Development Implications and Sustainability of Biogas Plants in Njombe District, Tanzania

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Declaration

I, Linn Gulbrandsen, declare that this thesis is a result of my research investigations and findings. Sources of information other than my own have been acknowledged and a reference list has been appended. This work has not been previously submitted to any other university for award of any type of academic degree.

Ås, June 20th 2011

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Asanteni

Abstract

This thesis focuses on biogas as a sustainable energy source compared to traditional fossil fuels commonly used in rural areas in Tanzania. It also examines the household's usage and behaviour towards biogas, and if introduction to this technology can improve the development for the farmers in the area. Interviews with 11 farmers who had established biogas plants and 11 farmers without biogas were carried out. The methods used were both qualitative and quantitative in the form of in-depth and semi-structured interviews together with a survey. This study was conducted in Ibumila and Lunyanywi village within Njombe district in Tanzania. Biogas technology is highly relevant for the households keeping dairy cattle in Njombe with regards to cover the needs of cooking and lighting. The use of firewood, charcoal and kerosene has been significantly reduced after establishing biogas and women have more time to rest after the demand for firewood has been reduced, leading to improved health. From spending 2.5 hours collecting firewood, they are now using 20 minutes to perform the tasks for biogas production. This extra time is used for work on the farm and for other income generating activities, and the independence from traditional fossil fuels can save the households USD 375.65 annually. Biogas has led to a radical change in the division of labour. Gathering firewood was mainly the women´s responsibility, but after introduction of biogas the women only have the main responsibility in 4 of the 11 households, while in the remaining 7 households the fathers have got an increased responsibility of gathering the inputs for biogas production. This is also the case for cooking, where the lack of soot and smoke, together with the simplicity of cooking have resulted in 6 households were the father and mother have equal responsibility of cooking, and 5 where all the members share this responsibility, previously only performed by women. This shows that introduction to biogas have empowered women and differ highly from the households without biogas plants. Biogas technology is contributing in achieving 7 of the Millennium Development Goals, but there are also some limitations to biogas in the two villages. The total cost of establishing a biogas plant is USD 1,954, and even with a 50% subsidy covered by the farmer groups, the amount paid by the households is equivalent to double the annual income for the farmers without biogas plant, leading to a slow uptake of the technology and a trend where only the farmers who are more well off will be able to acquire it. The awareness regarding the technology is rather low, and there is also a limitation that the pipes are mainly leading into the kitchen, limiting the use of biogas for lighting other rooms and for heating, meaning that the households still have to use firewood, charcoal and kerosene to some extent.

Table of Content

List of Tables

List of Figures

List of Acronyms

ELCT	Evangelical Lutheran Church in Tanzania
EPINAV	Enhancing Pro-poor Innovations in Natural Resources and Agricultural Value-chains
HPI	Heifer Project International
MDG	United Nations Millennium Development Goals
NGO	Non Governmental Organization
PANTIL	Programme for Agricultural and Natural Resources Transformation for Improved Livelihood in Tanzania
RETs	Renewable Energy Technologies
SACCO	Savings and Credit Cooperative Society
SHDDP	Southern Highlands Dairy Development Programme
SHIPO	Southern Highlands Participatory Organization
SUA	Sokoine University of Agriculture
TARP II	Food Security and Household Income for Smallholder Farmers in Tanzania: Applied Research with Emphasis on Women
TDBP	Tanzanian Domestic Biogas Programme
UMB	Norwegian University of Life Sciences

1 Introduction

Over 2 billion people worldwide and 89% of the population in south-Saharan Africa use biomass for cooking and heating. This creates a great pressure on the surrounding biodiversity due to the amount of forest being cut for fuel, together with time-consuming work and health issues (Brown 2006). The worlds increasing population, especially in developing countries, will accelerate the demand for fuel wood and deteriorate deforestation to a point where sustainable land use become impossible (Schulte-Bisping et al. 1999). It is therefore important to find alternative energy sources that are less damaging for the environment and that put less pressure on the forest. Introduction of renewable energy sources have occurred in developing countries for several years, but the focus on this field have risen the last years due to the increased awareness on the global environmental status. The most common types of renewable energies introduced in developing countries are hydropower, biogas, solar energy, wind energy and geothermal energy. These forms of renewable energies have predominantly been introduced on the Asian continent with great success, but there have now been an increase in projects focusing on renewable energy in Africa (Qurashi & Hussain 2005).

In Tanzania the majority of people in rural areas use firewood and kerosene for lighting and cooking. The use of these fossil fuels leads to discharge of toxic gasses and smoke, and may lead to serious consequences for the health of the ones who inhale it. The ones most exposed are women and children who are responsible for cooking together with the physical job of gathering fire fuels for the household (Kupaza 2010). The Tanzanian government states that livelihoods cannot be improved and the country cannot get a modern economy without an improvement with regards to modern energies for the rural areas (Rural Energy Agency 2011). Only 1% of the rural population in Tanzania has access to grid connection while the rest are dependent on firewood. The large amount of people dependent on firewood leads to an unsustainable pressure on the surrounding environment causing destruction of forests followed by reduced biodiversity, destruction of water sources, and soil erosion (Kupaza 2010). Environmental destruction on this level will complicate the livelihood of the people living in rural areas since a majority of these people depend on agriculture and livestock keeping, and therefore rely on productive soils (Kupaza 2010).

Modi et al. (2005) states that*" energy is central to sustainable development and poverty reduction efforts"* meaning that development cannot be enhanced to a sustainable level without emphasising on energy. This has also been recognized by other development organizations and Flavin & Aeck (2005:13) claims that "*"modern" energy services… can greatly assist societies in reducing poverty and hunger and meeting the heath, education, gender, and environmental elements of the Millennium Development Goals".* This indicates that a successful implementation of renewable energy in developing countries may improve several fields of development together with enhancing the environment.

1.1 Aim of the Study

The aim of this study is to see if biogas is a sustainable solution to fossil fuels and if the implementation of biogas as a renewable energy source is enhancing the development in Ibumila and Lunyanywi village in the Southern Highlands of Tanzania. The suitability of biogas as a renewable energy technology in the area will also be studied to find the appropriate substitution for fossil energy in the given areas.

1.2 Research Objectives

The purpose of this research is to study if the implementation of biogas plants has caused any improvements with regards to development in two villages in Njombe district and to assess the sustainability of biogas plants for cooking and lighting. If introduction of renewable energy may enhance the development in rural areas in Tanzania, it may also be a substitute wood fuels and kerosene, and this can preserve the environment.

The focus in this thesis is *to look at the development implications and sustainability of the establishment and use of biogas plants in Ibumila and Lunyanywi village in Njombe district, Tanzania*. To answer this I have three objectives. The first objective is *to find out what it requires to run the biogas plants in a sustainable way*. To get a successful implementation of biogas it is crucial that it doesn´t entail more workload than their previous energy source, and that they have proper knowledge on biogas technology and its user area. It´s also vital that the amount of produced gas can substitute their use of traditionally fossil fuels and that capital requirements are relatively low so that it is affordable for rural households.

The second objective is *to understand the farmer's behavior towards the establishment of biogas plants and use of biogas.* The farmer's behavior towards the introduction of a new technology is crucial for a successful adoption. This is dependent on the farmer's acceptance of biogas with regards to e.g. social and cultural norms. I would also like to see how the awareness and behavior toward biogas is perceived by the households who don´t have biogas plants.

The third objective is *to see the development implications of biogas, and see if there are any significant differences between farmers with biogas plants and farmers without biogas plants*. It has been stated in prior research that implementation of renewable energy sources may enhance the development in rural areas. Due to this prediction, farmers in possession of a biogas plant are more likely to be better off than farmers without a biogas plant. The implementation of renewable energy technology is also said to help achieve the United Nations Millennium Developing Goals (MDGs).

1.3 Previous Research on Biogas

Biogas is not a new invention. Asian countries like China, India and Nepal have been subjects for a great amount of research concerning biogas. Much research in Europe and USA has been done on large-scale biogas production, but this research is not comparable to the biogas production in developing countries. There are particularly few papers on biogas production in Africa since biogas in this area is not as widespread as in Asia hence less research on biogas has been conducted here. Observations have shown that research carried out in sub-Saharan countries mainly deal with the technical aspect of biogas production such as anaerobic digestion, design of biogas plants and research on the effect of temperature and on fermentation. Biogas slurry and its application, qualities and advantages have also been carefully researched together with research that addresses the policy aspects of biogas together with economic evaluation of the technology. This also applies the biogas research carried out in Tanzania, where the greater part is carried out in the northern parts of Tanzania, specifically in Arusha region.

1.4 Structure of the Paper

The second chapter will introduce the relevant theories used in this research project and the third chapter will give a contextual background on the area of research, environmental problems and the status on renewable energy in Tanzania together with an elaboration of the concept of biogas. The fourth chapter will be focusing on the research methods used for the research, while the fifth chapter will present and discuss the findings of my research and challenges with regards to biogas in Njombe together with the way forward for this technology in the area. At last, the sixth chapter will sum up the paper with a conclusion.

2 Theoretical Framework and Literature Review

2.1 Definition of Key Concepts

2.1.1 Renewable Energy and Renewable Energy Technologies in Developing Countries

According to Flavin & Aeck (2005:14) "*Renewable energy sources capture their energy from existing flows of energy, from on-going natural processes, such as sunshine, wind, flowing water, biological processes, and geothermal heat flows.*" By finding different technologies to harness these energy sources, they can be turned into energy services that meet individual energy demand for e.g. lighting, cooking, heating, electricity etc. (Table1). The demand for these renewable energy technologies (RETs) have increased in recent years, especially in developing countries due to the unstable price of fossil fuels together with a decline in cost of RETs (Flavin & Aeck 2005).

Table 1: Major Renewable Energy Technologies and Applications (Flavin & Aeck 2005)

Renewable Energy Technology/Application	Energy Service	Local of Application
Solar PV	Residential and industrial electricity (grid-connected)	Mostly urban
Solar Home Systems (SHS)	Lighting (homes, schools, streets) and other low-to-medium voltage electric needs (telecommunications, hand tools, etc.)	Urban and rural
Solar PV Pumps	Pumping water (for agricultural and drinking)	Mostly rural
Solar Thermal	Residential and industrial electricity (grid-connected)	Mostly urban
Solar Water Heaters	Heating water	Urban and rural
Solar Cookers	Cooking (for homes, commercial stoves and ovens)	Mostly rural
Solar Dryers	Drying crops	Mostly rural
Wind Turbines	Residential and industrial electricity (grid-connected), Mechanical power and low voltage electricity needs (small stand-alone)	Urban and rural
Wind Pumps	Pumping water (for agriculture and drinking)	Mostly rural
Biogas	Residential and industrial electricity (grid-connected), cooking and lighting (household-scale digesters), motive power for small industry and electric needs (with gas engine)	Urban and rural
Solid Biomass	Cooking and lighting (direct combustion), motive power for small industry and electric needs (with electric motor)	Mostly rural
Liquid Biofuel	Transport fuel and mechanical power, particularly for agriculture; heating and electricity generation; some rural cooking fuel	Urban and rural
Large Hydro	Grid electricity (residential and industrial)	Mostly urban
Small Hydro	Lighting and other low-to-medium voltage electric needs (telecommunications, hand tools, etc.), process motive power for small industry (with electric motor)	Mostly rural
Geothermal	Grid electricity and large-scale heating	Urban and rural
Village-scale Mini-grids and Solar/Wind Hybrid Systems	Lighting (homes, schools, streets) and other low-to-medium voltage electric needs (telecommunications, hand tools, vaccine storage, etc.)	Mostly rural, some peri-urban

2.1.2 Sustainable Development

Sustainable development became a concept through the Brundtland commission in 1987 with the report "Our Common Future". The Brundtland commission defined sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland 1987). Economic growth is often undermining ecological wealth, but the term sustainable development tries to unite both economic growth and preservation of the environment together with community development (International Council for Local Environmental Initiatives 1996).

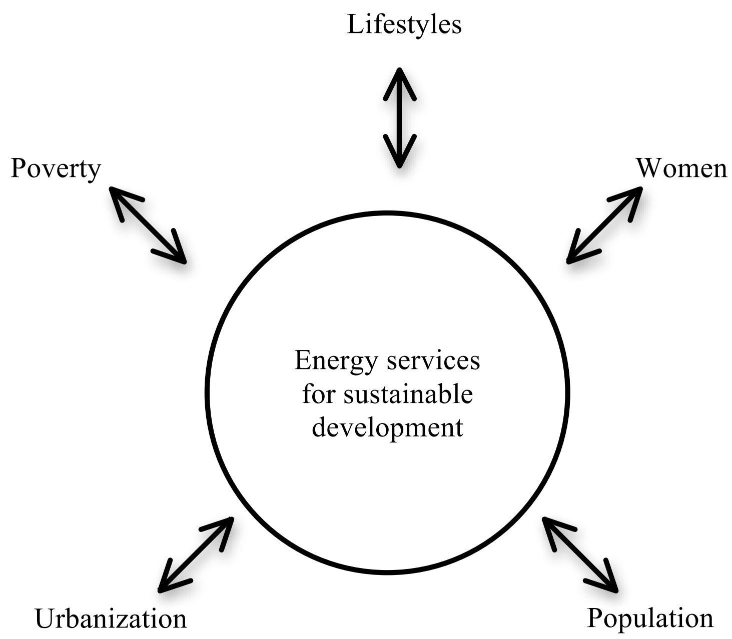
2.2 Renewable Energy for Development

As mentioned in the introduction part, there are more than 2 billion people worldwide relying on traditional biomass for cooking and heating together with 1.6 billion people who have no access to electricity. Energy poverty is a decisive obstacle for social and economic development and is a vital matter for sustainable development. World Energy Assessment (2000:44) defines energy poverty as "*the absence of sufficient choice in accessing adequate, affordable, reliable, high quality, safe and environmental benign energy services to support human and economic development.*" The past 50 years of development efforts have hardly accomplished to provide sufficient energy for the poor people living in rural areas (Flavin & Aeck 2005). According to UN-Energy (2005:2) this lack of energy technologies *"entrenches poverty, constraints the delivery of social services, limits opportunities for women, and erodes environmental sustainability at the local, national, and global levels."*

Introduction to RETs will not alone achieve development but is a means that will assist economic and social development (Wilkins 2002). Access to affordable energy sources, especially in rural areas of developing countries is critical for development and for alleviating poverty. In many of these areas, grid connection for electricity is infeasible due to their location, unreliable services, insufficient economical situation, and lack of infrastructure (Flavin & Aeck 2005). In these cases, RETs can play a crucial role, providing reliable and affordable energy services for people who otherwise would have no access to it, together with enhancing the social and economic development in the area.

Introduction to RETs have both direct and indirect influence on development. With renewable energy, women and children are less exposed to hard work concerned with harnessing fuel wood together with toxic fuel from the indoor pollution when burning firewood. This leads to more time for education and income generating activities together with possibilities of lighting beyond daylight, which may create the opportunity for improved education, evening classes and improved informational work for women and children, increase the family´s income, and improve living standards. Introduction to renewable energy may also contribute to increased quality on the local schools by providing electricity and get access to educational media, which may improve the student's attendance. The local clinics may also improve due to the possibility of refrigerating medicines, sterilizing of equipment, easier access to freshwater and more advanced sewage systems to reduce diseases (Martinot 2005). In other words, RETs can change lifestyles by interacting with social issues, empower women and reduce poverty, urban migration, and population growth.

Figure 1: Energy and social issues (Wilkins 2002)



Flavin & Aeck (2005:13) claims that a stronger focus on RETs in developing projects and by governments in developing countries can help to achieve 7 out of the 8 United Nations Millennium Development Goals (MDGs) and in this way *"greatly assist societies in reducing poverty and hunger and meeting the health, education, gender and environmental elements of the MDGs."*

Table 2: Importance of Energy to Achieving Specific Millennium Development Goals, modified table from (Flavin & Aeck 2005)

MDG	Modern Energy Contributions
1. Cutting Extreme Poverty and Hunger	• Reducing share of household income spent on cooking, lighting, and space heating. • Improving ability to cook staple foods. • Reducing post-harvest losses through better preservation. • Enabling irrigation to increase food production and access to nutrition. • Enabling enterprise development, utilizing locally available resources, and creating jobs. • Generating light to permit income generation beyond daylight. • Powering machinery to increase productivity.
2. Universal Primary Education	• Providing daylight for reading or studying beyond daylight. • Creating a more child-friendly environment (access to clean water, sanitation, lighting, and space heating/cooling), which can improve attendance in school and reduce dropout rates. • Providing lighting in schools, which can help retain teachers. • Enabling access to media and communications that increase educational opportunities. • Reducing space heating/cooling costs and thus school fees.
3. Gender Equality and Women´s Empowerment	• Freeing women´s time from survival activities, allowing opportunities for income generation. • Reducing exposure to indoor air pollution and improving health. • Lighting streets to improve women´s safety. • Providing lighting for home study and the possibility of holding evening classes.
4,5,6. Health	• Providing access to better medical facilities for maternal care. • Allowing for medicine refrigeration, equipment sterilization, and safe disposal by incineration. • Facilitating development, manufacture, and distribution of drugs. • Providing access to health education media. • Reducing exposure to indoor air pollution and improving health. • Enabling access to the latest medicines/expertise through renewable-energy based telemedicine systems.
7. Environmental Sustainability	• Boosting agricultural productivity, increasing quality instead of quantity of cultivated land. • Reducing deforestation for traditional fuels, reducing erosion and desertification. • Reducing greenhouse gas emissions. • Restoring ecosystem integrity through land management.

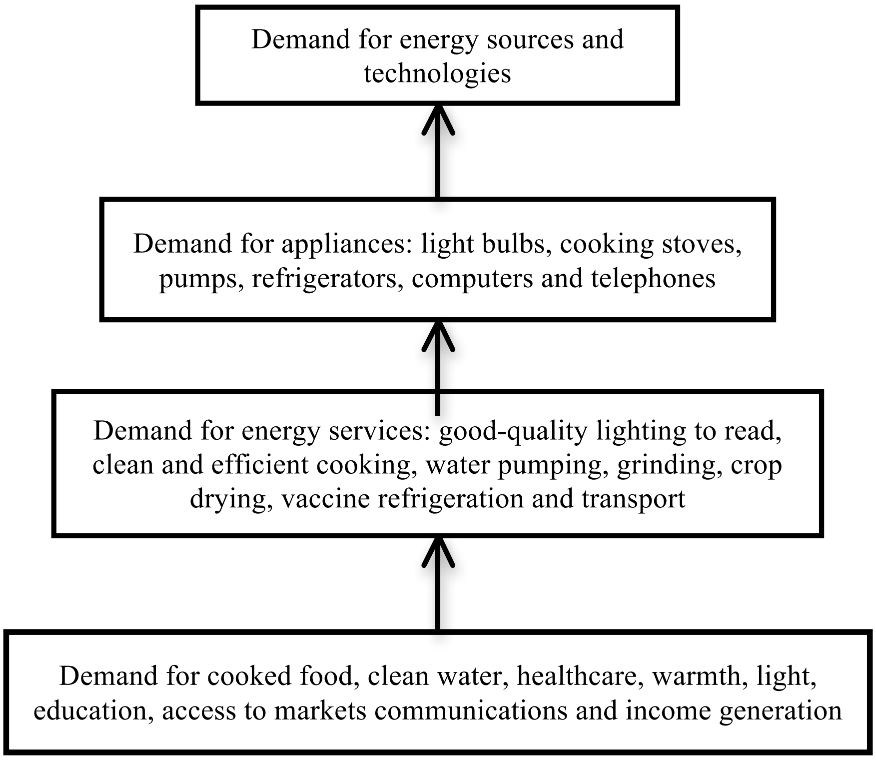
2.3 Transfer of Appropriate Technology

Technology transfer can be defined as "*the diffusion and adaption of new technical equipment, practices and know-how between actors (e.g. private sector, government sector, finance institutions, NGOs, research bodies etc.) within a region or from one region to another." (Wilkins 2002)*

According to Wilkins (2002) there are five important aspects of getting successful technology transfer: affordability, accessibility, sustainability, relevance and acceptability. The profitability of adopting a new technology needs to be higher than alternative and traditional technologies and must be easy accessed in the local community. The technology needs to be adapted to the local conditions and meet the energy needs for the people, it´s also vital that the technology will be accepted by the recipients in concern to the risks of adopting and cultural acceptance. "*Technology*" is not only the equipment, but also the knowledge required to fund, manufacture, operate and maintain the equipment, while "*transfer*" is the process of converting the concept of the technology into a sustainable framework that is understandable for the local people and in that way the technology can be utilized in a sustainable manner and increase the amount of successful implementation (Wilkins 2002).

Wilkins (2002) states that energy is a derived demand, where people don´t demand their specific fuel for energy, but rather desire the services a fuel can provide. In developing countries the priority is energy that can cover cooking and space heating, followed by lighting, water pumping, radio, communications etc.

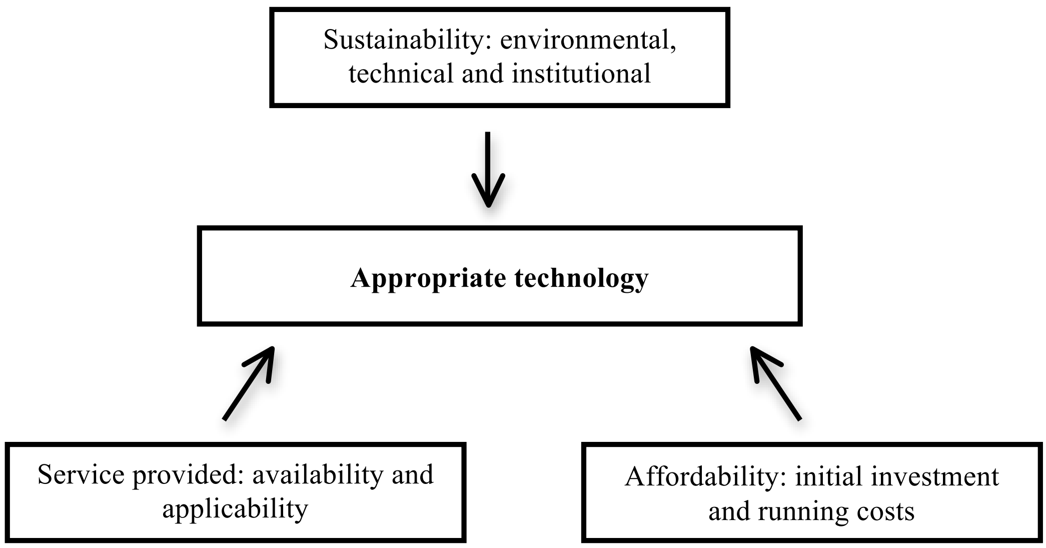
Figure 2: Energy, a derived demand (Wilkins 2002)



Since the majority of the people living in developing countries today use firewood and charcoal for the two most prioritised services, cooking and space heating, and kerosene for lighting, it is not likely that they will invest in new technology that will achieve the same results without being made aware of what advantages new technology can bring with regard to physical health, time-saving, less hard work, cost efficient, or environmental improvements with regards to the local environment and indoor-pollution. But even with awareness of what the new technology can bring about, the issue of capital to invest in these technologies might be absent.

When introducing RETs in developing countries it´s important that the most appropriate technology is selected. Wilkins (2002) believes there are three main criteria that need to be considered concerning this selection (Figure 3). The technology introduced need to be sustainable in the sense that it covers required energy services in the area, are environmentally sound, and are affordable based on the population´s economic situation. When introducing a new energy technology there need to be a market for the service and the technology have to be easily available and affordable for the users. It is therefore substantial that socio-economic factors are taken into consideration together with the local environment and the current energy technology used in the area.

Figure 3: Criteria for transfer of appropriate technology modified (Wilkins 2002)



2.4 Diffusion of Innovation

The diffusion of innovation theory tries to explain how and why individuals and organizations absorb and adopt to innovation and at what rate it spreads through social systems. Diffusion is *"the process by which an innovation is communicated through certain channels over time among the members of a social system"* (Rogers 1995:10). According to Rogers (1995) there are four main elements in the diffusion of innovation: innovation, communication channels, time, and the social system.

2.4.1 Innovation

Innovation is the idea, practice or object that a person or organization perceives as new. It consists of two components, hardware and software, where the hardware of an innovation is the physical tool of a technology, while the software is the knowledge base for the technology. According to Rogers (1995) there must be five attributes of an innovation that makes individuals adopt it. First, the innovation needs to have relative advantage by being better than previous innovations i.e. time saving, more financially sound and require less work etc. Second, it needs to be compatible with previous or existing innovations with regards to values and be incorporated with the needs of the individuals. Third, the innovation cannot be too complex for an individual to use as it can result in rejection of the innovation instead of adoption. Fourth, it needs to have trialability in the way that the innovation can be examined and evaluated by the individual before it is being adopted, and in this way it can be rejected if the innovation is too hard for the individual to use. Fifth, the innovation must have observable result, and in this way communication between individuals may spread negative or positive reactions about the innovation.

2.4.2 Communication Channels

Communication channels create knowledge of an innovation by sharing information between individuals who has knowledge of, or has experienced the innovation to individuals who have no knowledge or experience with the innovation (Rogers 1995). This information exchange through communication will create certain attitudes toward the innovation and influence individuals' decision to adopt or reject an innovation. Information about innovations that are subjective evaluated by individuals who have adopted an innovation is more likely to come through rather than scientific research by experts. Rogers (1995) claims that interactions between individuals who have different attributes, heterophily, are more problematic than interaction between individuals with similar attributes, homophily, when communicating about an innovation, but within the diffusion of innovation, heterophilious interaction is most common, which easily leads to ineffective communication.

2.4.3 Time

The third main element in the diffusion of innovation is time. This element is divided into three components consisting of the innovation-diffusion process, adoption categories, and rate of adoption.

2.4.3.1 Innovation-Diffusion Process

The innovation-diffusion process concerns the process of an individual to adopt or reject an innovation. This process, according to Rogers (1995), has five steps before an individual will decide to adopt or reject an innovation. First is the knowledge stage where the individual is first exposed to the innovation, but has a lack of information about the innovation. Second, in the persuasion stage, the individual gets increasingly more interested in the innovation and will try to get more information about it. Third, the individual will weigh the advantages and disadvantages before it decides to adopt or reject it in the decision stage. The fourth stage is the implementation stage where the individual determine if the innovation is as useful as expected before the fifth stage with the final decision to use or not to use the innovation is taken.

2.4.3.2 Adopter Categories

The time of adoption of an innovation tend to differ between individuals, and according to Rogers (1995) it follows a S-shaped curve where there are only a few individuals who primarily adopt the innovation. With time, more individuals will adopt the innovation and the diffusion rate will rise before it will descend over time.

Rogers (1995) divides the different adopters into five categories where the innovators are the first to adopt an innovation. The characteristics of the innovators category are that they are risk-takers of young age with the highest social class, great financial control in the sense that they can absorb failure, and have close scientific sources and other innovators. Early adopters are the second category to adopt an innovation. They feature the ones with the highest degree of opinions and are of higher education. The early adopters are as the innovators, of young age, high social status, and great financial control, but are more cautious than the innovators.

The third category consist of the early majority who are individuals that adopt at a slower rate than the first two, but have contact with the early adopters and have higher social status than those in the last two categories. The category of late majority will adopt the innovation later than the majority of the society due to their sceptical view on innovations. This category is characterised by having a social status that are below average, low financial lucidity, but still have contact with the early majority and others in the late majority category. The last category is the laggards who usually are of older age, rely more on traditions, are reluctant to change, and are therefore the last to adopt an innovation. This category has poor economy, low social status, and only has contact with the closest of family and friends.

2.4.3.3 Rate of Adoption

The rate of adoption is the time individuals of a social system use to adopt an innovation. The time an individual use to adopt depends on its affiliation to the adopter categories. The categories that adopt early are the ones who usually require a short adoption period, while the ones who adopt late need a longer adoption period. According to Rogers (1995) the innovation will reach a point where the amount of individuals who have adopted the innovation is high enough to make it self-sustaining and with this reached the critical mass.

2.4.4 Social System

Social systems influence individuals, groups or organizations through communication networks and create diffusion of an innovation. Interpersonal communication is used to exchange information and experiences that will result in the innovation-decision to adopt or reject an innovation. According to Rogers (1995), there are three main types of innovation-decisions. First, there is the optional innovation-decision where an individual independently choose to adopt or reject an innovation without any input from members of the social system. Second, the collective innovation-decisions choose to adopt or reject in consensus with the majority of the social system, and at last, the authority innovation-decision, where a few powerful individuals with high social status or expertise decide if the innovation should be adopted or rejected.

3 Contextual Background

3.1 Area of Research

The United Republic of Tanzania is located in East Africa and consists of the mainland and the islands of Zanzibar, Pemba and Mafia. Tanzania is bordering Kenya, Uganda, Rwanda and Burundi in the North and Northwest, and Democratic Republic of Congo, Zambia, Malawi and Mozambique in the West and South while the eastern part borders the Indian Ocean (Marree & Nijboer 2007).

Figure 4 Map of Tanzania
Source: (Magellan Geographix 1997)

Tanganyika became an independent state from the United Kingdom in 1961 followed by the independence of Zanzibar in 1963. Together Tanganyika and Zanzibar merged together as Tanzania in 1964, but Zanzibar is today a semi-autonomous state with separate election. In 1974, Dodoma was declared the capital of Tanzania, but Dar es Salaam is still the largest city in Tanzania and is considered the commercial capital of Tanzania (Bryceson et al. 2011). The estimated population in Tanzania is 42,746,620 consisting of more than 130 ethnic groups. Population growth rate in Tanzania are 2,002% and the life expectancy at birth is 52.85 years (The World Factbook 2011).

Tanzania is one of the poorest countries in the world with an estimated GNP per capita of USD 280 in 2000 with a projected growth rate on 0.3% per year (The World Factbook 2011). Their economy is largely based on agriculture with major crops as cotton, coffee, corn, rice, cloves, sisal, cashews, and tobacco. Its economy also benefits from minerals like gold, diamonds, gemstones, coal, and natural gas (Bryceson et al. 2011).

3.2 Njombe District

Njombe district is located in the Southern Highlands of Tanzania and are one of seven districts in Iringa region.[1] The district is divided into 5 divisions, 36 wards, 154 villages and 780 sub-villages. The total surface area of Njombe is 7680 square kilometres (Njombe District Council 2010).

3.2.1 Population

The majority of the people living in Njombe district are from the Bena tribe. The latest census showed that the population size in Njombe district was 362,441 people where 173,972 are males and 188,469 are females. The growth rate in Njombe district was from 1988 to 2002 at 2.1% and the estimated projection from 2002 to 2012 are 1.3%. In 2002, the average household size in Njombe district was 4.2, and this has increased in 2010 to 4.8.

The population density in Njombe district was in 1967, 18 people per square kilometre and is estimated to be 48 people per square kilometre in 2012. This indicates that the population growth in Njombe increasing, and this occur especially around the trading areas. Urbanization in Njombe district has increased the last years from 7.4% in 1988 to 22.6% in 2010 (Njombe District Council 2010).

3.2.2 Climate and Topography

The common landform in Njombe district is big plateaus dominated by mountain ranges with Kipenge mountain ranges in the south and Lupembe mountain ranges in the north. Njombe district have two climatic zones: highland zone and lowland zone. The highland zone is continuation of the Southern Highlands. The temperature in the highland zone lies below 15 degrees with a humid climate, and the amount of rainfall lies between 100 and 1000mm per annum. The soils in the highland are volcanic and the vegetation is planted and natural forest, fruit trees, shrubs and grasslands. The lowlands border the Great Rift Valley, and the whole area is between 1000 to 2000 meters above sea level. The climate in the lowlands is hot and dry with an unreliable rainfall between 600 and 1000 mm per annum and temperatures

[1] At the time of writing, Njombe district is still a part of Iringa region, but plans of making this its own region are in work. (Njombe/Njoluma region)

between 15 and 20 degrees. The soils in the lowland are gravel sandy soils covered with thorny bushes (Njombe District Council 2010).

3.2.3 Agriculture

Agriculture and livestock keeping is the dominant activity for the population in Njombe district and the largest sectors in Njombe districts´ economy. The major cash crop cultivated in the area is tea followed by Irish potatoes and timber. Peasantry farming are the most common way of farming but the crops cultivated in the highlands and lowlands differ. Crops in the highlands include maize, bananas, garden peas (green peas), tea, coffee, wheat, pyrethrum, temperate fruits, while the lowlands mainly cultivate maize, beans, sweet potatoes, cowpeas and fruits (Njombe District Council 2010). Livestock keeping mainly concerns indigenous cattle, while improved dairy cattle only covers 2.89% of the total population of cattle. Other livestock keeping include pigs, sheep's and goats.

3.3 Deforestation in Tanzania

Deforestation and forest degradation is an increasing threat to the Tanzanian environment. Forest and woodlands cover about 40% or 33.5 million hectares of Tanzania´s mainland, and yearly estimates of deforestation range from 100,000 – 500,000 hectares (Vatn et al. 2009). The two most common reasons for deforestation in Tanzania are the removal of forest cover to establish agricultural land and consumption of wood fuels like firewood and charcoal for energy use (UN-REDD 2009). According to Vatn et al. (2009), 95% of the annual consummated wood in Tanzania is for fuel for domestic purpose. Tanzania´s continuous populations growth will deteriorate the forests when the need for land increases together with the growing demand for wood fuels (UN-REDD 2009). Government subsidies on agricultural inputs may also lead to deforestation when the quality of soils deteriorates and the production decreases to the point that the farmers have to expand their agricultural land (Vatn et al. 2009).

Other causes for deforestation in Tanzania may occur due to livestock grazing, wild fires, commercial timber extraction, illegal extraction of timber, construction of houses, building of roads etc. The use of timber are in many cases essential for human needs, but deforestation as a consequence may lead to conflict, loss in biodiversity and climate change (Lindsley 2007).

3.4 Renewable Energy in rural areas of Tanzania

By investing in renewable energy technology, some of the major environmental challenges in Tanzania may be reduced and the high pressure on their forests will decline. The greatest pressure on the environment is in the rural areas of Tanzania where there are few options to fuel woods, and it's therefor important to spread the knowledge and technology of renewable energy to these areas. It is today several renewable energy technologies available in Tanzania, but the common problem related to introduction of these technologies are the lack of knowledge, local expertise and materials (Sheya & J.S. Mushi 2000). The most promising renewable energy technologies in Tanzania today are solar thermal technology for heating of water, solar photovoltaic technology for electricity, refrigeration and water pumping, hydro plants, geothermal- and wind energy for electricity, and biogas (TASEA 2005).

3.5 Biogas

Biogas technology is one alternative to an environmentally friendly substitution for fossil fuels and reducing the pressure on forests. It can be used for e.g. cooking, lighting, refrigeration and engines, and replace the use of fossil fuels totally within these fields (Sudi & Ngowi 1999). Besides deforestation it can also reduce the burden of women to gather firewood. The less forest there is, the longer the women have to walk to collect the necessary amount of firewood for the household, and this is very exhausting and time-consuming. When using biogas as a substitute for traditional fuels, women save time and energy, which can be used on other activities on the farm (Fjørtoft & Grimsby 2011). When traditional fuels no longer is in use, women and children are not exposed by in-door pollution and can prevent diseases like pneumonia, chronic respiratory diseases and lung cancer which is responsible for the death of 1.6 million people every year (Bruce et al. 2002), they also avoid running eyes and sore throat, which is common when cooking with traditional fuels such as firewood.

Biogas is a clean combustible renewable gas, made by organic waste. The most commonly used waste is agricultural waste, manure from cows and pigs, but sewage sludge, energy crops, and industrial organic waste is also compatible (Balat & Balat 2009). The ingredients needed for the production are organic waste, bacteria, anaerobic conditions and heat. In the biogas process, bacteria are converting the organic waste into methane gas in a non-oxygen environment called an anaerobic digester (Fleming & Soos 2009). The biogas consists of 55-65% methane, 35-45% carbon dioxide, 0-3% nitrogen, 0-1% hydrogen and hydrogen sulfide (Balat & Balat 2009).

Biogas slurry is the by-product from the biogas production. After the digestion, the residues will come out in liquid form, and this slurry is a valuable fertilizer that can supplement the use of inorganic fertilizers (Fjørtoft & Grimsby 2011). The biogas slurry contains high amounts of nitrogen, phosphorous and potassium, which are essential nutrients for the crops (Ghamunga & Ngowi 1999). By using the biogas slurry as fertilizer, it supplies the soil with essential nutrients, enhancing the water holding capacity of the soil and in this way maintain the soils fertility. It furthermore accelerates the growth of roots, increases the production of crops and reduces the spread of weed seed. Since the slurry is liquid, it will be easily absorbed by the plants and enrich the soil. Biogas slurry can also be dried or mixed together with composted manure, but by doing this the nitrogen level will decrease and can decline by 90% (Vasudeo 2011). Use of biogas slurry as a fertilizer can also help against pests and acts as a natural pesticide for the soil (Gurung 1997). The slurry does not have any odour and in this way it does not attract mosquitos of flies (Ghamunga & Ngowi 1999).

Biogas production has no other geographical limitations than areas with persistent sub-zero temperatures and is neither complex nor monopolistic. Production of biogas, through anaerobic fermentation, is possible from 3 degrees Celsius until around 70 degrees Celsius, and with an unheated biogas plant the satisfactory temperature is no less than 18 degrees Celsius on daily average or an annual mean around 20 degrees Celsius. With lower temperatures the gas production will be decreased to a volume that is not economically feasible, and higher temperatures may increase the gas production dramatically (Information and Advisory Service on Appropriate Technology 1999a). In a satisfactory temperature, the fermentation process take between 20 to 80 days depending on the inputs used.

Table 3: Amount of days of fermentation with different inputs (Information and Advisory Service on Appropriate Technology 1999)

Substrate	Days
Liquid cow manure	20-30 days
Liquid pig manure	15-25 days
Liquid chicken manure	20-40 days
Animal manure mixed with plant material	50-80 days

3.5.1 History of Biogas

Biogas was first used in heating baths in Assyria as early as 10 BC, and in 1859, biogas was used for lighting and emergency power from a wastewater purification plant at a hospital in Mumbai, India. In 1884, Louis Pasteur produced biogas from horse dung collected from the streets in Paris, while the streetlight in Exeter, England started to run on biogas from wastewater in 1897, at the same time the first biogas plant was constructed in China (Steinhauser & Deublein 2008). During the 2^{nd} world war, biogas was produced on farms in France to produce methane as a substitute for petroleum, a fuel it was very difficult to access during the war. More recently, the use of biogas has been popularized in Asia and on commercial farms in USA, UK, Australia, China, India and Kenya. The biogas technology has also been embraced in Europe with modern, large-scale biogas plants used by farmers and wastewater management (Fjørtoft & Grimsby 2011).

3.5.2 Biogas Plants

There are three main types of biogas plants commonly used for households in developing countries (Figure 5). One alternative is the balloon plants, which use a plastic digester bag to store the gas, and both the inlet and outlet are attached to the bag. When piping the gas from the balloon to the desired place of use i.e. kitchen for cooking or living room for lighting or heating, pressure is added by putting weights on the balloon(Spuhler 2010). The advantages with the use of a balloon plant are that they have the lowest construction costs together with low workload and simplicity of construction, high temperature in the fermentation process and easy to maintain with regards to cleaning. The balloon plant has a short lifespan and is easily exposed to damages due to it´s plastic cover (Information and Advisory Service on

Appropriate Technology 1999a).

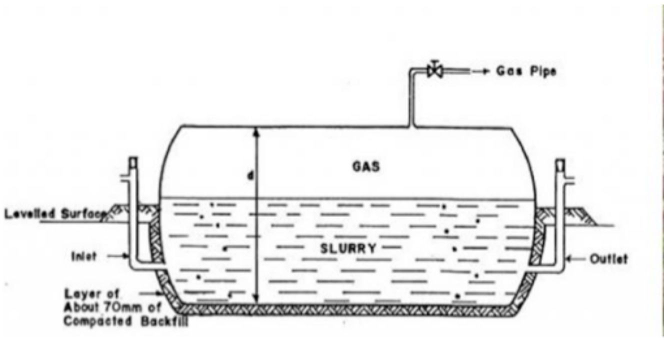
The second option is the fixed-dome plant with an unmovable gasholder on the top of the digester. When producing biogas, the liquid manure is inserted into the digester and the pressure from the gas production is pushing the biogas slurry in the compensation tank. The advantages with a fixed-dome plant are the low costs, no movable parts and a long life span if well constructed, together with space saving due to the underground construction. The underground construction may work as an isolation in cold areas but also be a disadvantage due to the general low temperatures. Other disadvantages of the fixed-dome plant may be leaking of biogas due to cracks in the brickwork and it is therefore advised to construct the fixed-dome plant with experienced technicians (Information and Advisory Service on Appropriate Technology 1999a).

Thirdly, there is the floating-drum plant. The floating-drum plant has a moving gasholder with an underground digester. The gasholder floats directly on the input of liquid manure or in a water jacket. The gasholder rises or declines based on the amount of gas stored, and it is prevented to tip by a guiding frame. Advantages of the floating-drum plant are the simplicity of the plant with easily understandable operation, constant gas pressure and easy construction. Some disadvantages are high material costs and the use of steel material, which can easily rust. This implies that the floating-drum plant have a shorter lifespan than the fixed-dome plant and requires more maintenance hence higher costs (Information and Advisory Service on Appropriate Technology 1999a).

The fixed dome plant and the floating-drum plant have three chambers. The mixing chamber is where the inputs are mixed together to a liquid form before it´s poured into the digester chamber where the inputs are fermented and turned into gas. As the gas rise in the digester chamber, the liquid manure will be pushed down and go into the expansion chamber. When the gas is being used, the slurry will go back into the digester chamber to push the gas further up, and when the volume of slurry is high enough it will float up in the expansion chamber and be drained out. (Information and Advisory Service on Appropriate Technology 1999a)

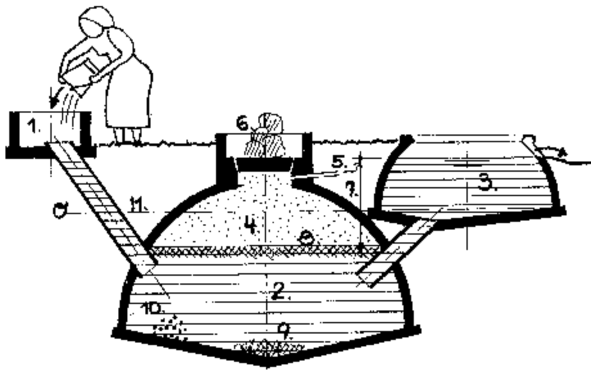
Figure 5 Three main types of biogas plants

Balloon Plant



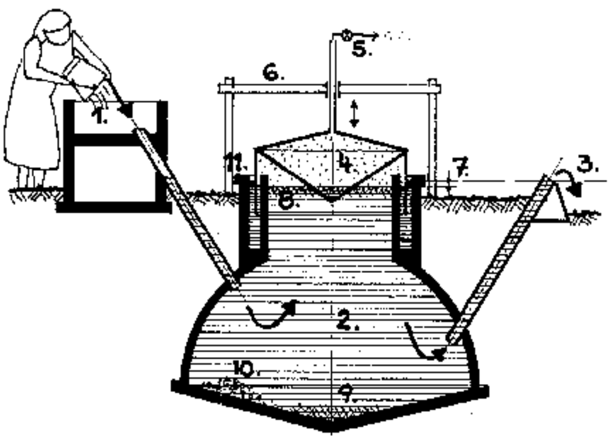
Source: (Consolidated Management Services Nepal (P) Ltd & Food and Agricultural Organization of the United Nations (FAO) 1996)

Fixed-Dome Plant



Source: (Sasse 1984)

Floating Drum Plant



Source: (Sasse 1984)

3.5.3 Biogas in Tanzania

In 1975, Small Industries Development Organisation (SIDO) introduced and adopted the biogas technology used in India for usage in Tanzania. The introduction of these biogas plants did not succeed due to the design of the plants, which were wrong for the area. This led to a failure in implementing biogas plants in Tanzania and the biogas activity was almost non-existing. 7 years later, in 1982, Centre for Agricultural Mechanization and Rural Technology (CAMARTEC) together with German Appropriate Technology Exchange (GATE) established Biogas Extension Service (BES) with the intention to improve and establish a biogas program that would fit the Tanzanian requirements (Sudi & Ngowi 1999).

A survey done by BES on biogas technology in Tanzania showed that there were several reasons for the failure of biogas plants in the country. Biogas holders of metal rusted quickly and required costly maintenance, it was unable to connect the plants directly to the cowshed, which resulted in higher work labour or underfed biogas plants, lack of knowledge, training and monitoring resulted in poor construction, gas leakages and malfunctioning, and high expenses on limited spare parts (Sudi & Ngowi 1999).

After establishing the faults on the prior biogas plants, BES started to test out new design and ended on adopting the Chinese mixed dome model with alterations to fix up errors and adjust it to Tanzanian requirements with easy accessible local materials. This new design was called "CAMARTEC fixed dome design" and BES had developed the whole unit (Sudi & Ngowi 1999).

Later, when GATE withdrew from BES, they had provided approximately 1900 biogas plants installations, mainly in the Northern part of Tanzania. Over time, the governmental support to CAMARTEC was reduced decreasing their role as a leading biogas organization in Tanzania.
There has been several other small-scale biogas projects carried out in Tanzania by governmental organizations and NGO´s, but in 2008 the big-scale Tanzanian Domestic Biogas Programme (TDBP) was funded. This is a private public partnership between Netherlands Development Organisation (SNV), The Humanist Institute for Development Cooperation (HIVOS) and CAMARTEC, where SIDO, Vocational Educational Training Centres (VETA), Evangelical Lutheran Church in Tanzania (ELCT), Village Community Bank (VICOBA), Dodoma Biogas and Alternative Energies Organizations (MIGESADO) and Friends in Development (FIDE) are implementing partners. Their goal is to build 12,000 new biogas plants in a five-year period (Tanzania Domestic Biogas Progamme 2011).

3.6 PANTIL

Programme for Agricultural and Natural Resources Transformation for Improved Livelihood in Tanzania (PANTIL) is a programme implemented by Sokoine University of Agriculture (SUA). The PANTIL programme is a continuation of previous SUA projects like Food Security and Household Income for Smallholder Farmers in Tanzania: Applied Research with Emphasis on Women (TARP II), "Gender-sensitive Research and Against Smallholders Farmers Poverty" (GRASP) and "Future Opportunities and Challenges in Agricultural Learning" (FOCAL). Through training and research, PANTIL´s mission is to improve livelihoods of rural people, empower farmers and create a basis for agricultural and natural resources research. The goal of PANTIL is to "*attain increased economic growth, reduced poverty and improved social well-being in Tanzania through transformation of the agricultural and natural resources sectors"* (Sokoine University of Agriculture 2005:11), by improving the farmer´s knowledge and access to technology with regards to agriculture and natural resources. The targets for PANTIL are the rural poor, women, small and medium scale producers and SUA graduates (Kurwijila & Tarimo 2009).

PANTIL´s projects are divided into zones where the demand of the clients is relevant for the specific zones. One project carried out from PANTIL was to improve the livelihoods for smallholder dairy cattle farmers in Njombe District. Their assignment was to develop a sustainable dairy production system that would fully exploit the benefits of having dairy cattle and in this way improve the livelihoods of the dairy farmers in Njombe District. An outcome of this project was another project focusing on biogas for the farmers with diary cattle. Since the farmers were already sensitized on several important aspects of running a biogas plant like manure management and feeding strategies for the dairy cattle, there was constructed 5 biogas plants in Njombe; 4 in Lunyanywi and 1 in Ibumila. From before, Ibumila had 4 biogas plants from the time of TARP II, but these plants were no longer in use when PANTIL started their biogas project (Sokoine University of Agriculture 2010).

The PANTIL programme started in 2005 and lasted until 2009, and in 2010, Enhancing Pro-poor Innovations in Natural Resources and Agricultural Value-chains (EPINAV) was established to continue the work done by PANTIL.

4 Methodology

In this research both qualitative and quantitative methodology was used, but the majority of research methods was qualitative. The main methods concerning qualitative methods were based on in-depth and semi-structured interviews and observations. Quantitative methods were used with regards to close-ended questions for quantification using a survey questionnaire.

4.1 Methodology

4.1.1 Qualitative Methodology

Qualitative methodology is usually chosen for research on micro scale, gathering more detailed information from fewer respondents than used in quantitative methodology. This type of research methodology is most common in social studies. It is of a more verbal character and gives a deeper understanding of a phenomenon than with quantitative research methodology. Qualitative research brings out more personal answers from the respondents knowledge and feelings and are a good way to look into people´s perspectives and understanding (Bryman 2008).

The types of qualitative research used in this research are primarily in-depth and semi-structured interviews. In-depth interviews let the interview object talk freely with minimum guidance from the researcher, and in this way, more information can be revealed than if the researcher was to ask and direct the whole interview (Bryman 2008). *In-depth interviews are useful when you want detailed information about a person's thoughts and behaviors or want to explore new issues in depth* (Carolyn Boyce & Palena Neale 2006). Semi-structured interviews includes an interview guide with both closed- and open-ended questions where the researcher have the opportunity to add questions based on the research objects response (Wildemuth 2009).

4.1.2 Quantitative Methodology

Quantitative methodology is more structured and systemized than qualitative methods and measures numerical data gathered from a large number of respondents. The typical research methods used in quantitative methodology are surveys and structured interviews where the respondents are given exactly the same questions and all the questions are closed. Answers are coded and quantified before the result is ready, and it is seen as more timesaving than qualitative methods. Since this research method is only based on numeric data, there is less chance for the researcher to become biased and make personal interpretations (Bryman 2008).

4.1.3 Format of Research

The format for this research is a case study. A case study involves a thorough and detailed analysis of a setting within a location. There are several types of case studies and this research is based on representative or typical case, or as Bryman (2008) calls it, exemplifying case. This kind of case study is used to describe broad types of cases. The objective for this kind of case study is to *"capture the circumstances and conditions of an everyday or commonplace situation"*, rather than extreme and unusual cases (Yin 2003:41 in Bryman (2008))

4.1.4 Selection of Study Area

The study area for this research is Njombe District in the Southern Highlands of Tanzania. Tanzania is a country where there have been a lot of development projects over the years, and there are increasing projects that focus on RETs. It´s to my understanding that much of the contemporary development projects are emphasizing on energy for rural development, and with my background in developing studies, social change and environment I see this as highly interesting.

SUA in Tanzania with support from the Norwegian Agency for Development Cooperation (NORAD) and participation of researchers from the Norwegian University of Life Sciences (UMB) are engaged in PANTIL programme and their previous programme TARP II, which have achieved a lot with regards to agricultural development and improved livelihoods in Tanzania. Based on their previous projects they have managed to get a biogas project in Njombe district, which seemed very interesting to study. Since I have been to Tanzania before in relation with my previous education and I have certain knowledge in their culture it was very attractive for me to do research there.

4.1.5 Selection of Respondents

In this research I wanted to interview the households who had biogas plants, and households who did not have biogas plants to see if there are any significant differences between the two groups. At the time of research there where eleven households with biogas plants in Njombe where five was in Ibumila village and six in Lunyanywi village. Due to the low amount of households with biogas plants I had 100% representation from that group.

When selecting the representatives from households without biogas plants I decided to only include households who had dairy cattle. After testing some interviews based on simple random sampling, representing all the inhabitants of the village, I quickly found out that it was too difficult to compare these households to the ones with biogas plants due the major differences in variables such as households with no animal husbandry. Since owning dairy cattle are one of the requirements for implementing biogas plant for a household, together with several other preferred demands like cowshed, pasture land, manure management etc., choosing household with more similar training and lifestyles will make clearer results on exactly what implementation of biogas can result in. Households with indigenous cattle who did not have dairy cattle where therefore not included as representatives from the group of households without biogas plant, neither were households who did not practice animal husbandry or cultivation of land. The sampling procedure for this group were therefore purposive since the group of respondents were predefined as households without biogas plants who own dairy cattle, and in this way there was not equal chance for the whole population to be selected. Purposive sampling is a non-probability sampling were the ones selected are in a group relevant to the research. Purposive sampling can therefore not generalize a whole population. This type of sampling is not a random sample, neither convenience sample. With convenience sampling the respondents available by chance are selected, while with purposive sampling the researcher select the respondents because of their position and relevance to a social phenomenon.

4.1.6 Sample Size

Since there where five households with biogas plants in Ibumila village I wanted the same amount of households to represent the group of households without biogas plants but with dairy cattle, the same was the case for the six households in Lunyanywi village with biogas plants, and together this resulted in eleven households without biogas plants but with dairy cattle. The selection of these households was done through stratified random sampling where the dairy farmers with biogas were removed from the list. In Ibumila, the office in charge of collecting milk from the dairy farmers had a complete list of all the households with dairy cows in the village, and after removing the households with biogas plants I was left with 57 farmers who had dairy cattle but no biogas plant. In Lunyanywi I got the list of households who had dairy cattle from the chairman of the local dairy community group, and the same procedure as in Ibumila was performed and I was left with 25 households who had diary cattle but no biogas plant in this village. After this process I performed simple random sampling of the households without biogas but with dairy cows and got five random households in Ibumila and six random households in Lunyanywi who did not have biogas but dairy cattle, a total of eleven respondents.

4.2 Data Collection

4.2.1 Household Interviews

When conducting household interviews I visited all the households myself, but since the interviews took place in Kiswahili I hired an interpreter who also had the task of being my research assistant. The interviews with households owning a biogas plant started with an in-depth interview where they were talking about their views, experience and history of getting biogas. I chose this method to get more detailed information about their experience with biogas and their apprehension of biogas that might have been left out with only a questionnaire. After the in-depth interview I proceeded to a semi-structured interview with open and closed questions. The time spent per household with in-depth interview and questionnaire was from 1 hour and 15 minutes to 1 hour and 30 minutes. Interview with households without biogas lasted between 40-50 minutes. These interviews did not include in-depth interviews.

There are mostly women who are responsible for the households in Njombe, and since biogas is mainly used for cooking, lighting and the biogas slurry for fertilizer, it is the women who are experiencing the majority of benefits when using biogas. Because of this I mainly interviewed the women of the household, but in some in-depth interviews I also talked to the man of the household to get details concerning building of the biogas plant and other relevant information. Due to the short time I had to carry out my fieldwork, testing of questionnaires proved to be difficult, but I managed to test out two questionnaires where some questions were deleted and others modified.

4.2.2 Semi-Structured Interviews with Relevant Institutions

Before I started with my fieldwork I talked to the District Executive Director for permission to do research in the area and presented myself, and my intentions with the research. After getting permission from the district level I had to talk to the Village Executive Officer in each village to show the permission from Njombe District Council and ask for their cooperation. The Village Executive Officers then approved that I could do my research in their village and helped me with the logistics to arrange meetings with the households and gathering the respondents for information about my work and interviews. Since Ibumila and Lunyanywi village is located in two different wards I interviewed the Ward Executive Officers in each ward together with Village Executive Officers from each village to get their views on biogas and the state of development and environmental status in the area. Later, I interviewed a representative from the District Office handling development Njombe district. The Policy and Planning Department at Njombe District Council helped me with regards to a socioeconomic profile of Njombe updated in 2010.

When trying to find out what development implications biogas had led to, I found out that there have been a number of different NGOs in the two villages who have helped the households in improving several factors. I therefore had interviews with relevant NGOs located in Njombe to map different developing projects in the two villages so that I could make clear what improvements was a result of biogas use and what was achieved by the NGOs. Semi-structured interviews with the relevant NGOs in the area were also performed to talk about the environment and development in the area, and also to see their views on biogas and if they had any plans of starting up any new biogas projects.

I also had interviews with the local dioceses in Njombe to see if they did any work in the local community with regards to development and to find out their views on the environment and to get their perspective on biogas in the area. The relevant churches were the Roman Catholic Church, the Lutheran Church and the Anglican Church. A more specific interview was carried out with the Lutheran church with regards to their position in Tanzania Domestic Biogas Programme (TDBP).

4.2.3 Collection of Secondary Data

I got secondary information from Njombe District Council in the form of an updated socioeconomic profile of the district. I also got some reports from the local churches and NGOs containing information about their work in the area. Concerning information about PANTIL, I received reports from their office at Sokoine Agricultural University, together with other relevant reports regarding biogas in Tanzania.

4.2.4 Data Analysis

When interviewing I used manual noting instead of a dictaphone since use of a dictaphone can result in the respondent holding back information and be more unwilling to be interviewed. If the respondents never has been introduced to such technology before it may appear daunting and result in poor information(Kendall & Kendall 2002). This resulted in greater workload, but due to the negative effects that can occur using a dictaphone I wouldn´t jeopardize it. Data from the interviews was transcribed every day and categorized. While transcribing, information from observations and additional comments where added.

When analyzing quantitative data there are several good programs to use. I my case I chose to use SPSS, which is a widely used program in social research. Data from the quantitative research was collected from the survey, which was then coded and placed in SPSS for further analysis.

4.2.5 Reliability and Validity with Qualitative Research

Qualitative research is claimed to be of a subjective character and it is therefore difficult to prove the reliability and validity of the research in the same way as quantitative research. Within quantitative research, the role of reliability and validity are to assess the quality of the research by how reliable a measure is and if a variable are measuring what it is supposed to. There is currently no specific way to measure this in qualitative research, but proposals exist. Guba and Lincoln in Bryman (2008) claim that it is important to establish a way to assess the quality of a qualitative research and propose two criteria for assessing a qualitative study:

trustworthiness and authenticity. Trustworthiness can be achieved through four criteria; credibility through research of good practice and sharing the findings with the participating respondents of the research; transferability through thick description were not only behavior is described but also context to make it meaningful to an outsider; dependability through an auditing approach were all the records from the research process is kept; confirmability through acting in good faith. To ensure authenticity the important points are to represent all the different viewpoints from the respondents, help the respondents to appreciate and see others´ viewpoint and the research should be an encouragement for the respondents to change their situation (Bryman 2008).

4.2.6 Challenges and Limitation

As in all research there are challenges and limitations, and this research is no different. The main challenge for me regarding this research was the amount of time I had in the field. Due to some difficulties in getting all the required permissions for the research together with the correct visa for researchers, I was one month late for my fieldwork. But highly effective fieldwork together with a returning visit in January resulted in finished fieldwork. A limitation to my research was the number of respondents in this research. Since there were only eleven households in the area with biogas plants the response was of a smaller extent than desired. According to Bryman (2008) there is a greater chance for sampling errors when using a small sampling size. Increased sample size would also increase the precision of a sample and thereby reduce the chance for sampling error.

The area of research had minimal knowledge of English, and therefore I had to hire an interpreter. Use of an interpreter in research has the possibility to create errors and misunderstanding when information in translated from one language to another. I only used one interpreter for the whole research to minimize errors. My interpreter’s English skills and understanding of my work was very good, and I think this also has led to minimal errors regarding the use of an interpreter. Another limitation to my research is that my background is in social science only and caused my research to be mostly based on social research something that may have had an influence on the width of the research.

4.2.7 Ethical Considerations

In this research all the participants are given full confidentiality. Before each interview started the participants was given information in their first language about who I was, what I was doing, why I was doing it and what it would be used for. They were also told that their personal information would not be revealed and that the information would only be used in my research. All the participants in this research consented to my presence and to participate in the research.

5 Results

In this chapter will present the findings and results from my study. I will first go through the social demographics in the area, together with developmental and environmental status of the two villages. Second, I will present how the households were introduced to biogas and how they utilize this type of energy. I will also look at the technology transfer in the villages and if this encourages sustainable use of biogas. Third, I will show the farmers behaviour towards biogas and its establishment in the area, and also see how the process of adoption took place. Fourth, I will take a look at the development implications with the use of biogas, and see if the farmers who have biogas have any advantages compared to the ones without biogas, and also look at biogas as a mean to achieve the MDGs with its benefits, before I at last will go through the challenges of biogas in the two villages and look at the future of biogas in the area.

5.1 Social Demographics and General Information regarding environment and development

5.1.1 Social Demographics

The average household size in Ibumila and Lunyanywi is 5.5 people, with 4.8 children. The educational level is in average primary education. Farming is the main occupation, but some have additional occupations like security guards, carpenters, photographer and training of other farmers. The average size of land in the two villages are 2,2 hectares and this land is mainly inherited, but some have bought or rented additional land plots.

The average income for the farmers in this research is USD 977 per annum, and their income comes from selling crops, mainly maize, but also Irish potatoes, wheat, beans, sweet potatoes, fruits and vegetables including carrots and green vegetables. Animals are also income generating with selling of goats, pigs and poultry, together with animal products like milk and eggs. Another source of income is sales of poles and timber.

5.1.2 Environmental Challenges in Ibumila and Lunyanywi

The environmental challenges in Ibumila are according to the village executive officer deforestation, destruction of watersheds and wild fires, and they are in the stage of planting more trees over a bigger area to reduce the rate of deforestation and improve the environment in the area. They are also planning to conserve 8-15 water sources in the village by planting what they call environmentally friendly trees like banana trees and a specie that resemble bamboo. The high amount of eucalyptus trees that previously were planted in the village will be removed due to their lack of environmental benefits and replaced with other species of trees. Firebreaks have been made to reduce the spread of wildfires, but in recent years these firebreaks are no longer as wide as required. To prevent this, they will make wider firebreaks to reduce the amount and volume of wild fires.

In Lunyanywi, environmental challenges are the same as in Ibumila with cutting of trees, destruction of watersheds and wildfires. To improve these environmental challenges they want to emphasize more on education and training of the inhabitants to make them more aware of the consequences of environmental destruction. By-laws are also a tool they use to deal with environmental destruction by fining people who are destroying watersheds, burning of land without permission and cutting more trees than allowed. On the issue of environmental conservation they plan to plant trees near water sources to maintain the quality of the water, together with information work regarding distance to the water source to prevent destruction.

5.1.3 Development Status in Ibumila and Lunyanywi

The level of development in Ibumila is generally good, especially for the households keeping dairy cattle who get good income by selling milk, and have knowledge that increase the agricultural condition. According to the village executive officer in Ibumila is the unemployment rate in the village high due to introduction of new technologies in the local tea estate, which employed many people from the village, together with problems of theft from people without work, preventing the development in the village. Environmental destruction is also a factor that limits the development in the village and might lead to underdevelopment e.g. destruction of water sources that might lead to decreased amount of water available, resulting in less water for the households and crops.

The level of development in Lunyanywi is improving. More people are now sending their children to secondary school, while they in the past only completed primary education. According to the village chairman in Lunyanywi, the income in the village is increasing due to livestock keeping, especially diary cattle, were they get income by selling milk together with health effect of drinking more milk. But there are also factors that are worrying like alcoholism and unemployment.

5.2 Introduction to Biogas and Sustainable Use of this Energy Source

5.2.1 Introduction to Biogas

Biogas project in Njombe first started with the SUA project TARP II were four fixed-dome biogas plants were built in Ibumila in 2004. The purpose of biogas plants was to change the farmer’s energy source into more environmentally friendly energy, together with an energy source that would require less hard work for the women. In this way they could cover the needs of cooking and lighting with resources they already had on their farm; manure from dairy cattle.

One year later, TARP II had been merged in the PANTIL programme and an evaluation of TARP II´s biogas project showed that the biogas plants constructed in Ibumila the year before were not operational. It appeared that the biogas plants, which where given free of charge by TARP II had not been put to use, and it was explained that since the biogas plants didn´t cost anything for the farmers they didn´t make any commitment to change from traditional fuels to biogas. Also, the information and training regarding how to use the biogas plant and it´s residues, together with the benefits of changing energy sources was too vague for the farmers and did not appeal for them to suddenly change their traditions.

In 2005, PANTIL continued the biogas program that TARP II had started. Under PANTIL´s project to improve the livelihoods for smallholder dairy cattle farmers in Njombe, they had sensitized farmers on appropriate livestock feeding strategies and proper manure handling and utilization and this was a good basis for introduction of biogas. Several households in Ibumila and Lunyanywi went on a study trip to Mbeya region where they were introduced to biogas, and saw how they worked and how this could improve their everyday life. After this, four households in Lunyanywi and one household in Ibumila received biogas plants of the fixed-dome type, and the four already existing biogas plants in Ibumila started working again. Representatives from PANTIL performed house-to-house training telling them how to use the biogas plant in a sustainable way by mixing and adding one bucket of manure and one bucket of water per day. When constructing the biogas plants, the farmers were divided into groups so that they could learn how to construct a biogas plant from the technicians and use this knowledge later to help other households constructing their plants. The size of the biogas plants built in Ibumila and Lunyanywi is $16m^3$ and should cover a household of 6-7 people.

Figure 6: Construction of biogas plant in Njombe (Source: Professor Ephraim Mtengeti)

5.2.2 Requirements for Biogas Plants

For the households to receive a biogas plant, PANTIL established a number of requirements the households needed to fulfil. The households needed a minimum of one dairy cow with cowshed and an area of pastureland for feeding. They also required the households to provide the materials used in the construction.

5.2.2.1 Dairy Cattle

One of the requirements PANTIL established for the farmers was the ownership of dairy cattle that would provide the farmers with a sufficient amount of manure for the biogas production. Dairy cattle are held stationary, meaning that they are in their stall all day being fed with fodder collected by the farmers, and in this way the manure is easily collected. The establishment of dairy cattle was well established in Ibumila and Lunyanywi due to the presence of two programmes focusing on introducing dairy cattle for milk production and income generation.

Southern Highlands Dairy Development Programme (SHDDP) and Heifer Project International (HPI) introduced and established dairy cow keeping in Njombe. A representative for SHDDP who also was involved with HPI helped me to map their activities in Njombe. In 1978, the SHDDP, funded by the Swiss government, was established. Their objective was to crossbreed dairy cattle with indigenous cattle so that the local people could get dairy heifer for milk production to improve nutrition and income generation. The programme, where the farmers got their dairy heifer for free, was active in 6 villages in Njombe, but the programme phased out in 1984. After the programme phased out they started to sell diary heifers for USD 2.6 per calf, but four years later, in 1988, the price on dairy heifer had increased to USD 98 leading to an end to the purchase of dairy heifer due to the high price.

In 1992 the dairy cattle programme started up again, this time under HPI. HPI established some requirements that the farmers had to fulfil. Before receiving a dairy heifer they had to prepare a cowshed and 0.4 hectare of pasture plot. When this was in place, they would receive one female calf for free, with the condition that the first female offspring should be given to another household in the village. The second calf, male or female, had to be given to the church, which acted as a guarantee due to the trust issues with the government, and was sold to get income to the project. The recipients of the dairy calf should come from poor categories, and the group leaders where responsible to pick out those who should get a heifer. HPI was gender sensitive and women were preferred as owners of the cows due to the belief that if the women got developed, the whole family would benefit. The established farmer groups was represented by a minimum of 5 women per 10 group members, and in this way the role of the women was strengthened. The farmers got training from the German NGO MISEREOR on organic farming, manure management and utilization, and pit farming, together with contribution of extension staff and veterinary services from the government.

HPI is still going on, but is slowly phasing out in the region. Since this programme has been present for 9 years it can continue on its own and the households have formed groups, which will continue the process. When they started in 1992 they had 20 cows, and in 2008 there was 600 dairy heifers and 200 dairy bulls. The HPI project in Njombe lead to increased income due to sales of milk but also improved farming. Since the farmers provide fodder to the dairy cattle while they are in their stalls, the manure from the dairy cattle are used in farming and has more than doubled the production and reduced the costs. This increase in income lead to higher education for the children and 3 farmers have sent their children to university. They have also improved their housing, were out of 30 farmers, 25 had improved their houses. Health improvements have also occurred and a survey done by SUA showed that households with dairy cattle had reduced malnutrition.

SHDDP and HPI laid a good foundation for the biogas program to succeed due to the households experience with dairy cattle. The people involved in HPI had already established their cowshed and pastureland together with relevant training in manure management.

Figure 7: Cowshed for dairy cattle (Source: Linn Gulbrandsen)

5.2.2.2 Material and Financial Requirements

Beside the requirement of dairy cattle, the farmers needed to provide material to build the biogas plant. According to a respondents these materials consisted of 3.5 tons of stones, 2000 bricks, 3.5 tons of gravel, 1.3 tons of cement, and 8 tons of sand for a 16 m^3 biogas plant which was the recommended size by PANTIL. They also had to prepare the pit where the biogas plant was supposed to be placed while the pipes and technicians were provided by PANTIL. When the introduction to biogas plants started in Njombe in 2004, the total amount for one biogas plant was USD 913 and in 2009 this was more than doubled to USD 1,957 due to increased prices for materials.

The biogas project led by TARP II didn´t succeed as planned, and among the major reasons for this was the fact that they got the biogas plants for free and were not trained on the benefits of the biogas slurry as a potential fertilizer for their crops. When PANTIL continued this project, they had made changes to the funding scheme and the households had to pay half of the total amount of the biogas plant while PANTIL would pay the other half. In addition, PANTIL also trained the dairy famers on the benefits of the biogas slurry as a potential fertilizer to improve their home garden productivity. In this way the households would be more committed to make the biogas plants work since they had invested their own money into the project and had been properly sensitized on the utilization of biogas. When PANTIL phased out from this project it was planned that it would still go on with the help of credit unions and farmer groups. The farmer groups consist of 15 farmers in each group, and they will rotate until the whole group have established a biogas plant. When a household start to build their biogas plant they will get all the funds as a loan from the Savings and Credit Cooperative Society (SACCO), the local credit union. When the biogas plant is built they have to pay back half the amount of the money they borrowed, and this amount will go to another household in their farmer group. The remaining amount of USD 978.5 is covered by the households´ farmer group who earn money by selling vegetables and maize for investment in biogas plants. The time for down payment was not set when I conducted my interviews, but the farmers planned to do this shortly.

5.2.3 Biogas as a Sustainable Energy Source

Before the households got their biogas plants, the main energy source used was firewood and kerosene. Charcoal was also used, but only by 5 out of 11 respondents, and mainly for space heating in the cold season. These energy sources were not available on their farms, and the average time used for gathering firewood was 2.5 hours per day for one household. Firewood was mainly used for cooking food, heating water and in some cases for heating the rooms, and it was the women who were responsible for gathering it, but three of the respondents also got help from their children. Firewood in the area was accessible for most of the respondents, but three households responded that it was difficult to get hold of sufficient amounts of firewood. They therefore had to go longer distances to collect enough firewood. Providing firewood required the women to leave their houses and walk to the nearest forest. This is very time-demanding work and caused physical tiredness for the women, leading to poorer health condition and less time to work at their farms and take care of their families. Kerosene was mostly the men´s tasks to buy and was easily available in Njombe town. All the respondents had been using kerosene for lighting but the increasing prices resulted in difficulties to afford the fuel.

Biogas in Ibumila and Lunyanywi are used for cooking and lighting, and they use an average of 20 minutes per day to carry out the tasks required to sustain the sufficient production of biogas. The tasks consist of mixing water and manure and remove impurities that can slow down the process of producing the gas, before it is released into the digester. Manure for the biogas production is stored in manure boxes at the farms and the manure that is not used for biogas production is used as a fertilizer for their crops, while the water comes from boreholes or wells on the household's property. The amount of inputs is sufficient for the households but one of the households have for the time being no dairy cattle and therefore have to rely on their neighbour to provide them with manure for biogas production.

The households are in average using 2 buckets of manure and 2.4 buckets of water, where 1 bucket is equivalent to 20 litres. This amount of inputs is according to the respondents producing enough biogas for the entire household, but guidelines from PANTIL suggest that the sufficient amount of inputs per day don´t need to be more than 1 bucket on manure and 1 bucket of water, suggesting that the amount of input the households use can be halved.

Figure 8: Manure ready to be mixed with water for biogas production
(Source: Linn Gulbrandsen)

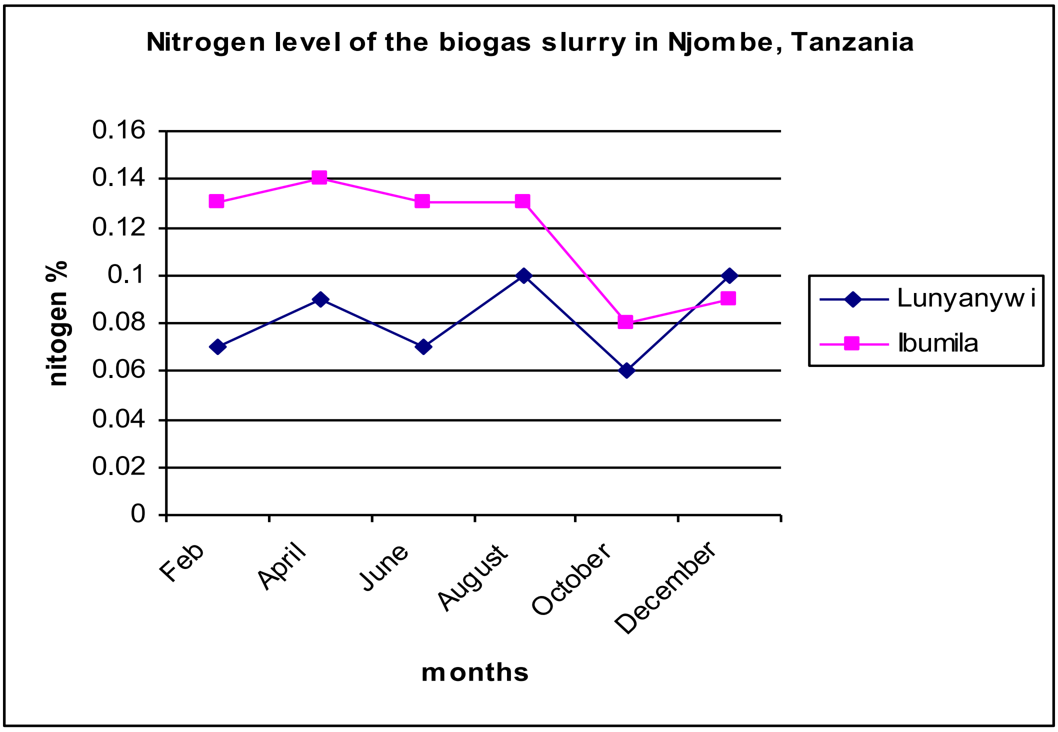
Time used on maintenance of the biogas plant is minimal. According to the respondents, there is no need for maintenance on the biogas plants, and none of them have ever experienced any damages, but they emphasize the importance of removing all the impurities from the mix of water and manure before it is added to the digester. If a situation would occur with leakage from the pipes or the like, spare parts are easily found in Njombe town at an affordable price.

5.2.4 Utilization of the Biogas Slurry

Another benefit with biogas is the residues from the biogas production. This proved to be a more nutritious fertilizer than the use of ordinary dried manure. Within PANTIL, the farmers who received biogas plants were also sensitized on how to utilize the biogas slurry as fertilizer in the best possible way. All the households with biogas plants use the slurry as fertilizer together with composted manure, and the pure slurry is a good fertilizer for their home gardens where they produce vegetables. The quality of the biogas slurry is, according to the households, unanimous better than composted manure, explained that the high amount of urea in the slurry works as a good nitrogen contribution to the soil. But the level of nitrogen in the biogas slurry in Ibumila and Lunyanywi are quite low comparing it to other studies where the nitrogen levels are approximately 1.8% (Vasudeo 2011).

Figure 9: Level of nitrogen in the biogas slurry in Njombe

(Source: Professor Ephraim Mtengeti)



The slurry is also more easily taken up by the plants and decomposes better. The crop responds quickly to slurry after it has been applied, but the farmers express difficulties with regards to transportation of the biogas slurry to their farming plots far away from the biogas plant since its form is liquid. There is a tendency that they in the dry season add the biogas slurry to the composted manure and let it dry, while they in the wet season use the pure slurry at their nearby fields and use composted manure, or a mix of composted manure and biogas slurry for their fields further away, but when the slurry is mixed together with the composted manure and dries, the nitrogen level will decrease.

Figure 10: Biogas slurry (Source: Linn Gulbrandsen)

5.2.5 Transfer of Biogas Technology

When TARP II started their biogas project there was a lack of proper training and transfer of knowledge regarding how to operate the biogas plant and how to utilize the slurry, resulting in 4 unproductive biogas plants. The funding scheme was neither in place, so the widespread of biogas plants in Ibumila at that time would be a challenge.

The biogas project provided by PANTIL had more emphasize on the knowledge of biogas ad its applications, leading to a more successful technology transfer. A deeper understanding on how to utilize the biogas and the slurry, together with more knowledge on what use of biogas can bring for the households have led to a desire to continue the use of biogas and also increased the demand for biogas plants among other households. After PANTIL´s withdrawal in 2009, the biogas programme has continued itself with two newly established biogas plants and there are several more households in the farmer groups that are waiting for their turn.

This suggest that the theory of Wilkins (2002), stating that technology is not solely the equipment, but also the knowledge behind the equipment in regards to funding, manufacture, operations and maintenance, are highly relevant for the technology transfer in Ibumila and Lunyanywi. The knowledge and equipment have to be converted into an understandable concept for the recipients so that they can utilize the technology in a sustainable manner, leading to a successful technology transfer.

Wilkins (2002) continue saying that there are five important aspects of getting a successful technology transfer; affordability; accessibility; sustainability; relevance; and acceptance. In the case of the PANTIL´s biogas programme all these factors have been taken into consideration when implementing biogas in the villages.

5.2.5.1 Affordability

According to Wilkins (2002) the new technology needs to be more profitable than their traditional energies, but it is difficult to put a price on how long it will take before the farmers have earned in the amount of money they invested in a biogas plant. The reason for this is difficulties in setting a price at the time they save by not fetching firewood, and that they have no economic costs for the firewood they gatherd. If the time they save by not gathering firewood had gone into paid work in form of a wageor it could have been calculated, but since it is the women who have the main responsibility for gather firewood, there are few or no employment opportunities for them and thereby difficult to calculate.

The time saved by women not gahtering firewood can be used for income generating activities on the farm, and in Ibumila and Lunyanywi this is usually in the form of production of various vegetables. A large part of the vegetable they produce is used by the family itself, and again this makes it difficult to calculate their income. According to Information and Advisory Service on Appropriate Technology (1999b) are people willing to pay for an improved quality of life and that it is almost imposible to put this in monitary terms. In this case, the improved life quality is in terms of a more easy everyday life consisting of more free time and comfortable cooking without soot and smoke.

If one were to assess their savings it might be estimated that one hour of work can be calculated to USD 0.27 based on the average income in the two villages with an assumed workday of 10 hours including manual work and womens labour in the house.

Table 4: Estimated hourly pay for a household in Ibumila and Lunyanywi	
Annual income in Ibumila and Lunyanywi	USD 977 per annum / 365 days
Payment per day/Estimated 10 hours workday	USD 2.67/10 hours
Estimated hourly pay	**USD 0.27 per hour**

By looking at the average 2.5 hours the households used per day collecting firewood and multiply this with the hourly payment of USD 0.27, this will result in USD 0.68 per day and USD 248 per annum. The average expenses on kerosene per week was USD 1.45 and in one year a household will save USD 75.65 not considering the rapid increasing prices of kerosene. When it comes to charcoal, not all households use this, but of those who use charcoal the average price per week is USD 1, which is equivalent to USD 52 per year.

Table 5: Expenses saved per annum on fuels	
Firewood	USD 248.00
Kerosene	USD 75.65
Charcoal	USD 52.00
Annual Saving	**USD 375.65**

Based on these calculations, a households will save USD 375.65 per year, and with 50% subsidies it will therefore take 2.6 years before the household have earned all their expenses back on the biogas plant. This represent households that does not use any traditional fuels anymore.

With regards to payment for the biogas plants there are still many lose ends since PANTIL has phased out. The households have reached a deal with SACCO to lend them the money to build biogas plants, but there is still a lot of work needed to establish the guidelines for down payment of their loans. The down payment is supposed to be carried out through SACCO. When the farmer is selling milk to the local milk factory, SACCO is responsible to pay out the money the farmer earns. Every two weeks the farmer can collect the earnings for the amount of milk sold, and with a loan on a biogas plant at SACCO the amount of down payment per month will be withdrawn from these earnings. In this way they are sure that the farmer will pay back the amount he owe to the credit union.

5.2.5.2 Accessibility

There is no problem getting access to material for constructing a biogas plant in Njombe. The farmers themselves make some of the materials, as in the case of burnet bricks, and other materials are easily accessible to purchase in Njombe town. When PANTIL sensitized the farmers on biogas, they also taught the farmers how to construct the biogas plants. This knowledge is now used to construct biogas plants for other households, and there is no need to hire technicians for building biogas plants.

5.2.5.3 Sustainability

Concerning the sustainability, biogas technology is working well in the two villages. None of the respondents have had any problems with their biogas plant. The biogas plants they use in Ibumila and Lunyanywi are fixed-dome plants and have been used and modified in Tanzania since the 1970´s. These customised plants are therefor working properly in Njombe district.

When asking the respondents if the amounts of biogas they produced was enough for the household, 8 out of 11 answered that they produced enough biogas. Still, their answers showed that they are all still using either firewood, charcoal or kerosene. Observation showed that most of the families had an annex used for cooking, and it was in this annex the pipes from the biogas plant were connected. When they were cooking solely with firewood, the smoke and soot would gather inside and it was therefore best to have a separate place to cook, hence the cooking annex, but it seems like this now can be a limitation for the use of biogas since they still need to use traditional fuels.

The frequency of using traditional fuels has been reduced, but there are still cases were the households are using it. The respondents mentioned that the lighting available from biogas was located in the cooking annex, and therefore 7 out of 11 respondents used both biogas and kerosene for lighting, while 2 households used solar in rooms where there were no pipes like the living room or the children´s room for lighting. The respondents were interested in expanding the pipes to other rooms of the house and in this way not being dependent on kerosene anymore, but it seemed like there was a lack of knowledge on how this could be accomplished. Due to the limitation of the pipes from the biogas plant, they also had problems regarding heating their houses. The mild climate in Njombe can in the cold season lead to a temperature near freezing point, and 8 of the 11 respondents said that they had to use charcoal or firewood for space heating. Another respondent answered that they used firewood to heath water for baths and did not think that the amount of biogas was sufficient enough for this purpose. Also, one household said that they usually cooked their beans with firewood, and that biogas would not result in the same taste and quality as beans prepared with firewood.

This suggests that biogas in Ibumila and Lunyanywi is to some extent sustainable. It covers their basic needs of cooking and to some extent their requirement for lighting, but the amount of pipes should be expanded in order to cover more of their needs. Due to the cold climate, means for heating their living rooms are necessary, and cannot be done with todays situation where they don´t have any pipes from the biogas plant into other rooms than their kitchen. With pipes from the biogas plant into other rooms of their house, the need for using firewood and charcoal for heating would no longer be necessary. This would also improve the lighting situation, and decrease the amount of kerosene they are now using or even stop their dependence completely.

5.2.5.4 Relevance

The most important energy needs to cover in Ibumila and Lunyanywi is energy for cooking and lighting. The respondents see electricity as a secondary energy source, and purchase of solar technology is prioritised after covering the needs for cooking and lighting with the use of biogas. This can be traced back to Wilkins (2002) theory of energy as a derived demand where the households in Ibumila and Lunyanywi desire an energy source that can provide for their basic needs first i.e. cooking and lighting, before they will demand energy that can cover other services. The relevance of biogas is therefor high in the two villages since it covers two of the most important energy needs. Biogas saves time by the fact that the women do not need to spend time gathering firewood, and they save money with reduced consume of kerosene for lighting. It also enhances their life quality, so the relevance of biogas is therefor very high

5.2.5.5 Acceptability

There have been no problems with acceptance of biogas technology in the two villages, and the households interviewed who do not have biogas plants to this date have also accepted the technology and are eager to establish a biogas plant of their own. By seeing how the households with biogas plants are improving their living standards, the risk of adopting is decreasing for the households who have not established a biogas plant yet. In the case of the households who established biogas plants under TARP II but did not utilize it, the reason for not using the biogas plant was due to lack of information and was not related to acceptance of the technology.

5.3 Adoption and Behaviour Towards Biogas and its Establishment

Through Rogers (1995) theory of diffusion of innovation I wanted to find out how the people in Ibumila and Lunyanywi adopted to biogas technology, why they are using the technology and at the same time see at what rate people are adopting to biogas technology. According to Rogers (1995) there are four elements that needs to be in place for a diffusion of biogas technology; the innovation of biogas; communication channel that can spread the word regarding biogas; time of adoption to biogas; and a social system that will influence other to establish a biogas plant. I also wanted to find out the behaviour towards biogas, both from the farmers with biogas plants and the farmers without to see if biogas technology is an appropriate technology option in the region. This also included the rate of awareness regarding biogas from the household who had not established biogas plants yet, but had dairy cattle.

5.3.1 Why they changed their Energy Source

When the farmers were first introduced to biogas through study trips to Mbeya region, they saw the effects of what biogas can result in. They observed how easily energy could be provided for cooking and lighting, and how much easier it would be to cook with biogas rather than with smoky and time demanding firewood. After talking to the farmers in Mbeya who already had established a biogas plant they were inspired to do the same. This is what Rogers (1995) calls the innovation-diffusion process where the farmers gather information about the innovation and make their decision regarding to adopt or reject the technology.

A lot of time was used for gathering firewood, and with the time saving aspect of biogas this made it a good alternative as a substitute energy source. The women had no time to rest after gathering fuels for 2.5 hours per day and after that they had to work on their fields, cook food and do other household related activities. With biogas, the frequency of gathering firewood would decrease immensely and they would have more time to rest and do other income generating activities. The fact that it also would replace their use of kerosene was a very positive effect since the price for this fuel was increasing and in this way they could reduce their expenses on fuel for lighting. The pressure on the nearby forests due to gathering firewood also motivated the farmers to change to biogas. Finding the sufficient amounts of firewood for their household became more and more difficult, and destruction of the environment was in many areas a fact.

Figure 11: Biogas burner for cooking and biogas lamp. (Source: Linn Gulbrandsen)

Biogas is an expensive investment for the households in Ibumila and Lunyanywi, but as shown in the previous part it can be estimated that it will take them 2.6 years to earn back the money they invested. This means that biogas is a cheaper alternative to the traditional fuels in the long run, and the farmers in Ibumila and Lunyanywi also saw this as a reason to invest. Since they now, after PANTIL phased out, can get a loan from SACCO, this make it easier for the farmers, since they don´t have to pay the whole amount right away. This shows that biogas has a relative advantage with regards to firewood and kerosene, and Rogers (1995) emphasize this as one of the main elements in getting a successful diffusion of biogas.

5.3.2 Adoption of Biogas

It is difficult to draw any conclusions regarding distinct differences between the groups that will explain why some have adopted to biogas and some not. Looking at different features between the adopters and the non-adopters there are some factors that differentiate them. The households with biogas plants have in general higher income and greater size of land than the households without biogas, but it is difficult to determine if this is a direct result of establishment of biogas plants or if they where better off financially before they adopted the technology. Since the respondents with biogas already have enjoyed the benefits of biogas and increased their income, it becomes difficult to use the average income as a measure for financial differences, and numbers on how much the families have increased their incomes proved to be hard to obtain. But due to the high investment costs of biogas it is clear that they must have had some wealth prior to their establishment of biogas plants. This also applies to some extent to their size of land, which is more than double the size of land than the non-adopters hold. The farmers with biogas plants may have purchased some additional land plots after they established biogas plant, but the average land purchased don't constitute any big differences with regards to average land size, suggesting that they had more financial security through their agricultural production.

Table 6: Differences between adopters and non-adopters

	Adopters to Biogas	**Non-Adopters to Biogas**
Average Age	48	42
Education:		
None	3	4
Primary	7	7
Secondary	1	0
Average Income	$ 2,671	$ 558
Average Land Size	2.8 Hectares	1.2 Hectares

The level of education between the two groups of households show that there are no differences, since the average educational level in both adopters and non-adopters are primary education. Concerning the average age of the households there are some differences, were the households with biogas are in average older than the ones who have not adopted to the technology. These factors suggest that the theory of Rogers (1995), claiming that the ones to adopt an innovation first are young people with higher education, great financial control and have a high social status, is not completely accurate concerning the adoption process in Ibumila and Lunyanywi. The households with biogas may have had some more financial control due to their greater size of land, but the factors concerning age and education are not connected to their adoption to biogas technology. It is also difficult to determine if these households have higher social status than the group without biogas plants.

Since biogas only have been present in the village since 2004, it is clear that it is still a new technology, and people are still waiting for it to be their turn in regards to the rotation in the farmer groups. This implies that the farmers without biogas belong to the group that Rogers (1995) calls the early majorities. This group have close contact with the ones who adopted biogas early, and are supposed to have higher social status than others who will adopt in at later date. People who belong to the two lower groups in Rogers (1995) theory have to be the farmers without dairy cattle, and are predicted to adopt to biogas at a much later period. But the description made by Rogers (1995) that these people are more sceptical, have low social status and low financial lucidity might not be representative for the ones who do not have dairy cattle.

The rate of adoption between these adopter categories is fairly low. For the early majorities, the farmers without biogas but with dairy cattle, the cost of a biogas plant with 50% subsidies is twice their average annual income, leading to limitation regarding adopting to this technology. For the farmers belonging to the two lower groups in Rogers theory, their rate of adoption to biogas will take long time due to all the requirements of establishing biogas plants concerning a sustainable dairy cattle operation

5.3.3 Awareness and Behaviour Towards Biogas

The awareness regarding biogas is important to get households interested in the technology and might lead to more people interested in investing in the technology. The behaviour towards biogas can establish the amount of awareness the households have together with a sense of what kind of information they have received regarding biogas. If a lot of misunderstanding concerning biogas is spread, this can lead to less interest for biogas and slow down the interest and spread of biogas technology.

In Ibumila and Lunyanywi, ten out of the eleven respondents who did not have a biogas plant had heard about biogas and had an idea of the concept, but not all of them had seen a biogas plant. Their knowledge of biogas was that it was used for lighting and cooking and the majority had the knowledge on how biogas was produced in the sense that manure and water are the ingredients. Information regarding biogas was received through neighbours, village meetings or a visit to the households who already had established a biogas plant. Some of the respondents had also received information from PANTIL and SUA staff, together with training on how to build a plant and utilize biogas. When asking them about their knowledge on biogas, only one of the eleven respondents was aware of the benefits of the biogas slurry, while the others only focused on biogas as a substitute for firewood and kerosene.

Reduced expenses due to less consumption of wood fuels and less time used for gathering firewood were seen as the most attractive advantages of biogas, but also benefits with cooking regarding no soot and smoke, easier and shorter cooking time was also much appreciated. Some of the respondents also mentioned the environmental effects of biogas with preservation and less cutting of trees together with better lighting opportunities as advantages of biogas. There was no knowledge about any disadvantages related to biogas.

All of the respondents who knew about the concept of biogas though that biogas clearly were a better choice of energy than the fuel they were using. They were also interested in changing their energy source to biogas instead of using traditional fuels like firewood, kerosene and charcoal, and some of the respondent was waiting for their turn to establish a biogas plant with regards to the rotation in the farmer groups.

For the dairy farmers without biogas, the main reason for them to not have established a biogas plant was the lack of capital to invest in it, but three of the respondent were members of a farming group and was therefore waiting for their turn. One of the respondents mentioned that since her husband had three wives, it was difficult to get enough capital so that the household could invest in a biogas plant. This was also a conversational topic with a representative from an NGO. Polygamy is practised in many parts of Njombe, and both in Ibumila and Lunyanywi there are several households who are affected by this. Polygamy in

Njombe is a symbol of status, and does not necessarily mean that the husband is financially secure. It is mainly the husband who is in charge of the household´s economy, but when the husband has several wives, the ability to provide for them all may prove to be difficult and become a limitation for the economic development in the area. With regards to biogas plants, the price per establishment is rather high and it may be hard for the husband to provide the means required for establishing a biogas plant for each of his households, which can lead to limitations in women´s development and their ability to invest in new technology that can make their life easier.

Awareness and knowledge concerning biogas technology in Njombe are today limited to Ibumila and Lunyanywi village, while the remaining villages in Njombe have little or no awareness about the technology. One reason for this can be the relative low amount of biogas plants in Njombe. According to Rogers (1995), the awareness will rise with the increase of established biogas plants. This will also apply for the knowledge surrounding biogas. Communication regarding biogas will therefore most likely increase, and this might lead to a diffusion of biogas technology. As Rogers (1995) claims, interaction between individuals concerning biogas is the most effective form of communication with regards to increasing the awareness and establishment of biogas plants. Also, the present awareness and knowledge of biogas technology in Njombe seem to have a higher focus in the social systems of the dairy farmers since they are the most likely to adopt to the technology due to their position. For a farmer without dairy cattle to invest in biogas technology, there is a long way before he can establish and use it in a sustainable way. As mentioned before, the HPI project is still active in Njombe, and more people are getting dairy cattle. But from the time to get dairy cattle to the time where the household is able to utilize the biogas in a sustainable way is long. But it is still highly important to create awareness regarding biogas and dairy cattle so that the HPI can proceed sustainably together with expansion of biogas plants.

5.3.3.1 Awareness of the Village Leaders

The village leaders in Ibumila and Lunyanywi were both well aware of the positive effects of biogas and what this has resulted in for the households who had established a biogas plant.
Reducing their use of wood fuels would also decrease the environmental destruction in the area with regards to deforestation. Biogas is leading to good development with income generating activities, which they before did not have time to do. The village chairman of

Lunyanywi also points out that they would very much like to collaborate more with SUA, and that they are welcoming PANTIL or other programmes that are dealing with biogas and development.

The village leaders are concerned with how to increase the amounts of biogas plants in the two villages, and they are both stating that there is a need for biogas in the area. In Ibumila, they are planning a meeting with all the dairy farmers so that the households with biogas plants can give farmers without biogas plants knowledge of the concept of biogas and how this has affected their lives. In this way they hope that the demand for biogas plants will increase. In Lunyanywi they are staying with the "Get biogas – Pay biogas" scheme where a household pay half of the price of a biogas plant while they get the rest as a loan from SACCO. In this way the groups will make sure that all the farmers with dairy cattle will establish a biogas plant. They also emphasize the importance of spreading and creating awareness about biogas as a mean to increase the amounts of biogas plants.

5.4 Development Implications with Biogas Technology

In this part I would like to see if there are any significant differences between farmers who have established biogas plants and farmers who have not established biogas plants. I want to find out what type of development the households with biogas plants have experienced in relation to the households who have not established a biogas plant. I would also like to see if implementation of renewable energy technology in Njombe has lead to any achievements with regards to the MDGs as the theory on renewable energy for development suggests. At the end of this part I will look at the challenges of biogas in the two villages, together with the future of biogas in Njombe district.

There have been several development projects in Njombe district, and the rate of success with regards to dairy cattle and biogas is largely due to what the previous project in the villages have done. The most present organizations in Njombe concerning development are the Roman Catholic Church´s development organization Caritas, Southern Highlands Participatory Organization (SHIPO), ELCT, CEFA, SUA, SHDDP and HPI.

Caritas have established a programme called Integrated Rural Development Programme in Njombe, focusing on sustainable agriculture, livestock keeping, environmental conservation and gender. This programme are dealing with 256 household in Njombe, training the farmers on establishing kitchen gardens and fruit trees, use of natural pesticide for agriculture, environmental protection to reduce soil degradation, and organic farming.

SHIPO is an organization that cooperates with the Dutch organization Connect International and the Dutch government, and are active in all of the 154 villages in Njombe district. SHIPO is contributing to a sustained improvement in the living standards of the poor people in the Southern Highlands. Providing the communities' access to water sources at good quality and quantity and training them on improved sanitation, several households in Njombe have established water sources like boreholes and water taps on their premises.

The ELCT are providing schools, training centres and orphanages, and are at the moment establishing a university college in Njombe. They are also dealing with dairy cattle and agricultural practises, and are an important partner in a newly established biogas project with TDBP. When it comes to CEFA, is this the milk factory in Njombe. They are responsible for collecting and buying all the milk produced in the district with the intention of processing milk, yoghurt and cheese.

SUA´s presence in Njombe have been extensive within agricultural projects, going back to TARP II´s projects on "Food Security and Household Income for Smallholder Farmers in Tanzania: Applied Research with Emphasis on Women" and up to the recent PANTIL programme "Integrated Dairy Production System for Improved Livelihoods of Small-Scale Dairy Farmers in Mvomvero and Njombe District", where there have been performed a number of project focusing on livestock feeding strategies, milking practises, manure handling and utilization, and strengthening of farmers group. SHDDP and HPI have been presented earlier in this paper with regards to their work on introducing dairy cattle and training the farmers on how to utilize and establish sustainable dairy cattle operations.

5.4.1 Agricultural Productivity

For the households in Ibumila and Lunyanywi, agriculture is the main economic activity, and it is crucial that their practises are sustainable so that they are able to support their household.

Introduction to dairy cattle in the area have to some extent increased the households income through selling milk, and implementation of biogas are predicted to further increase the household's financial situation with regards to higher yields of their crops. With increased income the households should also be able to invest more in livestock to further improve their livelihood. I will therefore in this part compare the households without biogas plant and the households with established biogas plants to see if there are any differences in their agricultural productivity.

5.4.1.1 Comparison of Livestock

The amount and type of livestock a household possess are a factor that can show a household´s wealth. In Ibumila and Lunyanywi the main livestock are poultry and cattle, including both traditional indigenous cattle and dairy cattle. Pig keeping is to some extent increasing in the area after Caritas introduced this to the famers to increase their income. Breeding and selling pigs are getting more popular as the demand for pig meet is rising as the households are increasing their income.

In table 7 it is shown the average amount of animals that the two groups own. Under the category of cattle, this contains both traditional indigenous cattle and dairy cattle. Ownership of dairy cattle will provide milk for the family as well as income from the sale of milk to the local milk factory, while the traditional indigenous cattle are useful for agricultural production concerning ploughing of fields but also economic security. Cattle can be seen as an investment and represent economic strength for the households, and comparing the two groups of biogas holders and non-biogas holders there are clearly that the latter possess in general fewer animals than the former.

Table 7: Average number of livestock per household

Livestock	Households w/out Biogas	Households with Biogas
Cattle	3.5	4.8
Goat	0.8	0
Pig	2.3	1
Poultry	8.2	17.3

Since the amount of respondents in this research only contain 22 farmers, 11 from each group, it can be difficult to draw conclusion of their animal husbandry, but in some cases the differences are more clear than in others. The households who have biogas plants have in average one more cattle than the households without biogas, and concerning poultry keeping there is a clear distinction between the two groups. Poultry keeping is of increasing interest in the area, especially among the farmers with biogas, and several respondents stated that they where interested in investing in poultry keeping and in a higher degree make this to an income generating activity since they now had more time to spare on their farms. This idea was not as prevalent in the other group of households since such an establishment is costly and is time demanding. Goat keeping was not particularly widespread in the area, while pigs could be found in some of the households. Manure from pigs can be used for biogas production since it can produce high amounts of methane, but the farmers engaged in biogas production who owned pigs did not use this manure in their production. Pig keeping was mainly used for income generation, and more prevalent among the farmers who did not have a biogas plant.

5.4.1.2 Changes in Livestock Keeping

The farmers with biogas have not done any changes to their livestock, while the farmers without biogas have acquired a more wide range of animal species with a greater investment of pigs. One farmer had also purchased guinea pigs and rabbits for income generation and dietary variation. Concerning dairy cattle, two of the households had just invested in dairy cattle, while one household had increased the number of dairy cattle. This shows that the distribution of dairy cattle is still going on in the area, and is increasing the income for the families. The farmers with biogas is dependent on having a well-established dairy cattle husbandry in order to run their biogas plants sufficiently, and in this way it might be difficult to have a wider amount of animal species in their daily operation of their livestock.

A reason for the households without biogas to invest in a broader range of animal species might be that some of them are still new to dairy cattle. When a farmer invest in a dairy calf, it can take two to three years before it gets its first calf and start to produce milk. This can lead to uncertainties in relation to financial gains of dairy cattle, and it is therefore more financially secure to have a wider selection of animals.

5.4.1.3 Problems that limit their livestock keeping

Problems that can limit their livestock keeping can also be a reason for a wider range of livestock species. In Ibumila there are great problems of diseases on their livestock together with lack of available feeds in the dry season, and of a total of ten respondents from Ibumila, regardless if they have biogas or not, eight of them are experiencing limitation due to these problems. Drugs and supplementary food for their livestock are too expensive and several households cannot afford to purchase these. In Lunyanywi, only three out of the twelve respondents, all from the group who haven´t established a biogas plant, are experiencing problems with their livestock in the form of diseases. Veterinarian services for the farmers are almost non-existent and in these cases it can be safer to have a greater variety of livestock.

5.4.1.4 Comparison of Crops and Crop Production

The tempered climate in Njombe favour production of good quality fodder and crops, and especially potatoes grown in the area are a desirable commodity all over Tanzania. The main crop grown in the two villages is maize, followed by potatoes, while wheat, beans and sweet potatoes are cultivated in a smaller extent.

Soil degradation is a fact in many developing countries and can lead to unfertile soils and have major consequences for the population. Training regarding crop management and production was not very widespread among the respondents. For the households who did not have biogas plants, only six of the respondents had received training on crop management and production concerning planting, pest control, organic farming, vegetables gardens and fruit production. For the households who had established biogas plants, seven of the respondents had training on seed selection, planting practises, land preparation and organic farming.

Manure management is an important knowledge for increasing their amount and quality of their crops, together with providing nutrients for the soil. For the farmers with biogas plant, all the respondents had received training in this field focusing on storage of manure, use of manure in their fields and the use of biogas slurry as a fertilizer for the crops. For the farmers without biogas, nine of the households had received training with regards to storing manure and to use manure in their farming practises.

All of the respondents had maize as their primary crop cultivated. The farmers without biogas used an average land of 0.64 hectares on maize production, and had an average production of 2,214 kg/ha. Numbers given by the respondents shows that there are big differences concerning the household’s production, which differs from 1,125 kg/ha at the lowest to 3,825 kg/ha at the highest. This might be explained by the amount and what kind of training the different households have received, together with the fertility of their soils and access to fertilizers.

According to the farmers without biogas plants, the soil fertility is decreasing more each year and the price for fertilizers are increasing. Problems with crop pest are also limiting their crop production and inputs like pesticide are too expensive for the households. For five of the respondents this has reduced their production and resulted in less income for the households, while the remaining six respondents have increased their crop productivity due to the use of manure on their fields and in some cases industrial fertilizer when affordable.

Concerning the households with biogas, their average land used for maize cultivation was 1 hectare, with an average production of 2,439 kg/ha. This result in an approximately 10% higher production per hectare for the farmers with biogas, and does not represent any significant differences between the two groups.

According to the farmers with biogas plants have the improved use of manure on their fields together with the use of biogas slurry increased their maize production, and they emphasize that an easier way to transport the liquid manure would increase their production even more. Also, the amount of training with regards to crop production may influence the yield. But it is important to note the differences in production with regards to the households with biogas between the two villages. The production of maize in Lunyanywi is almost twice as much as in Ibumila. In Lunyanywi they have an average of 3,096 kg/ha, while in Ibumila has an average of 1,665 kg/ha. This can be due to lower soil quality in Ibumila than in Lunyanywi, but also the practises on the use of biogas slurry might be different. There is a tendency that the farmers from Lunyanywi use a higher degree of biogas slurry on their maize than the farmers in Ibumila, where two of the respondents only used the slurry for their vegetable garden and on nearby fields. This can also imply that the fields in Ibumila are located further away from their house than they are in Lunyanywi, and therefore it get´s more difficult to transport the slurry. Farmers from the two villages was also experiencing problems with regards to crop pest and expensive prices on inputs like pesticide, seeds and industrial fertilizers.

Potatoes are the second most produced crop in the two villages and is cultivated by five farmers without biogas plants and eight farmers with biogas plants. Both groups use an average of 0.3 hectares for cultivating potatoes, and there is a production difference of 21% between the two groups. Average production for the farmers without biogas plants are 770 kg/ha, while the farmers who have established biogas has an average on 970 kg/ha.

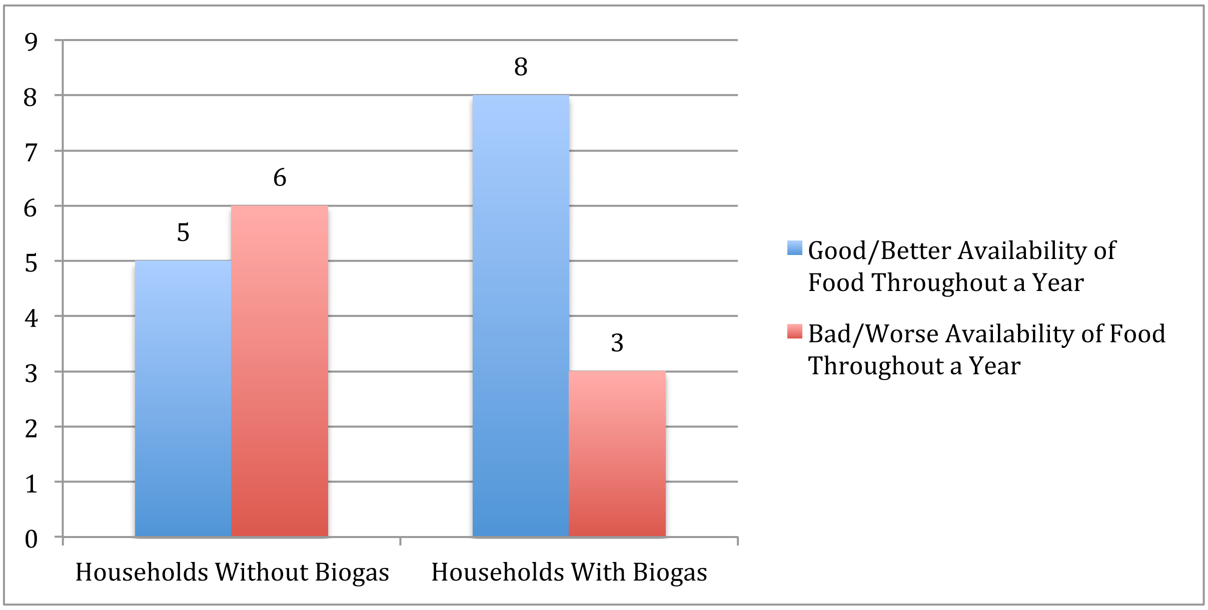
It is here a greater difference between the two groups of households concerning their amount of production than for maize, while there are no major differences in the production between the households in the two villages as it was with maize production. This can imply that the use of biogas slurry have had some influence on the household's productivity regarding cultivation of potatoes.

Additional crops cultivated in the villages are of a minor importance. Only one household from each group cultivates wheat, two households with biogas plants cultivate beans, while one household from the same group cultivate sweet potatoes. There is a tendency among the respondents that the farmers without biogas plants have a higher degree of monoculture, mainly focus on maize, and are reducing their production of other crops like potatoes, while the opposite is found among the households who have established biogas plant were they are cultivating a higher variety of crops.

5.4.1.5 Availability of food

Availability of food are concerning if the amount of food they produce or have access to is sufficient enough to cover their household through a year. The availability of food for the households with biogas plants have improved the last five years and according to the respondents this is due to of their increased knowledge on manure and the use of biogas slurry. The majority have sufficient amount of food available throughout the year now, while the situation for three remaining respondents suggest that they barely have enough food throughout the year for their household.

Figure 12: Availability of food throughout a year



For the households without biogas plants have the availability been worse or the same for six of the respondents, while five respondents say that their production have increased with their use of manure with their crops and therefore the availability of food have increased in recent years.

5.4.2 Economic Development

Introduction to dairy cattle in the area have clearly increased the economic development due to the income from selling milk to the local milk factory. This has to some extent led to economic development for the farmers leading them to increased welfare. All the farmers who have invested in dairy cattle state that they are better off financially now than before they started with dairy cattle, and the farmers with biogas plants emphasizes that they are significantly better off after changing their energy source. When comparing the annual income between the two groups there are clearly differences with regards to their wealth. Numbers from the households without biogas show that they have an average annual income of USD 558, while the households with biogas have almost five times their income with USD 2,671 per annum[2]. Whether these differences in income is a result of implementation of biogas or not are rather unclear much due to the small amount of respondents, and some

[2] There are uncertainties concerning these numbers, since they are calculated based on the numbers given by the respondents, and in some cases people are reluctant to give their accurate income.

households with biogas plant might have had higher income than the households without before they invested in biogas plants. There is a tendency that the farmers with biogas plants to a greater extent have purchased additional land for cultivation, which will increase their production of crops and thus increase their income. This has not occurred with regards to the farmers without biogas where all their land is either inherited or in a few cases hired for cultivation. This suggests that biogas technology to some extent is responsible for the increased income the farmers have experienced.

The big differences in income can furthermore be seen with regards to the respondent’s incomes per year. The households without biogas plants state in five cases that their income is not sufficient enough, while the remaining six respondents say their income is sufficient for supporting the household for one year. For the households who have established biogas plants there are seven cases where the annual income is sufficient enough to provide for the households throughout a year, while four do not have sufficient income reasoned by expenditure on secondary education at a private institution for their children. It is also clear that the households with biogas plant have more economic strength concerning the amount of hired labour they use. Hired labour for weeding and cultivation are used by ten out of the eleven respondents with biogas plants, while six of the respondents who don´t have biogas hire people for weeding and cultivation. This implies that the farmers with biogas plants to a greater extent can afford to hire labour for these tasks.

This supports the theory Flavin & Aeck (2005), who emphasize that establishment of renewable energies in developing countries are likely to improve the economic development for the households together with improvements of their living standards. Small improvements with regards to energy sources and increases in energy consumption can often enhance the quality of life for the world’s poor since energy consumption can relate to both increased welfare and economic growth.

All of the households in Ibumila and Lunyanywi who have established biogas plants had done improvements with their housing situation since the last five years, which is also claimed by Flavin & Aeck (2005). When comparing the two groups of households it was easy to see differences with regards to the appearance of their houses. The houses that belonged to the group of households with biogas plants was mainly built from burnet brick, had glass windows and corrugated iron sheets for roof, while the houses belonging to the group without biogas was mainly constructed with mud bricks and had mixed roofing with grass and corrugated iron sheets. Other improvements were purchasing of furniture, plastering of their houses and increased structures for animal husbandry where cowsheds made by wood where being improved with burnt bricks. One household had also been able to invest in a solar system for her house as a result of the money she now saved by using biogas, leading to electricity and purchasing of a television. The financial improvements had also led four of the households to purchase agricultural tools such as a power tiller, seed machine and oxen and ploughs to ease their workload. The households without biogas had also done changes to their houses to a great extent, and this was made possible due to the income from dairy cattle. They had all started to make changes with their roofing, from grass roof to corrugated iron sheets, they had also started plastering their houses and some made improvements by changing from mud bricks to burnet brick.

5.4.3 Development and Distribution of Labour

Flavin & Aeck (2005) states that introduction to modern energy services will save a lot of time for the women who usually have the main responsibility of providing water and firewood, and to cook for the household. This is time demanding and exhausting activities that influence the households and the development of women. Reduced drudgery of women´s labour can lead to improvements regarding health and education. It can also stimulate development of micro-enterprises, which will strengthen the economic development in the region. Since polygamy is practiced in the two villages, women have often more responsibility for the work in some of the households, but there are also work that are seen as women´s responsibility regardless of their marriage practises.

5.4.3.1 Water

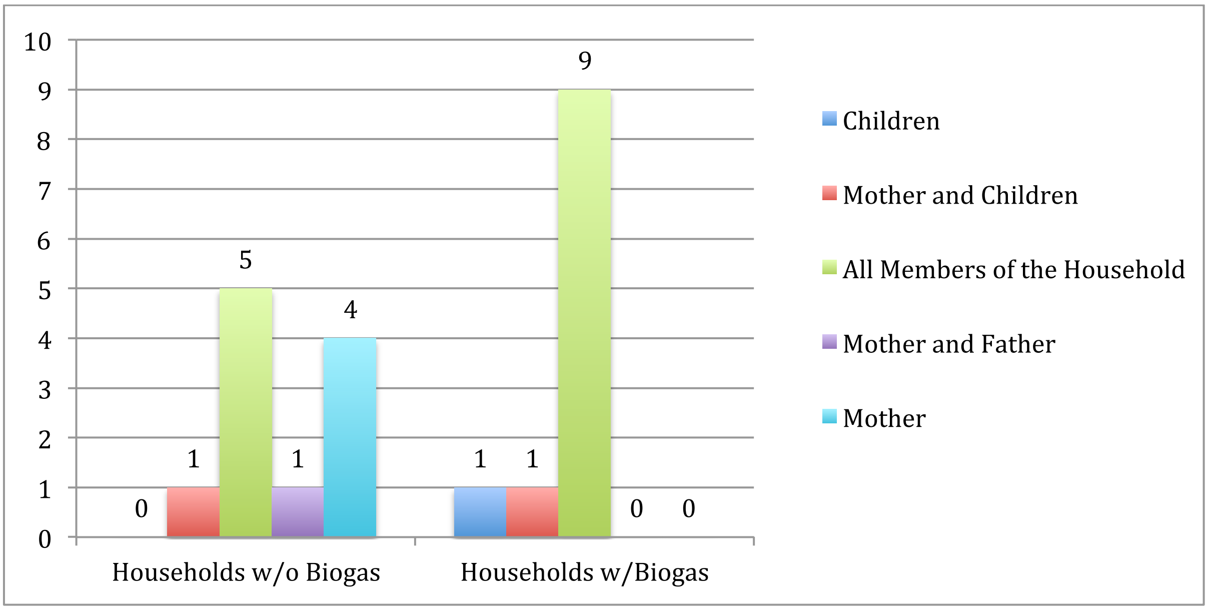
The water situation in Njombe has been improved the last years where SHIPO have been establishing boreholes and tap water for a large number of households. These upgrades are located at the household's plots and are usually not shared with any other household. This implies that the household saves time and effort avoiding fetching water from the natural spring. Improved access to water may also lead to better sanitation and have health benefits for the households. Numbers from the respondents implies that the use of water have increased among the households that have established a water tap on their premises with an average amount of 54 litres per day compared with the households who rely on a natural spring as their water source. The households who rely on the natural spring use an average of 40 minutes to walk to and from the natural spring, and the amount of water they gather are challenging to transport.

When comparing the water facilities between the farmers who don´t have biogas and the farmers who have established biogas plants there are a higher degree of households with water tap on their premises for the latter group. But it is also important to point out that it is clear distinction between the households in Ibumila and Lunyanywi with regards to access to water. In Ibumila, the five respondents who don´t have biogas are all relying on the natural spring as their water source, and do not have access to tap water or have any other water source on their property. This is also the case for two of the households who have established biogas plants in Ibumila. This differs highly from the situation in Lunyanywi where all the respondents, regardless of establishment of biogas, have tap water on their premises.

Looking at the distribution of work between the two groups there are remarkable differences with regards to the division of labour. For the households who did not have biogas plants, the main responsibility for collecting water from the natural spring was on the mother of the household, while two households responded that it was either the mother and child or the mother and father who had the responsibility to carry out this task. For the households who had established water taps on their premises it was an equal responsibility for all members of the household to get water for their own needs.

Concerning the households who have established biogas plants there are only two households that are relying on the natural spring, where in one case the children had the responsibility and in the other both the mother and children collected water. For the cases where the respondents have established a water tap on their premises, all the members of the household participated in collecting water.

Figure 13: Responsible for collecting water



This suggests that establishment of boreholes and water taps at the household's property saves time for the women, but also that there are higher amounts of water taps among the households who have established biogas plants. If this is a result of higher income or just the work of SHIPO is not clear, but it is also evident that SHIPO has not been as active in Ibumila as they have been in Lunyanywi, but they are still working on expanding the amount of farmers with water taps, which will lead to more establishments and thereby less work with regards to collection of water.

Since there is a low amount of households that rely on the natural spring from the group that have biogas plants, it is hard to say if there is a trend that the mother in the household have less responsibility when it comes to collecting water within this group and it is therefore difficult to state if the establishment of biogas plants have had any influence regarding this subject.

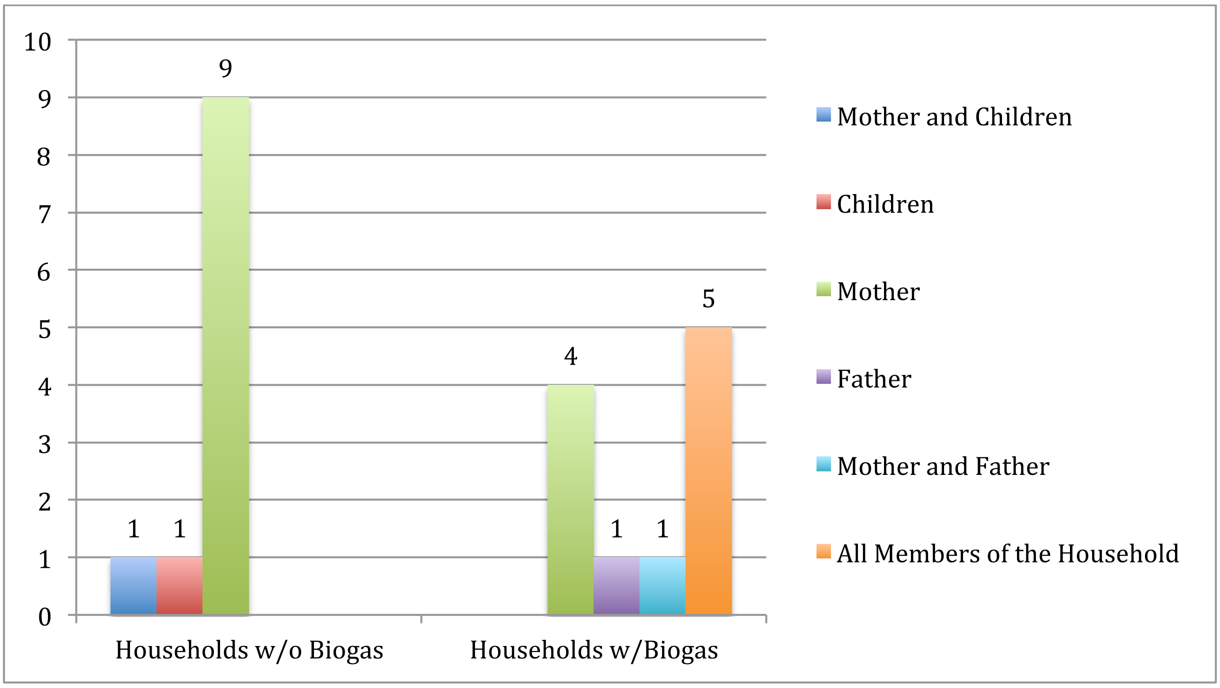
5.4.3.2 Energy Sources

The prices for inputs with regards to cooking, heating and lighting have increased and are continuing to increase according to the respondents, but the farmers with biogas plants state that these costs have been reduced significantly since the amount of traditional fuels have decreased to a great extent.

For the households without biogas pant, the main energy sources are firewood and kerosene, while in some cases they use charcoal for heating of rooms. They consume an average of 1.4 litres of kerosene per week with an average expenditure of USD 1.2, which correspond to the amount used by the other group before the invested in biogas. According to Flavin & Aeck (2005) there is in general women and children who have the responsibility of gathering fire fuels for the household in developing countries, and the families who have not established biogas plants use an average of 2 hours per day to accomplish this task. The supply of firewood in the area is relatively accessible were the majority of the respondents stated that they have little trouble with regards to gathering firewood, while three respondents found the availability of firewood to be hard and difficult to access. But all of the respondents had noted that the availability of firewood was reduced and still was decreasing in the area, leading to more difficulties securing their needs of firewood now than it was five years ago. Some of the respondents also had to pay a fee to get access to the forests where they gather firewood, and this fee had also increased to some extent in recent years.

Looking at the division of labour within the group of households who have not established a biogas plant, there is as Flavin & Aeck (2005) claims, a high majority of women who have the responsibility of gathering firewood, and in two instances, also the children are responsible for this, either together with their mother or have the sole responsibility. Children´s responsibility regarding the work of gathering firewood can lead to serious consequences for their education and thereby their general development. Using large amount of time to gather firewood can indicate that their education is being underestimated together with less time to study, and implementation of renewable energy can free up time for the children so that they can attend education. Children's education in developing countries is according to Flavin & Aeck (2005) important to increase the development for the next generation, and will help to eliminate the gender disparity in these countries.

Figure 14: Responsible for fetching firewood or inputs for biogas production



For the households with biogas plants the division of labour have changed remarkable. Before, these households where in nine instances relying on the mother to gather their firewood, and in three other cases the children helped their mothers. Now, after they established biogas plants, there are only four households where the mother has the sole responsibility of providing the inputs for biogas production, while there is a small majority were the whole household share the tasks of gathering inputs. Also the father of the household has more responsibility where he in one household is solely in charge of for providing the inputs and another where the mother and father have equal responsibility. The improved gender distribution with regards to gathering inputs for cooking can be explained with the location of the inputs together with the new technology where the gender roles are not as set as when gathering firewood. All the inputs are now at the farm, and are among the tasks performed when dealing with the livestock, and in this way the father of the household have taken more responsibility. As mentioned before are many of the families who use biogas still using some amounts of firewood, mainly for space heating. The women in the household are still carrying out this task, but the amount of firewood used and the frequency gathering it has significantly decreased. This suggests that the women´s workload have been reduced after they invested in biogas plants, and the distribution of work within the household is more divided. The fact that the families have invested in biogas technology also make the family members more concerned with regards to taking care of the biogas plant and use it in a proper way so that the households can get the most out of their investment. This can also the a reason for the fathers in the household to be more involved in the production of biogas, since it is they who have the primary responsibility of handling the finances of the household.

5.4.3.3 Nutritional Trends

The introduction of dairy cattle in Njombe has improved the household's nutrition with an increased consumption of milk, but also income from selling milk to the local milk factory have increased their income and made them able to buy more varied staple food. The families diet and nutrition have changed for all the households in this research, and the diet for the families without a biogas plant, consist mainly of potatoes, milk, green vegetables, rice, ugali; porridge made by maize flour and water, kande; a mix of beans and maize, and more increasingly a diet with meat or fish due to their income from selling milk. For the households who have biogas, the diet is much the same as for the ones without biogas, but there is a more frequent element of meat and fish.

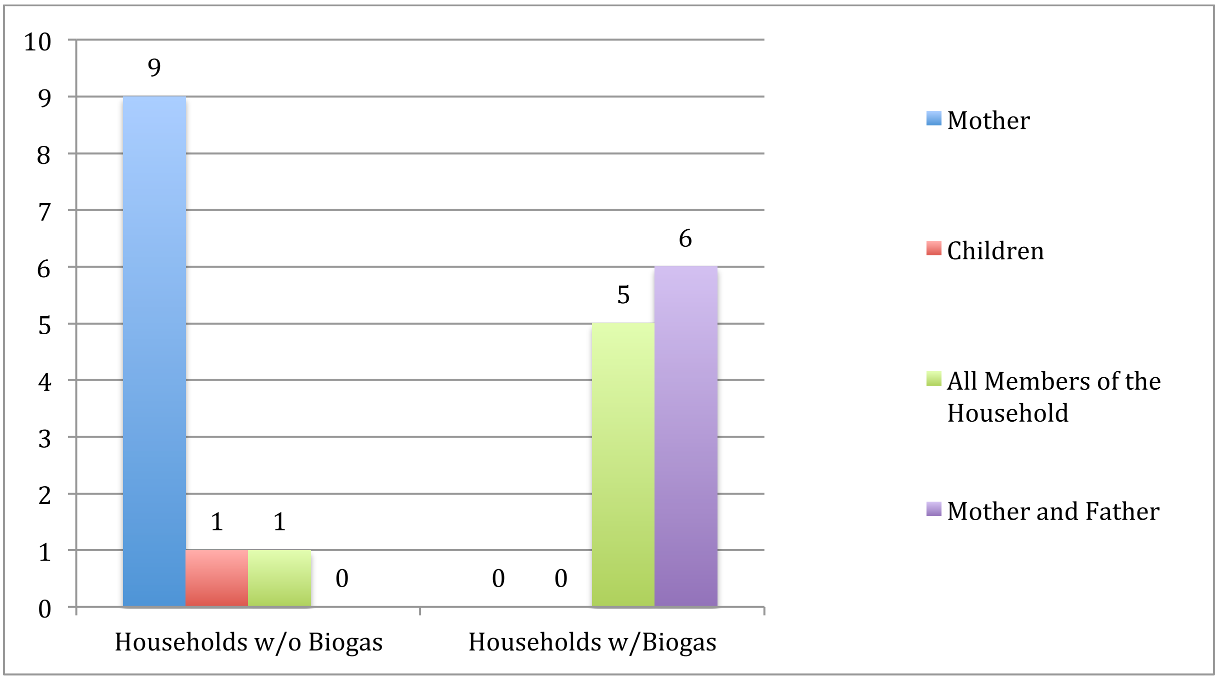
With the money the households now save on their decreased usage of kerosene and income from selling milk, they can afford more nutritious food and have more variability regarding the type of food they eat. The households with biogas also emphasize that they now have increased their amounts of meals per day as a result of biogas, since the task of cooking now are much easier than before when they used firewood. Prior to their establishment of biogas, they had an average of 2-3 meals per day, which is the same amount as the households without biogas plants have now, but after investing in biogas they make an average of 3-4 meals per day, which implies that they have increased their amount to one more meal a day. This suggests that the task of cooking is easier and less time consuming with just turning on the gas. This has also resulted in cooking breakfast for their children before school, which was too time demanding before, and is not as common in the group who don´t have biogas.

The change in diet and nutrition for both of the groups has also been the main reason for the improved health condition in recent years. For nine of the respondents who don´t use biogas for cooking, their health conditions have been improved due to the increased consumption of milk and a more balanced diet as a result of the investment in dairy cattle. The most common diseases among the households who don´t use biogas for cooking, is chest pains, coughing, colds and eye infections for the women and the children. This health effects has also been a problem for the households who have biogas, but these are now declining to an extent were some of the respondents claims that their household has no more diseases after starting with biogas. Improvement of health is therefore also a factor for the households who have established a biogas plant, and all of the respondents state that their health conditions have improved since they changed their energy source. Some of the explanations of their improved health was due to the benefits of having dairy cattle, but the main reasons mentioned was increased time to rest and less inhalation of toxic smoke from cooking with firewood. The reduction of toxic smoke is also a reason for why their children are healthier, together with the increased amounts of meals. Also their experiences with cooking have improved. The cooking is always clean since they avoid the soot and smoke, and the task of cleaning the kitchen and its appliances are much easier than before.

This indicates that the establishment of dairy cattle have important dietary and nutritious effects on the households, together with health improvements for the families in the two villages, and that investment in biogas will increase these improvements. According to Flavin & Aeck (2005), indoor air pollution from cooking with firewood can cause lung diseases and to reduce the extent of this, the most effective change is to switch from solid fuels to renewable energies like biogas.

For the households without biogas plants, the women are responsible for cooking in nine of the eleven cases, while the two other cases rely on either the children or all the members of the household to cook. When it comes to the division of labour among the households who are cooking with biogas, the gender roles have been significantly changed. Before, it was the mother of the households who primarily carried out the cooking, but after they replaced firewood with biogas, the responsibility of cooking has been more evenly shared between the household members. In five cases all members shared the responsibility equally, while in six cases the father was as much involved with the cooking as the mother, which did not occur prior to biogas due to all the soot and smoke generated from the firewood.

Figure 15: Responsible for the households cooking



According to Flavin & Aeck (2005), will introduction to renewable energy in developing countries free up time for women and children who are most likely the ones who are left with the task of fetching water, gathering fuel wood and cooking, and allow them the opportunities of education and enterprise development. In Ibumila and Lunyanywi it is clear that the establishment of biogas plants have altered some fundamental thinking regarding gender roles in their society, and freeing up time for women and children as predicted by Flavin & Aeck (2005). This increased free time has also improved the heath condition for the women and are changing their everyday life.

5.4.3.4 Education

In Ibumila and Lunyanywi, all the children of suitable age are attending school, except in two cases where the first child was suffering of a chronic eye disease and the second case where the child was disabled. In Tanzania, secondary education is not free of charge as opposed to primary education. This implies that households have to pay for their children´s education, which can lead to children leaving the educational system after they have finished their primary education. For the households in Ibumila and Lunyanywi were all the children suitable for secondary education attending. This suggest that the families, regardless of biogas, could afford to pay for their children's education and much of this is due to the increased income by selling milk. But there are some differences between the two groups of households. One of the households had been able to afford to send their child to university reasoning it with their increased wealth after being introduced to biogas, together with a higher rate of children attending private secondary school from this group. Another household stated that after they established a biogas plant they could send their children to school, while they before had too much work to do on their farm together with gathering firewood, and was therefore dependent on the help from the children and could not afford to send them to school.

There are also differences with regards to the children´s performance in school. All of the respondents stated that their children´s performance in school had improved after they acquired biogas plant, where one of the children had become the best student in his class. This was believed to be due to the increased access to lighting, which mean that the child got more time to study. Also the increase in meals per day was assumed to have influence on their improvement in school, since the children now get breakfast before school and is able to concentrate to a higher degree. School performances among the children in households without biogas were mainly rated as fair by their parents, and in some cases the children had good performance in school. These differences can mainly be explained by the improved access to lighting for the children to study beyond daylight. For the households without biogas there was only one household where the children did not have access to light beyond daylight, while the others had access to light beyond daylight with use of kerosene. The majority of households with biogas use both kerosene and biogas for lighting, but two other households have invested in solar power and use this together with biogas, while two respondents solely rely on biogas for lighting. Availability of light beyond daylight for children living in a household with biogas are to some degrees higher than among households without biogas. Since lighting produced by biogas is cheaper to use than kerosene it is more likely that it is more restriction on the children´s use of kerosene hence reduces their time to study.

This suggest that RETs have an influence on the children´s education as stated by Flavin & Aeck (2005). They emphasize that introduction to RETs can improve the children’s possibilities for education and their performances in school. Responsibilities for collecting water and fuel wood can keep the children out of the classroom, which especially affect the girls. In this case, establishment of RETs can free up time for the households and thereby free up time and enhance the children’s ability to go to school and in this ways raise the children attendance. Introduction to RETs, such as biogas, will increase the household’s access to light beyond daylight, making it easier for reading and studying after school, which can improve the children's performance in their education.

5.4.4 Sustainable Development and the MDGs

According to Wilkins (2002) can renewable energy services lead to sustainable development. He claims that establishment of renewable energies will improve lifestyles, reduce poverty, empower women, reduce the population growth and slow down the urban migration in the rural south. My study shows that the three first factors have been relevant for the households in Ibumila and Lunyanywi who have invested in biogas technology. The two last factors Wilkins mentions, decreased urbanization and population growth, is too early to estimate and need to be observed over time.

It is also suggested that introduction to RETs in developing countries will help to achieve the MDGs. Flavin & Aeck (2005) states that renewable energy will not alone solve these goals, but it can be an important factor in achieving them. Concerning biogas and achievement of the MDGs they have an impact on 7 of the 8 goals set by the United Nations.

Biogas has increased the wealth of the farmers invested in this technology, and the money saved by using biogas have to some extent been used for purchasing of additional and plots for cultivation. This may improve the quality and quantity of their crop and thereby have a big impact on the first MDG, which are to cut extreme poverty and hunger. The farmers with biogas also save money by not using kerosene and are able to purchase food.

The second goal of the MDGs is to achieve universal primary education. Primary education is available for all the children in the two villages and the reduced workload by using biogas technology are helping the households to send their children to school. Biogas has also improved the children´s performance in school since they now have better access to lighting beyond daylight for studying and reading, together with the possibility of making breakfast before school, which improves endurance to concentrate. Since the families save money by not purchasing kerosene, the children have a better chance to attend secondary education or even university.

There are some remarkable changes regarding the division of labour within the households who have invested in a biogas plant. The responsibility of the mother in the household has been reduced leading to more rest for the women together with possibilities for other income generating activities. This indicated that the achievement of the third MDG, to promote gender equality and empower women, could be achieved to some extent with implementation of biogas.

The fourth, fifth and sixth MDGs are all related to health. Biogas is showed to improve the households health conditions by leading to more rest for the women, together with less inhalation of toxic smokes related to the use of firewood. The households have also more nutritious diets due to increased wealth, leading to improved health. The last goal that can benefit from biogas is environmental sustainability. By not using fossil fuels as their primary energy source, emission of greenhouse gasses will be reduced. Also, reduced use of firewood and charcoal will reduce the pressure on the local forests and improve the water quality in the natural springs. After experiencing the effects of what biogas technology can result in, the respondents unanimously say that this is a better option than their traditional fuels, heavily emphasizing that their general well being had increased and continue saying that they will “use this technology until their death”

Table 8: Benefits of Biogas use in Ibumila and Lunyanywi

Environmental Benefits	• Reduced amount of firewood and charcoal decrease the rate of forest degradation and will help for environmental conservation. • Improve the quality of water in the natural springs • Reduced emissions with reduced consume of fossil fuels
Health Benefits	• Improved health due to lack of inhalation of toxic smoke from cooking with firewood • More rest for the women with reduced frequency of gathering firewood and easier to cook • More nutritious diet • Increased amounts of meals
Gender Equality	• More equal distribution of work • Decreased frequency of gathering firewood leads to more free time for the women and more time for the children to study, especially the girls
Financial Benefits	• Less expenses on fuels • More time for more income generating activities • Improved economic development
General Well Being	• Improved living conditions • Enhances life quality
Educational Benefits	• Children have greater access to light beyond daylight leading to better conditions to study • Better school performances • Ability to pay for secondary and even university education for the children • Breakfast before school
Agricultural Benefits	• Use of biogas slurry as fertilizer

5.4.5 Challenges of Successful Biogas Utilization in Njombe

Even tough the biogas technology have had a great impact on the people in Ibumila and Lunyanywi, there are some challenges to get a successful implementation of biogas. There are many requirements for the successfulness of biogas plants, and for other farmers to have the same success, a lot of training required. Farmers without the accurate training have a bigger chance of failure, and thereby investing a lot of money in a technology they will not be able to use in a sustainable way.

First, the farmers need to have established sustainable dairy cattle operation, including building a cow shed, establish pasture land for fodder and have training with regards to appropriate livestock feeding and procedures that will provide fodder in dry and wet season, established a sustainable income by selling milk which requires knowledge on proper milking practises. The farmers also need the appropriate amount of manure from the dairy cattle, together with sustainable breeding of dairy cattle to continue the spread of dairy heifers in the area.

Second, when having established a successful dairy cattle operation the farmers need knowledge and capital for establishment of a biogas plant. For production they need manure and water, and without water on premises, this task can be as dreadful as collecting firewood, especially if the distance to the nearest water source is far. Concerning the manure used for biogas production, this has to be performed in a way where the access to the appropriate manure is available, which require training in manure management. Manure management also includes practises leading to improved farming and higher yield. Training on manure management and improved farming practises also include utilization of biogas slurry as fertilizer, which is an important benefit with biogas, since soil degradation and low yields is a problem in the area.

Last but not least, the farmers need to have appropriate knowledge on utilization of biogas. There are many farmers in Njombe who knows how to construct and use a biogas plant, but it is highly necessary that the farmers who receive a biogas plant know all the details on how to run it in a sustainable way together with potential problems that can occur. Much of this recommended training can be transferred from the farmers who already have adopted the technology through the farmer groups they are members of, but the success or failure of biogas can be at stake if this is not done properly.

Biogas is an expensive technology to purchase for the households in Njombe, and there are today many uncertainties with regards to the subsidies when establishing a biogas plant. Establishment of one biogas plant equals double of the average annual income for the households without biogas plants. There are no clear guidelines on the financial situation concerning the down payment of their loans, and there are also uncertainties if the subsidies programme through SACCO is sustainable. For every biogas plant built in Ibumila and Lunyanywi, USD 978.5 is being subsidised from group savings. This implies that the spread of biogas plants in Njombe will be slow, which also can be observed through the two biogas plants that have been built since PANTIL phased out. It is therefor a need for more affordable prices on biogas, or there can be a development where only the households with a strong economic status will improve their energy source, hence their development. But there is already a tendency that this is occurring in Njombe. The SHDDP and HPI projects was supposed to provide dairy cattle for the less fortunate households in the area, so that they could have an income to improve their development. But this turned out to be difficult since they had to establish a cow shed and pasture land, which requires capital. Since the establishment of a biogas plant requires a dairy cow, this becomes a bad circle, where only the people fortunate enough to afford the requirements for dairy cattle will be able to invest in a biogas plant. Therefore, the gap between the poor and the less poor continue to increase, leading to a very difficult situation for the less fortunate people in Njombe.

5.5 The Future of Biogas in Njombe

Biogas has a bright future in Njombe district. It is providing many benefits to the households, and for the people who have awareness of biogas are interested in investing in the technology. TDBP in collaboration with the ELCT – Southern Diocese are now starting up a biogas program in Njombe village. The construction was supposed to start in January 2011, but is now postponed until June 2011. This project will start in four villages Mtwango, Ikelu, Kichiwa and Igongolo, which are working as pilot villages for the project. The information received from the ELCT was that they were building biogas plants with digesters on $6m^3$, corresponding to less than half the size of the digesters that PANTIL provided.

The lower the operating temperature is in the area, the more digestion space is needed. Since the temperature in Njombe is fairly cold compared to other areas in Tanzania, they require more inputs and bigger digestion chamber. PANTIL had performed research to determine the desired digester size for the two villages with the intention that it should be sufficient for a family size of 6-7 people, and therefore decided to build a digester on 16 m^3. It is therefore a possibility that TDBP´s digesters are too small, and thereby not be able to produce sufficient amount of biogas for the households. If a family have to use firewood and kerosene to subsidise their use of biogas to a greater extent there is a chance that they might not use biogas at all. This can also lead to a bad reputation for biogas, and the demand for biogas plants can decrease, leading to a negative status for the technology.

6 Concluding Remarks

In this thesis I have looked at the development implications and sustainability of biogas plants in Njombe with a main focus on what the requirements behind the establishment and sustainable use of biogas were; what the general behaviour and awareness towards biogas in the area was; and if the implementation of biogas have led to any development for the farmers in question and if this energy source has been suitable and sufficient for them. The conclusions that can be drawn from this research is that biogas is in most contexts a sustainable energy source, resulting in reduced consumption of firewood, kerosene and charcoal, and an easier everyday life for the women, which are relieved from the task of gathering firewood for 2.5 hours per day, a task that have been replaced by 20 minutes of gathering and preparing inputs for biogas production. The division of labour within the households with biogas have changed radically, evening out the gender roles as the father of the household is taking more responsibility in tasks such as collecting water, inputs for biogas production and are participating in cooking, which before was seen as tasks performed by the women. Also the economic development among the farmers with biogas has increased, suggesting that it has some financial benefits, like saved expenses on kerosene and ability to purchase more land plots for increased income within agricultural production. But the research also concludes that there are some factors that are unsatisfactory. As the amount of gas they produce are sufficient for their use, and it is therefore unfortunate that they only have access to biogas in their kitchen. An increase in the availability of biogas within a household can result in complete independence from traditional fuels, and thus, leading to an even stronger sustainability of biogas in the area. This limitation, together with the price of establishing biogas plants is two major factors limiting the sustainability of biogas in the area. Biogas is still a new technology in Njombe, and the case of funding may improve in the years to come, but the situation now, where the establishment of biogas with 50% subsidies cost twice of the average annual income for a household without biogas, will limit the expansion of this technology and also create a big gap between the less fortunate households and households with economic strength. Biogas is a desirable technology for the households who have some knowledge regarding the technology, however there is generally a very low awareness of biogas among the farmers without dairy cattle and farmers outside the two villages. It is therefore important to raise the awareness about biogas, and particularly to continue the spread of dairy cattle, as this is the major requirement for establishing a biogas plant. Farmers who have acquired a biogas plant have increased their livelihood conditions greatly, and by making it more financial available this could have major impacts on the development in the area.

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