CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

INSTITUTE OF TROPICS AND SUBTROPICS

Proposal of Feedstock Supply for Biogas Plants at Habitat Research &Development Centre (HRDC) in Katutura Windhoek, Namibia

Msc THESIS

Department of sustainable technology

Author: Bc. Saara Nghifingali Tulipomwene Hangula

Supervisor: Ing. Jana Mazancová, Ph.D.

Prague 2012

DECLARATION

I, Saara, Nghifingali ,Tulipomwene ,Hangula, declare with full Indubitableness that this thesis has satisfied the proficiency of requirements for the Msc degree in the Institute of Tropics and Subtropics of the Czech University of Life Sciences Prague. This work is entirely my own work other than referenced.

In Prague, 2012

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Saara Nghifingali Tulipomwene Hangula

ACKNOWLEDGEMENTS

The undertaking of this research thesis was physically and psychologically demanding but it is amazing how quite a number of people assisted me along the bumpy road.

With all profound gratitude, I would like to say a big thank you to Ing. Jana Mazancová, Ph.D. for her unspeakable encouragement admonition and guidance all through the period of this study and a steady stand by and help during my preparation of writing this thesis project. I am grateful to my family and friends who stood by me to make this project a success.

Abstract

Feedstock is produced from different sources which are suitable for the anaerobic digestion and to be converted to useful product of energy. In Namibia 25199600 tons of manure are produced per year and other organic wastes which are suitable for anaerobic digestion. The aim of this work is to investigate the possible ways of feedstock supply, at the Habitat Research &Development centre in katutura to feed their plant since there is a shortage of feedstock.

To achieve this goal the study was divided in several parts. The first part dealt with the importance of feedstock in anaerobic digestion process .The second part was focused on the current status of biogas in the country. The third part was about the feedstock supply situation in Namibia, taking into consideration the feedstock currently used in biogas plants in Namibia and the potential of feedstock supply in Namibia. The third part was results and discussion where the proposal of feedstock at the centre was done by calculation and the optimization of available feedstock composition which is available locally were used and it showed that by supplying 11.30kg of dry matter per day produced 2.7m^3 biogas and when converted this can give out 103.8 MJ which gave 28.7 kwh and this can be used to balance the energy at the centre, since it has a deficit of 20 Kwh .The SWOT Analysis was presented and the last part was conclusion and recommendations.

Key words : Feedstock, Anaerobic digestion,Biogas,Organic matter ,Katutura-Namibia

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List of abbreviations

AD	Anaerobic Digestion
CO_2	Carbon dioxide
FAO	Food Agricultural organisation
HRDC	Habitiat Research & Development Centre
HRT	Hydraulic Retention Time
kWh	Kilowatt hour
MAWF	Ministry of Agriculture,Water and Foresty
MJ	Mega joules
MME	Ministry of Mines and Energy
MRLGHRD	Ministry of Regional & Local Government, Housing & Rural Development
NEB	Namibian Electricity Board
NGO	Non-Governmental Organisations
NH3	
OBP	Ongendo Biogas Project
OPCSP	Okahao Quick Cooking Stove Project
REEEI	Renewable Energy and Energy Efficiency Institute
SGP	Small Grant Programme

SWOT	Strengths, Weaknesses, Opportunities and Threats
TWh	Terawatt hour
UNAM	University of Namibia
UNDP	United Nations Development Programme
VFA	Volatile Fatty Acids
WHO	World Health Organisation

1. Introduction

Everyday waste is produced all over the world, an incredible amount of 1, 2 billion tons coming from different resources such as kitchen, agricultural, animals and industries. About 34.2 million of tones of organic waste is scattered around the world (Curry& Pillay, 2011). Living in the environment with waste causes diseases and it also damages the ozone layer which protects human beings from the high frequency of sunlight. According to the World Health Organization (2010) there are a high percentage of people dying every year due to unclean environment which these people live in.

Technology and energy are the key factors to the development and these variables go hand in hand with development. As long as there is development is going on different Feedstock are produced from different sources which are suitable to be converted to useful product of energy. Therefore, Biogas technology can manipulate the feedstock available and this can be done by converting organic matter through the process of anaerobic digestion to produce biogas (Obeng *et al*., 2007). The biogas technology has come as tools to solve the problem of organic waste in the world and also to increase the use of renewable energy as well as the availabilities of energy.

Biogas technology can be an answer to Namibia as energy supply, since Namibia imports about 70% of its energy from neighbouring countries and yet it has much waste produced every day. According to the Ministry of Mines and Energy (2011) the ministry spends more money on importing energy every month and at same time; the Namibian Electricity Board keeps on increasing the price of electricity since their provider increase their rates too. This makes the Namibian people to pay high prices of electricity especially those who live in the cities.

Therefore, the biogas technology will reduce government spending on energy and thereby enabling government to look at other areas like health problems.

2. Literature review

This chapter provides an account of the literature review under numerous headings. Section 2.1 explores the process of anaerobic digestion and the importance of feedstock in the anaerobic digestion process. Section 2.2 focuses on the different biogas plants that are found in Namibia. Finally, the feedstock supply situation in Namibia is found under section 2.3 and it is mainly focused on the feedstock currently used in the biogas plants.

2.1 Anaerobic digestion

Anaerobic digestion is a process used to treat organic waste to produce biogas and fertilizer (E-Mahad *et al.*, 2010). According to the literature anaerobic digestion has been used for many decades and it is regarded as the oldest technology in the world and technology has extensively been used in developed and developing countries as the tool to treat water waste.

Feedstock

Feedstock is a raw material which is used for the industrial process and there are many types of feedstock such as organic matter, metals, timbers, crude oil and minerals (Smith, 2003). Different feed stocks are produced in the world, due to the technology and development which is taking place. Feedstock has different purposes, some can be used for feeding animals and some can be converted to energy. Therefore, there is need to characterize the feedstock according to the use, since the waste is produced from different sources and is divided in two categories inorganic and organic waste.

The organic waste can be converted to energy sources such as gas or can be used to fertilize the soil. The organic waste is normally from agriculture residual, animal waste, municipal waste and it is digestible by the anaerobic digestion.

Inorganic waste is produced from indigestible sources such as factory produce like plastic, heavy metal and they are not suitable for anaerobic digestion or has low rate of digestion.

2.1.1 Importance of feedstock in Anaerobic Digestion process

Feedstock is regarded as food for anaerobic digestion and it has an important role in the process. Feedstock is converted to produce gas and fertilizer which is rich in nutrients. Since the anaerobic digestion process is carried out by a consortium of bacteria, so the feedstock are from organic matter because the bacteria which are in organic matter are the ones which allow the process of anaerobic digestion to happen. The composition and characteristic of organic waste is different, therefore, they have a different impact on the effectiveness of anaerobic digestion (Li *at el*.,2011).There are many sources which produce suitable feedstock for the anaerobic digestion such as agriculture, municipal and industries.

The feedstock from different source has different reaction to anaerobic digestion such as the retention time, PH, and the digestibility for example the organic from waste food has been approved by the researchers and people who use the waste food as the feed- stocks for their biogas production claim that it has high amount of organic soluble and it can be easily converted to VFS (Clo., *at el* 1995). If there will be any extra conversion which may happen in early stage of the digestion, the PH will drop and this will slow down or inhibits the methanogenesis process. One way to prevent this to occur is to use the co-digestion carbohydrates –rich feed –stocks and mix it with the other feed-stocks (Li., *at el* 2011).

The residual from agriculture such as maize stover, rice straw, wheat straw, grasses and poor hay are recommended to be used as feed-stocks for biogas production .The good thing about the agriculture residual is that they are mostly available and are very cheap even if you have to buy them. The crops residual which has polysaccharides can be used straight for the fermentation while the one that has cellulose or hemicelluloses needs to go under pre treatment so that it will allow the carbohydrates in lignocelluloses biomass to break out free (Lu *et al.,* 2007).

This is the combinations of wastes from food and garden that are used for the production of the gas and are the most important which have to be considered all the time when it comes to the collection of these wastes. As indicated in many sources that the procedure of waste collection affect the characteristic of municipal waste, and the process of anaerobic digestion (AD), this will affect the biogas yield as well, so the good procedure has to be taken in account (Bolzonella e*t al* .,2006).

Feedstock and its involvement in various aspects of anaerobic digestion

Feedstock is an extensive subject which has a big relationship with anaerobic digestion. Therefore, there is an interaction between feedstock and anaerobic. Feedstock is pondered that it has an influence on the composition of reactors as well as the expansive impact on the physiology of the bacteria (Steffen, 1998).

According to the literature the compound structures of the feedstock are different and each feedstock needs special design so that it increases the digestion process (Zhang *et al*., 2007). Steffen (1998) went further by saying that feedstock with higher solid polymeric compound contain waste and it requires a different design than the readily biodegrade waste. The difference is that feedstock which has lignin needs some weeks so that it can breakdown, while the feedstock which has hemicelluloses takes only a few days to degraded, therefore the compound structure has an influence on the digestion time of the feedstock.

Feedstock is the driver of the quality of the products which is produced in the anaerobic digestion; therefore, taking care of feedstock is needed because it determines the methane. Nevertheless, the waste source and economic factors have to be taken care of for the feedstock which requires further and expensive treatment or reactor. The main purpose for using the municipal solid waste is to reduce the waste and to produce clean energy which is biogas. Energy crops are suitable for the anaerobic digestion whereby the biomass has to be treated and stored for the future use as feedstock in the digester. (Nordberg, 1997 in Steffen, 1998)

Characteristics of the various feed stocks and their impact on the anaerobic digestion process.

Substrate composition

The inclusive nutrient ration in waste is very important for the microbial biodegradation process. The carbon to nitrogen ratio 30:1 in the organic matter need to be taken care of since it has a side effect on the production of gas .The higher level of nitrogen leads to production of other gasses such as nitrogen monoxide (N_2O and ammonia (NH_3).The animal waste has more nitrogen while the crop residue has carbon (Kara *et al*., 2007), So the ration needs to be kept at the optimum level because if not the whole process will be negatively affected.

Water content should be suitable for the micro organism and other metabolic processes need water, the adequate water content needed is about 90%. The main point for the water is not to increase the yield of the feedstock and to heat up the input which is required per cubic meter. Insufficient water will lead to harmful toxins (Chynowelth *et al*., 2001).The changing of total solid content has a side effect on fluid dynamic of the substrate and the result is from the bad mixing process which is offered to the digester.

The macromolecules of feedstock such as proteins, fats and carbohydrates have to be taken care of because they cause the formation of Volatile Fatty Acids

(VFA), during the degradation. The higher concentration of fat causes the Volatile fatty acids to rise and high protein leads to ammonia (Steffen, 1998).

Undesirable in component

The fluid dynamic and degradation is affected by the component of feedstock such as straw, inorganic matter like sand, must be avoided because it causes failure in the process, therefore, it needs to be to be limited. According to Steffen, (1998) chicken slurry have sand most of the time and the co-substrate from biogenic waste and industrial causes inconvenience in the components.

Inhibitory component

The concentration of VFA in slurry need to be taken care of because it has an effect on the degradation process which causes quick degradation of the macromolecules especial carbohydrates from agro industrial. The inhibitory substance are most found in agro industrial, since they are produced during the processing of products, hence the end product like NH_3 or H_2S regularly has high effect. The incensement of the VFA causes instability in the reactors when the PH is low. When the biodegradation of organic waste is higher it causes problems in the digester. Animals which are treated with chemicals such as antibiotic produce feedstock which contain some inhibitory even though it does not have any much effect on the biodegradation. The feedstock which contains pesticides is obtained from the crop residues. The concentration of harmful substance in animal, agricultural and agro-industrial has no much effect when the substances are diluted.

Biodegradation

The biodegradability of feedstock depending on the substrate composition, determine the biogas yield is by the percentage of total solid which is broken down in anaerobic digestion (Zhang *et al*.,2007). It has been reported that domestic sewage has surfactants which has negative impact on anaerobic biodegradability; these can lead to inhibit the process to take place (Tarek *et al*., 2001). According to Steffen (1998) feedstock which contain higher fat is regarded to produce high amount of the biogas but the rate of degradation is longer than feedstock which has carbohydrates, animal feedstock are the ones which has high carbohydrates.

Cofermentaion

The cofermentaion is when you apply different varieties of feedstock to the plant which is called co substrate. According to the literature the non agriculture organic waste has been chosen to be used in the digester in other to increase the quantity and quality of feedstock. feedstock is obtain from the organic waste from fermentation slop, waste food from prison, boarding school, hospitals, hotels ,restaurant and animal waste from slaughterhouse. According to Steffen most of the co substrate are digested with the combination of cattle manure since it has high content of carbon .The digestion of the co substrate it provide the rich fertilizer which can be used to improve the soil fertility.

Handling of feedstock

The handling and transportation of feedstock is very important because if the feedstock is not well handled, it will have a bad effect on the anaerobic digestion process since it may contain some waste which are not suitable for the process .The feedstock need to go under treatment in order to avoid some inhibit of the process and leads to low yield of biogas .The treatment of the waste it depend on the source where the feedstock is from like manure from cattle may contain pathogens depending on their origin Therefore all the feedstock need treatment according it origins. It has pointed out that treatment of garden waste, food waste and biogenic waste it not economical because it requires expensive procedures. The distance for transporting the feedstock has to be consider and storage capacities since it has detrimental effects on the overall process economics (Steffen, 1998).

Utilization of Feedstock by anaerobic digestion in digester

The feedstock has to be sorted out before it enters the digester, since not all the feedstock is suitable for digestion (Zábranská in Chudoba *et al.*, 1991). When it enters in the digester, the microorganism which is found in many environments, especial in animal intestine and landfill take over.

Phases of Anaerobic Digestion

There are two processes that anaerobic metabolism goes through and their characteristic differ in the response to the environment and the final product decomposition. The AD process takes place in an airtight container, known as a digester. According to Zábranská in Chudoba *et al*.,(1991) the biological process which takes place in the AD are divided into four phases and are described below as well as the visual scheme of the phase figure1; Hydlosis, acidogenesis and methanogenesis. The bacteria break down the organic molecules in to amino acids, fatty and simple sugar. The enzymes which are present in this stage are called anaerobic hydrolysis bacteria (Boone *et al.*, 2006). They are converted by the acetogenic bacteria to high volatile fatty acid, H2 and Acetic acid (Zabranska in Chudoba *et al*, 1991). Methagonetic bacteria convert H_2, CO_2 and acetate to CH_4 (Sam-Soon *et al*., 1987).

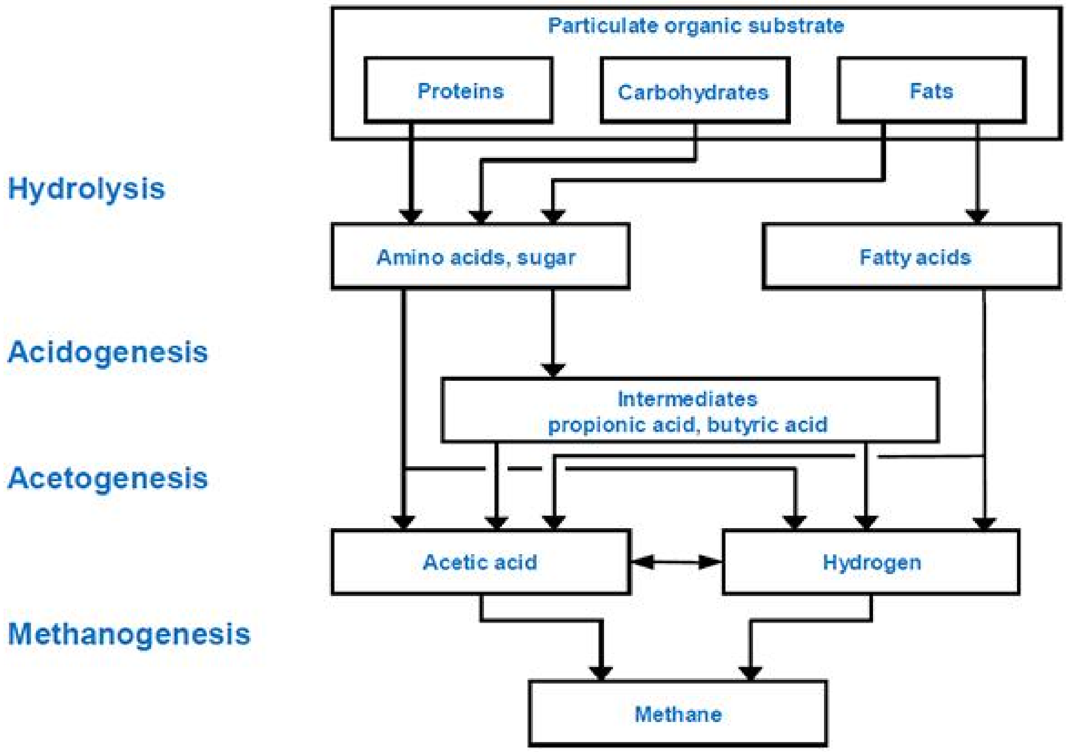


Figure 1: steps involved in breaking down the organic matter to produce biogas (Sources: Serna, 2009 Figure 1)

2.2 Current situation of biogas plants in Namibia

This section focuses on the national policy on renewable energy and different biogas plants found in Namibia. It gives an in depth analysis of each biogas plant found in different regions of Namibia. The aim of this section is to find out the current utilization of these plants in terms of biogas production and rules and regulation applied to renewable energy. This will enable the researcher to make proper recommendations.

2.3 National policy on renewable energy in Namibia

The Namibian national policy on renewable energy is based on four directives, these include;

White paper on energy policy which was established in 1998 which takes in to consideration all types of energy resource needs.

The Rural electrification programme which was established in 2000 has a main objective to connect all rural homes, villages which do not have electricity. It aims to identify unelectrified rural localities and consider them for the future.

The Namibian renewable energy programme was established in 2003 and its mandate is to promote all the renewable energy resources in Namibia.

There is also the cabinet directive of mines and energy ministry which was established in 2007 which aims to ensure, secure adequate and reliable supply of sustainable energy support to the growing needs and also address the inequalities in energy supplies to all households.

Namibia has a limited experience of biogas technology due to the fact that many people are not interested in it. Although the installed biogas plants have increased from 4 in 1999 to 19 biogas plants in Namibia nothing has changed the awareness of biogas technology. All the plants were constructed by the experts from India, China and Lesotho. International organization such as Small Grant Programme (SGP) and United Nations Development Programme (UNDP) has sponsored the biogas projects in Namibia.

The Okondjatu project established by the Germany Company, is situated few kilometers form the capital city of Windhoek and it has been working since 2003. The Project has built four Chinese dome biogas plants for demonstration each plant has a capacity of 10 cubic meters. The community used to feed the plants with animal manure since there is a lot of cattle manure available. The other feedstock is human waste since the digester is connected to community toilet. The biogas has brought changes on the community life, the Okondjatu project has managed to reduce the use of firewood by 1, 5% (SGP, 2005).This does not only give a relief to women and children since they are the ones who have to go and collect firewood but to the environment as well and also to the country as whole since it will not suffer from deforestation.

Goreangab dam is situated in the north part of Windhoek and there are six Chinese dome digester with a capacity of 20 cubic meters each .The feedstock which is used to feed the plants is sewage, since the Goreangab dam is where the sewage from the whole city is treated. At moment the plants are not working since the generator which is used for pumping is broken down, also plants need some renovation, when we visited the place we saw some holes on the digester which cause the methane to escape from the digester. The people who stay close to the dam have been involved in the construction of the plant and some job opportunities were created. Apart from the gas, fertilizer; is one of the most by product the community liked, they used it on their small gardens, and the fertilizer has high nutrition and has improved the growth of their plants. The project has done a bit in reduction of poverty (Claassen & Pelser, 2007)

The biogas plant at Henties bay was constructed by the University of Namibia whereby it is under the supervision of University of Namibia (UNAM). There is one Chinese dome plant with the capacity of 10 cubic meters and the communities are the ones who feed the digester with domestic waste. The main reason for the biogas is to reduce the domestic waste and in return the community benefits by getting fertilizer which they use on their gardens while the gas is used for the research centre. The current progress of the plant is unknown since no data is provided

The Ongendo Biogas project which received funds from the UNDP's global environmental served under the SGP to run the project from November 2007 until June 2009. The vision of the project is to transfer the relevant skills to the rural people of Omaheke Region that will in turn contribute toward the ongoing program of biogas project and modification of animal waste into energy for cooking, lights and refrigeration. Currently the project is still under process, the Chinese dome plant with capacity of 120 cubic meters was constructed and the feedstock for the plant is animal manure and crop residues (SGP, 2010).

The Okahao Quick Cooking Stove Project is found in the northern part of Namibia (OQCSP) which started in 2009. The aims of this project is to encourage people to use alternative energy sources for household energy needs through marketing of fuel efficiency stoves and biogas digesters and also provide space for production and storing of fuel efficiency stoves. The project has one constructed Chinese dome with the capacity of 10 cubic meters and the feedstock is animal manure and crop residue. The communities are still benefiting from it.

The Agama Company in 2009 constructed six Chinese domes in Caprivi Park and the plants are 10 cubic meters, all of the digesters are fed on sewage and food waste. The community is benefiting from gas and fertilizer produced from these plants. No current information about the biogas plant in Caprivi is available.

Biogas plants in different regions

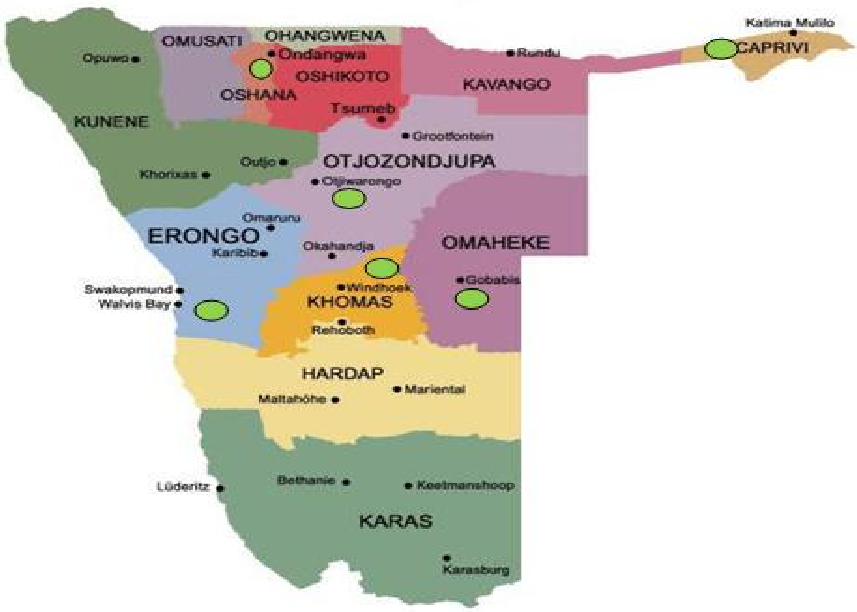


Figure 2: Map showing biogas plants in Namibia (Source: Nel, 2003 edited by Hangula, 2012)

The figure 2 it shows the region which has biogas plant in Namibia and each biogas use different feedstock as is mentioned in the chapter of current situation of biogas plant in Namibia

2.4 Feedstock supply in Namibia

The aim of this section is to focus on the different types of feedstock that are available in Namibia. The different types of feedstock currently available which include; animal manure, human waste, crops will be discussed at length and also the potential they have on the overall feedstock supply situation in Namibia.

2.5 Feedstock currently used in Namibia

A different type of feedstock is produced everyday as long as there are different human activities that take place. In Namibia different feedstock are found from different sources, some suitable for the anaerobic digestion while others not.

Agriculture is one of the source which produce different feedstock in namibia. Crop residues such as straw, leaves, grasses and shafft.The straw is produced during the harvesting time when the millet tail which contain seed is removed for the thressing process. The straw that remain in the field can be haversted for animal feed, and also used for roof thatching for their houses or to start the fire. During the threshing the shaff are produced which are always abubant and are the thresing palce (Mallet&Plessis,2001).The fields are cleaned before the next rain season and the waste are burnt. According to the SGP (2010) the crop resuides are used to feed the plant.

2.5.1 Animal manure

There is a momentous livestock population in Namibia distributed both in rural and commercial agricultural sectors, this is one of the source of feedstock for the biogas plants in namibia (SGP, 2010), livestock such as cattle ,goat, sheep and pig are the commom domestic animal in namibia (MA,2012).These livestock produce large amount of manure since the animals are kept in the kraal during the night for the protection of preditors and thieves, therefore, the manure are abandunt in their kraals, and it is easy to collect manure from the kraal.The manure are used as fetilizer for the soil which is done only once in a year before the cultivation start. The cattle manure is the common feedstock which is used to feed biogas plant in rural area (SGP, 2010) there rest of manure are just left on open space, futhermore slurry from pig house is not not used at all and it is just dumped on the landfill and covered with soil.

2.5.2 Domestic waste and sewage

Domestic waste and sewage is the feedstock which is used to feed the plant especially the one in the city, this is because plants are connected to the toilet and some are built at the waste plant treatment, therefore the effluent is one of the major feedstock used to feed biogas plants in the urban area (Claasen & Pelser, 2009).

2.5.3 Potential of feedstock supply in Namibia

There is a big potential of feedstock supply in Namibia since the country has many industrial activities going on every day. About 70% of population who lives in rural are it depended on agriculture (NPC, 2012). The total livestock in the country which is estimated by FAO (2010) is as follows; cattle 1.2 million, sheep 2.7 million, goat 2.1 million, pig 52 000, horses 46 000 and donkey 160 000. Apart from the above mentioned animals there is poultry, ostriches, mule in the country (Sweet &Burke, 2008).

2.5.4 Crops

Since the population depends on agriculture, the crop production is found in 6 regions which are Ohangwena, Oshikoto, Caprivi, Oshana, Kavango and Omusati. The crop farming is depended on rainfall; therefore, the crop residuals are produced once in a year by the communal farmers. While the commercial farmers depend on rainfall and irrigation (Mushendami, et al, 2008), the dominant crops in Namibia are Mahangu, maize and sorghum, and apart from the crops mentioned above, there are vegetables which are within the crop fields (natural environment). According to Herman et al 2011 the silage from sorghum and maize are suitable for biogas. A number of crop residues which are produced in Namibia have a high potential of energy. The farmers have certain hectares of land where they produce their crops. Cultivation season start from December to May .The products harvested are mainly for house consumption and the residues are used for feeding animals during dry season and much of it ends up in direct combustion, mostly in open fires.

2.5.5 Energy crops

Castor is one of energy plant grown in Namibia by the subsistence famers. Colin(2007) reported that, there are some private farmers who want to grow castor bean for the production of biodiesel ,however, in 2010 the Namibian government signed a contract with the foreign initiated multimillion dollar project to produce biodiesel .The project is about growing Jatropha trees in Caprivi region. The 300 000 hectares of land was awarded to the project and about 20 000 plants of Jatropha trees have been planted. (Inambao, 2010).The jatropha seed cakes which are produced after the extracting of oil can be used for the biomass as a feedstock (Gubitz, 1997; Akintayo, 2004 in Rehaman Mondal, 2012)

2.5.6 Municipality solid waste

The municipality waste has many different compositions which are very good for anaerobic digestion as a feedstock. There are many places where the organic waste are obtained such as hotels, shops, hospitals ,schools, slaughtering houses, household, etc. The municipality is responsible for the collection of the solid waste whereby they provide each house or each institution with the green plastic bin which has a capacity of 240 liters which they collect every week. According to Hasheela (2009) about 26 44.23 ton of garden waste is produced in Windhoek every year whereby 2 204.27 are produce every month and it is dumped on the landfill. The average waste produced per person in a day is around 0,19kg and 0, 7 kg this average is according to the household and is dumped on landfill. Since there is unequal distribution of income the people with high income per month has more kg than the one with low income.

2.5.7 Sewage sludge

The sewage sludge is suitable for anaerobic digestion process, therefore treatment of sewage sludge for many decades(Jingura &Matengaifa,2007) .The sewage sludge in Namibia it treated by anaerobic digestion ,sewage sludge it has high positive impact on the production of energy in form of biogas(Berchtold, 2009). Namibian cities are growing in numbers due to the fact that many people are moving from rural area to urban area, so the more the urbanization is high the more sewage waste is produced .Due to the regulation and policy of municipalities in Namibia the amount of sewage produce especial in Windhoek where they treat the waste water with anaerobic digestion was not provided but yet it has potential to produce substantial quantities of biogas from sewage sludge in the country.

2.5.8 Slaughterhouse

Abattoir is one of the places which produce waste which is suitable for anaerobic digestion. According to literature there is a certain percentage of live animal waste, these waste are like blood and intestines, etc. Since there are many abattoirs in Namibia these have a good impact on the availability of organic waste. This is based on the animals that are slaughtered every day, and the wastes which are produced have good quality of nutrients that can increase the biodegradation during the anaerobic digestion. According to Steffen *et al*., (1998) the estimate used to generate waste per slaughter unit, is shown in the table below.

Table 1: The biogas yield slaughterhouse

Feedstock	Total Solids [%]	Volatile Solids [% of TS]	Biogas Yield [m^3* kg^{-1}VS]
Rumen content	14.3	88.5	0.35
Stomach contents	16.5	82.5	0.68
Animal fat	89-90	90-93	1.00
Blood from bleeding area	9.7	95	0.65
Homogenized animal carcasses	33.6-38	90-93	1.14
Waste water	33	60	2.3
Pig slurry	3-8	70-80	0.25-0.50

Each waste from the live animal has different biogas yield and with animal is the highest with 1m^3 this is because it has 89-90 total solid the more the total solid is the high the yield of gas produce.

3. Aim of the work

The General aim of the Study is to assess the proposal of feedstock supply for biogas plant in Namibia with specific emphasis given to Habitat Research & Development centre.

Specific aims

- Determining the amount of feedstock which is produced in the country.
- To investigate possible ways of supplying feedstock's for biogas plant that will produce energy, heat and nutrient rich fertilizer for the Habitat Researcher & Development Centre Windhoek Katutura Namibian town.
- The energetic requirements of the centre will be assessed.
- To determine the future potential of feedstock supply for the Habitat R&D Centre.

4. Methodology

Comprehensive procedures for collecting and analyzing data necessary to react to a given situation can effectively guide the investigator to achieve the objectives of the research study. (Tuckman,1994). This section will cover research design, population, sample, sampling procedure, research instrument, data collection procedure, data presentation analysis procedures and limitations.

4.1 Research Design

In this research, a case study of Katutura in Windhoek Khomas region Namibia was used, the method focused on exposing the amount of organic waste produced per household and to find out if the waste is suitable for the anaerobic digestion. To find out if the waste is suitable for the anaerobic digestion, a combination of primary and secondary research methods were used to gather qualitative and quantitative data required data. After collection of the statistical data, it was analyzed and presented. Such an approach aimed to investigate, describe and explain the phenomenon of interest through obtaining different view points as the researcher interacted with various participants (Maree, 2008). This approach helped the researcher to develop an understanding of organic waste availability in each household which can be use as feedstock.

4.2 Population, Sample and Sampling Procedure

Characteristics of target group

In this study, the target group was comprised of different households in the suburb of Katutura. The main chosen population was made up of people who stay near the biogas plant. This population was chosen so as to minimize costs of carrying feedstock supply to the biogas plant. These households have different family backgrounds, number of family members and might lead to the suitable data for the research purpose. Therefore, the representative sample was taken from this population.

4.3 Sample

According to Best and Kahn (1993), sample refers to a small group of a population selected for survey and analysis. In this study the chosen sample was made up of 150 households who were selected randomly from Katutura housing list and volunteered to respond to the questionnaires. Of the 150 households chosen, only 90 managed to answer the questionnaire in full. The sample population was chosen because of the proximity to the Habitat centre.

4.4 Research Instruments

Records of organic waste

Secondary data of sewage waste, food waste, dairy farm was collect from local authority offices, private companies and farmers. This data was used to established a total quantity of waste produce per given day

Questionnaire

Best and Kahn (1993) viewed the questionnaire as a data gathering instrument through which respondents answer questions or respond to statements in writing. The advantage of this instrument is that it facilitates the acquisition for any qualitative information, which can be objectively quantified. This research instrument had the following to increase its validity and reliability:

All the questions were framed in a manner that the respondents would understand. Bias that might encourage the respondents to give an answer that the researcher expected them to give was avoided. To a lesser extent, open-ended questions or items were used to allow the respondents to provide answers in their own words. This presented the respondents with the chance to give their view, which the researcher would have overlooked. To a larger extent, restricted questions or closed items were used to ask the subjects to respond by choosing an answer from a set of alternatives. This provided a control over the respondents' range of responses by providing specific response alternatives.

A structured questionnaire was designed to collect data related to production of waste per given household and a total of seventeen open and closed questions made up the questionnaire. The questions were written in English because not all the people in the sample area can speak the same language. A total of hundred and fifty questions were distributed and ninety of the questions were filled and returned back. The questions were hand delivered to the randomly selected sample. As such, the questionnaire was divided into four parts; the first part was seeking personal information concerning age, gender, occupation, level of education, marital status and the number people in a single household. The second part of the questionnaire was seeking information on waste food produced within the households and the third section of the questionnaire was asking information on garden material and the fourth part was dealing with usage of energy resources.

4.5 Data Presentation and Analysis Procedures

The primary data were sorted out and analyzed by adding them together to get the total kilograms of kitchen waste produced per day in each household. Secondary data were sorted, analyzed, interpreted and presented in tables, graphs by using the formulas for each specific calculation

There is a couple of factors need to be considered when it comes to the feedstock composition for anaerobic digestion. C/N ration and dry matter content is one of the important factor.

T he C/N ration is obtained by using the following formula

$$C/N = \frac{\mathrm{C}}{N}$$

C: content of carbon in dry mass

N: content of nitrogen in dry mass

The calculation of feedstock input the for dry mater content needed was calculated using the following formula.

$$\mathrm{DM} = \mathrm{WM} * \mathrm{M}$$

WM: amount of wet mass

DM: amount of dry mass

M: moisture content

The main purpose for this formula is to determine the amount of feedstock which is optimized for the Fixed Chinese dome and what will be the sludge after the process of anaerobic digestion.

The optimal of carbon to nitrogen is very important for the digester therefore, cattle manure was used as source of carbon and rest of material used according to the availability. To obtain the optimal the basic formula was used

For this is used formula:

$$Qm = \frac{25(\mathrm{Q1N1} + \mathrm{Q2N2} + \cdots) - \mathrm{Q1C1} - \mathrm{Q2C2} \ldots}{\mathrm{Cm} - 25\mathrm{Nm}}$$

QM = amount of cattle manure (kg of dry mater)

Cm = content of carbon in cattle manure

Nm = content of nitrogen in cattle manure

Qn = amount of material (kg of dry mater)

Cn = content of carbon in material

Nn = content of nitrogen in material

The content of from 8 to 10 % by weight of dry matter, it has to be established limits according to formula express below;

$$Q = \frac{V * \frac{Qdm}{100}}{t}$$

Q = total content of dry matter per load

V = total dimension of feedstock per cycle

Qdm = needed content of dry matter in %

t = number of loads per one cycle

This has been done in order to limit the content of dry matter ,so that it reach the calculations of feedstock input and MS excel program was used. Since the amount of cattle manure was calculated in previous formula to reach the optimal carbon to nitrogen content, it was not necessary to calculate it again.

Water is one of the requirements needed during the anaerobic digestion, so the amount of water it has to be calculated to see water needed per load and minus water content in each material.

Below is the formula

$$W = \frac{V}{t} - (WM1 - DM1) - (WM2 - DM2) \ldots$$

V = total dimension of feedstock per cycle

t = number of loads per one cycle

WMn = content of wet matter per load

DMn = content of dry matter per load

The amount of manure quantities available in Namibia per year from different livestock was calculated by using the basic formula shown below;

TJ=P* DM* DY * EV

TJ= Total energy potential

P= Population of species

DM= Dry matter

EV= Energy value

The biogas yield from different livestock was calculated using the formula expressed below;

TBY= TJ* AF* TDA *BYF

TBY=Total biogas yield

TJ= Total energy potential

AF = Availability factor

TDV= Total dung available

BYF = Biogas yield factor

SWOT (Strength, Weakness, Opportunities, and Threats) Analysis was also carried out to identify constraints and challenges that hinder effective participation as well as opportunities and strengths that would enhance effective supply of feedstock. The analysis of the SWOT formed the basis for formulating key strategic aims and action plans to effectively provide the potential of the feedstock supply.

4.6 Limitations of the study

There are quite a number of obstacles experienced in this study. One of the limitations was data collection which was not easy to obtain at all. However, efforts were done by consulting different stakeholders, although only a few could comply. Some certain institutions, the municipality of Windhoek in particular could not give their data or even sell as they considered it as private and confidential. On the other hand, the government statistics bureau could not give theirs as well due to the national policy on statistics.

4.7 Ethical Considerations

Since the issue of asking people personal questions is very sensitive, the researcher explained to the target population on the nature of the study and also the benefits that can be obtained after completion of this study. An informed consent was obtained from the sample population and no names were recorded on the questionnaire. The participants were assured that they would not be prejudiced or victimized whether they agree to participate or not. All the participants were assured of anonymity and confidentiality.

5. Results and Discussion

This chapter focuses on the results and discussion of the study. It also discusses, in depth, the study that was carried out on the feedstock supply for Biogas plants at Habitat Research &Development Centre (HRDC) in Katutura Windhoek, Namibia. The discussion is mainly based on the findings drawn from the study. On the basis of the discussion and analysis of results, conclusions and recommendations would then be presented.

5.1 Feedstock potential in Namibia

Animal manure

According to FAO(2010) the total livestock in the country is as follows, cattle 1.2 million, sheep 2.7 million, goat 2.1 million, pig 52 000,horses 46 000 and donkey 160 000. Apart from the above mentioned animals there is poultry, ostriches, mule in the country (Sweet &Burke, 2008). Animal manures are found in 13 regions of Namibia, This is because the only six region can be able to grow crops due to the climate and the whole 13 regions have farming animals (MAWF,2011). The approximately number of livestock, a small farmer can have, varies as follows 10-20 cattle, 15- 35 goats, 8-25 chicken and 4 pigs. Many people in Namibia heavily depend on farming. Manure is obtained from different places from communal and commercial farms. Manure is one of the feedstock which is suitable for anaerobic digestion and it has been used for many decades

Below is the annual amount of waste from different animal which are found in Namibia and this is calculated based on the formula stated on section 4.4 which is data presentation and analysis.

Table 2: Manure quantities from different livestock and energy their output (Source *(FAO 2011), ** (Hall DO, 1995))

species	**Population*** **in thousand**	**Dry dung **output kg (head^{-1}-day^{-1})**	**Total annual dung output(t)**	**Energy** value(GJ t^{-1})**	**Total energy potential(KJ)**
Cattle	1200	1.80	788,400	18,5	14 ,585,4000
Sheep	2700	0,40	394,200	14,0	5518,8000
Goat	2100	0,40	306,600	14,0	4292,400
Pig	5200	0,80	730,000	11.0	8,030,000

The amount of manure which is produced annually in Namibia has shown a positive effect on the potential of feedstock in the country as shown in table 2 above. This show that there is future supply of feedstock in the country and can be used to convert to produce biogas to reduce the waste in the country, allow the animal to move free in their kraal since manure is compact in their house.

The table 3: below shows the amount of biogas yield which can be obtained from the available animal manure in the country per year and this was calculated based on the formula stated in section 4.4 which is data presentation and analysis.

Table 3: The Biogas yield from animal manure (Source *(Hall DO,1995))

Species	**Total annual dung output(t)**	**Availability* factor**	**Total dung available (t)**	**Biogas* yield factor a (m^3/t)**	**Total biogas yield (m^3)**
Cattle	14,585,4000	0,45	6,563,430	281	1,844,323,830
Sheep	5518,8000	0,35	1,931,580	120	231,789,600
Goat	4292,400	0,35	1,502,340	120	180,280,800
Pig	8,030,000	0,80	6,424,000	649	4,169,176,000

5.2 Dairy farm

There is another potential for feedstock anaerobic digestion, the excrement from the dairy farms. They produce large quantities of organic waste .There are many dairy farmers in the country but due to some policy in other farmer we could not get all the number of animals at each farmer but we managed to get data from two dairy farms which belong to the O & L groups. They have been producing milk for many decades. The Gogerganas dairy has around 6000 head of cattle see types of cow that are on the farm on the graph below, they milk three times a day and the waste they produce is dumped in the open ponds. Super farm is about 300hectres and has 4000 heads of cattle, see the number of different types of cows, in the graph below and it is for dairy farming and they also milk three times a day, the slurry they produce is processed to fertilizer which is used for the fodder (Hanse, 2012).Below is table for types of animal found in each farm.

According to Straka (2003) a diary cow which weighs 550 kg, produces excrement per day of 6 kg dry matter, 30 kg of original state with moisture give 283 yield of biogas. Both Gogerganas and Super farm have an ability to produce enough manure of the plants in Namibia based on the Straka calculation. These have shown a potential and availability of feedstock. Below is a table showing the amount of manure that two dairies produce per day and the yield of biogas.

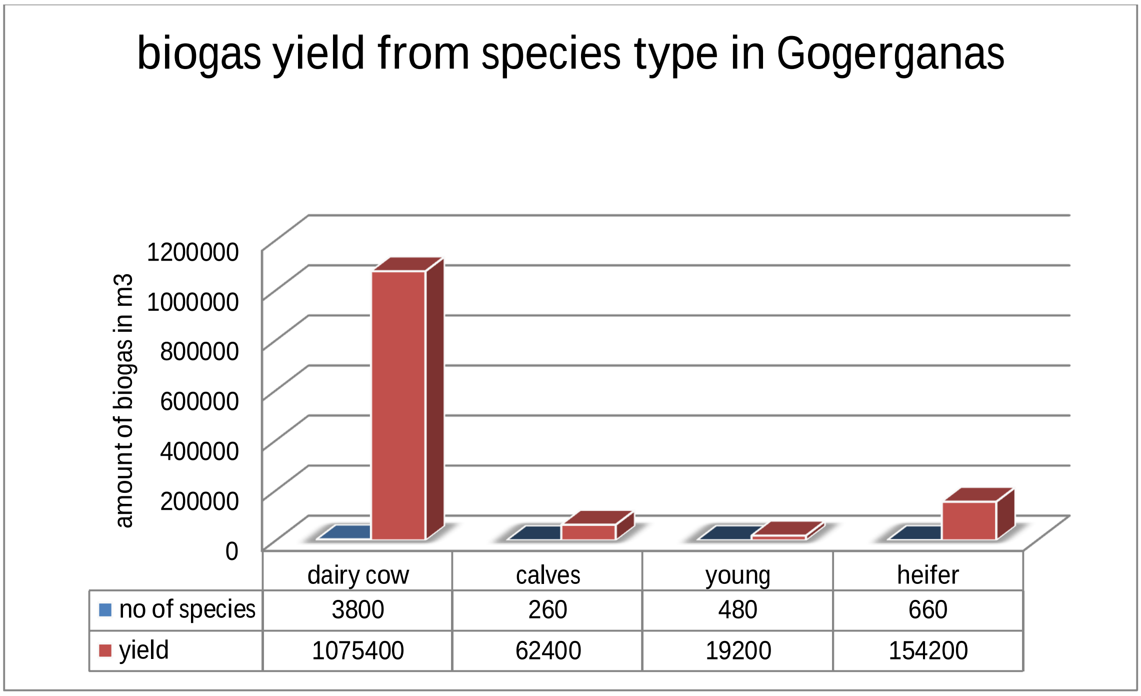
Table 4: Excrement from each dairy farm

Animals types	Dry matter produce per day at each dairy farm	Original state of excrement/day at each farm	Yield of biogas at each dairy farm per (m^3)
Dairy cow			
Super farm dairy	17400 kg	174000 kg	820700 m^3
Gogerganas dairy	22800 kg	228000 kg	1075400 m^3
Calves			
Super farm dairy	400 kg	4320 kg	55200 m^3
Gogerganas dairy	325 kg	3510 kg	62400 m^3
Young			
Super farm dairy	840 kg	8400 kg	112000 m^3
Gogerganas dairy	1440 kg	14400 kg	19200 m^3
Heifer			
Super farm dairy	1750 kg	17500 kg	128500 m^3

Gogerganas dairy	2310 kg	2100kg	154200 **m^3**

The excrement amount from dairy farm is high at gogerganas because it has more dairy cows and has high production of dry matter 6 kgs per and the original state of excrement 60 kg per day compare to young 3 kgs dry matter ,30 kgs per day of original excrement ,heifer 3,5 kg dry matter ,35 kg of excrement per day and calfs 1,25 kg of dry matter and 13,5 kg of original excrement per day

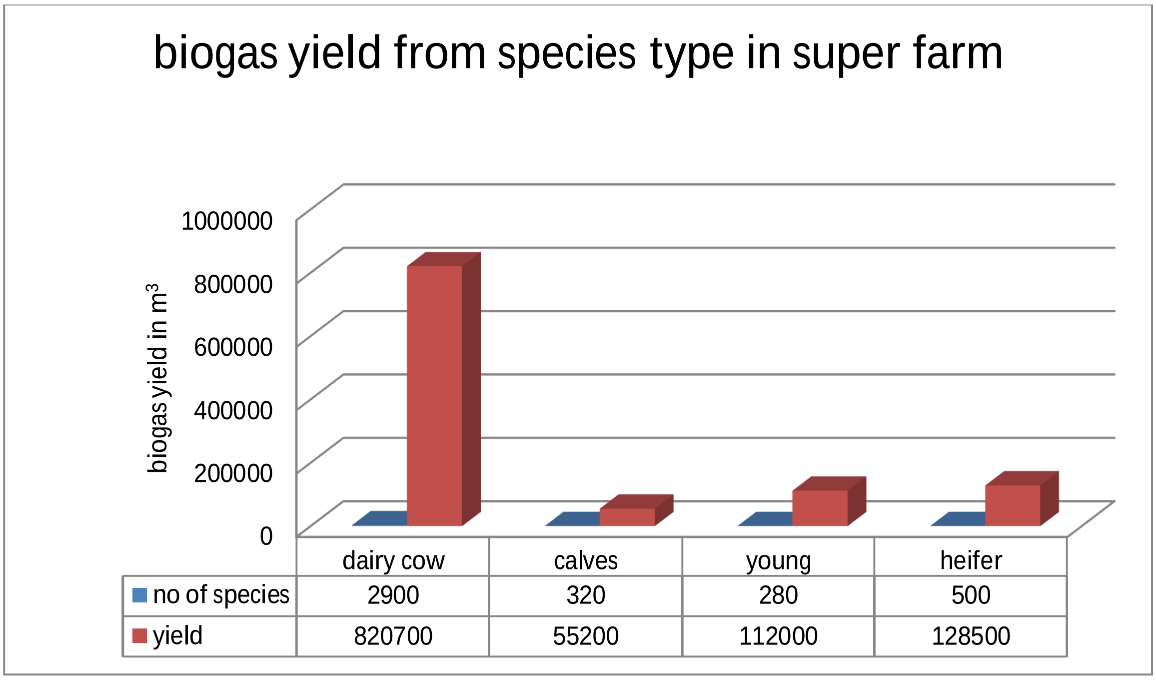
The graph below show the biogas yield from different animal this give the clue that those dairy farm can installed biogas plant because they have enough material for the anaerobic digestion and they can produce energy for the farm as well us for the community who live around the farm.



Graph 1: Animal type and yield at Gogerganas farm

Gogerganas farm has high yield of biogas because it has more dairy cow and heifer as shown in the gragh 1 above.

Compared to Gogerganas farm above, Superfarm has high yield from young, heifer as shown in gragh 2 below.



	dairy cow	calves	young	heifer
no of species	2900	320	280	500
yield	820700	55200	112000	128500

Graph 2 :Animal type and yield at Super farm.

By comparing the graph 1 and graph 2 above from the two farms, this shows that there is a very huge potential of feedstock supply in terms of cattle manure.

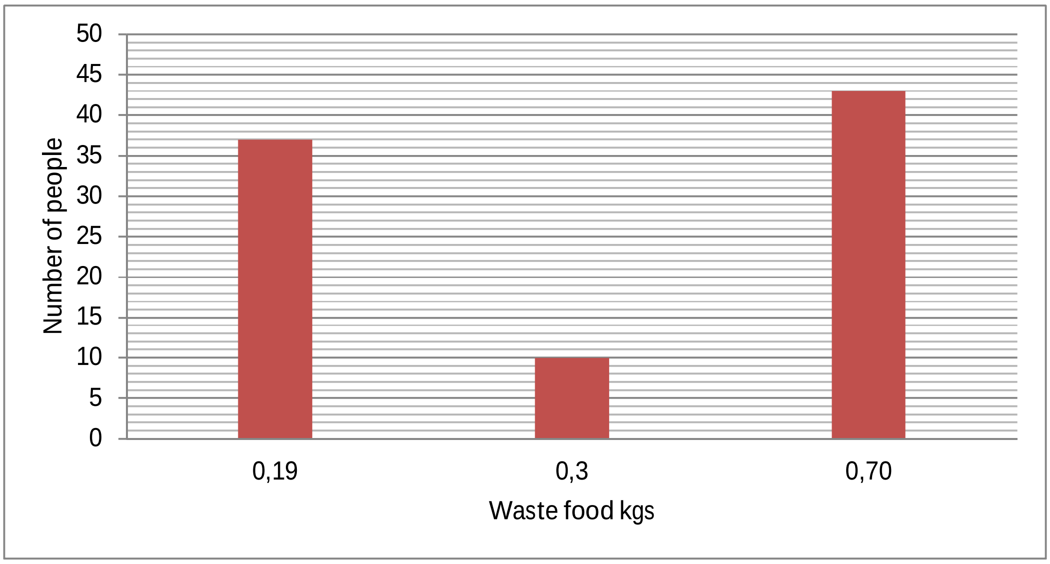
5.3 Result from the questionnaries

The data presented below shows results from the different reponses from the questionnnaire.

Graph 3: Number of times people cook per day

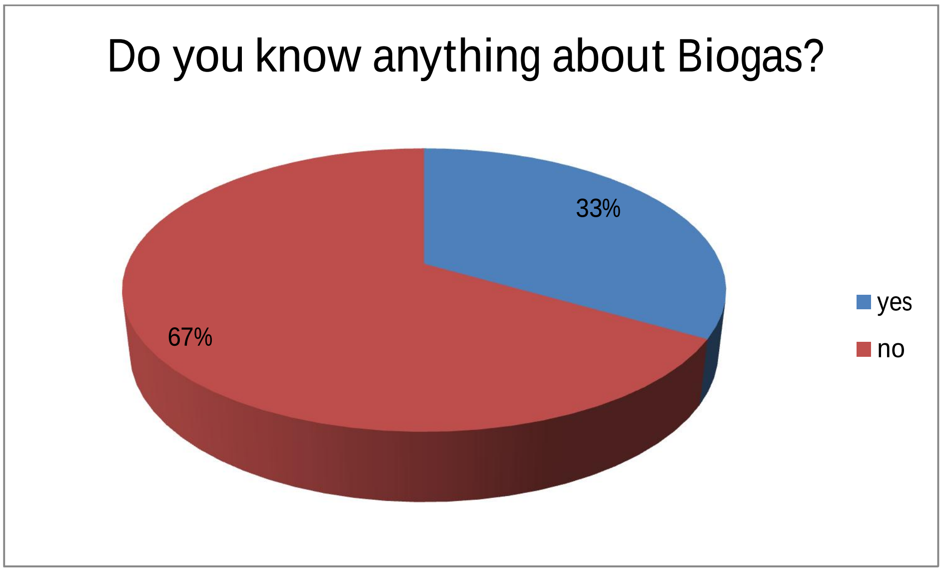
The number of meals taken per day was divided into three categories as shown on the bar chart above. Twenty seven respondents said they only have one meal per day, thirty nine respondents said they have two meals per day and twenty four have three meals. This, has an effect on the supply of food waste material, this means that if the food waste is properly harnessed, there will be enough supply of feedstock at any given time.

The bar graph below (number 4) shows the amount of food waste produce per each household with different number of people .This was to determine the amount of waste food available for feedstock supply. From the information shown it show that there is enough waste food for the biogas plant when the total kilograms have been added together for a given day.



Graph 4: Amount of food waste produced per household.

The pie chart below (number 1) shows the numbers of people who know anything to do with biogas and willing to use biogas. From the presented results this shows that many people are not yet familiar with biogas technology and production. Hence, there should be more awareness and production of biogas.



Graph 5: number of people who know anything about biogas

Cross-tabulation of willingness to use biogas (rows) against gender (columns)

	[No]	[Yes]	Total
[**Male**]	13	22	35
[Female	19	36	55
TOTAL	32	58	90

Pearson chi-square test = 0.0629758 (1 DF, p-value = 0.801853)

Fisher's Exact Test:

Left: P-value = 0.684403

Right: P-value = 0.48804

2-Tail: P-value = 0.824559

The P –value of 0.824559 is greater than the alpha value of 0.5 and this means that we accept the null hypothesis and conclude that there is no interdependence or relationship between willingness to use biogas against gender; this means that, it does not mean matter whether one is a female or male because everyone uses biogas.

5.4 Overview of Habitat Research &Development centre

Habitat Research and Development centre is situated in the north part of the capital city of Namibia Windhoek which is located in black town called Katutura in khomas region. The centre is founded by the Ministry of Regional and Local Government, Housing and Rural Development (MRLGHRD) as a national research institution .The MRLGHRD was the one who provided the funds for the construction and operation of the centre.

The design and architecture was in such a way that, it should not disturb the ecosystem of the area that is they took into consideration aspects concerning rivers, flora and fauna. The buildings were designed in such a manner that they would be warm in winter and cool in summer. The roof was also designed in such a way that solar panels would absorb a lot of energy throughout the course of the year.

The building materials which were used to build the centre are made up of natural and manmade materials. A combination of steel, concrete and clay bricks was used, some of the materials were imported from South Africa and some of the materials were collected within the area. Due to the diversity of the materials used the structure of the buildings are very strong.

Water and sanitation of the center is that, the roofs of the buildings are linked to water tanks to ensure rainwater is collected and runs into the tanks; this water is then used for air conditioning purposes. There are also dry sanitation systems to handle every aspect of the sanitation at the center and these toilets are fixed with extractor fans to ensure steady flow of air so as to prevent condensation (Martin, 2010)

5.5 Other roles done by HRDC

It works with higher educational institutions, NGOs and CBOs, professional organizations, private sector, local, regional and central government institutions in order to achieve their objectives. The centre still depends on the donor and stakeholders because they sponsor them for their projects.

The vision of the centre is to reach the first class in housing researcher and development by administering the new methods and ideas of science technology for the sustainable development of the Namibian housing sector.

The Habitat research &development centre objectives is research and development of Namibian housing sector which is aimed at promoting sustainable human settlements. The centre is focused on promoting and facilitating ecological sanitation, water conservation, renewable energy and biodiversity.

There are many activities which are taking place at the centre such as renewable energy, gardening and food production promotion, alternative sanitation biogas, dry sanitation, land tenure, urban profiling, housing studies education training ,building materials and design, advisory and consultancy services and support policy formulation(HRDC booklet, 2008).

5.6 Energy use at the centre

The centre has many activities which require energy; therefore, the centre has two energy sources in order to perform their duty well. The two main energy sources which are fossil 40% and renewable energy 60%, the centre depends heavily on the fossil which is produced at the Van Eck power station, it is produced by the boiler it feeds with coal then the burn to produce heat which heat up the water in the boiler tube and turn the generator (Nampower, 2012).

The are two renewable energy source at the center which is solar and biogas, during construction, solar technology was installed to generate electricity, this is because Namibia is a country in the world which has highest solar radiation level, it receives 3,300 hours sunshine per year (Kisting ,2008), the solar is used to heat the water in the geysers at the centre and when there are sunny days, the centre can use the solar energy to full capacity but is only when there is less activities taking place at the centre. Due to the solar system at the centre, it has enabled them to promote solar cookers which are manufactured in Namibia. Another source of energy produced at the centre is biogas but due to the lack of feedstock the production of gas is very low which leads it not to use it all. The renewable energy is one of the objectives of the centre (Martin, 2010)

Energy balance at the centre

Energy balance is the energy that is used, which comes from different sources of energy and it illustrated below.

The total energy needed at the centre is 75 kilowatts per day, solar energy is contributing 45kwh and electricity from National grid is contributing 10 kilowatts per day so there is a deficit of 20 Kwh per day, from the optimization of feedstock composition the 10 m^3 plant which is used on the 4/5 capacity which is $8m^3$ is produces 2.7 m^3 per day. Conversion of $2.7m^3$ of biogas is equal to 103.4 mega joules which gives an output of 28.7kilowats per day, from the plant will fill in the deficit as shown in the table below.

Table 5: Energy balance (Source:* (Wienecke & Mawisa, 2008))

Types	**Amount**	**Usage**
Solar	45 Kwh*	-offices -library -water heaters
Electricity	10 Kwh*	-Kitchen -other offices without solar panel.
Biogas	28.7 Kwh	-lighting -cooking -in biogas plant to ignite the engine.
Total energy	83.7Kwh	

5.7 Characteristics of the biogas plant

The biogas plant was built in 2004 and has a capacity of 10 cubic meters. Chinese dome is the plant which is at the centre. The plant is connected to the two toilets which are close to the conference room .The main feedstock for the plant is effluent from the toilet. The plant with the capacity of 10 cubic meters can produce

$3.8cm^3$ gas per day. According to Wienecke and Mawisa (2008) .The $3.8cm^3$ biogas was used to lighting the 60 watt bulb for 22.8 hours, and it was used in the kitchen to cook the 3 meals for 20 people who came to the conference which was taking place at the centre, it replaced the 2,66kg of fuel, he further states that it can run a 1kW motor power for 4.75 hour and generate 4,75 kilowatts hour of electricity.

The plant has a digester with inlet and gas outlet, a discharge chamber and a reed bed system. The methane released after the slurry in the plant is fermented, the gas is trapped on the top of the chamber, and then the gas is released from the outlet and then used in the kitchen at the centre and other purposes as well. The sludge is released through the overflow chamber and then settles, it can be used as fertilizer. The centre used in their garden which they have in order to increase the soil fertility. The water is flow natural by filtration in to a reed bed, can be used for irrigation (Wienecke & Mawisa, 2008)

5.8 Current feedstock used

At moment the plant is just using human waste around 0.57kg is produced, since a human being produce 0.1134kg volatile waste per day whereby the methane and carbon has a ratio of 0, 35 and about 50% of material will produce methane that use for heat which is 5, 55 and the 10^4kj /kg, the total energy a human produce per day is 1102, 2kj/day (Cook, 2010).Therefore, there are five people at the centre and they produce 5510kj/day

In 2004, when they had many people who were attending conferences and students coming to the library, they produced some gas and they emptied the plant which was recorded but due to the management of centre no information was provided about the amount of the gas which was produced and for how long the gas was produced in that year, then from there they never produced gas until now. Therefore, the plant has been there without any production .Since they don't have enough material for the plant they turned it for educational purpose biogas plant to show students and farmers how the plant works.

5.9 Proposal of feedstock supply for habitat development centre

Since research is about the feedstock supply to the plant at Habitat R&D Centre .The study mainly focused on the material which suitable for the anaerobic digestion, availa:bility, composition which will get the clue on how many methane is produce per feedstock and it can determine the biogas yield too.

Below are the suitable inputs of feedstock, quantity, location where the centre can get it and the biogas yield expected from each substrate.

Table 6: Material (Source [A]Cook (2010), [B](Straka et al. 2006), (Haug, 1993) , (Richards, 1996), [C] Steffen (1998),[D]Zhang(2007))

Material	Quantity	Location	C/N ratio	Excepted biogas production (m^3)
Cattle manure	39 tons/day	Okapuka feedlot (5 km)	19 [B]	0,29 [B]
Maize straw	8 tons /per year	Otavi crop farmer (60 km)	68 [B]	0.18 [B]
Kitchen food waste	0.39 tons/day	Community in katutura(200m)	20[D]	0.40[D]
Garden waste	314.8 ton/day	Community in Katutura(200m)	21[C]	0.19[C]
Human waste (sewage)	0,57 tons/day	Workers at the centre	13[A]	0.35[A]

The volume of reactor was set up of 10 m^3 which filled to 4/5 of 8m^3 (8000kg) per load, and excepted biogas 3 m^3 per day which the centre can use it for the lighting and cooking the loading time is 45 day and the material need to be changed within those days. Chinese fixed dome is a continuous because it can feed once or multiple per day .It means 178kg is load per day and the dry matter content should be 8-10%.According to Hill (1979) the optimal for the carbon to nitrogen is 25:1 Dry matter load of fixed Chinese dome is around 11.30 kg to 14.59 kg which has a weight 8% to 10%. Maize straw are the main source that provide carbon and due to the different size of hectares that farmer has in Namibia is complicated to estimate the kg of the straw they produced per day.

Table 7: Calculation Optimal of feedstock at the centre (Source: [a]Electrigaz (2012 , [B]Cook (2010), [C] (Straka et al. 2006), (Haug, 1993) , (Richards, 1996) [D] Steffen (1998),[E]Zhang(2007))

Material	Amount per loading dry (kg)	Dry Matter	% C	% N	Amount per loading wet	Excepted Biogas production
Cattle manure	7.00	0.81 [C]	45.60 [C]	2.4 [C]	8.64	2.03
Maize straw	2.55	0.85 [C]	58.5 [C]	0.85 [C]	3	0.45
Food waste	0.17	0.46[A]	52.8 [E]	3.3 [E]	0.38	0.06
Garden waste	0.11	0.20[A]	50.3 [D]	3.2 [D]	0.57	0.083
Human waste (sewage)	0.44	0.22[A]	48.8[B]	0.65[B]	2	0.11

Total dry matter = 11.30, this dry matter with a 8 to 10% weight is obtained by using the formula of dry matter.

Total V/N ratio =24.62, the C/N ration was obtain by using the formula of determine the C/N.

Water completion (l) = 173.47, this was obtain by using the formula of water need per load found in section (methodology).

Expected total methane production m^3= 2.7, this was obtain by multiplying the amount of the dry mater loaded with each biogas yield for each substrate and we add all the biogas yield and we get the total of 2.7m^3

5.10 Comment on the optimized feedstock input

By using those feedstock which is locally available the plant which is at can produced 2.7m^3,this can take use of 103.8 MJ which will give 28.7 kwh ,which the center can use for lightning in their office , cooking and for heating water. Literature has pointed out that one person meal will approximately 4 MJ (Anozie et *al*., 2007). Since the main aim of the centre was to use only renewable energy this will help the centre to meet their goals in use of renewable energy and fill the gap of their energy shortage .The centre will not only not benefit on the gas but the fertilizer to which they can use to fertile their garden which is they have .It will help the centre to have enough energy and can sell to the community around them .Therefore we propose that the centre should use that available feedstock because it have more benefit for the centre and they will gain more as time goes.

5.11 SWOT analysis of feedstock supply in Habitat R&D centre

The feedstock supply at the Habitat R&D Centre is major stumbling block .However; the Swot analysis presented below will present the Strength, weakness, opportunities and threats of the centre.

Table 8: Swot analysis

Strength	**Weakness**
▪ Experienced staff who can operate ▪ Lack of competitors in the nearby area ▪ Favorable weather conditions ▪ Stable economy enables people to keep buying food materials ▪ Stable energy production	▪ Lack of availability of feedstock ▪ Lack of biogas awareness in the area ▪ Lack of funding to develop further ▪ Higher cost of transportation of feedstock ▪ Lack of suitable vehicle for feedstock. ▪ Storage place for feedstock incase there is more feedstock.

Opportunity	Threats
▪ Donor funding to expand the centre. ▪ More production of biogas enhances more inflow cash. ▪ Creation of good relations with the community ▪ Employment creation for the local people ▪ Improve their renewable energy status. ▪ Creates a better clean environment by taking control of waste material ▪ Allow the centre to utilize feedstock from different household which are economically viable.	▪ Competition from other biogas plants in other areas ▪ Unexpected change of weather like drought and the irregular water supply will cause a shortage of feedstock supply ▪ The policy of city of Windhoek on solid waste may affect the collection of organic waste. ▪ Waste handling by the community can have side effect on anaerobic digestion by mixing organic matter with inorganic.

The strengths of the centre are that, they have experienced staffs who know how to operate the different machines which can be used to produce biogas. The centre has also the advantage of constant supply of energy which enables the processing of feedstock.

The major problem at the centre is that lack of feedstock supply, the feedstock supply is available in the community but there no collecting procedures to get the feedstock to the centre. There is no enough storage facilities incase the feedstock come in large quantities. Because of the stability of economy of the country people can afford to keep buy food of which there will always be waste food material.

There is an opportunity to get donor fund from the government and private sectors, since there is a policy which was put in place by the government to sponsor all the organizations concentrating on renewable energy. If the feedstock increases there is a big opportunity for the centre to make money because there is a huge market which requires biogas which is cheap form energy than other sources of energy for example hydro electric power. The involvement of the community in the operations of centre empowers the community and thereby increases good relations. If feedstock increases biogas production also increase the more people required to work at the centre.

The viability of the centre and its returns can create emerging competition which can be threat. In terms of too much use of fertilizer on crops by community in their gardens, this can affect the quality of feedstock .The policy of the city of Windhoek can also act as threat because they are the sole organization which is responsible for waste collection.

6. Conclusion

The result shows that there are many different feed stocks which is produced in Namibia and can be used for the anaerobic digestion. The feeds stocks which are found in Namibia are agriculture residues, animal manure, food waste and municipal waste. There is a potential for feedstock due to the number of the livestock and crop production which are in Namibia, and also the young people are moving from rural areas to look for better life in the city and this increases the food waste in the city especially Windhoek where the biogas plant is installed.

The collection of organic waste it reduces the abundance of waste of it in the area and the community will live in clean environment, reduce the contribution on the damage of ozone layers.

It also gives the opportunity for the centre to interact with different people since it will collect waste organic from different people from different cultures. There is positive supply for the centre to have feedstock according to the result which we got from the community around the centre and the organic which is produced per year in Namibia as whole.

The livestock in the whole Namibia produce 25199600 tones of manure per year which give the yield of biogas 2673311830m^3 per year. This shows that there is a big potential for feedstock supply in Namibia as well us to the centre and it can be used to produce energy since the country import energy from other countries and it can be used at the centre as well as in Namibia is which has high unemployment of 52% (MIF,2011), therefore, the feedstock supply to the centre can reduce the rate by employing the local people to collect feedstock and sort out them .It will also contribute to strength their renewable energy since one of the main objective is to promote renewable energy.

The plant at the centre is depended only on the human waste as feedstock which is not enough source because only 5 people who work there and 0.57 kg of volatile is produced per day by the workers at the centre, but this is just based on the formula Cook (2010). This shows that the centre really needs other sources of feedstock so that it has enough feedstock for the centre. The co digestion feedstock increases the biogas yield.

The optimal compositions of feedstock input show that 2,7m^3 of methane was produced this has given a clue that from the local available feedstock to feed the plant with 11.3 kg of dry mater per day it will 103.4 mega joules which gives an output of 28.7kilowats per day.

The growth of biogas technology in Namibia is very slow because most of the plants which are there are for demonstration and the main problem is that Namibia is a dry country and for the production of biogas water is needed to avoid inhibit of the process.

The centre will transport the feedstock from nearby farms, feedlot, community therefore handling and transportation of feedstock is very important because if the feedstock is not well handled, it will have a bad effect on the anaerobic digestion process since it may contain some waste which are not suitable for the process (Steffen,1998) .Also the long distance will cost more for the transportation in this case the Habitat R&D Centre the only have one feedstock which is maize straw will cost them to transport it since it far ,but it transported only twice year since they produce once in year ,therefore the centre need a storage for it to avoid transport cost and to keep the large quantity since they only get once in year.

7. Recommendations

According to the literature we are recommending the centre to use food waste, garden waste, because it was used in India which can be used at the centre too. It will increase the biogas yield for the centre because the composition of feedstock has side effects on the biogas yield. The retention time for the food waste is short compared to cattle manure. Also the biogas yield from the different feedstock has high yield of biogas.

The government and private companies should help the centre by providing them enough finance so that they can be able to transport enough feedstock from a long distance and build enough storage to keep the feedstock at the centre to avoid incurring more costs.

The centre should make agreements with different farmers, industries which produce organic waste that is suitable for anaerobic digestion so that they have many sources of the feedstock.

To make it easy for collecting waste food from household, the centre should sign a contract with the plastic company to buy plastic drums and give to each household which is willing to cooperate with the centre in terms of feedstock supply. They must employ the people who drop out of school since it not easy for them to get jobs without education.

Since this work was just based on theory, further study is needed to put the work in practice.

8. References

Anoziea, A.N,. Bakarea, A.R,. Sonibarea, J.A and. Oyebisib, T.O., 2007. Evaluation of cooking energy term cost, efficiency, impact on air pollution and policy in Nigeria. Energy. Volume 32, Issue 7, Pages 1283-1290, ISSN: 0360-5442

Bolzonella, D., Pavan, P., Mace, S., Cecchi, F., 2006. Dry anaerobic digestion of differently sorted organic municipal solid waste: a full-scale experience. Water Science and Technology; 53(8):23–3.

Claassen, P Pelser, A. (2007). *Small-Scale Biogas-Technology: An Appropriate Sustainable Solution to Reduce Peri-Urban Poverty? The Case of Greenwell Matongo, Windhoek*, *Namibia*. Namibia Development Journal. Namibia 2007, vol. 1, no. 1.

Cho JK, Park SC, Chang HN. (1995).Biochemical methane potential and solid-state anaerobic-digestion of Korean food wastes. Bioresource Technology; 52(3):245–53.

Chynoweth, D. P. et al. (2001). *Renewable Methane from digestion of biomass. Renewable energy agen afl, edu. 2001.*

Colin, C. (2007). Kavango bio-fuel project: Plantations of *Jatropha curcas*. Namibia, Windhoek 2007

COOK, P.A.(2010). Design of a Household Human Waste Bioreactor.

<**http://large.stanford.edu/courses/2010/ph240/cook2/**>

FAO.(2011). Livestock brief in Namibia. http://www.fao.org/ag/againfo/resources/en/publications/sector_briefs/lsb_NAM.pdf

Gubitz GM, Mittelbatch M, Trabi M. Exploitation of the tropical oil seed plant Jatropha curcas L. Bioresour Technik 1997;67:73e82.

Hall DO H.(1995).Biomass energy flows in Zimbabwe. Biomass and Bioenergy; 8(3):151–73

Hamed M. El.-M. et al. (2004). Effect of temperature and temperature fluctuation on thermophilic anaerobic digestion of cattle manure. *Bioresource Technology*. 2004, vol. 95, no. 2, pp. 191-201.

Haug R.T., The Practical Handbook of Compost Engineering, CRC Press; 2 Sub edition. 1993. ISBN: 0873713737

Hills D.J., Effects of carbon:nitrogen ratio on anaerobic digestion of dairy manure. Agricultural Wastes, 1 (4), pp. 267-278, 1979

http://www.nampower.com.na/pages/van-eck.asp

Biogas calculation and measurement of dry matter of substrate <**http://electrigaz.com/contact_en.htm**>

Inambao, C. (2010). Namibia to produce own biodiesel. [ref. 2010-02-24].

<http://www.worldenergymedia.com/News7070_Namibia-to-produce-own-biodiesel---by-Chrispin-Inambao.htm>

Jerome Kisting (2008). OPPORTUNITIES IN THE RENEWABLE ENERGY SECTOR IN NAMIBIA **http://www.highcommissionofindia.web.na**

Kára J.,Pastorek Z.,Přibyl E.:Výroba a využití byoplynu v zemědělství, VÚZT 2007

Lu SG, Imai T, Ukita M, Sekine M. (2007). Start-up performances of dry anaerobic mesophilic and thermophilic digestions of organic solid wastes. Journal of Environmental Sciences-China; 19(4):416–20

Martin Andreas Wienecke (2010)Promoting Alternative Technologies: Experiences Of The Habitat Research & Development Centre (HRDC) Human Settlements Review, Volume 1, Number 1, 2010 **http://www.dhs.gov.za**

Mushendami,P., Biwa,B., Gaomab II,M. (2008). UNLEASHING THE POTENTIAL OF THEAGRICULTURAL SECTOR IN NAMIBIA Ref 13/1 BoN Occassional Paper

Nathan Curry, Pragasen Pilla (2011). Biogas prediction and design of a food waste to energy system for the urban environment .*Renewable Energy vol.41 pp200-209*
Obeng, A. K. B. et al. (2007).Integrated Science. Department of Biochemistry. Oxford University. United Kingdom 2007. pp. 889.
NPC. National Planning Commission.(2011). Unemployment status in Namibia.(ref. 2011-04-08) <www.npc.gov.na/unemplyment/index.htm>

Raili Hasheela (2009). Municipal Waste Management in Namibia:
The Windhoek Case Study

Raoul Herrmann and Michael Brüntru (2010).Bioenergy value chains in Namibia: Institutional challenges for rural development and food security WS3.3 – Sustainable biofuel production in developing countries: “Green” energy as the key for development European IFSA Symposium, 4-7 July 2010, Vienna (Austria)

http://www.environment-namibia.net/tl_files/pdf_documents/selected_publications/Waste%20Management_Hasheela__2009.pdf

Reheman.H &Mondal S(2012).Biogas production potential of jatropha seed cake biomass and *bioenergy volume 37,February 2012,page 25-30*

Richards T., On farm composting handbook. Natural Resource, Agriculture, and Engineering Service. 1996.

Sam-Soon, P. L. et al. (1987). Hypothesis for Pelletisation in the up flow anaerobic sludge bed reactor. *Water SA*. 1987, vol. 13, pp. 68-80.

SGP. Small Grant Programme. (2010). Outase biogas energy supply project. Namibia.

<http://sgp.undp.org/web/projects/6435/outase_biogas_energy_supply_project.htm l

Steffen, R.; Szolar, O. and Braun, R.(1998). Feedstocks for Anaerobic Digestion **http://www.adnett.org/dl_feedstocks.pdf**

Straka F.*et al.* ., Bioplyn – II. Rozšířené vydání, GAS,2006

Sweet, j and Burke, A.(2008). The profile was prepared by the author in (2010) and modified by S.G. Reynolds in August 2011 to update some livestock statistics.

Zhang, R. et al.(2007). Characterization of food waste as feedstock for anaerobic digestion; *Bioresource Technology, Volume 98, Issue 4, March 2007, Pages 929-935* .

9. Appendices

Dear Respondent

My name is Saara Hangula am student at Czech university of Life science in Prague .I kindly ask you to fill in my questionnaires which is part of my thesis research. The topic is focus on the waste which is produced and suitable for the anaerobic digestion to produce biogas. All the personal information will be kept privately and confidential.

Thank you for your time**.**

Age

Under 20 B) 21-30 C)31-40 D) 41-50 E) 51 above

Gender

A) Female B) Male

Marital status

A) Married B) Single C) Divorce D) Widowed

4) What is your occupation?

A) Student B) Other …………………..

5. Educational level

A) Primary B) Secondary C) University

6. How many people live in this household?

A) 3 B) 4 C) 5 D) 6

7. How many times do you cook per day?

A) Once B) Twice C) Three times

8**. Approximately how many kgs of food waste do you produce per day**?

A) 0.3kg B) 0.19 kg C) 0.70 kg

9. **How big is your yard?**

……………………………………..

10**. Do you have a garden?**

A) Yes **B**) No

11**. Approximately how many Kgs of garden waste do you produce per month?**

1. 2kg 2. 5kg 3. 10kg

12**. Do you apply any fertilizer to your garden?**

A) Yes B) No

If yes which one and after how long do you apply?

13**. How many times do you clean your garden?**

A) Once in a month B) Twice in month C) Once in a year D) Twice in a year

14**. Can you estimate the sewage you produce per day?**

15**. Which source of energy do you use?**

A) Biomass

B) Fossil fuel

C) Electricity

16**. Do you know anything about renewable energy?**

A) Yes B) No

If yes explain

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17**. Do you know what it is biogas?**

If yes explain what it is biogas.

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Comments