their daily activities, whether they are profit based or for the well being and development of communities. Energy used by these institutions could be traditional energies or conventional energies, but still all are needed for the everyday functioning of people (Foley 1990). Traditional thermal energies include wood, dung which are part of biomass while conventional energies include paraffin, candles, coal, LP gas and electricity.

Due to the increase in oil prices in the 1970's which led to greater dependence on wood for energy, developing countries today are experiencing a fuelwood crisis (Kgathi and Mlotshwa 1997; Best 1992). For three quarters of the population of developing countries, wood is the main source of energy, accounting for 34% of the total energy consumption (Kgathi and Mlotshwa 1997). Wood, as the main source of thermal energy in rural areas is becoming scarce because of deforestation (Smil and Knowland 1980). If there is wood available for fuel, it is either too expensive for the rural poor or far away and takes too much time to collect. The problem with most conventional energies is that they are also expensive for poor people. The other option to resolve the problem of rural energy shortage is electrification, but for most rural people this seems like a dream that will take ages to come true. Rural electrification is often unaffordable and will be dealt with in detail later. Developing countries have masses of unused renewable energy sources which are not only environmentally friendly but are also easily available and affordable and these renewable sources could be used to minimise the problem of energy scarcity (Karezeki and Ranja 1997).

The literature review is structured in such a way that it will give insight into how biogas can be of value to rural people. Increasing energy needs and use of traditional energy – wood as source of thermal energy will be looked at. Disadvantages of using wood as a source of thermal energy will also be discussed followed by electrification of rural areas which does not provide a solution to the energy problem.

The role of renewable energies in communities and that of biogas will also be discussed. Gender plays a large role in energy in that gender differences impact on energy acquisition and use. It is therefore important to also look at gender and energy. Government involvement in renewable energies in terms of policy formulation will be discussed as government can play a major role in making renewable energies available to the people. A summary of the literature review will also be given.

2.1 Increasing energy needs

Wood, which is available for free from forests, has been supplying people with fuel for thousands of years, with wood being used as the most common source of energy for cooking, space heating and manufacturing. Half of the African continent's energy comes from firewood and firewood is used as primary fuel for most developing countries (Baird 1993). Energy needs in developing countries increase as populations grow in numbers, with the demand for firewood rising above what is available thus causing physical shortage of firewood for countless world communities. The existing energy sources, especially those that are affordable, accessible and needed by the poor are becoming limited and the delivery systems to meet the increasing energy demands are also limited (Hislop 1992). The National Academy of Sciences (1977) said that because of the ever-increasing demand for energy, fuel energy reserves will eventually be exhausted, and for those developing countries that have higher needs because of their increasing populations, the impact of energy shortage on the poor would be greater. Smil and Knowland (1980) agreed with the above statement by saying that growing populations have made the demand for firewood wood rise, at the same time prices of firewood rise above affordability level of the poor thus affecting a large number of people.

Keyun (2001) gives an example that almost 80% of the people in China live in rural areas, where the most acute shortage of energy resources occurs because trees cut down are not being replaced. This shortage and unavailability of energy in rural areas impacts badly on rural development in general, economic development specifically and it also prevents improvements in people's living standards. Meeting the growing demand for energy supply in developing countries, especially rural areas in ways that are sustainable and efficient could significantly improve economic growth and well being of rural people (Keyun 2001).

2.2 Traditional thermal energy

The traditional thermal energy resource base in most developing countries, especially in rural areas has been mainly in the form of wood, with other forms such as dung, coal and crop residues being used. The most used energy source in rural areas is wood. According to Rivett-Carnac (1982) firewood accounts for more than 90% of the domestic energy demand in the rural areas of the less developed countries. Hislop (1992) agrees by saying that over 80% of total energy used in some developing countries can be accounted for by wood. In a study done in Cambodia in 1996 (Johnston 2002) it was found that for 92% of Cambodia's households, wood was the major fuel used for cooking. Wood provides mainly heat forcooking, space heating and sometimes for lighting.

Johnston (2002, p234) is quoted saying that " in principle, wood is a renewable source which can provide household energy needs infinitely." However, wood is often consumed at a greater rate than it is replanted – potentially causing degradation of forests and a range of other problems. Use of wood for thermal energy needs in rural areas has its disadvantages. A number of those problems will be discussed below so as to justify the need for other sustainable energy sources in rural areas.

2.2.1 Burden on women

All over the world, women have always and still do perform the household chores, such as looking after the family, cooking, cleaning and collecting firewood (Lawbuary 2001). Women carry the burden of collecting and carrying wood long distances which can be the most time consuming task of a woman's day – taking more than four hours to finish the whole wood collecting task each time (Lawbuary 2001; Kgathi and Mlotshwa 1997). In a study done in Tanzania it was found that sometimes it was very difficult for women to find wood due to scarcity at certain times of the year, making women walk up to 30 km looking for wood (Sweetman 1998). In Clancy (2002) it is said that because of the heavy loads that women carry on their heads, sometimes more than 20kg, back problems are more prevalent while Nhete (2002) says that women may walk up to ten kilometres with loads of wood weighing almost 35 kg. Loads of wood carried by women may be more but it is very difficult to measure because scales are not used in the process of wood collection.

Weight of loads might be indicated by referring to a head load or stack of wood, with varying weights but all the same the loads are still heavy (Researcher observation). The wood collection activity may leave women with little time and energy to carry out other important activities. So finding relief from this duty is important for women.

2.2.2 Health hazards

As has been said above, women perform most of the household chores and the health of their families is also their concern. Because of the gases and soot emitted by fire when using wood for inside cooking or space heating, health problems arise, which affect the family. Women suffer most as they are the ones who are mainly busy at the fires. They suffer from indoor air pollution, which worsens during summer rains when wet wood does not burn easily and produces much smoke (Keyun 2001). Common smoke related conditions are eye conditions (itchy and red eyes), chronic diseases such as respiratory infections and asthma (Lawbuary 2001). These conditions influence the well being of family members and impact on expenditure, which could have been spent on other important activities but now must be spent on health care.

2.2.3 Environmental problems

The ever-increasing consumption of wood in rural areas leads to serious environmental consequences which makes it hard to sustain the environment and support the people's needs (Kgathi and Mlotshwa 1997; Ishuzuka and Hisajima 1995). Deforestation is one of the major problems. There is much unsustainable dependence on forests for firewood in rural areas. People cut trees down for wood without replacing them. This causes destruction of the environment, because forests are badly damaged and then eliminated entirely, and large areas of topsoil are left exposed to rain and wind.

Erosion of the topsoil contributes to downstream flooding and accelerates the loss of the land's productivity because nutrients are not returned to the soil as they are washed away during flooding, therefore making the soil less fertile (Sekhwela 1997). This imbalance also affects people, as they are dependent on the soil for food and shelter. As the soil is depleted, it becomes difficult to grow food crops (Ishuzuka and Hisajima 1995).

With all these problems, the questions to ask is – what can be done to overcome the demand on access and limited availability of energy resources in rural areas, and also to introduce energy which is environmentally friendly and sustainable to rural communities? The solution could be to introduce renewable energy technologies which have the potential to supply rural communities with much needed energy (Anon 2003; Wentzel 2003; Hislop 1992;). This is because renewable energy sources can be renewed by natural processes and therefore their supply is endless, provide security and sustainability, which other sources of energy do not supply (Anon 2003; Wentzel 2003).

2.3 Grid electricity connection for rural areas as a solution to energy needs

Grid electrification is by far the most common method of providing energy for rural and urban people because it is envisaged that by providing rural communities with electricity, economic development and an improved standard of living for the people is achieved (Seeling-Hochmuth 2002). This means that rural electrification could be the answer to the rural energy needs.

In South Africa, the Reconstruction and Development Programme (RDP) targeted rural electrification as a most needed service not only for households but also for schools, clinics, shops and small farms (Seeling-Hochmuth 2002). The fact, is that over 1,8 million rural households will not be electrified or connected to the grid by 2010 (Seeling-Hochmuth 2002). Electricity distribution in South Africa is highly unequal, although it is said that electricity is being produced at a surplus and sold to other African countries. Electricity is mostly provided to urban areas, leaving the rural people with no option but to rely on more expensive and less convenient energy sources like LP gas and paraffin (Theron 1992). The reality is that rural electrification is a far-fetched dream for many rural communities.

One reason for this is that average rural incomes are very low and large numbers of people live below subsistence level (Foley 1990). According to Mapako (1997) most Zimbabwean rural households rely heavily on the sales of agricultural produce and livestock. These sales are mostly seasonal, making it difficult for the regular payments of service charges such as electricity bills. This results in low economic demand for electricity in rural areas.
Even if rural households do acquire electricity it is rarely used for cooking (Foley 1990).

The reason for this is that rural poor find it expensive to pay for electricity connections and to make monthly payments for electricity consumed, especially when it is used for cooking. In addition, appliances are still needed and are very expensive. Rural people still tend to use wood for cooking reserving electricity is for home lighting to lower monthly electricity payments (Foley 1990).

Heavy investment required for rural electrification is another major reason for many non-electrified rural areas. According to Samantha and Sundaram (1983) who looked at electrification in India, penetration of electrification in India has been hampered by the heavy investment needed. This meant that priority was given to larger areas located near powerlines and justified by the fact that the higher the number of consumers along any particular length of line, the lower the average costs per connection will tend to be and the lower the total investment needed. Rural areas are therefore, at a disadvantage because rural households are generally scattered, far away from main roads and sparsely spread over large areas. Because of this, most electricity utilities face difficulties on being able to cover the costs of electricity production and distribution and expect to obtain an adequate return on investments they have made (Mapako 1997; Samantha and Sundaram 1983). This lack of availability of grid electricity leaves rural people with few options, one of them being renewable energy.

2.4 Role of renewable energy

Solving the problem of energy generation, availability and distribution is central to economic development, especially in rural areas. Renewable energy can play a major role in providing rural people with the energy they need, is sustainable and can significantly reduce environmental problems (Anon 2003).

Renewable energy is ideal because it could be a less expensive option for the poor and can also help developed countries reduce the emission of greenhouse gases (Moreno 2002). An ideal renewable energy source is one which is locally available, affordable and can be easily used and managed by local communities.

Rural areas have large supplies of materials such as animal waste and crop residues which can be converted into usable energy sources. Other renewable sources that can be used are the sun, wind and water, but they cannot be converted to produce thermal energy (Anon 2003, Wentzel 2003). The challenge facing countries with an energy crisis is to adapt quickly enough to using renewable energy to reduce dependence on non-renewable and commercial energy sources which are not sustainable or too expensive for rural people (Rivett-Carnac 1982).

2.5 Biogas energy

One of the renewable energy sources that can relieve the energy shortage for rural people is biogas which uses cow dung, human, chicken and pig waste and also agricultural residues to produce domestic energy in the form of methane gas (Keyun 2001). Biogas is one of the alternative forms of energy that can be used to provide much needed energy in rural areas. Biogas can be a useful substitute for expensive electricity and other disadvantageous traditional sources of energy. Biogas can be used for lighting, refrigeration, water pumping, running small industrial tools and can be converted to produce electricity through a gas generator (TERI 1994).

2.5.1 Biogas formation

Biogas is a colourless combustible gas which is produced when organic matter contained in animal excrements like cow dung, agricultural residues (cassava, sugar cane) and human excreta are anaerobicaly fermented in air and water-tight containers called biogas digesters (Hislop 1992). The useful gas that is produced during the process of anaerobic fermentation (in the absence of air) is called methane gas with a chemical composition of one part carbon molecules and four parts hydrogen molecules (TERI 1994). The anaerobic fermentation process, also called methanogenesis, involves three stages (Lawbuary 2001; SANTAG 2001). All these stages take place in the biogas digester when it has been fed with the dung / human waste and water mixture. The first stage is called hydrolosis whereby the organic wastes, which contain carbohydrates (cellulose), fats, proteins and other trace inorganic materials, are broken down into simple soluble compounds by fermentative bacteria.

The second stage is called acidification. In this stage acid-producing bacteria convert the end products from stage one into acetic acid, hydrogen and carbon dioxide. Acetic acid is most important in methane formation as it accounts for approximately 70% of the methane produced. The final stage is methane formation. In the last stage hydrogen, carbon dioxide and acetic acid are decomposed by methanogenic bacteria to produce methane and carbon dioxide (Lawbuary 2001; SANTAG 2001). The gas produced is flammable and colourless and has no unpleasant smell. Approximately 60% methane and 40% carbon dioxide is produced with traces of other gases such as hydrogen, nitrogen and hydrogen sulphide produced (Smil and Knowland 1980).

Emerton (1997) and Smil & Knowland (1980) describes the floating dome biogas digester as having a hemispherical dome with a concrete floor constructed underground. This unit is constructed underground because of structural considerations (space), and to limit temperature fluctuations. The advantage of building the container underground is that better thermal insulation is achieved which reduces the cracking of the structure which could occur if it was built above ground where moisture and temperature change often (United Nations Environment Programme 1981). There is an inlet tube on one side and an outlet on the other. Cow dung and water is mixed in a mixing tank built around the top of the inlet tube with the inlet closed with a plug during the mixing process and afterwards removed to let in the mixture and then replaced. Toilets can be connected to the biogas digester so as to allow the human excreta to enter the digester directly.

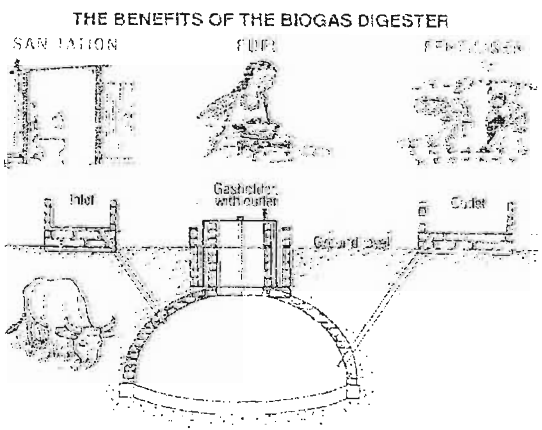

Figure 2.1: How the biogas system works and its benefits

The Watt Committee on Energy (1979) and Lawbuary (2001) say that for the digester to work, water should be mixed with cow dung in a proportion of 2:1. When properly mixed into a thick liquid, the mixture is fed down into the inlet pipe of the digester. The feeding is done daily. As the anaerobic digestion takes place in the underground structure, the gas generated puts the system under pressure. As the gas is lighter than the liquid contents of the digester, the gas rises to the top and collects in the steel gas holder drum which is then pushed upwards. The methane gas formed flows through a pipe and is fed into a gas stove in the household. A liquid residue is excreted out of the outlet pipe when the gas formation process is finished. The residue or effluent is used as fertiliser for crops.

Safety is important in the handling of biogas as it is combustible which has the danger of exploding. Proper insulation and replacement of worn out biogas digesters should be carried out when needed to avoid danger of gas pipes bursting (Karezeki and Ranja 1997). People should also be made aware of the dangers of tampering and misusing the gas pipes for their own safety.

2.6 Types of biogas digesters

2.6.1 The floating dome biogas digester

There are many kinds of biogas digesters available but only the two relevant to this will be explained here. The first is a floating dome / fixed pressure biogas system which comes in varying sizes. This kind of digester produces gas at a constant pressure and has the advantage of being able to also supply gas to a gas fridge or a gas generator. The floating dome biogas digester has a variable volume dependent on the amount of gas produced. This type of digester is constructed with a metal dome over a cylinder of bricks. In South Africa this type costs approximately R15 000 plus labour and is said to have a lifetime life expectancy (Solar Enginering Services 2001; SANTAG 2001).

2.6.2 The PVC plastic fixed volume biogas digester

The other type is a fixed volume digester which is made of PVC plastic. This digester produces gas that has variable pressure depending on the amount of gas being produced.

The fixed volume digester is cost effective as it costs less than R1 500 but is less durable than the floating dome digester, with a life expectancy of approximately four years when the plastic will need replacing (Solar Enginering Services 2001; SANTAG 2001).

2.7 Factors that may affect biogas production

2.7.1 Temperature

According to Lawbuary (2001) and Rivett-Carnac (1982) temperature at which the stages of biogas production take place is very important as they affect the process. The methanogenic bacteria, which help produce methane in the last stage are very sensitive to temperature changes. The optimum temperature needed for the methane generation process is between 33-38° Celsius. Below this temperature the anaerobic process is slowed and very little gas is produced while temperatures higher than recommended kill the bacteria, stopping gas production. It is important to ensure that proper insulation is installed in places where temperatures are very low or change often. That is why the structure is often built underground, where the earth acts as an insulator against temperature fluctuations.

2.7.2 Dung availability

Dung is the main ingredient in the whole process of biogas production as it produces methane gas most efficiently. Availability of dung usually depends on the number of cattle that a family owns. In many cases the more wealthy families in rural communities who maybe in less urgent need of biogas tend to have the most animals, while the poor have fewer or none. These discrepancies in cattle ownership do not help the situation of the poor, because if they do not have enough cows or access to cow dung to run a biogas digester then they cannot afford to have one (Yang 2001). Dung in communal land is regarded as free in some countries, but in other countries such as India, it is a form of income generation, meaning that dung is a saleable commodity. In Lesotho for example dung sale has been common practice, with almost 10% of household income being spent on the purchase of cow dung to be used as fuel, therefore meaning that people needing cow dung for digesters may also have to purchase the dung (Bembridge, Coleman and Lategan 1992). Cow dung is also used for floor cleaning and plastering in most rural areas.

In a study done by Bembridge et al (1992), they found that using dung for floor cleaning was the second most important use next to fuel. This may also contribute to a possible shortage of dung.

According to Barnard and Kristoferson (1985) access to dung also depends much on grazing practices. Where animals are kept entirely closed up in the kraal, all the dung is produced in the kraal which means the owner has control over the dung produced; but where animals are free grazed for all or part of the day, dung becomes public property and ownership of dung is difficult to prove. It is also much more difficult to collect as people have to move around looking for dung, and this implies more time spent on looking for fuel. Smil and Knowland (1980) give an approximation that a medium sized cow kept in a kraal can produce an average of 10kg dung per day which is much higher than when people have to go out and collect. However the quality and quantity of dung produced by the animal depends on the diet of the animal. Lawbuary (2001) mentions that due to climatic instability in other areas, the occurrence of drought may reduce dung availability as cows may defecate less or even die because of lack of grazing grass.

2.7.3 Water availability

Water has to be easily available as it is also one of the main ingredients in the biogas production process, both for cow dung and human waste. Moulik (1981) cited by Lawbuary (2001) says that water scarcity or difficulty in obtaining it may act as a constraint in the operation of the biogas digester in the rural environment. A biogas digester requires water and dung to be fed into it at a ratio of 2:1 in order for it to function properly and for a 9.4m^3 digester 50 litres of water to 25 kg of dung is needed every day (Solar Engineering Services 2001). This imposes a significantly higher daily water demand over domestic needs. In many rural areas water is carried by women from rivers that are mostly far from their homes and in valleys (TERI 1994). If a household has a biogas digester, then women have to make several trips carrying heavy containers of water for domestic use and for the biogas digester. This again places a burden on women which was supposed to be relieved by the introduction of biogas digesters. If there is difficulty in obtaining water, then the maintenance of a biogas digester may not be worthwhile.

For biogas digesters using human waste, water availability may not be a problem, as the digester should already be connected to flush toilets. Even if water use is limited in the toilet, that can be compensated for by urine.

2.7.4 Number of cows

Dung availability is dependent on the number of cows that a family owns. For the smallest family biogas digester, three or more cows are needed to provide the necessary quantity of dung to operate the digester (Karottki and Olesen 2001; Lawbuary 2001). Smil and Knowland (1980) also said that about three to four cows are needed to produce dung enough for gas needed by a family to cook three meals a day (about 1.4m³ per day). The biogas digester is not operationally viable if producing less than this. But the size of the family is omitted by all these authors.

Ishuzuka and Hisajima (1995) and Cortsen et al (2001) suggest that a household needs at least two mature cows to run a biogas digester to produce amounts of gas needed to be used by a family of six people. Barnard and Kristoferson (1985) confirm what has been said in a previous section, that the richer have more cows while the poor have fewer or none. Poor rural families are often able to raise a few goats, pigs and chickens (but not enough to run a biogas digester) but no cows as these are expensive to buy. This does not allow these families to have efficient biogas digesters in their households because in order for a biogas to provide enough gas for cooking for a family of six to eight people, they would need to have at least 27 pigs or 404 chickens (Emerton 1997). For the poor, this is not feasible and requires more resources than the poor can access. This means that biogas, which could benefit the poor, cannot serve them as they do not have the sufficient resources to run the biogas digesters.

2.7.5 Affordability

In rural areas of Indonesia, biogas has not been popular due to the expense of installing the biogas digester, which many people cannot afford. In Thailand, it was found that the cost of biogas digesters were beyond the purchasing powers of most rural households, who were used to wood that was available freely to them (Ishuzuka and Hisajima (1995).

In an evaluation on biogas digester systems that were installed in the villages of Tanzania, Cortsen et al (2001) found that out of thirty nine farmers who had biogas digesters installed, fewer than ten farmers had started paying for them two years after installation because of lack of financial resources. An additional conclusion drawn by Cortsen et al (2001) was that it was important for people to pay for the biogas digesters as they would value them as their own property. The solutions to non payment were to demand a deposit from the household before a biogas digester was installed and to establish an effective and financially sustainable credit system agreed upon with the people that would ensure payment for the biogas digesters. Providing biogas may seem to be the solution to the thermal energy limitations in rural areas, but whether rural people can afford to pay for the biogas digester systems is an important aspect to be investigated before dissemination of information and marketing could take place.

2.8 Community digesters

Most methane use and production in developing countries has generally been from domestic biogas digesters (Karezeki and Ranja 1997). A community biogas digester is different from the domestic biogas digester in that the resource requirements differ from the smaller family biogas digesters because of the large number of people they have to serve. The large scale biogas digesters can also be used to generate electricity by using biogas to run generators (Smil and Knowland 1980).

2.8.1 Problems with community digesters

Firstly the community digesters require a large supply of raw materials (water and cow dung). This might pose a problem in that the required amount of dung may not be easily available and may have to be carried from one place to another. This may lead to the digester constantly being underfed with dung, as was the case in community digesters in Punjab, India (Lawbuary 2001). In Punjab, the biogas digesters were underfed because not all families had equal access to raw materials and conflict arose about the sharing of the gas produced (Lawbuary 2001). This may not be the case if the digester is connected to toilets to supply additional input materials.

Another problem that may be encountered with a large scale biogas digester is that of the need of higher managerial and technical skills for operation (Lawbuary 2001). In a biogas project in Punjab, India half of the beneficiaries of seven biogas plants were randomly selected after the biogas were operational for one year (Singh 1988, cited in Lawbuary 2001). It was discovered that social, technical and economical problems were encountered. The biogas digesters were underfed with cow dung due to incorrect division of labour, and to low pay which did not compensate for the work done by the people on the biogas plants. Two plants were not operational and there was also competition for dung with those people who used it for fuel. It became evident that the community digesters would need a person who would monitor and manage the biogas digester on site as it might be vandalised. Feeding the digester may also have to be done by one person to counter conflict caused by division of labour whereby other people may not carry out their duties properly like misfeeding the digester (Lawbuary 2001). National Academy of Sciences (1977) says that the problem of limited skills may be overcome by devoting time to training community members on managing the biogas digesters.

2.9 Human excreta for biogas generation

Human excreta has been mentioned in above sections as a material which can also be used to produce biogas. According to Srivastava (2002) and The National Academy of Sciences (1977) human excreta and urine has the potential to produce biogas as it contains much the same materials as cow dung. Human excreta does not require additional water to achieve optimum conditions for biogas production as it is already mixed with urine and flushed water. Litchman (1983) cited in Lawbuary (2001) says that installation of biogas digesters can function as a waste disposal system for human waste, and can therefore prevent potential sources of environmental contamination and the spread of pathogens. Although human excreta input into biogas digesters benefits people by producing much-needed energy, it may have negative connotations as a substance that is dirty and not supposed to be reused once it has been disposed of. This may influence perceptions regarding the process of biogas production (Srivastava 2002).

2.9.1 Negative perceptions towards human excreta

Cultural practices may hinder the adoption of biogas digesters using human excreta by the people. Almost all people share similar values on defecation. According to Srivastava (2002) people want to avoid contact with human excreta as much as possible, as it is regarded as dirty and unhygienic. In some societies people use the left hand to cleanse the act of defecation, and the 'dirty' left hand is regarded as unhygienic and never used for eating or shaking hands, regardless of how well it is washed. These perceptions have made biogas produced from human excreta unacceptable. But these perceptions seem to have different impacts for different reasons. From observations by workers on one biogas project in India, (Srivastava 2002) high rates of illiteracy among the non users was present, meaning they lacked knowledge and were stereotyped. Secondly for those who did accept the biogas, it was never used as cooking fuel but only for lighting and electricity generation and lastly urban users were found to be more accepting of the gas than their rural counterparts.

2.9.2 Health issues

Human excreta, in its normal form contains a number pathogens which cause diseases like cholera, typhoid and gastroenteritis. These diseases are easily transmitted if human excreta is not properly disposed of. The presence of pathogens may affect the fertiliser (effluent) but not the methane gas as the gas has few negative consequences for health (United Nations Environment Programme 1981). For the fertiliser to be used on crops, certain requirements have to be met: no schistosoma eggs or hookworms should be found in the manure; roundworm eggs should be reduced by 95% or more; E Coli should not be more than 10^{-3}, and mosquitoes and flies breeding in the fertiliser should be prevented (United Nations Environment Programme 1981).

In a study done in India on biogas digesters using human excreta, pathogen inactivation can be achieved when a temperature of 55-60° Celsius is used, but with anaerobic digestion the temperatures are very low and never reach the mentioned level of temperature meaning that the pathogens were not inactivated Srivastava 2002). Sun drying for two to three weeks of the fertiliser removes all of the pathogens as the temperature is much higher (Reed and Shaw 2003; Srivastava 2002;)

2.10 Human excreta biogas digesters

Rivett-Carnac (1982) says that in China, public flush toilets are connected to biogas digesters wherever possible. In India, Sulabh, an NGO working to make the social conditions of people better has been working on installing biogas digesters using human excreta for the last twenty years (Srivastava 2002). In the last few years the NGO has been working with almost 4 600 public toilets and installing biogas digesters Nepal has also taken to using human excreta for biogas generation. In a village called Jantemod, public toilets have been connected to biogas digesters and the gas generated is used for lighting inside and outside the toilets for safer public use. At a later stage the aim is to provide nearby houses with the gas. A watch man who works in the site uses some of the fertiliser in his garden (Karki and Gautam 2000). This reflects a growing trend to using human excreta for biogas generation.

2.11 Benefits of biogas

Biogas energy brings many benefits to rural communities, especially for women who are more involved in the chores of the household. Some of these benefits, in addition to saving fuelwood mentioned earlier, are easy availability of gas for cooking, health improvement, good crop fertiliser and relief of burden to women.

2.11.1 Biogas for cooking

Biogas can provide an alternative to wood and other conventional energies for cooking. When operated properly, biogas digesters can provide much more efficient and effective fuel for cooking than traditional wood fires (TERI 1994). Biogas, as a cooking fuel is cheap and convenient as it is available right in the kitchen with a flick of a switch (TERI 1994). It is also convenient as cow dung to run the biogas digester is available on the property most of the time when cows are kraaled at night for ease of collection the next day, and even if people have to collect dung, it is seldom as far away as they would have to go to collect wood.

With the heat produced by methane, a 2 m^3 biogas plant could replace the "fuel equivalent of 26kg of LP gas which is nearly two standard cylinders or 37 litres of kerosene (paraffin) or 88kg of coal and even 210kg of firewood every month" (Karottki and Olesen 2001). Availability of biogas makes it easier for women to cook their family meals in time and with less effort and in much less time than when cooking with firewood (Karottki and Olesen 2001).

2.11.2 Crop fertiliser

Another end product besides the gas produced in the process of anaerobic fermentation, is a watery residue which is a good fertiliser for crops. King and Cleveland (1980) say that the fertiliser obtained from the biogas process is richer in the nutrients needed for plant growth than that obtained from conventional composting, or using cow dung in its normal form. If the effluent is used in its effluent watery form, it contains about 0.08 nitrogen, 0.06 phosphorus, 0.10 potassium and humic acid. The values are higher if the effluent is left to dry. All these nutrients are absorbed by plants, therefore enhancing soil moisture and fertility. It is also free from pathogens and parasites such as schistosoma eggs, roundworm, mosquitos and flies normally found in cow dung that could affect crops (US Department of Energy 2003; United Nations Environment Programme 1981).

Karottki and Olesen (2001) say that people in Nepal and India have gained more enthusiasm in their garden patches because of the top quality fertiliser from the biogas that guarantees better crops. In India, biogas fertiliser has been shown to give up to 17% higher yield of wheat than the equivalent weight of ordinary compost. This could be attributed to the high content of active nutrients in biogas fertiliser (Karottki and Olesen 2001).

2.11.3 Income generation through biogas

Income generation could be one of the biggest benefits that biogas can offer to rural communities. Biogas may not directly generate income, but it supports opportunities for income generation. In a study done by Keyun (2001) in China, it was found that the biogas system called the 'four-in-one' had many benefits for households. The four-in-one model included a greenhouse, a pigsty or hen house and a biogas digester all in one yard.

This set of buildings combined biogas production from pig or hen manure, supported poultry or pig breeding, fertiliser collection and subsequent sales from improved vegetable and fruit production, all from the yard. These four activities relied on and promoted each other and they all contributed to income generation in the household as the household sold fruits, vegetables, meat and the fertiliser. These income-generating activities were mostly carried out by women which helped them increase the economy for their families.

2.11.4 Time for women

As it has been said in above sections, women spend much of their time in a day collecting firewood for cooking. This leaves them with little time for themselves and also no time to carry out other activities such as income generating activities. The introduction of biogas in a household means that women will spend less time collecting firewood and have more time to do other important things (Lauridsen 1998; Rivett-Carnac 1982). In Tanzania firewood collection and requirements have been reduced by up to 50-70%, leaving women with more free time to engage in other social activities (Cortsen et al 2001). In Nepal, the introduction of biogas has given women a sense of self worth and time to engage in more activities outside the home. Biogas plays a major role in the lives of women as free energy and time is used for the benefit of the whole household (Anon 2001a). In a study done in Tanzania to evaluate the impact of biogas on women, one woman reported that she used to spend seven hours a week on wood collection before she had biogas but now she does not collect wood anymore and she used to spend five hours per day cooking on fire but the time has been reduced to three hours with the biogas (Lauridsen 1998). The above evidence shows that biogas does release women from the drudgery of wood collection and leaves them with time to do other things.

2.12 Gender and energy

Women in developing countries, especially in rural areas are fully involved in all aspects of social and economic life. They do most of the farming, planting and harvesting, they fetch water and wood, walking long distances and also cook and look after the whole family (Ahmed 1985). This results in very low personal energy levels in women and reports of constant tiredness.

In studies done in countries like China and Vietnam, it was found that gender played a big role in the division of labour in the household (Rijssenbeek 2002c). Women usually worked the longest hours and did most of the physically demanding work around the household. Rukato (2002) defines gender differences as the basis for designing "certain tasks, rights and responsibilities along sexual lines." When one considers the multitude of tasks that women perform and the limited tools they use in performing these tasks, it is obvious that the introduction of appropriate energy technologies holds the promise of considerable benefits to women, which will eventually also benefit their families. Energy is critical in the daily lives of women, especially in the rural areas where access to energy is difficult.

According to Clancy (2002) perceptions of women and men differ very much when it comes to the benefits of energy, whether it is renewable energy or conventional energy and this can be attributed to gender differences. Barnett (2000) cited in Clancy (2002) says that men mention leisure and quality of life as the important benefits that electricity brings along whereas women see electricity as reducing their workloads, saving on expenditure and improvement of household health. Generally men would prefer to purchase recreational appliances first before buying appliances which would help women in their everyday household chores (Rukato 2002). The above statement shows that men do not view energy as important for the reduction of labour to women but as something that supports luxury. For women, social benefits are also important because gender makes women feel like second class citizens, but with access to television and radio they report higher levels of self-esteem (Barnett 2000 cited in Clancy 2002)

However, access to credit and loans are essential for women to have access to renewable energy technologies. Without any form of capital, women cannot afford to purchase technology, which would be of benefit to them and their families. According to Everts (1998) improved technologies, (including energy), that are economically appropriate, in the sense that they (the technologies) pay back their costs, are often inaccessible to women because they lack the capital to buy the technologies. The major reason for lack of capital for women for is that the capital in the households mostly lies in the hands of men who do not understand the plight of women (Everts 1998). Men also manage ordinary credit programmes. The situation could be different in female headed households.

Rukato (2002) says that in these households, the male roles are taken over by the female and she makes all the decisions including those of a capital nature in the household. But female-headed households are usually found in poor communities where their income is even lower than that of male headed households (Rukato 2002). Therefore, supportive financing mechanisms and better energy resources are essential if women are to be released from the burden of using firewood and other types of energies.

2.13 Extent of biogas use in other countries

India has been the pioneer of biogas since the first plant for methane generation was set up in 1900 using waste. Unfortunately this case did not mention what kind of waste (Smil and Knowland 1980). In the 1930's scientists in India began research on the anaerobic digestion of cow dung. Their objective was to produce methane as a source of fuel at the same time retaining and improving qualities of the residual substances after the process as crop fertiliser. After extensive research, biogas digesters were designed for family and village use which were acceptable for cooking and lighting. Since experiments began in India, many thousands of biogas digesters have been built in that country – most of them in rural areas serving from one to several families at a time. Karottki and Olesen (2001) say that India is one of the countries that has adopted the use of biogas at a great rate and success, with more than 5.25 million biogas plants having been built so far. This has been made possible by the support from government by subsidies. This kind of technology has now expanded rapidly in other developing countries (Karottki and Olesen 2001).

In Pakistan the biogas technology project started in 1974 and in 1990 the Pakistan government had commissioned 4550 biogas units which provided for lighting and cooking (Anwer 2001). The biogas programme was carried out in three stages. In the first phase the government provided the first 100 biogas plants on a grant as they were demonstration units. In the second phase the beneficiaries and the government shared the cost of the biogas digesters. In the last phase, the government pulled out with financial support but carried on to providing technical support to beneficiaries. The withdrawal of government's financial support put a stop to the programme because people said they could not afford the digesters on their own. In Pakistan, the potential for biogas technology is still large as Pakistan is agriculture based, producing enough cow dung to run biogas digesters.

At present, cow dung is used as a source of fuel in its dry form (Anwer 2001). Another country that has adopted the use of biogas as source of energy is Nepal. In January 1999, there were 49 500 biogas digesters in operation and 39 certified companies installing biogas digesters (Devkota 1999). By 2003, the Nepalese government has envisaged the installation of another 100 000 biogas plants through a programme called the Biogas Support Programme which will provide some form of financial support (Devkota 1999).

The evidence above shows that biogas has the potential to provide people with energy, provided there is some form of financial support available, especially from the government.

2.14 Government and renewable energy

Government support is one of the critical factors in any development initiative including that of renewable energies. Good policies, subsidies, loans and technical support could be some of the actions that governments can take to provide full support for the dissemination of renewable energy technologies.

2.14.1 Government policy

In order for renewable energy projects and development to be less expensive and difficult to manage, favourable policy at all government levels is important. A clear national policy that supports the renewable energy development for rural energy needs is needed, with governments realising that compared to grid electricity, renewable energy can be cost effective in providing energy to rural communities (Anon 2001a).

According to Karezeki and Ranja (1997) it has been evident from experience that the introduction and success of any renewable energy technology is to a large extent dependent on government policy on energy. Government policy can create an enabling environment for renewable energy technology dissemination and encouraging private sector investment. But in some governments participation and interest in renewable technology has not been persuasive enough, has fluctuated and been erratic while in some countries government has contributed much in terms of policy formulation.

An example is that of the Nepalese government whereby policy regarding the development of renewable energy, including biogas has been criticised for inconsistency and irregularity (Devkota 1999). For the past two decades Nepal government has provided support through subsidies and loans for biogas installation on an irregular basis. High interest rates were being charged on loans, which were in fact too high for poor people for whom the biogas was intended. This was attributed to the lack of a clear-cut policy. The lack of support from government could also be attributed to lack of understanding about problems of energy acquisition faced by poor people.

Nepalese organisations involved with biogas have hoped for better circumstances because in the last two years the Nepalese government has pledged its support for the implementation of biogas support programmes and also committed itself to developing an institutional setup for the development of renewable energies including biogas (Devkota 1999).

In Zambia, the government has provided an enabling environment for renewable energies. The Zambian government responded to the crisis in conventional energy shortage by outlining renewable energy policy proposals in its development plans (Karezeki and Ranja 1997). This plan was envisaged to develop alternative forms of energy, including biogas as partial substitutes for conventional energy sources. To carry out the plan, research and development programmes of various renewable energies were targeted in the plan. A number of responsible councils were formed to be in charge of implementation programmes. On implementation of these programmes they proved fruitful for the people as the energy shortage was alleviated (Karezeki and Ranja 1997). Government involvement in renewable energy technology is of great importance and it should be mobilised and encouraged for renewable energy to play its role in the lives of people.

2.14.2 South African government's involvement

The Constitution of SA (Act No. 108 of 1996) clearly states that "energy should be made available and affordable to all citizens, irrespective of geographic location and the production and distribution of energy should be sustainable and lead to an improvement in the standard of living of citizens (Department of Minerals and Energy 2002, p15)."

The South African government realises this and has taken a firm stand on the support of renewable energies by clearly stating the importance and benefits of renewable energy in the white paper on The Promotion of Renewable Energy and Clean energy (Department of Minerals and Energy 2002). In the paper it is clearly stated that renewable energies have a major role to play in promoting sustainable development.

The government realises the negative impacts that some of the fuels used have on the environment and the people (in terms of affordability and accessibility) which is why one of the government's objectives in the policy is to reduce dependence on the use of wood and dung for domestic fuel. Not only does South Africa have abundant sources of renewable energies, but also they are lower in maintenance and operation costs compared to the existing fuels (Department of Minerals and Energy 2002).

Biogas has been mentioned in the policy as having the potential to provide energy. Biogas is rarely mentioned except that manure from cattle, pigs and chickens could be used to generate methane gas. In the policy it is said that assessments need to be carried out in order to find whether biogas can be given the status of being an Independent Power Producer (IPP) which means that the national grid can be fed with electricity from biogas bought by electricity distributors.

Although renewable energies have an important role to play, barriers exist in the implementation of programmes as reported in the policy. One of those barriers is that renewable energies are expensive because of fairly high capital costs and investment. Also there is lack of awareness among people of the benefits and opportunities of renewable energy. This may be overcome though establishment of appropriate legal and financial support, enabling environment and capacity building for the people to realise the benefits and opportunities of renewable energies (Department of Minerals and Energy 2002).

2.15 Summary

This review has looked at some of the important aspects of biogas digesters producing energy for the people. The needs of rural people in terms of energy has been discussed in order to understand the extent of the energy problem, thereafter discussing traditional energy and electricity that are used by people and its disadvantages which will outline the crucial need of biogas renewable energy. From the discussion of these above issues the importance of providing people with energy resource that is reliable, affordable and efficient was highlighted. Renewable energies, especially biogas which is the main focus of this overview was also discussed, with all its benefits and disadvantages outlined and the different ways that some of the problems can be overcome. Gender in energy has been looked at in terms of the roles that it played in energy acquisition. Government support in terms of a sound policy is essential for proper dissemination and management of renewable energy.

CHAPTER 3
DESCRIPTION OF THE STUDY AREA

Maphephetheni is a rural village situated approximately 80km west of Durban in the Valley of a Thousand Hills (see Figure 3.1 area 2). The village has two sections, the lowlands and the uplands and these two sections are further divided into eight wards. There is a dam called Inanda dam and Umgeni river, which feeds into the dam. The western and northern boundaries are formed by the Umgeni river and Mqeku river and the southern boundary by the dam. The Eastern boundary is formed by high cliffs of Pisweni and Matata mountains. Maphephetheni is very mountainous and is sparsely populated, with dirt roads that are poorly maintained (Dube 2002). The area is covered with alien plant called chromaleana that kills much of the grazing land.

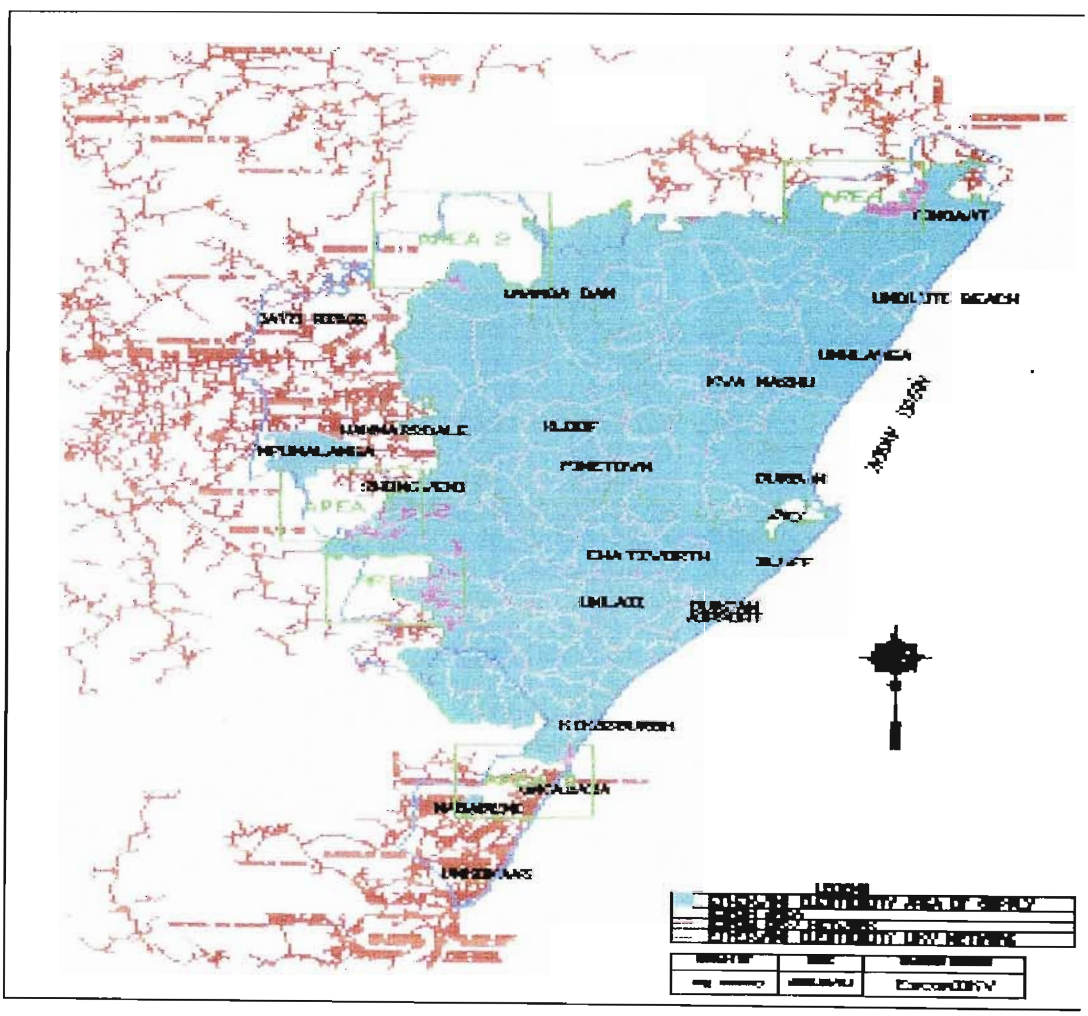

Figure 3.1: Maphephetheni map with electrical grid lines in red

Maphephetheni has an estimated population of around 8 000 people with an average of eight members per household. A monthly income of R1 300 was found to be the average for households (Green and Erskine 1998). In a survey done in 2003, it was found that the income in Maphephetheni was now reduced by R300 per month (Ndokweni and Green 2003). The Maphephetheni community is stable as not much migration into and out of the area happened.

There are three high schools that go up to grade 12, one in the uplands that goes to grade ten, 11 primary schools, numerous creches and a number of churches. Some households close to the Umgeni water pipes have on site taps in their yards, while the rest access potable water from about 29 Umgeni standpipes around the area. About 15 shops selling a variety of goods are available with a number of spaza shops. Two clinics have been built, but they operate fortnightly with mobile clinics as there is no electricity yet to store vaccines. The courthouse serves as a community hall and pension payout point. There are no other formal buildings which could support technology (Green and Erskine 1998). The situation is still the same in terms of formal buildings (Researcher observation).

There are a number of renewable energy technologies available in the area. One floating dome biogas digester installed in one household, one plastic biogas digester in one household but not functional and a school which provide thermal and electrical energy. There are six treadle pumps and one ram pump that provide water for crops in community gardens. Four solar cookers are used by households for cooking. Ten solar dryers used for preserving food by means of drying are found in community gardens. PV solar panels on 32 homes and a high school provide electricity. Three solar telephones that use pre-paid cards are available (Green 2002).

In Maphephetheni, a mixture of energy resources are used for thermal, lighting, space-heating needs by the majority of households. Wood is the most popular source of thermal energy and space heating in Maphephetheni, followed by paraffin for thermal energy (see Table 3.1) (Green 2002; Green and Erskine 1998). In Maphephetheni collection of firewood takes place 2.4 times a week and it is the women who collect wood. Gas and cow dung are also used for thermal energy.

Candles and Solar Home Systems (SHS) are used for lighting. SHS, dry battery, car battery, petrol generators and gas generators are also used for running appliances, particularly radios and television sets (Green 2002).

Table 3.1: Energy use and average monthly expenditure in Maphephetheni households (Green and Erskine 1998).

Fuel type	Percentage of families	Resource cost (rands/monthly)	Transport cost (rands/monthly)	Combined cost (rands/monthly)
Candles	81.5	21.56	2.27	23.83
Wood	76.0	2.19	0.00	2.19
Paraffin	50.5	31.43	5.81	37.24
Car battery	30.5	17.84	13.34	31.18
Dry battery	22.0	16.33	1.46	17.79
Gas	15.5	83.28	34.15	117.43
Gas generator	14.0	98.14	34.11	132.25
Dung	11.5	1.30	0.00	1.30
SHS	10.5	78.10	0.00	78.10
Charcoal	6.5	9.85	4.67	14.52
Petrol generator	3.0	141.67	50.05	101.72

Maphephetheni was selected as the study area because it was a rural community that was not going to be connected to grid electricity for at least the next five years. Figure 3.1 shows the extent of the electrical grid. Because of the sparseness of the population and the hilly nature of the terrain, the area is isolated from general grid related activities. Also from the results of the 1998 survey (Green and Esrkine 1998) the greatest energy need for Maphephetheni was found to be an alternative method of cooking to reduce reliance on wood and its collection.

CHAPTER 4
DUBE CASE STUDY

The aim of this study was to investigate the acceptance, impact, affordability and feasibility of a biogas digester in providing a household with energy for cooking. To carry out the case study, one household was selected from a remote area of Maphephetheni and an inexpensive plastic fixed volume biogas digester was installed. The household investigated was from the population of upper Maphephetheni village. The household was selected because the head of the household was an Induna and an influential man in the area.

4.1 Methodology

The household was selected for the biogas installation pilot project because it had three cows and easy access to water, which were the requirements for a biogas digester. Water and cow dung were the main requirements for a biogas digester to function properly (Solar Engineering Services 2001). To carry out this qualitative study, structured interviews, informal interviews and observations during regular visits were to be used which would allow for direct participation of the respondents in the study. The interviews were to be used because with them information was gathered through oral questioning and written responses. The questionnaires were specifically designed for this study. Interviews can also be designed to measure variables as simple as demographic characteristics or as complex as attitudes, preferences and lifestyle patterns and they are also a more accurate way to collect information because of the face to face involvement of the researcher and the subject (Alreck & Settle 1995; Sarantakos 1993).

Through convenience sampling two other households in close proximity and with similar housing conditions as the household with the biogas were selected to act as controls. Similar housing conditions meant choosing a household with the same number of buildings and condition of the buildings as that of the case study household. They were interviewed using the same questions as the case study household. They were selected so as to compare results of the study after biogas monitoring and see whether changes were significant in terms of the impact and feasibility of the biogas digester for energy provision.

Base line data from the selected household and the two control households before the installation of biogas was collected. This included household demographics, household income, agricultural activities, cooking habits, household responsibilities including wood collection, income generating activities, and fuel expenditure were collected. This information was collected so as to monitor any changes in the variables outlined above that would influence the results of the study. Because women were regarded as the people responsible for most of the tasks outlined above, the women responsible for cooking in each household were interviewed.

4.2 Household description

Table 4.1: Household demographics in Maphephetheni uplands

	Dube Household	Control A	Control B
Household size	9	7	6
Number of adults employed	1	None	None
Number and type of animals owned	3 cows, few chickens	6 chickens	None
Type of garden	Household and community garden	Community garden	Community garden
Water source	Communal standpipe	River	River
Fuel source for cooking	Wood, LP gas and paraffin	Wood	Wood and paraffin
Income	Not given (formal pension)	None	R170
Head of household's age	68 (man)	37 (woman)	45 (woman)
Cooking times	Morning, midday and afternoon	Morning and midday	Morning and afternoon

Table 4.1 above describes the Dube household and the two controls chosen for the study. Income was not only in terms of wages or salary from work but also from pensions, child grants and any type of income coming into the household monthly. In the Dube household, the head of the household was working casually as he had since retired from his formal job but the wife did not know how much he earned. In control A no one was working and income from control B was from a child grant (R120) and from selling sewing which was very irregular (R50). The Dube household sometimes cooked only in the morning and midday, eating what was left during midday for the afternoon. Control A and ate what was left from midday meal in the evening. Control B cooked in the morning and afternoon.

A 5m³ biogas digester made of plastic was installed in the household garden which was below the household. It had a fixed volume and produced gas at a variable pressure. This biogas digester was more cost effective as it cost R1500 compared to the other prototype which was the floating dome digester which cost R15 000. The digester had an inlet and outlet pipe surrounded with a brick structure and a strong plastic bag where the gas was produced. Gas was led by a pipe to a gas holder plastic bag, placed in a hole that was to be covered, above the household dwelling. The plastic gas holder would need replacing every four to five years.

Figure 4.1: The Plastic biogas digester

The inexpensive plastic tube fixed volume biogas digester was installed in June 2001 by Solar Engineering Services working together with the household's members. The household members helped to build the inlet container which is at the top of the digester and the outlet hole which is at the bottom of the digester and were instructed to feed the digester with cow dung and water daily.

4.3 Results and discussion

The aim of conducting this study was to investigate the acceptability, impact and feasibility of biogas digesters in Maphephetheni. The results presented below are for the inexpensive fixed volume plastic biogas digester.

4.3.1 Results and discussion to subproblem one

Does the inexpensive fixed volume plastic biogas digester have the potential to provide a household with energy that is an acceptable, affordable, efficient and sustainable alternative to existing forms of energy and also increase opportunities from income generation?

The biogas digester was commissioned after starting to produce gas which at the time was not connected to any equipment in the household as the biogas digester was still being primed. Within the commissioning process problems started to occur. Because of pressure build up in the digester because of too much methane produced and not being used the system developed a gas leak. The methane gas produced was collected in a strong gas holder plastic bag, which, even after clear instructions from the engineer to cover the hole so that nothing gets inside, was not covered. Thereafter a cow fell into the hole and damaged the integrity of the storage bag. Also the household members who were responsible for the digester were old people (the husband was 68 years and the wife was 67 years) and did not understand or follow the instructions given (in English) on how to feed cow dung in the digester and they fed the digester with water only instead of water and cow dung. They also did not follow the instructions on how to build the inlet and the outlet holes. They were told to build the inlet hole higher than the outlet hole but they built them at the same height. All these problems were documented during the five visits which took place while the biogas was being built and commissioned.

4.4 Conclusions

Because of the problems experienced, the subproblem "Does the inexpensive tubular plastic biogas digester have the potential to provide a household with energy that will provide acceptable, affordable, efficient and sustainable alternative energy to existing forms of energy and also increase opportunities for income generation?" was never tested. But it can be concluded that language and age of the beneficiaries seem to diminish understanding of instructions. Using labour that was not experienced in building biogas digesters may have also had an impact on the failure of the biogas digester. The Dube household had never seen or built a biogas digester before. Also the plastic chosen for the biogas was not durable enough because it developed leaks early in the commissioning process.

CHAPTER 5
GWALA CASE STUDY

Biogas is said to be able to provide households with gas that can be used for cooking, lighting, refrigeration and electricity generation. This study was undertaken to investigate the acceptability, impact, affordability and feasibility of a domestic biogas digester called the floating dome digester in a rural household in lower Maphephetheni that was used for cooking. This chapter presents the research methodology used, the description of the households, analysis of the results and the conclusions drawn from the obtained results. The household investigated was from the lowlands section of Maphephetheni village.

5.1 Methodology

The household was selected to test the acceptability, feasibility and impact of the floating dome prototype of a biogas digester. The head of the household was an Induna which meant he was an influential person in the area and the company installing the biogas had worked with the household before. This made the household the ideal place to pilot the project. Water and cow dung were the main requirements for a biogas digester to function properly and this household had four cows which were enough for the production of biogas and had easy access to water from a tap in the yard. The household was also doing water harvesting which was collecting water from the rain by a gutter on the roof and the gutter fed the water into a drum (Solar Engineering Services 2001).

To carry out this qualitative study, structured interviews, informal interviews and observations during regular visits were used which would allow for direct participation of the respondents in the study. The interviews were used because information could be gathered through oral questioning and written responses. The questionnaires were designed for this study. Interviews can also be designed to measure variables as simple as demographic characteristics or as complex as attitudes, preferences and lifestyle patterns and they are also a more accurate way to collect information because of the face to face involvement of the researcher and the subject (Alreck & Settle 1995; Sarantakos 1993).

Convenience sampling was conducted to select two other households without biogas digesters which were in close proximity to the case study and a similar number of buildings in the same conditions. They were interviewed using the same questionnaire as for collecting base line data for the case studies. This was done so as to compare results of the study after biogas monitoring and see whether the changes were significant in terms of the impact of biogas in the case study.

Base line data from the selected households before the installation of biogas was collected. This included household demographics, household income, agricultural activities, cooking habits, household responsibilities including wood collection, income generating activities, and fuel expenditure were collected. This information was collected so as to monitor any changes in the variables outlined above that would influence the results of the study. Because women were regarded as the people responsible for most of the tasks outlined above, the women responsible for cooking in each household were interviewed. Time series data as above, excluding demographics was collected over one year and information about changes in lifestyle in the household and the role played by biogas as seen by household members was also collected.

In the Gwala household, a 12.5m^3 biogas digester called a floating dome/fixed pressure biogas digester was installed. The biogas digester was later connected to a flush toilet. This biogas digester produces a constant gas pressure and has the advantage of being able to supply gas to a fridge or a gas generator. But in this case it only provided gas for cooking because the household did not have a gas fridge and could not afford to buy one. The biogas digester was built using local labour with the idea that when other community members wanted to copy the digester, there was a team available to do this.

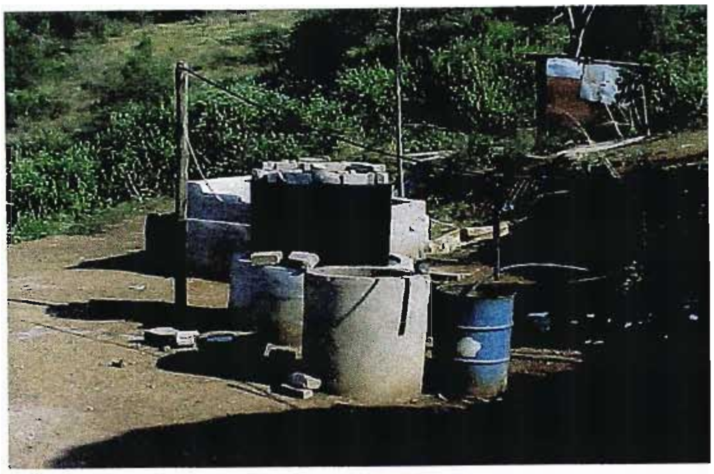

Figure 5.1: The floating dome biogas digester at Gwala household

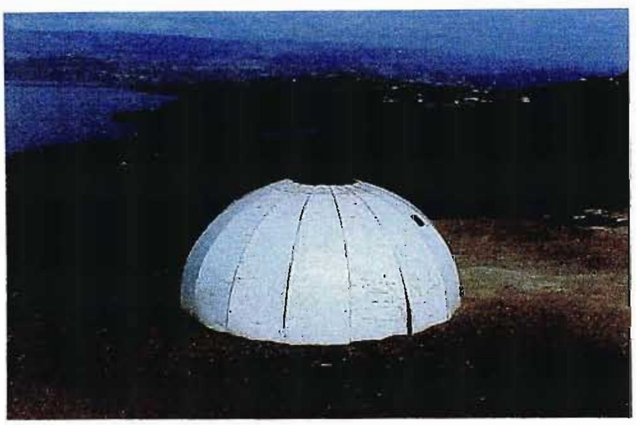

Figure 5.2: The hemispherical shape used for the underground storage tank

This type of digester is constructed with bricks and in 2001 it cost approximately R15 000 including labour. This floating dome biogas digester had a hemispherical storage tank with a concrete floor constructed underground where the biogas formation processes happen. An inlet hole on the right side of the digester where the water and dung mixture is mixed and enters. An outlet hole on the left side is where the fertiliser comes out. Both inlet and outlet structures are built with bricks. The biogas digester was fed every morning with 10 litres of cow dung collected from the household kraal and 20 litres of water. The fertiliser was collected in large containers on the other side. Building of the digester started in July 2000 and the biogas digester was commissioned in November 2000. Fortnightly monitoring and evaluation of the biogas digester started in March 2001 and ended in August 2001. Afterwards, monthly visits were carried ending in February 2002.

Table 5.1: Visits to the Gwala household

Date of visit	Feeding of digester	Gas production	Women's activities	Problems encountered
March 2001	Biogas digester fed correctly with two ten litre containers of water and two five containers of cow dung	Average dome height	The daughter-in-law was still selling vetkoeks and fish at a nearby school	Gas was getting finished before food was properly cooked. Dung taking longer to go down the inlet hole
April 2001	Fed correctly	Maximum dome height showing excellent gas production	The women were busy with household chore	They would like to have a gas fridge to be connected to the biogas but they cannot afford it.
May 2001	Fed correctly	Maximum dome height	Sitting at home	None
June 2001	Fed correctly	Maximum dome height	They were working in their community garden	Watery fertiliser not coming out of the outlet but cow dung coming out.
July 2001	Fed correctly	Average dome height	Daughter-in-law was working in community garden and the older lady was child minding	None
August 2001	Fed correctly	Maximum	Sitting at home	None
September 2001	Biogas was not fed with cow dung for two weeks	Gas production was maximum	The old lady was sick and the head of hhs had found a temporary job	No problems
October 2001	Fed correctly	Minimum dome height showing very little gas production	The women were peeling carrots harvested from household garden	There was little gas produced. They cooked on fire. This was because the digester was not fed for previous 2 weeks
November 2001	Fed correctly	Average dome height	Daughter-in-law was in church and old lady was child minding	None
December 2001	Fed correctly	Maximum dome height	Daughter-in-law was washing clothes, old lady was harvesting mealies from hhs garden	None
January 2002	Fed correctly	Maximum dome height	The women were chatting to visitors	None
February 2002	Fed correctly	Maximum dome height	Old lady was sitting with grandchildren, daughter-in-law was in town	Too much fertiliser collected, they do not know what to do with it

During the monitoring and evaluation process, the household was asked questions pertaining to the functioning of the biogas digester and their perceptions of the technology. The researcher checked whether the biogas was working properly, what the women in the household were doing and found out from the household members whether they were experiencing any problems with the biogas system and their perceptions of the technology (see Table 5.1). The interviewees, who were women, were also encouraged by the researcher to use the biogas for income generation during the visits.

5.2 Household descriptions

Table 5.2: Household demographics in Maphephetheni lowlands

	Gwala household	**Control A**	**Control B**
Household size	9	8	5
Number of adults employed	1	1	1
Number and type of animals owned	4 cows, 4 chickens	2 cows, 7 goats and 12 chickens	None
Type of garden	Community and household	Household garden	Household garden
Water source	Tap in yard	Tap in yard	Tap in yard
Fuel source for cooking	Wood and paraffin	Wood, electricity, LP gas and paraffin	Electricity, wood and paraffin
Total income	R620	Not known	R820
Head of household age and gender	43 (male)	45 (male)	51 (male)
Cooking times	Morning and midday	Morning and midday	Morning and midday

In Table 5.1 the description of the three households is given. The interviewees in control A could not give the amount earned by the person working in their household as they did not know or it was taken as confidential. The income given for the Gwala household was for a pensioner. There were two younger women working casually in the household but their income was not included as the interviewees did not know how much they earned. Control household B total income was from a disability grant (R620) and wages (R200) from the person working. All three households cooked midday and ate the food again in the late afternoon. Only control B was involved in an income generating activity, as they owned a tuckshop.

5.3 Results and discussion

The aim of conducting this study was to investigate the acceptability, impact and feasibility of biogas digesters in rural Maphephetheni. Data pertaining to the subproblem will be presented together with the discussion of the results and conclusions will be drawn. The results presented below are for the floating dome biogas digester installed in the Gwala household.

5.4.1 Results and discussion to subproblem number two

Does the floating dome biogas digester have the potential to provide households with energy that will provide an acceptable, affordable, efficient and sustainable alternative to existing forms of energy and also increase opportunities for income generation?

Acceptability of biogas to the people would ensure that they continue to use the biogas system in the future. On the acceptability of the biogas digester to the people, the household members interviewed said they had no problem using the biogas digester. This response was maintained after the biogas digester was connected to the household toilet. They said they were told by the engineer and understood that what went into the biogas digester would not affect the flavour, the taste or colour of the food. The household found that this was true as there was no change in the food. This is contrary to what has been found in India. Srivastava (2002) documented that people in India had negative perceptions towards biogas digesters connected to toilets. They did not accept the biogas as they wanted to avoid contact with any product from human excreta as they felt it was dirty and unhygienic. These perceptions made dissemination of the biogas technology using human excreta in India impossible, but this has not been the case with the Gwala household.

On the use of biogas fertiliser in the gardens for better crop yields, the household with the biogas digester and the controls had all used dry cow dung as fertiliser prior to biogas installation. The household with the biogas reported that they now used the fertiliser from the biogas in their gardens and did not have a problem with the digester being connected to the toilet. They encouraged other people to use the fertiliser as it was good on their crops.

The women reported that their crops were looking healthy and the yield had increased compared to that of their neighbours who were using dung in its natural form and that they were very happy. It was difficult to document how much the yield had increased because they did not measure what they harvested and only harvested enough to eat on a particular day. In a study done in India and Nepal (Karottki and Olesen 2001) it was found that people gained more enthusiasm in their gardens because of the improved quality of the biogas fertiliser that guaranteed better crops and increased yield. The better yield was because the watery biogas fertiliser contained more active and rich nutrients than the cow dung in its dry form. The Gwala household accepted the biogas generated using cow dung and human excreta for cooking and the fertiliser for their crops.

Trials on crops were conducted at the University of Natal's Ukulinga farm using the fertiliser from the Gwala household. It was found that cabbages benefited significantly from the biogas fertiliser over compost and commercial fertiliser trials (Smith 2003). Even though no mention of the testing of fertiliser has been mentioned in reviewed literature, in this pilot project it was important to test the fertiliser effluent for pathogen content. Tests were carried out by Durban Metro Wastewater Department on the fertiliser. They tested the fertiliser from cow dung and from cow dung and human excreta. Both the tests found that the fertiliser was not of a standard to be used on leafy vegetables according to the standards of the USA Environmental Protection Agency (Solar Engineering Services 2002). This evidence calls for further tests to be done on the fertiliser before it could be promoted as good fertiliser.

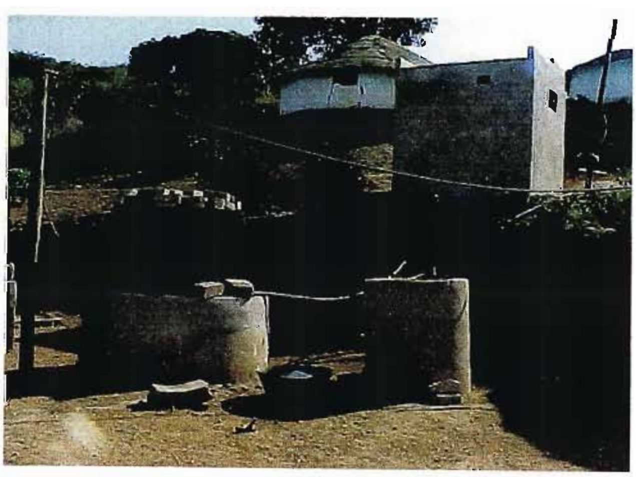

Figure 5.3: The biogas digester connected to the flush toilet

Affordability was looked at in terms of how much income was coming into the household, savings on energy expenditure and whether the household members felt that they could afford to pay for the digester if they had to buy it. The biogas digester in the household was installed free by a company called Solar Engineering Services as the biogas project was experimental and funded by the Department of Minerals and Energy (DME).

The members of the household (the two women), when asked whether they could afford to pay for the biogas digester said they could not afford to as it was very expensive, unless if they would be allocated some kind of subsidy which would cover almost half of the money and they pay small installments every month. When asked how much they could afford to pay every month if they were allocated a subsidy, they said it would depend on how much money was available in the household, but they would not pay less than R100. They were relying on a pension (R620) from one person and the unstable income of undisclosed amount from one adult employed casually which would influence the reliability of payment. The two control households also said that they liked the idea of a biogas digester as they would save on energy expenditure but it was also too expensive for them. The engineer involved with the project estimated that in six year's time the cost would have broken even in terms of buying fuel and spending time collecting wood.

Table 5.3: Fuel expenditure or time spent monthly on cooking

Biogas household fuel types	Spending in R/time monthly before gas	Spending in R/time monthly after biogas	Savings monthly	Potential savings
Wood	32 hours (twice a week)	Nil	32hours	
Paraffin	R90	R7	R83	
Control 1 fuel types				
Wood	28 hours once a week	N/A	N/A	28 hours
Paraffin	R70	N/A	N/A	R55
Electricity	R250*	N/A	N/A	
LP Gas	R60	N/A	N/A	
Control 2 fuel types				
Wood	20 hours once a week	N/A	N/A	20 hours
Paraffin	R43	N/A	N/A	R34
Electricity	R50*	N/A	N/A	

*Includes use for refrigeration, lighting and running other appliances

Before biogas installation the household with the biogas digester was spending more time and money when compared to the other households on wood collection (32 hours per month) and R90 on paraffin (see Table 5.3). After biogas installation they did not spend any time collecting wood and bought much less paraffin (R7) than before the biogas digester was installed. This is in agreement with what Karottki and Olesen (2001) said, that a 2m³ biogas plant could replace the fuel equivalent of 37 litres paraffin or 210kg of wood every month. Fuel expenditure of the two households without the biogas digester had obviously not changed in any way. In terms of the potential savings shown in Table 5.3, the two control households without the biogas could be saving an average of R45 per month on paraffin and 24 hours on wood collection. These results show that biogas not only provides fuel for cooking but also saves spending on energy and time while collecting wood or purchasing fuels resources, which the household can use for other important activities.

The household spent 32 hours a month on wood collection. It is difficult to put a market related price on women's time in Maphephetheni, therefore making it impossible to value the 32 hours spent monthly collecting wood. On average, wood purchasing households in Maphephetheni spent R25 a month (Ndokweni and Green 2003). Assuming that the Gwala household bought wood instead of collecting it for 32 hours, this meant that in a year the household would have spent R300. The household bought paraffin for R90 a month, and in a year they spent R1080. This meant that in a year the household would have spent R1 380 on fuel. The cost of the biogas digester was R15000 and dividing this amount by the cost of fuel per year, the cost of the biogas digester would have broken even in 11 and a half years, that is if no other income was generated through the biogas digester and ignoring the increase in crop production. However inflation and capitalisation must also be taken into consideration. The 11 years is much longer than the engineer's estimate of six years. Although the household was assumed to save R300 a year if they bought wood, which amounted to R1080 when the cost of paraffin was included, the biogas digester which cost R15000, was less likely to be affordable for the household.

Efficiency was investigated by asking questions on availability of biogas for cooking when needed. Biogas was readily available to the household because with constant availability of dung/human excreta and water and correct feeding of the biogas digester, "gas for cooking was always available right in the kitchen with flick of a switch" (TERI 1994).

The interviewees said they had a problem with the gas getting finished before food was ready when the biogas was still new, especially when they cooked food like samp and beans which needed longer cooking times. This happened for the first two months and after that the women reported that they could now cook any kind of meal without the gas finishing, and they cooked two times a day. The shortage occured because the biogas digester needed time to produce gas optimally. This meant that biogas was efficient as it was always available when needed.

The continuous availability of biogas was very dependent on those household members responsible for feeding it correctly all the time. The household members once complained that they had been out of biogas for almost a week and had been using paraffin and wood for cooking. When this was investigated, it was found that they had not been feeding the biogas digester for almost two weeks while the lady responsible was sick and the head of the household had found a casual job. The daughter-in-law reported that she could not feed the biogas digester as she was not allowed to enter the kraal because of cultural beliefs. The women reported that during the non feeding stage gas was still being produced. They thought the waste from the toilet would compensate for the non-feeding. The engineer stressed that it was crucial that the digester was fed everyday so as to ensure a steady supply of gas. This means that gas would always be available in the household, as long as the feeding was done correctly every day.

Sustainability was investigated by looking at maintenance, commitment to continuous feeding of the biogas digester, availability of manpower and time and availability of resources to feed the biogas digester. Looking at maintenance, the interviewees reported that the biogas system did not need any major maintenance, as no major cleaning of the whole system was required. They just had to make sure that no dung blocked the inlet pipe and that the fertiliser effluent was constantly collected by placing a container at the outlet pipe. On observation of the digester in one of the visits, the outlet pipe was dirty and nearly clogged. The reason for this was that there was dry fertilizer on top where weed had been growing. After being reminded, the members of the household cleaned the top. The gasholder also needed to be painted once a year, which was not done. The household was also provided with a biogas user manual for future reference when the engineering team had gone.

In terms of manpower and time required for the continuous feeding of the biogas digester, two household members (the head of the household (male) and the grandmother were responsible for collecting dung to feed the digester. Dung was collected from the kraal in the household where the cattle were kept overnight. Collecting fresh dung from the household kraal and feeding the digester took them 45 minutes to one hour. There were only two instances where they had to go out and collect dung from their neighbours and nearby veld, and that took them less than an hour. This was when the cows were not kraaled overnight because the shepherd was not there. They reported that the task of collecting dung and feeding the digester was not time consuming at all, was easy to carry out and they were happy doing it. In a study conducted in some villages in India where biogas was being used, it was found that the biogas was convenient as cow dung was normally available on the property, with people seldom having to go out and collect it from places as far way as where wood had been collected (TERI 1994). The Gwala household did not have to collect water from the tap to the biogas site. A pipe from the tap collected the used water going to the drain and filled a drum near the biogas digester. This collected grey water was mixed with the cow dung. It could be concluded that collecting dung and feeding the biogas digester was not a menial and time consuming task at all and the people responsible were committed.

Income generation through the sale of cooked food could be an opportunity for the household as they would not have to buy or collect fuel but use free biogas instead. Before the biogas installation, one adult woman (the daughter in law) in the household was selling cooked food at a nearby school (vetkoeks and fish) but had recently stopped two weeks after the time of our entry. She had stopped because she was not getting enough profit and because of time constraints as she had to look after her daughter's baby. A year after the biogas digester installation, the household was still not selling food cooked using the biogas. When probed on whether they had any ideas on income generating opportunities using the gas stove, the woman said she would like to cook and sell to school children again, but this had not happened yet. The reason for this might be that the biogas digester was donated to the household and there was no urgency to repay any loans, therefore no pressing need for extra income. Another reason might be that they did not view the biogas as something they could use to generate income but rather for cooking for the household only. Unfortunately there was no literature available which documented income generation through the sale of cooked food using biogas.

On generating income through the sale of fertiliser, the household sold the fertiliser to the community to generate income for the household. The household had gained some income from the sale of the fertiliser, which was selling for R2 per 5 litre container. Near the end of the monitoring and evaluation stage the household had managed to sell five containers to the community and two large containers to the University of Natal farm at R100 per container. The sale of fertiliser to the community was going very slowly and this could be attributed to the fact that fertiliser was only in demand during planting season which was between June and October. The interviewees also mentioned that the community were used to using dry cow dung as fertiliser and were not keen on using fertiliser they had never seen before in their gardens, especially since it was connected to the toilet which they viewed as not clean enough to be used on crops. The community also was not aware of the benefits of the fertiliser. This is supported by Srivastava (2002) who said that people want to avoid contact with human waste at all costs as they view it as dirty once it has been disposed of. This was attributed to a high presence of illiteracy in the non users, which may be the case in Maphephetheni. Also most of the community members did not know about the benefits of this type of fertiliser and it was not marketed widely.

The household was asked whether they sold extra crops from their gardens to generate income, and they said they did not because they consumed everything at home. When probed as to why people would not buy, they said it was because the others had their own gardens. Also they did not see the need to sell when the household can actually consume all the crops.

One of the perceived benefits of having a biogas digester is that it saves time for the women in terms of time spent collecting firewood, preparing the fires and cooking. The perception was that the women would use the released time in income generating activities. The women were asked questions on how much time they spent cooking before the biogas digester was installed and after the biogas was installed. They reported that before the biogas was installed, it took them almost six hours to prepare meals for their families per day when they cooked on an open fire. They cooked twice a day. This included cooking porridge and tea in the morning and cooking lunch midday which would be reheated for supper. On a paraffin stove the time spent cooking was less but they used paraffin only once or twice a week for cooking before biogas installation as it was expensive. Paraffin was normally used for ironing. After the installation of the biogas digester it took them three to three and a half hours to cook meals for the day. In Tanzania, a study was done to evaluate the impact of biogas and one woman reported spending three hours a day cooking on biogas compared to the five hours she used to spend when cooking using firewood. She also used to spend seven hours a week on wood collection but she did not have to collect wood anymore after using the biogas except when there was going to be a big feast or party (Lauridsen 1998). This study showed that the introduction of biogas digesters in households meant that women did not have to go out collecting firewood as the biogas was available at a flick of a switch right in the household's kitchen and spent less time than they used to, cooking.

It is assumed that with the released time women would be involved in beneficial activities. Support for this assumption comes from a study conducted by Cortsen, Lassen, and Nielsen (2001) in Tanzania who found that firewood collection was reduced by almost 70%, leaving women with time to carry out other activities. In this Maphephetheni study, the women reported that they had more time to spend in the gardens, with the daughter in law attending church during the week and joining the local sewing club. The daughter-in-law was also keen on returning to her business of selling to the school children. During following monitoring visits after the women had said they were involved in these activities, it was found, however, that the women did more sitting around the house during their free time than being involved in beneficial activities. Therefore, having more released time did not encourage the women to be involved in income generating activities, but they had more time to relax and carry out usual household chores.

5.4 Marketing in Maphephetheni

Although marketing was not part of this study, through observations during visits into the area and through informal communication with community members, information on marketing in the area was compiled. In Maphephetheni, people produce surplus crops, especially those who have community gardens. This food ends up rotten in the gardens or at home or is given away to neighbours and relatives for free. If there was a market, this surplus could have been sold for profit. In Maphephetheni there is no formal market place for local produce. The only place where people were observed selling crops was at pension pay out points. But people who were found selling their crops on these days were outsiders who came in their small trucks and sold their crops from the back of their vehicles.

Another reason supporting the lack of a market in Maphephetheni is that people plant almost the same crops in their gardens, limiting the need to sell to other people who are likewise producing. Transport was also observed as another major constraint. A taxi to Durban and Inanda where people could sell their crops cost R16 return. The person still has to pay for an extra seat, or seats, if they are carrying boxes or bags as there is no outside space in a taxi. This demotivates people who would like to sell and demands upfront financing for transport. Advertising is a strong tool for a business, but in Maphephetheni the people are not used to advertising which limits the exposure of one's sales.

It is also important to try and convince people that buying what has been produced locally is cheaper than taking a taxi to town with extra transport costs to buy vegetables. Therefore, for people who produce surplus crops, including those using biogas fertiliser it is important to create a market to be able to sell their crops.

5.5 Conclusions

From the results presented above, it was found that the household accepted the gas from the biogas for cooking and also the fertiliser to use on their crops. The household could not afford the cost of the biogas digester from the income the pooled income in the household. Although the household did save on fuel expenditure as they did not have to buy paraffin and collect wood, the savings could not amount to the cost of repayment for the biogas digester. Therefore the biogas digester was not affordable to the household.

The biogas was found to be efficient as gas was always available in the household, but gas availability was reliant on correct feeding of the biogas digester. The biogas digester did not need any major maintenance while manpower needed to feed the biogas digester was minimal compared to the wood collection task. Time spent on collecting dung and feeding the biogas digester was a maximum of one hour, which to the people responsible for feeding was a very short time. The biogas was found to be sustainable.

The household did no sell any food cooked using the biogas digester. Some income was generated from the sale of the fertiliser, but this stopped. This was attributed to the fact that the community did not know anything about the benefits of the fertiliser. Marketing of the fertiliser was needed to widen sales. No extra crops were sold in the household because the household did not see the need to sell when all the crops could be consumed at home. The woman responsible for wood collection did not have to collect wood anymore, which meant that she had released time which could be used for other income generating activities. The released time was not used for income generating activities, but was used to carry out normal tasks carried out before and to relax. It can be concluded that the biogas was not used to generate income in the household.

The second subproblem investigated whether the domestic floating dome biogas digester had the potential to provide a household with energy that is an acceptable, affordable, efficient and sustainable alternative to already existing forms of energy and also increase opportunities for income generation. The conclusions drawn were that the biogas had the potential to provide energy that was acceptable to the household as the household did not have a problem using the biogas. It was not affordable in terms of purchasing it but it did save expenditure on energy. The biogas was efficient and sustainable as long as correct feeding was practised. The biogas did not provide income generating activities for the household, except for fertiliser sale, which generated some income for a short period but did not carry on as expected.

This chapter has given the methodology used in the case study, description of the households and the interpretation and discussion of the results according to the questionnaires, informal interviews and observations. Where possible the results were discussed in correspondence with Chapter 2 (Review of related literature) so as to substantiate what has been found in the study with what has been already found in other studies. Conclusions were also drawn in relation to the research subproblem and the results obtained.

CHAPTER 6
MYEKA HIGH SCHOOL CASE STUDY

This study was carried out to investigate the acceptability, impact and feasibility of institutional biogas in Myeka High School. The school was using LP Gas to run the Home Economics room appliances (fridge and stoves) and to supplement the solar Photovoltaic (PV) system backup generator to run the computer room, photocopiers, overhead projectors, televisions, compact disk copier and printers. The PV solar system did not provide sufficient power for all the school's power needs and occasionally the school experienced problems. The school was then forced to supplement the PV solar system with LP Gas, which was very expensive for the school to purchase.

Therefore the biogas was seen as a potential alternative for providing the school with thermal energy for running appliances and providing gas, which would run a generator and be converted into electrical energy. The biogas project was funded by the Department of Minerals and Energy. It was envisaged that the biogas digesters would use human excreta from school toilets as primary input during school days, and during the weekends and holidays, the biogas digesters would be fed cow dung. The plan was that cows would be kept at the school as part of the subject of agriculture and also support the school biogas project so as to provide dung during holidays and weekends. A school vegetable garden and grass grown for the cows was also to be part of the biogas project so that the fertiliser from the biogas could be used on the vegetables and grass for the cows. The vegetables and the fertiliser would be sold to the community to generate income for the school.

This discussion will give the description of the school, the pre installation and impact assessment surveys, the methodologies applied in the surveys, the results of the surveys and the conclusions drawn from the results.

6.1 Description of Myeka High School

Myeka High School was situated in rural Maphephetheni, KwaZulu Natal. The school offered Grade eight to Grade 12 classes. It had 24 teachers, 850 learners and 16 classrooms. It was the only high school out of three in the area, which boasted renewable energy technology. The school was not connected to grid electricity but had 14 donated solar PV panels, which provided energy to the computer resource centre, all other computers and TV's in the school, the Science laboratory, photocopy centre and general classroom lighting. LP Gas was used to run the appliances (stoves and fridges) in the Home Economics room and also to power a generator which supplemented the solar PV energy. This provided electricity for the whole school (Dube 2002).

Myeka High School was chosen as an opportunity to study biogas technology because it was the only school in the area already using some other forms of renewable energy technology and also the principal was receptive and supportive of renewable energy. The school was equipped with pit toilets and one tap with potable water, which was an opportunity for the school to be equipped with flush toilets and at the same time be provided with biogas technology.

6.2 Pre installation survey

A survey on toilet usage was carried out at Myeka High School so as to determine the required capacity for the biogas digester system to operate. The survey was also conducted to identify the pattern of breakfast and lunch consumption of the students. Eating habits as may pose a problem for the biogas system if the students ate too little and did not use the toilets enough. Studies done on teenage and adolescent eating patterns revealed that while they do eat, their eating patterns were very variable. In studies done on American teenagers, breakfast, the most important meal of the day was skipped most often (Hunter 2002, Musso 2002). This was the most common pattern among teenagers, instead they opted for snacks that were not filling. Reasons given for not eating breakfast were not having enough time to eat in the morning and not feeling like eating. An assumption could be made here that because of not eating breakfast teenagers may not have used the toilets as expected (Hunter 2002; Musso 2002).

A study was also done in South Africa whereby breakfast and lunch eating patterns of primary school children were looked at. Although the study was of younger children than those at Myeka High School, it can be postulated that a similar pattern may occur.

In two South African primary schools, one white and one black, researchers found that a higher percentage of black children were not eating breakfast (Wolmarans et al 1995). Reasons for not eating breakfast were found to be that there was no time to eat breakfast with the children leaving home early to travel long distances to school and also that most of the time there was no food to eat in their homes. It was found that low socio-economic status contributed to skipping breakfast (Wolmarans, Jooste, Oelefse, Albertse and Chalton 1995).

Wolmarans et al (1995) said that not enough was known about South African children's eating patterns which might contribute to there being insufficient evidence available from which to predict the eating habits of teenagers. From the results of the above studies, it became important to carry out a pre survey to find out the eating and toilet patterns of the Myeka high school students.

6.2.1 Methodology

To carry out this survey, a sample of 207 students was randomly selected from a population of 850 students using class lists provided by the school. Of the 207 students selected, 194 students provided useable questionnaires. Structured interviews using purpose designed questionnaires were used as the survey material. The researcher and the engineer working on the biogas system designed the questionnaire. The researcher selected volunteer interviewers from the students and trained them on interviewing techniques. Each student interviewer was assigned ten names of students to be interviewed.

The questionnaire was structured with sets of related questions relating to breakfast eating patterns, school break eating patterns, toilet usage patterns to assess the amount of use that the present toilets enjoyed, changes that students would like to see take place in the toilets and also questions on outsiders using the school toilets. Meals were separated into light and heavy meals. Heavy meals meant eating foods like bread and something on the bread, porridge, cereal, left over food and similar food that would make a person full for breakfast. During school break foods considered heavy were vetkoeks, sandwiches, muffins, fried fish, and boiled eggs. Light meals were described as eating a fruit, a packet of chips , juice, sweets, peanuts and biscuits. Questions were asked to determine how much the students ate and how often they used the toilets and, subsequently the capacity of the biogas digesters was calculated.

6.2.2 Results and discussion

Data was first coded and then entered and analysed using the Statistical Package for Social Science (SPSS).

The section below presents the results assessing the quantity and quality of the inputs required for the design of the biogas digester system.

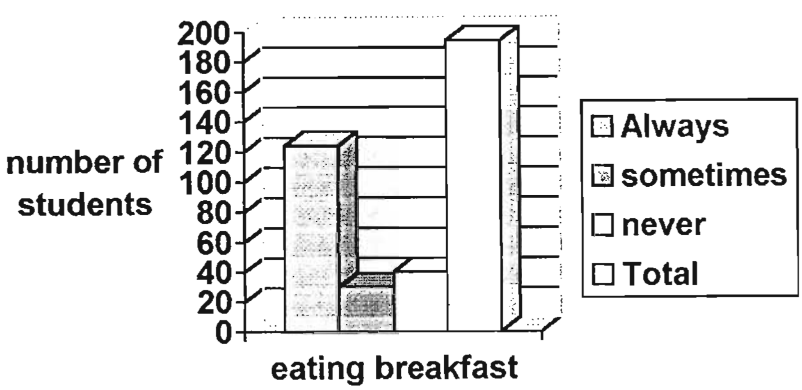

Figure 6.1: Students eating breakfast

Results in figure 6.1 indicate that 124 (63.9%) of students always ate breakfast before school, 40 (20.6%) never ate breakfast while 30 (15.5%) sometimes ate breakfast. From these results it is clear that almost two-thirds of the students did have breakfast every day.

Table 6.1: Students eating heavy/light meal for breakfast

Breakfast	Number of responses	Percentage
Students eating heavy meal	157	80.9
Students eating light meal	16	8.2

Table 6.1 represents the kind of meals taken by students during breakfast. 157 (80.9%) of the students had heavy meals for breakfast while only 16 (8.2%) had light meals. The remaining 19 students either did not have breakfast or did not answer the question. The discrepancy between the responses on Figure 6.1 where 154 students said they ate breakfast and Table 6.1 where the number of students reporting eating breakfast was 173 could be attributed to the fact that some students did not consider drinking tea or juice as breakfast. But when they were asked about what they drank, the researcher took their responses as light meals. Three quarters of the students did eat a heavy meal breakfast which is contrary to what the study by Wolmarans et al (1995) reported. They reported that black children had a higher percentage of not eating breakfast because they had no time to eat as they travelled long distances to school. This was supported by Hunter (2002) and Musso (2002) who, in their study, found that most teenagers skipped breakfast.

Table 6.2: Type of meal eaten during lunch at school

	Number of responses	**Percentage**
Students eating heavy meal	161	83
Students eating light meal	17	8.8

Results in Table 6.2 represent type of meal eaten by students during break at school. 161(83%) of the students said they had heavy lunch at school while 17 (8.8%) reported having a light meal during school lunch. This shows that more than three quarters of the students eat substantial food while at school.

Table 6.3: Student's toilet usage

Toilet usage	Number of responses	**Percentage**
Yes	171	88.1
No	23	11.9
Total	194	100

Results in Table 6.3 reveal that more than 3/4 of the students do use the school toilets. 171 (88.1%) said they did use the school toilets while 23 (11.9%) of the sample said they did not use the school toilets.

Table 6.4: Students urinating at school

Urinating times a day	Number of responses	**Percentage**
Once	39	20.1
Twice	65	33.5
Three times	40	20.6

Only 39 (20.1%) of the students said that they urinated once at the school toilets, 65 (33.5%) urinated twice while 40 (20.6%) students urinated three times. Very few students reported urinating three times. The average amount urinated is said to be one litre per day (Anon 2003c).

Table 6.5: Students defecating at school

Defecate times a day	Number of responses	**Percentage**
Once	105	54.1
Twice	34	17.5
Three times	7	3.6

Out of a sample of 194 students, 105 (54.1%) of students defecated once, 34 (17.5%) defecated twice while only seven (3.6%) students defecated three times. These results reveal that at least half of the students in the sample used the toilet once to defecate. The average daily defecation was reported to be 200g (Anon 2003c).

Cross tabulation analysis was carried out to see whether there was a relationship between the type of meal a student had eaten for breakfast and toilet use for defecation.

Table 6.6: Students eating light meal and defecating

			Defecate at school per day			Total
			1	2	3	
Eat light meal before school	Yes	Count	4	3	1	8
		% within Defecate	5.6%	13.0%	14.3%	7.9%
	No	Count	67	20	6	93
		% within Defecate	94.4%	87.0%	85.7%	92.1%
Total		Count	71	23	7	101
		% within Defecate	100.0%	100.0%	100.0%	100.0%

Table 6.7: Students eating heavy meal and defecating

			Defecate at school per day			Total
			1	2	3	
Eat heavy meal before school	Yes	Count	68	20	6	94
		% within Defecate	94.4%	87.0%	85.7%	92.2%
	No	Count	4	3	1	8
		% within Defecate	5.6%	13.0%	14.3%	7.8%
Total		Count	72	23	7	102
		% within Defecate	100.0%	100.0%	100.0%	100.0%

So only 102 out of 174 defecate at school – sort of 60%

The results showed that the relationship between eating a light meal or a heavy meal for breakfast and defecation at school was insignificant ($p = 0.42$ for light breakfast, $p= 0.40$ for heavy breakfast). Therefore it meant that use of school toilet was not determined by the type of meal that a person had.

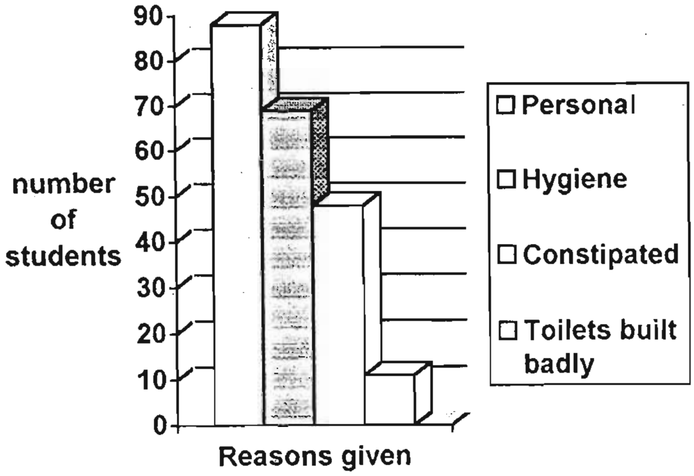

Figure 6.2: Reasons for not using school toilets

Students who did not use the toilets or did not use the toilets often had a choice of giving more than one reason. Personal reasons (not being able to relieve oneself when there were people waiting outside and only using home toilets) were given by 88(45.4%) of the students. Hygiene reasons (toilets not clean, no basins to wash hands) were given by 69 (35.6%) of the students while constipation was mentioned by 48 (24.7%) students. Forty eight (24.7%) of the students mentioned reasons that the toilets were badly built (no doors, no lights, uncomfortable seats and not flushable toilets). From the results in Figure 5.2 personal reasons were mentioned as the most important reason for not using the school toilets, hygiene followed closely.

Table 6.8: Suggested changes for toilets to be user friendly

Changes wanted	Number of responses	Percentage
Well built toilets	159	82
Cleanliness/hygiene	130	67
Toilet paper	51	26.3

Table 6.8 represents the changes that students would like to have in the toilets for them to be more user friendly. For this question students also had the option of giving more than one answer. One hundred and fifty nine (82%) of the students mentioned the building of good toilets (proper lighting, comfortable seats and lockable doors) as something they would like to have in the toilets while 130 (67%) mentioned cleanliness. The need for toilet paper was also mentioned by 51 (26.3%) students

These results reveal that well-built clean toilets were the most important incentives for frequent student usage.

Students were also asked how many outsiders used the school toilets during community functions/meetings and during school hours. Twenty two percent of students reported that between 20 and 50 might use the toilets during the rare functions and meetings held at the school and that between two and five outside people may use the toilets during school hours. These were not significant numbers and were not included in subsequent calculations

6.2.3 Conclusions from the pre installation survey

What can be concluded from these results is that a large proportion of the students did eat breakfast and lunch that was substantial. Toilet usage by the students was also fairly high with 88% of the students using the school toilets daily, but there was no relationship between the type of meal that a student had and defecation at school. Only a small number of students did not use the school toilets. Personal reasons and hygiene were important reasons for not using the toilets. If changes such as building better toilets and cleanliness could be improved then most of the students could use the school toilets often.

From the results of the survey, the capacity of the digesters was decided upon. The school had 850 students who it was assumed would each pass about 400g of night soil and urine per day (Solar Engineering Services, 2002). Retention time in the biogas digesters was approximately 40 days. The toilets at the school were to be built using one litre water per flush. From the above results it was calculated that 1 litre flush + 400ml urine and night soil would be equal to 1.4 litres per person per day (Solar Engineering Services 2002). A human being would pass a standard of about 33kg (Vinneras 2001) to 110kg (Del Porto 2000) of feaces and 365 to 550kg urine in a year (Anon 2003c). If 365kg of urine was used, then a person would pass 1 litre of urine per day (24 hours at 1ml =1g).

In this case, students spend at the most six hours at school which translates into .25kg when divided by four. On average a person would pass 72kg feaces per year which could translate into 200g per day. Assuming that feaces have more density than water (50%) then it would be 0.3litres per day plus 1 litre flush which equals 1.55 litres which is similar to the 1.4 litres calculated from the Myeka High School data. Eight hundred and fifty students would pass about 1190 litres a day, using the results that more students use the toilets once a day and assuming that better built toilets would encourage all students to use the toilets at least once a day. Retention time which is 40 days times 1190 litres = 47600 litres.

Two 20 cubic metres floating dome biogas digesters and 16 toilets were built at the school using local labour, and the capacity was divided between the two digesters (Solar Engineering Services 2002). These biogas digesters had a constant gas pressure which ensured a steady supply of gas as long as the biogas system was fed correctly. The floating dome biogas system had an inlet hole, where cow dung was fed into the storage tank built underground, a steel gas holder dome which stored the gas produced and an outlet hole which let out the fertliser. The gasholder domes were placed on top of the underground storage tanks in round water seals which allowed the gasholder to float in the water. The biogas digesters were connected to the new flush toilets. The toilets were built in two sets of buildings, eight designated for boys and eight for girls. One biogas digester was connected to the girl's toilets (see Figure 6.1) and the other to the boy's toilets. The toilets were connected to the school's existing water system, but in order to compensate for increased expenditure on water by the school, rainwater harvesting was incorporated into the system. Water tanks were built which fed into the biogas system, by providing water to the flush toilets.

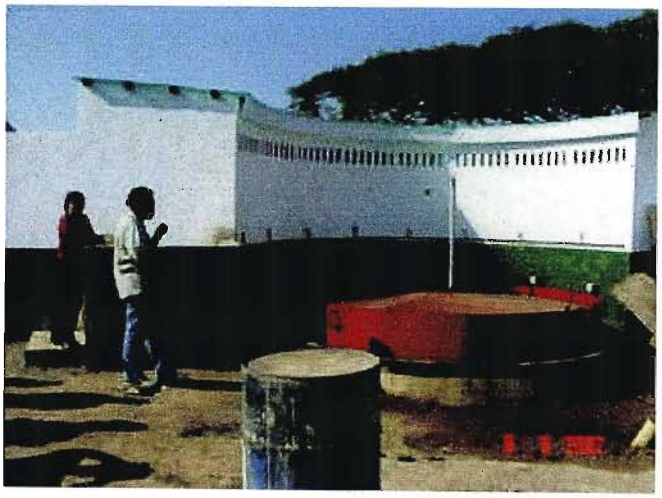

Figure 6.3: The biogas digester connected to the flush toilets atMyeka High School

6.2.4 Functioning of the biogas digesters

After the biogas digesters were built, they were primed with water and cow dung so they could start producing gas. During the priming period, to show that the biogas was working and actually produced gas, piping was done and a gas cooker was modified by enlarging the gas jets for the biogas. Food for the project staff was cooked on the cooker using the biogas. In the Home Economics room, an LP Gas stove and a fridge were modified to work off biogas and were connected. During two visits made to the school, for a period of two months, the fridge and the stove were working. Staff and students were very happy because the fridge and stove had not been working for some time (due to unavailability of LP gas) and they could not carry out practicals. The LP Gas was then used to run a gas generator to provide power to the school when the PV panels were inoperative. The generator which was to run off the biogas to produce electrical energy was connected shortly before this study was completed.

Community members managed a vegetable garden at the school as part of the biogas project. The garden was there before the digesters were commissioned which meant no fertiliser was produced at that time. After at least three months of very low yield produce, the vegetable garden was gone. The few vegetables that were produced were used by the Home Economics class for practicals. Community members had lost interest and the garden was no longer managed properly. The school had not gained any income from the vegetable garden, but had saved slightly on expenditure for the Home Economics practical classes.

Commissioning of the biogas digester took place during July and August 2002. The problems encountered prior to this were primarily construction problems, with one gasholder dome not fitting into brick walls built to hold it as it was damaged during transportation. This problem was resolved. It was also discovered that the area where the underground biogas tanks were built had a high water table that kept on seeping up during construction. The water was drained into a hole outside the construction site and used to complement water provision into the toilets. The water seal was found to have a crack and water was seeping out. After many failed attempts to seal the crack, it was decided to rebuild the brick water seal. This delayed the commissioning date.

6.3 Impact assessment survey

A second survey was carried out at Myeka high school in order to evaluate the use of the new toilets connected to the biogas digester by students and also their knowledge of how the biogas digester worked and its management. This survey was conducted two months after the biogas system was commissioned. As it has been said before, proper functioning of biogas relies greatly on the availability of enough human waste, water and the proper management of the whole system.

6.3.1 Methodology

The survey was carried out by randomly selecting a sample of 220 students from a population of approximately 900 students using class lists provided by the school. In this survey, the number of students enrolled at the school for that year had increased, making the population size different from the first survey. Students in Grade 12 were excluded from the sample because the survey was carried out during final examination time and it was inconvenient to include them. Structured interviews using original pre designed questionnaires were used as the survey material. Some of the interviewers (six) involved in the first survey were used because of their knowledge of interviewing and the biogas system, but new ones (16) were also included. They were all trained on interviewing techniques and each assigned ten students to interview.

The questionnaire was structured with sets of questions relating to the use of the new toilets (whether students were or were not using the toilets) and what they liked and did not like about the new toilets. General knowledge on how the biogas digester worked, information on how to use the new toilets, source of this information and toilet / biogas management were also included in the questionnaire. Perceived benefits of the biogas and general comments were also part of the questionnaire.

This survey was carried out in order to evaluate how the students were perceiving and using the new toilets, and also to heighten awareness of the proper use and management of the toilets. Knowledge on biogas would also enhance correct toilet use by the students.

Interviews with the school principal and staff involved with the biogas management were also conducted.

6.3.2 Results and discussion

Of the 220 students chosen, for the sample, 175 produced useable questionnaires. Results were analysed using the SPSS programme.

Table 6.9: Students toilet use

Toilet use	**Number of responses**	Percentage
Yes	143	81.7
No	32	18.3
Total	175	100

Results in Table 6.9 show that more that ¾ of the learners do use or have used the new toilets connected to the biogas digester. 143 (81.7%) said they did or have used the new toilets while 32 (18.3%) said they had never used the toilets. This survey was carried out before the old toilets were demolished, so some students still liked to use the old toilets that they were used to. From both surveys, when looking at old and new toilet use, there seems to be not much change in toilet use (compare Table 6.9 with Table 6.3). The old toilets had been used by 88% of students while 82% used the new toilets.

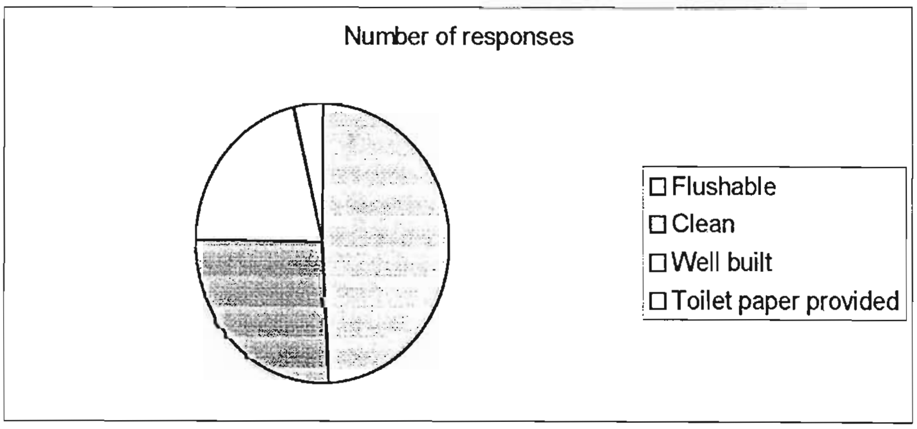

Figure 6.4: Reasons for using the toilets (n=143)

The students who said they did or have used the toilets were asked to give reasons as to what they liked about the new toilets. This was an open question whereby learners could give more than one response to the question. The toilets being flushable was given by 83 (47.4%) of the students as the main reason they used the new toilets as is seen in Figure 6.4. Other reasons offered were cleanliness of the toilet by 44 (25.1%) students while 36 (20.6%) mentioned the toilets were built nicely. Toilet paper provision 6 (3.4%) was the least chosen reason for toilet use. From the results on Figure 6.3 it is clear that the students liked the idea of flush toilets more as it was mentioned by nearly half of the users.

Table 6.10: User dislikes about the toilets (n=143)

Reason given	**Number of responses**	**Percentage**
Difficult to flush	94	53.7
Not safe, might explode	10	5.7
No dislike	6	3.4
No place to smoke	1	0.6

Table 6.10 represents results on responses given by toilet users when asked what things they did not like about the toilets even though they used them. Again students had a choice of giving more than one response. Ninety four (53.7%) of the students mentioned the fact that sometimes the toilets are not flushable, no water comes out and the waste is left lying visible in the pit while ten (5.7%) mentioned safety as their concern. They said that the toilets were not safe as the biogas digester might explode if someone smoked in the toilets or near the digesters. Six (3.4%) students said there was nothing they disliked about the toilets while only one (0.6%) student mentioned that he had no place to smoke as smoking was prohibited in the new toilets. Toilets not flushing properly seemed to be a problem as it was mentioned by almost half of the toilet users.

Table 6.11: Reasons for not using the toilets (n=32)

Reasons given	Number of responses	Percentage
Dirty	15	8.6
Personal	12	6.9
Difficult to flush	9	5.1
Not safe	3	1.7

Students who did not use the toilets were asked to give reasons why. They also had a choice of giving more than one response. Dirtiness of the toilets was mentioned by 15 (8.6%) students while personal reasons (no need to use toilet while at school) was mentioned by 12 (6.9%) students. Nine (5.1%) said the toilets were difficult to flush and three (1.7%) said they did not use the toilets because they were not safe as the whole system including the toilets might explode if somebody smoked near them. In the pre-survey students had mentioned personal reasons and hygiene/dirtiness as the reasons why they did not use the school toilets, again in this survey these two aspects were important. This might mean that the changes that took place with the toilets were still not adequate.

Of the 175 students, 151 (86.3) said they had been given information on how to use the toilets while only 24 (13.7%) said they were not given any information. More than ¾ of the students were given information on how to use the toilets.

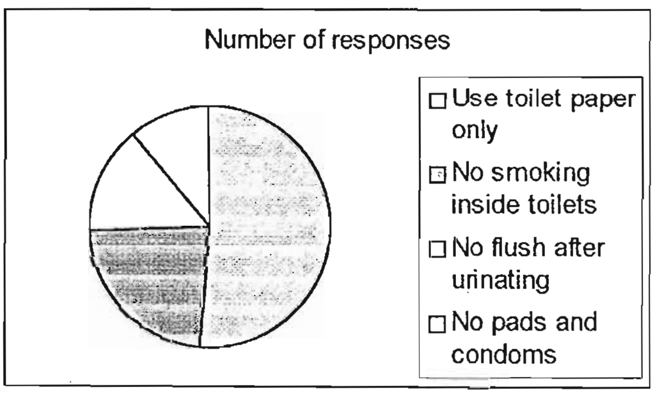

Figure 6.5: The kind of information given during talks on biogas

Asked about what type of information they were given, 101 (57.7%) of the students said they were told to use only toilet paper in the toilet, 46 (26.3%) said they were told not to smoke in the toilets, 29 (16.6%) said they were not supposed to flush when only urinating while 22 (12.6%) said they were not to throw condoms and sanitary pads in the toilets. The responses given by the students were all accurate in terms of what is not supposed to be done in the biogas system.

Table 6.12: Knowledge on how biogas works

Response given	Number of responses	Percentage
Do not know	116	66.3
Uses human excreta	34	19.4
Uses cow dung and water	25	14.3

Table 6.12 represents results on student's knowledge about how the biogas worked. Interpreted from their responses, 116 (66.3%) students did not understand how the biogas system worked. Thirty four (19.4%) only knew that it uses human excreta to produce gas while 25 (14.3%) mentioned cow dung used by the biogas digester to produce gas. The results show that more than half of the learners did not understand how the biogas system worked, despite the talks given by teachers explaining the biogas digester system. Some of the Science students had built a biogas digester model to be shown off at the World Summit on Sustainable Development. This had obviously not really helped the majority of students to understand the functioning of the biogas digester system.

Table 6.13: Source of information (n=148)

Source	Number of responses	Percentage
Teacher	131	74.9
Other	8	4.6
Books and pamphlets	6	3.4
Other students	3	1.7

One hundred and thirty one (74.9%) students said they received the information about the functioning of the biogas system from their teachers, while eight (4.6%) said they heard it from other people (engineers who work with the biogas system, visitors). Six (3.4%) said they read about biogas in books and pamphlets while three (1.7%) said they learnt about it from other students. These results revealed that teachers were the major source of information.

Teachers reported that each class was given a talk and demonstration on the working of the biogas system and toilet use before it became operational. Seventy five of percent students remembered having these classes, but not really the correct content taught.

Table 6.14: Students involved in management (n=175)

Learner involved	Number of responses	Percentage
No	170	97.1
Yes	5	2.9

Students were asked if they were involved in biogas/toilet management. One hundred and seventy (97.1%) said no while only five (2.9%) said yes they were involved in biogas management. Most students were not involved with the management of the project. Those who said yes were probably members of biogas management committee, which was formed by students and teachers together and was involved in the biogas project. The initial plan was to involve classes by rotation in biogas feeding and toilet monitoring, but this apparently did not happen.

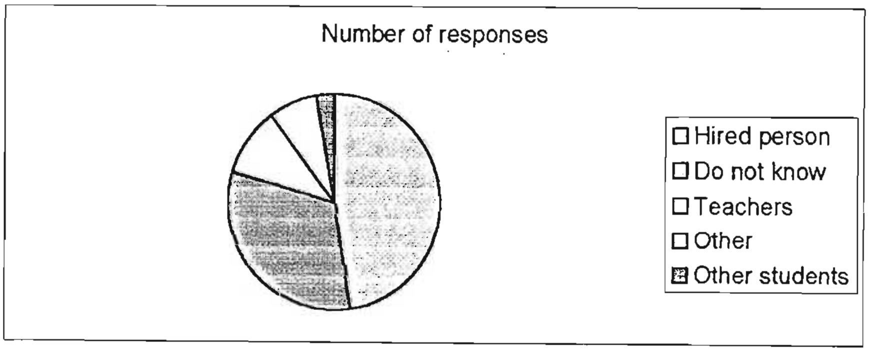

Figure 6.6: Management of toilets/biogas

Students were asked about whether they knew who managed the biogas/toilets. Eighty three (47.4%) students mentioned that there was a hired person, 56 (32%) said they did not know while18 (10.3%) said they thought the teachers managed the toilets. Others (the engineers, other people not from the area) were mentioned by 13 (7.4%) while only five (2.9%) mentioned other students as managing the biogas/toilets.

In reality, two people were employed to manage the biogas/toilets. One lady was hired to clean the toilets and issue toilet paper to the students while one man was hired to feed the digester with cow dung and water when needed and to repair the biogas system and the toilets.

Table 6.15: Perceived benefits of biogas

Benefit	**Number of responses**	**Percentage**
Gas and electricity	147	84.0
Do not know	24	13.7
Fertiliser	8	4.6
School saves energy spending	4	2.3

For this question, students had the choice of giving more than one response as it was an open question. Responses on Table 6.15 reveal that the most students 147 (84.0%) viewed the biogas for producing gas and generating electricity to run appliances. Twenty four (13.7%) students said they did not know how the biogas would benefit the school. Eight (4.6%) students mentioned fertiliser for school gardens, while school saving on energy expenditure was mentioned by four (2.3%) students. So the main outcome of the biogas system was well known to the students.

6.4 General comments given by students about the project

Students were also asked to give general comments on the whole biogas system. Some examples of these were that tourists would be attracted to the area because of the biogas system, their school will be popular around South Africa as the first one to use biogas, the educational standard of the school would be better because teaching aids (TV, photocopiers, video), Home Economics Centre, Science room and Computer Centre would be available for use almost all the time. Other comments were that they would like the toilet doors to have locks, hand washing basins and taps to be replaced as they were already broken and although much emphasis was placed on how to use the toilets to students, some still did the wrong things in the toilets such as smoking in or behind the toilets. There was general enthusiasm for the idea of biogas digesters, but for some a lack of motivation to change behaviour was apparent.

6.5 Information collected from the principal, secretary and the management committee

The school secretary and the principal were interviewed to collect information on energy expenditure of the school. The principal said the Solar PV panels which provided the school with energy were donated by Eskom and Shell. The problem with the Solar system was that when the sun was not shining, energy produced by the solar panels was very low and sometimes did not function at all. The principal also said it was impossible for the school to use all its equipment at the same time as the system would trip. The solar panels were also targeted by criminals and about nine panels had been stolen and not replaced, reducing the amount of electricity available to the school. Therefore, he saw biogas as having the potential to supplement the power supply of the solar system and the increasing energy needs of the school. However, he also felt that the extra management required by the biogas system placed an additional load on him and the teachers. This was outside of the conventional role of him as a principal of the school and the teachers, as they were already busy with their duties.

The secretary, who was responsible for the finances at the school, was asked questions relating to energy expenditure at the school. She reported that the school was using LP gas to run the fridges and stoves in the Home Economics room. The school had a 20kg cylinder that they refilled twice every month at a local shop. The school spent R224 every month to refill the LP gas for the Home Economics room alone. Spending on LP gas to supplement the solar PV energy supply when there are problems would be about R896 per month. This expenditure was the same even after some of the PV panels were stolen because spending was according to budget (the same for each month). The potential savings for the school, by using biogas instead of LP gas was R12 440 per year, which is R224 monthly for Home Economics room and R896 for PV supplementation.

The following information was collected during regular meetings of the engineers, the Myeka biogas management team and the researcher.

To ensure the sustainability of the biogas project at the school, a committee was formed comprising teachers, students and community members. For the biogas digester to function properly, proper management of both the toilets and the digester is essential. The community members were employed to manage the biogas system and the toilets. One lady was hired to clean the toilets and issue toilet paper to the students while one man was hired to feed the digester with cow dung and water when needed and to repair the biogas system and the toilets. The school was paying them. The engineers working with the biogas system at the school gave the hired man hands-on training. In spite of the training given to the cleaner, she used toilet cleaner in the toilets in the interest of cleanliness, which she was told not to use as it would disrupt the biogas production process. This stopped the biogas digesters functioning and it took three months to get the biogas system working again. The Management team reported that other teachers had negative perceptions towards biogas. The teachers had a problem with gas produced by human excreta and said it would be hard to use the gas for cooking practical at the school. But their perceptions changed when they had attended a meeting explaining biogas and after tasting food cooked on biogas. During one of the meetings, it was observed that there was no collection of fertiliser taking place.

Educating the students about how the biogas digester worked and how to use the new toilets was also important because if the toilets were not used correctly or the biogas digester was tampered with, the biogas system would not function properly. The teachers in the committee reported that each class was given a talk on how the biogas digester worked, what to do and not to do in the toilets, and also taken around the biogas site. Signs explaining the rules of toilet use were put up on toilet doors. Students were also encouraged to enter the Science Expo competition modeling the biogas.

6.6 Conclusions

What can be concluded from these results is that more than three quarters of the learners did use the new toilets to relieve themselves which meant that the biogas would be able to function properly. But the way the toilets functioned needed to be improved. Toilets not flushing properly, therefore making the excreta visible, was mentioned as the major inhibition to toilet use. Proper management of the biogas and toilets is important to proper functioning of the biogas digesters. Involvement of the students is essential as they are the ones who use the toilets and benefit from the biogas. Five students were involved in the biogas management committee, but other students were not clear on what they actually did in the management team. Student involvement with the biogas was thus non-existent, which translated into lack of interest in the project.

Because the school did not have flush toilets and biogas before the project, it was important to teach the students how they worked so they learned to appreciate what it could do for them. From the results of the survey, not even half of the students knew how biogas worked. On toilet use there were fewer than half of the students who had information on how to use the toilets, even though information collected from the teachers was that each class at the school was given a talk and a tour of the biogas site. It could be concluded that either the information given was not clear and sufficient or the students just did not follow the rules on toilet use.

The students did not view biogas as something that would economically benefit the school as only four (2.3%) students mentioned the school saving on energy expenditure and none mentioned sale of fertiliser or crops to generate income for the school. More than three quarters only mentioned that it would provide gas to run the Home Economics centre and electricity to run appliances and computers. From the information given by the secretary, it could be concluded that after the installation of biogas, the potential savings on energy expenditure for the school would be R12 440 per annum for the LP gas in the Home Economics room and during times when the PV solar panels did not function which was quite often. However the payment of the cleaner and biogas feeder would need to be subtracted from this amount. They each earned R200 a month.

Because of problems experienced with the biogas digester, such as poor design of the toilet flushing mechanism, the water pressure being too low in the bowl and the poor construction of the biogas digester, which resulted in leakages, and part of biogas digester being rebuilt, commissioning of the system was delayed. Although the biogas had been connected to provide energy to a fridge and a stove in the Home Economics room for two months, the gas generator was not yet operating in a trouble free manner. The methane from the biogas system had been connected to an adapted diesel motor for barely a month and there were a number of hiccups that still needed to be sorted out. The full impact of this aspect of the biogas system could therefore not be assessed. Few concrete results were available to draw a solid conclusion on the subproblem 'does a large capacity floating dome biogas digester have the potential to provide a school with energy that will provide acceptable, affordable, efficient and sustainable alternative to existing forms of energy and also increase opportunities for income generation.' But what can be concluded was that the biogas was found to be acceptable to the school as most students were happy with the new innovation as it would upgrade the standard of teaching and learning at the school through the provision of gas. The principal accepted biogas but felt that its management was going to be an extra burden to him and the teachers. The biogas system was efficient as it provided gas to the Home Economics room for two months, provided that there were no technical problems such as poor construction experienced. No income generating activities took place at the school. The sale of fertiliser and vegetables never took place, this was because there was no proper management of the vegetable garden and the fertiliser was never collected in containers for sale.

Chapter 6 outlined the description of the school, the pre installation and impact assessment surveys and the methodologies used in both, the results and discussion of the results of both surveys. Thereafter conclusions on the sub-problem were drawn.

CHAPTER 7
RENEWABLE ENERGY POLICIES IN OTHER COUNTRIES IN REALTION TO THE SOUTH AFRICAN POLICY

Renewable energy has a vital role to play in the provision of energy to people, whether it is thermal, electrical or gas production. South Africa for example, is endowed with several renewable energy resources that can be used productively to enhance development and improve the standard of living of people (Wentzel 2003). However, without proper support, renewable energy (as for grid electricity) cannot provide people with affordable energy. This is why government's support and involvement in a country that advocates using renewable energy is crucial. The way that country governments can provide support is through the formulation of clear, sound and working renewable energy policies. Pricing, taxes, subsidies, and other financial incentives, education and promotion, direct investments and technology development are some of the important aspects to be considered in order to achieve the desired goals of a country in terms of renewable energy (Munasinghe 1992).

This chapter will reflect on the goals of the South African White Paper on the Promotion of Renewable Energy and Clean Energy Development and give evidence as to whether what South Africa envisages in terms of renewable energy has been included in energy policies of other countries. This publication is not a policy as yet but it will provide insight into what South Africa envisages doing. Training, the Kyoto Protocol's Clean Development Mechanism and technology, financing of renewables and renewable energy technology development are the issues to be discussed in this chapter as they inform the basis for the South African White Paper (White Paper 2002).

7.1 The SA White Paper

In 2002, the Department of Minerals and Energy produced a White Paper on the Promotion of Renewable Energy and Clean Energy Development, but this document has not been passed as a policy, which means there is no formal policy for renewable energy in SA yet. The White Paper sets out the principles, goals and objectives of government towards achieving an enabling environment for renewable energy. For the purpose of this research, the discussion on this chapter will be based on this White Paper, with the hope that what is in the document will be part of the policy.

7.2 Training of stakeholders

Proper management and regular maintenance of renewable energy technology are some of the key elements for long term functioning and success of renewable energy assets. Training could reduce the high costs related to regular breakdowns because of repair personnel who lack the correct skills (Wentzel 2003, Davidson and Karezeki 2002). Regular training therefore, of suitable people, which could be on the job training or formal training, could be the solution to lack of skills, thus ensuring improved maintenance and management of renewable energy technology.

The South African government, in the White Paper (2002) has outlined training as one of the main foci to be included in the policy. The government is looking into developing standards recognised and accredited by the South African Qualifications Authority (SAQA) for training programmes on renewable energy for all stakeholders. The Energy Sector Education and Training Authority (ESETA) would fund these training programmes. The government also realises that information dissemination is important, so there is a need to form networks and information centres for renewable energy which will operate with multiple stakeholders like government, Department of Minerals and Energy (DME) energy demonstration centres and ESETA (White Paper 2002). The Government of Bangladesh is in the same position as South Africa, without an adopted policy on renewable energy, but in their draft policy on renewable energy, the government has mentioned the arrangements of training programmes and capacity building needed to support commercialisation and dissemination of renewable energy technology (Ministry of Energy and Mineral Resources 2002).

In Australia, the government has realised the importance of training to offset the failure of renewable energies due to lack of training and is supporting renewable energy research centres with the development of training courses for installers, maintenance workers and technology designers (Dale 2001). Consumers also have the opportunity of a Home Line Energy service that provides information about renewable energy, efficiency of appliances and other issues related to renewable energy through the telephone. Renewable energy training should not only take place as programmes supported by government, but the involvement of institutions of higher learning is important in order to produce engineers and technicians with skills and knowledge of renewable energy. Renewable energy should form part of universities' and colleges' curricula (Karezeki 2002). Involvement of higher education institutions is not evident in the South African White Paper.

7.3 The Clean Development Mechanism

The use of fossil fuels such as coal and petroleum to produce energy has led to major changes in the global climate (White Paper 2002; Grubb 1991). These types of fuels emit greenhouse gases (GHG) such as methane and carbon dioxide which (carbon dioxide) is responsible for over half of the effects on the climate (Grubb 1991). The use of renewable energy will result in the lowered emission of greenhouse gases, therefore reducing the speed of negative climate change. South Africa realises the importance of reducing greenhouse gases and has taken part in the signing of the Kyoto Protocol. The objective of the protocol is to reduce the concentration of greenhouse gases in the atmosphere to a level that is not dangerous to the climate (Sokona, Humphreys and Thomas 2003).

Because the emission of greenhouse gases in Africa is said to be low compared to industrialised countries, the Clean Development Mechanism (CDM) was born out of the Kyoto Protocol. It was formulated "to support sustainable development with respect to greenhouse gas emissions in developing countries while helping developed countries to comply with their commitments of reducing the emissions of GHG under the Kyoto protocol rules (Sokona et al 2003). The CDM would act as "a certification body for projects involving transfer of emission credits " (Sokona et al 2003). Developed countries would pay developing countries to run projects that reduce emission of greenhouse gases because the developed countries cannot reduce their own emissions easily.

South Africa is one of the developing countries from whom credits can be bought to achieve sustainable development through renewable technology projects (White Paper 2002). Although many countries signed the Kyoto protocol in 1997, evidence of projects run under the CDM is lacking.

7.4 Financing of renewable energy

"The existence of adequate financing institutions and support can be regarded as a prerequisite for the successful introduction of alternative (renewable) energy technology" (Wentzel 2003, p5). There is a need to institute financial programmes that are both innovative and sustainable for renewable energy technologies (African Energy Policy Research Network 1997). One way of ensuring that finances are available to support renewable energy dissemination is through governments acting as loan guarantors for people borrowing from lending institutions (Anon 2001a). In the White Paper, financial support for renewable energy has been included. In the document it is said that the DME will investigate appropriate financial support such as subsidies and also incentives in the form of low interest loans and tax rebates to manufacturers and extend the state support to these. The Central Energy Fund will also be investigated as to whether it can play a role in financing the implementation of renewable energy projects and increase support to consumers by acting as loan guarantor to reduce the risk for financing institutions (White Paper 2002).

The Nepalese Government has taken the route envisaged by South Africa and has been giving financial support to renewable energy. For example, families wanting biogas plants have been supported by a mix of subsidy from government, low interest loans from the Agricultural Development Bank and some small personal investment (Anon 2001a). In a survey conducted in January 1999, Nepal had 49 500 biogas digesters installed and functioning (Devkota 1999). This kind of financial support has jump-started the biogas industry and has afforded more people the opportunity of utilising biogas.

The Chinese government has also included financial support as one of the key elements in their renewable energy policy (Zhang, Li and Wan 1998). The government has been providing people with subsidies to support renewable energy, as well as subsidising research and demonstration projects. Low interest loans that are half that from commercial institutions were also made available to support renewable energies such as biogas, solar energy and wind energy. On top of this, the Chinese government has also established reduced value added tax to some renewable energy technologies, instead of 17%, biogas systems are charged at three percent. Import duties reduction could also play a role in the affordability of renewable energy technologies. China has applied low rate import duties for renewable energy technologies such as PV systems, wind turbines and power plants (Zhang et al 1998). However there is no mention of reduction of import duties on renewable energy technologies in South African White Paper but biogas technology has the advantage of using local materials.

7.5 Technology development

Technology development includes certification and quality standards of the renewable energy provided to people and there is a need for quality control (Anon 2001a; AFREPREN 1997). In the White Paper, one of the issues is that of standards and certification. The DME wants to implement "standards governing the design, installation and performance of renewable energy systems, together with a certification process to verify that systems meet these standards (White Paper 2002, p26)." The standardisation and certification would make sure that services, products and appliances for renewable energy sold to the consumer are not of poor quality and are manufactured to an acceptable standard.

In Nepal, the government has created a national certification and labelling programme for renewable energy in order to protect consumers from poor quality products (Anon 2001a). In a biogas project in Nepal, the government made sure that it gave different biogas plant manufacturers subsidies when they followed a uniform biogas plant design set by government to enforce quality control. This reflected a positive effect as high quality installations of biogas were observed. They have envisaged working closely with the Bangladesh Standards and Testing Institute to prepare standardisation and testing practices of different renewable energy technologies (Ministry of Energy and Mineral Resources 2002).

7.6 Summary

Policies on renewable energy generally seem to incorporate the following – training, the Clean Development Mechanism, financing and technology development. Training, whether in the job or formal training is important for long term functioning and success of renewable energy. Protection of the climate is important so that no negative changes that would impact on human life take place. The CDM is one way of protecting the atmosphere while promoting sustainable development. While the CDM is one way of financing renewable energy, financing in terms of loans and subsidies from the government is crucial. Governments could also support manufacturers of renewable technologies. It is also important for governments to put standards to which manufacturers adhere when providing services and products. That is why certification and standardisation is important.

Although renewable energy has been seen as having a great potential to meet the growing energy needs of countries, especially developing countries, the designing of effective renewable energy policies has been taken by very few countries (Anon 2000). Therefore the limited availability of renewable energy policy information could be attributed to the lack of country policies.

CHAPTER 8
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The aim of this study was to investigate the acceptability, impact, affordability and feasibility of biogas digesters in rural Maphephetheni, KwaZulu Natal. The South African government has realised the potential of renewable energy. The Department of Minerals and Energy has drawn a policy paper to support renewable energy. The reduction of the dependence on wood and cow dung as sources of fuel is mentioned in the policy. Biogas is one of the renewable energies that the policy has targeted.

8.1 Summary of results

The study was carried out in two households and one high school in Maphephetheni, Kwazulu Natal. The Dube household had the required three cows and a standpipe which was 100 metres away from the household. The household used wood, paraffin and LP gas for cooking. The second household was the Gwala household also had the necessary requirements, four cows and a tap in the yard. The household used wood and paraffin for cooking. The third case study was Myeka High School. Myeka High School offered Grade eight to Grade 12 classes and had 24 teachers. The school was not connected to grid electricity, but used a PV solar system to power its teaching aids and school lighting. The Home Economics room appliances were run on LP gas. All three case studies were chosen as good opportunities to study the impact of biogas technology.

In the Dube household, a 5m³ made of plastic tube was installed with the help of family members. The biogas digester had a fixed volume and produced gas at a variable pressure. The cost of the type digester was R1 500 and used cow dung and water. A domestic floating dome biogas digester was installed in the Gwala household using local labour. The floating dome digester could supply gas to a refrigerator or a gas generator. The total cost was R15 000 including labour. Myeka High School was equipped with a large capacity floating dome biogas digester system and 16 flush toilets which were connected to the biogas digesters. Cow dung and human excreta were used to feed both the Gwala and school biogas digesters. Besides producing gas, the biogas digesters produced a watery residue which was used as fertiliser for crops.

Quantitative data was collected in the two households using questionnaires. The questionnaires were used to collect baseline data before installation of biogas digesters. Monitoring and evaluation after biogas installation was also carried out through questionnaires and observations. Qualitative and quantitative data before and after biogas installation was collected for the school case study through survey questionnaires, interviews and observations.

8.2 Conclusions

The hypothesis for this study was that biogas technology had the potential to provide households and a school in Maphephetheni with energy that is acceptable, affordable, efficient and sustainable and creates opportunities for income generation. The hypothesis was not fully accepted. The biogas was acceptable to the Gwala household and the school because they agreed to having the systems installed and they were satisfied with the biogas generated from cow dung and human excreta to cook and used the fertiliser in their crops.

Further conclusions for the Dube case study cannot be drawn as the plastic biogas system failed before commissioning. However, the age and the language difference contributed to the lack of success. The floating dome biogas digester was not affordable as income in the household was not enough to cover the cost of the biogas digester within 10 years of repayments. Also the savings on expenditure for both the household and the school were not significant enough to offset the cost of the biogas digesters which for the Gwala household, the engineer said would break even in six years but the study found that the price would be offset in 11 years. Affordability for the school was seen as being part of the government provision of buildings and the contribution of biogas to reducing the school expenditure was substantial (R8000 per year).

The biogas was efficient in providing gas, as in the Gwala household there was always gas available for cooking, besides the two weeks when the biogas digester was not fed because the old lady was sick and the head of the household had found a temporary job. For the school biogas system efficiency relied more on proper management of the system in terms of regular cleaning of the toilets and feeding of the biogas system.. The cleaning lady once used toilet cleaner to clean the toilets, and that disrupted the biogas process for two months.

Besides this hiccup at the school, the biogas efficiently provided gas to the Home Economics room during the time it was monitored.

The domestic floating dome digester was sustainable because there was no major maintenance needed except for painting the gas holder dome once every year. The time spent collecting cow dung and feeding the biogas digester was minimal and the task was said to be easy and not time consuming. Although sustainability was not investigated at the school, it could be assumed that the biogas digester could be sustainable provided proper support was given. Training of the management team (cleaners and biogas manager who did repairs to the biogas system and fed the biogas digester with cow dung when necessary), dissemination of information to users on proper usage of the toilets and biogas and benefits of the biogas is very necessary.

There were few income generating opportunities through the biogas, such as the sale of fertiliser in the Gwala household. The household generated some income through fertiliser sales but it soon stopped because the community was not that much interested in the fertiliser and did not know its benefits. Many of the sales took place during the planting season. Although there was time released for the woman who was responsible for firewood collection in the household, because of biogas use, it was not used to generate income. Much of the time released was spent in the gardens and doing normal household chores. The school did not generate any income through the biogas because the vegetable garden failed before the biogas system had started to produce any fertiliser. Fertiliser was not collected therefore there were no sales.

This study concludes that biogas could provide energy that is acceptable and efficient and sustainable but sustainability has to be accompanied by proper management. Affordability could be made possible by support from the government and other financial institutions. Income generation through biogas could be made possible if a market for crops and fertilizer is created and also if household members are trained and encouraged to use their released time for income generating opportunities.

8.3 Recommendations for government policy

Renewable energy has the potential of providing communities, especially those who are not connected to grid electricity, with alternative energy that is affordable. It became clear in this study that people cannot afford to raise the capital needed for a biogas digester, therefore government involvement with renewable energies is crucial. Government should look into subsiding biogas as it subsidises grid electricity and provide provide level playing fields as a basis for installation. In this study it was found that people do not have regular income, making them a risk to lending institutions. Government should also underwite the risk to financial institutions to grant loans and credit to people who want to purchase biogas systems. Training of people on renewable energy, including biogas should also be provided by government. Traning of installers, repair personnel, extension staff and other relevant people should be done because the engineers will not be always available to help fix the technology.

People who did not have biogas in this study had no information on the benefits of biogas, therefore had no interest. Dissemination of information on biogas is important. For people to be able to use biogas for cooking and the fertiliser on their crops, it is important to give them information that will convince them that there is nothing wrong with biogas. For people to use the biogas for income generating activities, loans and subsidies should have income generation as a prerequisite for obtaining financial assistance.

8.4 Recommendations for improvement of the study

Assessment of the benefits of biogas on crops should be included in the study. Quantitative measurements of the yield before and after biogas installation is important so as to find whether the benefis are true. Further field trials on crops fed with dung fertiliser, commercial fertiliser and biogas fertiliser would help local community garden members to see the improved crop production for themselves. A comparison between LP gas and biogas in terms of the strength of the heat produced could be carried out. Quanitification of the gas produced would also provide more accurate monitoring.

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APPENDIX A Pre-biogas installation questionnaires household questionnaires

PRE-BIOGAS QUESTIONNAIRE FOR HOUSEHOLDS

Name of respondent................................ Date................

1. DEMOGRAPHICS

1.1 How many people live in this household? (Give their names, age, gender and educational levels)

Name of person	Gender	Age	Educational level

2. HOUSEHOLD INCOME:

2.1 Please list all household members who have any type of income, be it regular work, casual labour, remittance, disability grant or pension.

Name of person	Type of income	Income per month

2.2 How much livestock do you own? (give the number)

2.3 How many types of crops do you grow? (Name them)

2.4 Do you sell any of these crops or livestock? Yes No

2.5 If yes, can you estimate how much income do you make from selling the above per year? (Name the product and amount)

2.6 Any income from selling any other products? (e.g. beads, sewing etc)

3 COOKING HABITS AND ENERGY USAGE

3.1 How many people are cooked for in this household on a daily basis?

3.2 Who cooks the meals for the household?

3.3 When is the cooking done? List the times

3.4 How much time does it take to cook each meal listed above?

3.5a) What fuel do you use for cooking?

b) Which of these fuels do you use list or most?

c) How much do you spend each week/month on the fuel?

d) How much does transport cost for refilling/buying the fuel?

e) How long does this take (hours)?

f) How often do you have to buy/refill/collect the fuel? (Daily/weekly/monthly)

Fuel type	Least/most use	cost	transport	Hours	How often
wood					
dung					
Petrol for generator					
electricit y					
charcoal					
gas					
paraffin					

3.6 What cooking equipment do you use?

a) open fire b) paraffin stove c) wood stove d) electric stove e) gas stove

3.7 What kind of pots do you use mostly? (Ask them to show pots)

THANK YOU FOR YOUR COOPERATION AND TIME

APPENDIX B Post biogas installation household questionnaires

POST BIOGAS INSTALLATION SURVEY FOR HOUSEHOLDS

Name of respondent........................ Date...............

1.1 Who cooks the meals for the household?

1.2 When is the cooking done? (list the times)

1.3 How much time does it take to cook each of the meals mentioned above?

1.4 Do you use different fuels for cooking different meals? (If so, mention fuel and type of food)

1.5 What equipment are you using for cooking?

1.6 What kind of pots are you using for cooking? (ask them to show pots)

2a) What other fuels do you use for cooking besides biogas?

b) Which of these fuels do you use most or least?

c) How much do you spend each week/month on the fuel?

d) How much does transport cost for refilling/buying fuel?

e) How long does this take?

f) How often do you have to buy/refill/collect fuel? (daily/weekly/monthly)

3.9 How do you feel about cooking with the biogas?

3.10 Are you experiencing any problems with the biogas digester?

3.11a) Who fixes the digester when there are problems?

b) How quickly does that person fix the digester?

c) Are you satisfied with the fixing?

3.12Have you had to empty the digester yet?

3.13a) Do you sell any cooked food? Yes No

b) What food do you sell?

c) To whom do you sell?

d) How often do you sell the food?

3.14a) Is there any income generating activity that you carry out through biogas?

Yes No

b) If yes, what is that activity?

c) If no, do you see any chance of generating an income through the biogas?

Yes No

Fuel type	Least/most use	cost	transport	hours	How often
Wood					
Dung					
Paraffin					
Petrol for generator					
Electricity					
Charcoal					
Gas					

3. Biogas experience

3.1 How many cattle do you have in this household?

3.2 Are the cattle put into a kraal at night? Yes No

3.3 Who refills the biogas digester?

3.4 How much time is spent refilling the digester?

3.5 Do you always have enough gas to cook?

3.6 Is the gas pressure even?

3.7 Is there water forming on the stove? Yes No
If there is, how much?

3.8 Do you use the biogas for anything else?

d) What kind of income generating activity do you think of?

e) What do you do with the water residue that comes out of the digester?

f) Have you sold any of the watery residue, if not, do you think it could be an income generating opportunity?

3.15 What else would you like to be able to do with the biogas system?

THANK YOU FOR YOUR TIME AND CO-OPERATION

APPENDIX C **Myeka High School students' pre installation survey questionnaire**

QUESTIONNAIRE ON INPUTS FOR MYEKA HIGH – BIOGAS PROJECT

Learner's name: Interviewer:

Age of learner: Grade: Sex:

1. Breakfast eating habits

1a) Do you eat breakfast before coming to school?

Always Sometimes Never

1b) Do you drink anything during before coming to school?

Always Sometimes Never

1c) If you do have breakfast, what do you drink or eat?...................................

....

Eating habits at school

1d) Do you bring or buy lunch at school? Yes No

1e) If yes, what do you eat or drink (including water)

Small break..

Lunch...

2. Toilet usage at school

2a) How many times do you use the toilet a day/week?.............................

2b) If you do use, how many times do you urinate a day/week?.................

How many times do you defecate a day/week?........................

2c) If not using the toilet at all or always, give two important reasons on why not using the toilet... ....

....

2d) What would you like to see change in the toilets for you to use them freely?

....

....

2e) Is there another place that you use to relieve yourself? Yes No

If there is, where...

3. Toilet usage by outsiders

3a) Do you attend community functions/meetings held at the school? Yes No

3b) Do community members use the school toilets during these meeting/functions?

Yes No

3c) If yes, estimate how many people use the toilets.............................

3d) Are there any outsiders who use the school toilets during school hours?

Yes No

3e) If yes, estimate how many people use them.................................

THANK YOU FOR YOUR TIME AND COOPERATION

APPENDIX D **Myeka High School students' impact assessment survey questionnaire**

IMPACT ASSESSMENT SURVEY QUESTIONNAIRE

Name of leaner............................
Name of interviewer........................

Grade ....
Date......................

Sex of learner...................

1a) Have you used the new toilets connected to the biogas? Yes No

b) If yes, what do you like about them?

c) What do you not like about them?

d) If no, give reasons why you have not used the toilets?

2. Have you been given any information on how to use the toilets? Yes No

What have you been told about toilet use?

3. What do you know about how biogas works?

4. Where did you get the information from?

5a) Are you involved in any activities with the biogas/ toilets e.g. issuing of toilet paper, toilet management/cleaning, biogas management? Yes No

6. Who manages the toilets and the biogas?

7. How do you think the biogas system will benefit the school?

8. Do you have any other comments about the biogas / toilets?

THANK YOU FOR YOUR TIME AND COOPERATION

APPENDIX E Myeka High School secretary's questionnaire on energy resources and expenditure

Myeka High School questionnaire on energy usage and expenditure

Name of respondent........................... **Date..........**

1. What other sources of energy does the school use to run its equipment/appliances?

2 Which equipment/appliances use the energy sources at the school?

3. What problems do you experience with the availability of the energy sources?

4a) Which of all the energy sources do you use most/least?

b) How much do you spend each week/month on the energy sources?

c) How much do you spend on transport for refilling/buying/paying for the other energy sources?

d) How long does this take (hours)?

e) How often do you have to refill/buy/collect the energy sources? (weekly/monthly)

Energy source	Least/most use	Cost	transport	Hours spent	How often
Grid					
Solar					
LP Gas					

5. Does the school pay for the energy sources it uses or does the money come from outside sources?

6. Does the school have any agricultural activities – crop planting or cattle breeding?

Yes No

If yes, is there any income generated through the above activities? Yes No

7. How much money is made?

8. Are there any income generating activities that are carried out using the equipment/appliances run by the sources of energy? Yes No

If yes, which activities?

9. How much money is made through those activities?

THANK YOU FOR YOUR TIME AND COOPERATION