An-Najah National University

Faculty of Graduate Studies

Socio Economic Evaluation and Feasibility Assessment of Small Scale Biogas Units for Rural Communities in Palestine

By

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Dedication

To my parents, Faiz and Sabah,

My husband and my son, Ibrahim and Khalil,

And all of my family and friends.

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There are number of people without whom this thesis might not have been written, and to whom I am greatly indebted.

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Last but not least, I am thankful and indebted to all those who helped me directly or indirectly in completion of this research study.

Dania Maraka

الاقرار

انا الموقع ادناه مقدم الرسالة التي تحمل عنوان:

Socio Economic Evaluation and Feasibility Assessment of Small Scale Biogas Units for Rural Communities in Palestine

اقر بان ما اشتملت عليه هذه الرسالة انما هو نتاج جهدي الخاص, باستثناء ما تمت الاشارة اليه حيثما ورد وان هذه الرسالة ككل من او جزء منها لم يقدم من قبل لنيل أي درجة او بحث علمي او بحثي لدى أي مؤسسة تعليمية او بحثية اخرى.

Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

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Abstract

Any green energy utilizing scheme should support environmental sustainability, economic feasibility and social acceptability. The aim of this research study is to evaluate the economic feasibility and social acceptability of using floating tank biogas units at the household level in Palestine. In order to evaluate social acceptability, a social survey was performed to evaluate Palestinians knowledge, acceptance and trends toward biogas technology. In addition to that, practical experiments were performed on a floating tank biogas unit in order to estimate the biogas production from different waste mixtures , and perform economic feasibility study.

The social survey results indicated that 80% of the participants have known about biogas technology especially through schools and universities. Results have also shown positive trends in awareness toward biogas technology (average percentage, 80%).

Most farmers are willing to use biogas technology in their farms or homes if it has a financial profit (average percentage, 85.8%), but they also think that operating a biogas unit in the house or farm will require a lot of time

and effort (average percentage, 56.6%). There is a good level of acceptance and willing to use biogas technology but with some insurance such as providing support and help in terms of unit maintenance and operation. So, it seems that people do not have experience with the system.

The experiment was conducted using 1500 L floating tank biogas unit. Four different waste mixtures were tested for their biogas production in a continuous flow system. Results obtained from this experiment show that the highest biogas yields during 16 days of experiment are respectively sheep manure (22.9 kg), cow manure (22.6 kg), poultry manure (20.8 kg) and food residues mixed with cow manure (19 kg).

Non-linear procedure analysis was used to create a model of gas quantity produced as a function of mixture type, temperature and time. And a plot of measured versus predicted biogas quantity was drawn.

An experiment was performed in order to estimate a conversion factor for the family requirements of biogas if it replaced LPG. Results of the experiment show that the conversion factor is 3; this means that the 12 kg bottle of LPG is equivalent to 36 kg of biogas. This should cover on average 70% of the Palestinian family needs of cooking fuel.

In the economic evaluation of the biogas unit, the initial investment to construct a floating tank biogas unit is 1100 NIS and the monthly running cost is 12 NIS. The simple payback period is 1 year if the fertilizer is sold in the market and 2 years if the fertilizer is not sold.

In recommendations, it is encouraged to use biogas technology in rural Palestinian areas were feedstock is available and biogas unit outputs are usable. It is also recommended to carry out promotional programs aiming at educating people at rural areas about benefits of biogas technology.

Chapter One

Introduction

1.1 General

The past century witnessed high demand for energy due to the rapid increase in the world's population and the level of luxury. Researchers and scientists explore various methods to provide sufficient amounts of energy where needed. In the other hand, environmentalists are always concerned in finding an energy source that has the lowest negative influence on the environment. One of the innovative methods for producing green energy is to use a biogas plant that digests organic solid waste and animal manure to produce biogas and soil fertilizers. The biogas plant does not only represent a source of energy but it also represents an efficient method for organic solid waste disposal. The purpose of this research is to evaluate the potential of utilizing small scale biogas plants to serve rural Palestinian communities.

The basic technology of Anaerobic Digestion involves anaerobic fermentation of wet organic waste feedstocks to produce biogas (methane and carbon dioxide) and organic fertilizer, the methane is used for heating, electricity generation or as a transport fuel.

Biogas technology is increasingly used worldwide and plays an important role in producing energy for several uses like cooking, electricity production and heating.

Biogas units are in general designed and built to provide the microorganisms with the suitable conditions to digest organic material and produce biogas. Due to continuous improvements and developments in biogas technology, the applicability and the benefits of biogas units have frown in importance, especially in the developing countries.

Biogas production in the West Bank has not been given enough care and few intensive studies have been done. Biogas units in the West Bank were limited to a few small scale units that were constructed mainly for educational and demonstrational purposes. However, recently water and environmental studies institute at An-Najah National University have constructed and distributed number of floating tank biogas units under the fund of the American consulate at Jerusalem.

This research study aims to gain an understanding of socio-economic and feasibility aspects of the introduction of biogas technology in rural Palestinian communities. This is achieved through experimenting the operation of a small-scale floating tank biogas unit using different organic waste mixtures. And also, collecting and analyzing socio-economic data regarding biogas technology via especially designed questionnaire.

1.2 Objectives

The objective of this research study is to evaluate the potential of small scale biogas plants as an alternative source of energy for rural Palestinian communities. Such evaluation can be utilized in the development of best management practices that can be adopted to manage organic solid waste and lead toward understanding one of the possible energy sources that can be extracted from organic waste in rural Palestinian areas.

In the light of the above, the following objectives are considered:

To investigate the level of Palestinians knowledge and awareness regarding biogas technology and their willingness to use biogas technology in their homes or farms.

To compare the biogas quantity produced from different waste mixtures in a biogas unit.

To develop initial financial feasibility evaluation of the use of small scale biogas plants in rural Palestinian communities.

Modeling of biogas production as a function of operating parameters (temperature, time and waste type).

1.3 Importance and Motivation

One of the main challenges facing the world is to harness the energy sources which are environmental friendly and ecologically balanced. This compiled the motivation to search for other alternate sources of green energy. But unfortunately the new alternative renewable energy sources like the hydro, solar or wind energy sources require huge economical investment and technical power to operate, which seems to be very difficult for the developing countries like Palestine. This research aims to investigate whether we can consider the biogas energy - extracted from small scale biogas units - one reliable, easily available, socially acceptable and economically feasible source of alternative and renewable source.

1.4 Hypothesis

The biogas production from small biogas unit is sufficient to provide energy for one average Palestinian family.

Biogas quantity produced from a biogas unit differs depending on the type of the waste used.

Palestinians in rural communities show willingness to operate biogas units.

Chapter Tow

Literature Review

2.1 Anaerobic Digestion

Anaerobic digestion (AD) is a process in which microorganisms break down biodegradable material in the absence of oxygen. Anaerobic digestion can be used to treat various organic wastes and recover bio-energy in the form of biogas, which contains mainly CH_4 and CO_2. Methane could be used as a source of renewable energy producing electricity in combined heat and power plants. (Clemens, et al., 1999)

The process of anaerobic digestion can take place in uncontrolled systems - for example at waste dumps - and in controlled systems -for example in reactors, also known as anaerobic digesters -. In reactors especially human and animal waste are used as raw materials (Lardinois, et al., 1993). The process of anaerobic digestion in enclosed reactors is effectively a controlled and enclosed version of the anaerobic breakdown of organic waste in landfill which releases methane (Friends of the earth, 2007).

2.2 The Aim of Anaerobic Digestion Plants

There are two possible aims of using anaerobic digesters. It can be used either to treat biodegradable wastes or produce saleable products – heat/electricity, soil amendment -. Energy crops can be grown and then used for anaerobic digestion process. In this case, the aim is to produce as much biogas as possible and good quality soil amendment. Nevertheless the most valuable use of anaerobic digesters is to combine both waste management and by-products use. Especially for waste management, it is unlikely that anaerobic digesters will be a viable treatment without using the biogas and the digestate. Their qualities will vary depending on the feedstock and its contamination. The use of biogas and digestate can also involve further treatments, such as composting of the digestate and biogas upgrading (Monet, 2003).

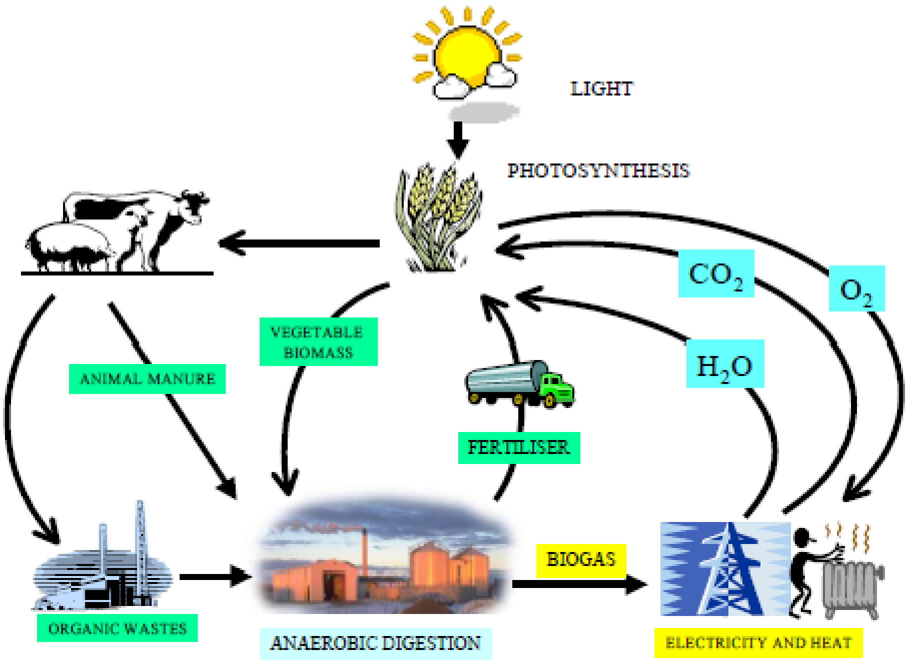

Figure 1: The sustainable cycle of biogas from anaerobic digestion (Al Seadi, 2001)

2.3 Digester Material and Pretreatment Processes

Only waste of organic origin can be processed in an anaerobic digester. As this makes up almost 60% of household waste in Palestine there is a considerable benefit in diverting this waste from landfill. The MSW contains organic waste as well as inorganic waste, the anaerobic digestion feedstock needs to be only organic material, moreover some of the organic matter such as coarser wood, paper and cardboard are slowly digestible.

These are lignocellulosic materials which do not readily degrade under anaerobic conditions and are better suited to aerobic digestion, i.e. composting (White, et al., 1995).

Mechanical separation can be used to separate an organic fraction of the waste if source separation is not available. The fraction obtained is more contaminated which will affect the heavy metal and plastic content of the final digestate composting product. In many countries compost derived from mechanical separation will not meet standards required for a soil conditioner product.

Joint treatment of municipal solid waste with animal manure/sewage slurry is a popular method in existing plants, the process tends to be simpler and is economically more viable than MSW only treatment system.

Having separated any recyclable or unwanted materials from the waste, the organic material must be chopped or shredded before it is fed into the digester. The organic matter is also diluted with a liquid, ranging from sewage slurry, to recycled water from the digestate, to clean water. In some systems an aerobic pre-treatment allows organic matter to be partly decomposed under aerobic conditions before undergoing anaerobic digestion (White, et al., 1995).

2.4 Operational Temperatures

The two conventional operational temperature levels for anaerobic digesters are determined by the species of methanogens in the digesters:

Mesophilic digestion takes place optimally around 30 to 38 °C, or at ambient temperatures between 20 and 45 °C, where mesophiles are the primary microorganism present.

Thermophilic digestion takes place optimally around 49 to 57 °C, or at elevated temperatures up to 70 °C, where thermophiles are the primary microorganisms present. (Song, et al., 2004)

2.5 System Classifications

A wide variety of systems have been developed to anaerobically treat MSW. They can be split into a variety of categories such as:

Wet or Dry: in wet systems the waste feedstock is slurried with a large amount of water to provide a dilute feedstock of 10-15% dry solids. While in dry system the feedstock used has a dry solids content of 20 – 40%.

Batch or Continuous: in batch systems the reactor vessel is loaded with raw feedstock and inoculated with digestate from another reactor. It is then sealed and left until thorough degradation has occurred. The digester is then emptied and a new batch of organic mixture is added. Whereas in continuous systems the reactor vessel is fed continuously with digestate material, fully degraded material is continuously removed from the bottom of the reactor.

Single-Step or Multi-Step: In single step all the digestion occurs in one reactor vessel, while in multi step the process consists of several reactors, often the organic acid forming stage (methanogenesis). This results in increased efficiency as the two microorganisms are separate in terms of nutrient needs, growth capacity and ability to cope with environmental stress. Some multistage systems also use a preliminary aerobic stage to raise the temperature and increase the degradation of the organic material. In other systems the reactors are separated into a mesophilic stage and a thermophilic stage.

Co-digestion with animal manure or digestion of solid waste alone: during co-digestion with animal manure the organic fraction of the waste is mixed with animal manure and the two fractions are co-digested. This improves the carbon/nitrogen ratio and improves gas production. But in digestion of solid waste alone the feedstock contains the organic fraction of solid waste alone, slurried with liquid, no other materials are added. (RISE-AT, 1998)

2.6 Important Parameters for Anaerobic Treatment

C/N Ratio: The relationship between the amount of carbon and nitrogen present in organic materials is expressed in terms of the Carbon/Nitrogen ratio. A C/N ratio of 20-30 is considered to be optimum for an anaerobic digester. If C/N ratio is very high, the nitrogen will be consumed rapidly by the methanogens to meet their protein requirement and will no longer react on the left over carbon content in the material. As a result the gas production will be low. In the other hand if the C/N ratio is very low, nitrogen will be liberated and accumulate in the form of ammonia. This will increase the pH value of the material, a pH value higher than 8.5 will start to show a toxic effect on the methanogenic bacterial population. To maintain the C/N level of the digester material at acceptable levels, materials with high C/N ratio can be mixed with those with a low C/N ratio, i.e. organic solid waste can be mixed with sewage or animal manure. (Monet, 2003)

Dilution: Different systems can handle different percentages of solid to liquid, average ratios are 10-25%, but some systems can cope with solids up to 30%.

pH Value: Optimum biogas production is achieved when the pH value of the input mixture is between 6 and 7 (Hassan, 2004).

Temperature: Methanogenic bacteria are inactive at extremes of high and low temperature. When the ambient temperature goes down to 10 ˚C, gas production virtually stops. Two temperature ranges provide optimum digestion conditions for the production of methane, those are the mesophilic and thermophilic ranges discussed above. (Verma, 2002)

Loading Rate: It is the amount of waste fed to the biogas unit per day per unit volume of digester capacity. This is an important process control parameter in continuous systems. Many plants have reported system failures due to overloading. This is often caused by inadequate mixing of the waste with slurry. If there is a significant rise in volatile fatty acids this normally requires that the feed rate to the system be reduced.

Retention Time: Wastes remain in a digester that is operating in the mesophilic range for a varying period of 10 – 40 days, the duration being dictated by differing technologies, temperature fluctuations and waste composition.

Toxicity: Mineral ions, heavy metals and detergents are some of the toxic materials that inhibit the normal growth of bacteria in the digester. Small quantities of minerals, (sodium, potassium, calcium, magnesium, ammonium and sulphur), also stimulate the bacterial growth, but heavy concentrations will have a toxic effect. Heavy metals such as copper, nickel, chromium, zinc, lead are essential for bacterial growth in small quantities, but higher quantities will also have a toxic effect. Detergents such as soap, antibiotics, and organic solvents also inhibit the bacteria. Recovery of digesters following toxic substances inhibiting the system can only be achieved by cessation of feeding and diluting the contents to below the toxic level (Verma, 2002).

Mixing/Agitation: Results from existing systems tend to show that a level of mixing is required to maintain the process stability within the digester. The objectives of mixing are to combine the fresh material with the bacteria, to stop the formation of scum and to avoid pronounced temperature gradients within the digester. Over frequent mixing can disrupt the bacterial community and it is generally considered that slow mixing is better than rapid mixing. The amount of mixing required is also dependent on the content of the digestion mixture (White, et al., 1995).

2.7 Advantages and Disadvantages of Anaerobic Digestion

Anaerobic digesters contribute to reducing the greenhouse gases by maximizing methane production but without releasing it to the atmosphere, thereby reducing overall emissions. Also it provides a source of energy with no net increase in atmospheric carbon which contributes to climate change (Yu, 2008).

Biogas stoves fueled by anaerobic digesters of animal, human and crop waste have been shown in laboratory studies to reduce health-damaging air pollution by up to 90% with a very low climate impact, and are being used widely in China and south-east Asia for household cooking and lighting (Smith, 2000). If the digester is also linked to a latrine, the resulting improvement in sanitation could help prevent worm infestation, diarrheal disease and malnutrition (Remais, et al., 2009) The feedback for anaerobic digesters is a renewable resource and thus does not deplete finite fossil fuels. On financial aspects, the advantage of anaerobic digestion is that it turns waste into useful products.

Disadvantages of anaerobic digesters arise from the fact that anaerobic digestion systems, as with many developments, will create some risks and have some potential negative impacts.

Anaerobic digestion has significant capital and operational costs. It is unlikely that anaerobic digestion will be viable as an energy source alone, it is likely to be effective for those who can use the resulting fertilizers.

About health and safety, there may be some risks to human health with the pathogenic content of feedstock but it can be avoided with an appropriate plant design and feedstock handling procedures. There may also be some risks of fire and explosion although no longer than natural gas installation (Monet, 2003).

2.8 Biogas Composition

Biogas is characterized based on its chemical composition and the physical characteristics which result from it. It is primarily a mixture of methane (CH_4) and inert carbonic gas (CO_2). However the name "biogas" gathers a large variety of gases resulting from specific treatment processes, starting from various organic waste - industries, animal or domestic origin waste etc.

Different sources of production lead to different specific compositions. The composition of a gas issued from a digester depends on the substrate, of its organic matter load, and the feeding rate of the digester (Naskeo

Environement, n.d). Table 1 shows the biogas composition for the biogas produced from different waste.

Table 1: Biogas composition for different waste (Naskeo Environement, n.d).

Components	Household waste	Waste treatment plants sludge	Agricultural waste	Waste of agrifood industry
CH_4 % volume	50-60	60-75	60-75	68
CO_2 % volume	38-34	33-19	33-19	26
N_2 % volume	5-0	1-0	1-0	-
O_2 % volume	1-0	< 0.5	< 0.5	-
H_2O % volume	6	6	6	6
Total % volume	100	100	100	100
H_2S (mg/m^3)	100-90	1000-4000	3000-10000	400
NH_3 (mg/m^3)	-	-	50-100	-
Aromatic (mg/m^3)	0-200	-	-	-
Organochlorinated or organofluorated (mg/m^3)	100-800	-	-	-

2.9 Economic Merit of Anaerobic Digestion

The success of biogas plants (projects) at an area depends on availability of organic materials, cost of constructing, founded energy sources and its costs, experience, knowledge, ambient climate conditions especially temperature, and acceptability for people constructing these plants (Hassan, 2004).

Anaerobic digestion is a technically feasible option for converting organic residues. It provides benefits to the environment through energy and nutrient recycling, while also mitigating odours, pathogens and atmospheric methane. However, like most renewable energy options, its economic merit relies on conditions dependent on a variety of factors. The decision to use anaerobic digestion for treating MSW rather than alternative technologies depends on a number of factors; such as waste quality, site specific circumstances, availability of outlets for the energy produced, energy prices and taxes, energy purchase tariffs, costs of alternatives/taxes on alternatives, policy, land prices, markets for compost and digestate and Level of capital and labour costs in each country.

Discussion of the economics of the digestion of MSW is complex due the wide range of parameters that affect the costs and the number of “external” benefits that are accrued. In addition to this, each country has different circumstances, infrastructure and fiscal arrangements that affect the relative and absolute costs of various waste management options. Even within a single country these costs will vary considerably (IEA Bioenergy, 2011).

A single farmer, a consortium of farmers or a municipality are usually the entrepreneurs likely to implement successful biogas projects. The success of the project depends on some factors that can be controlled and influenced by strategic decisions concerning investment and operational costs (Al Seadi, et al., 2008).

Al Seadi and others reported that in case of the single farmer biogas project – small scale biogas units- the project developer is forced to have a very close view to the different aspects of the project and, in case of cancelling the project, no external costs have occurred. (Al Seadi, et al., 2008)

2.10 Human Toxicity

Like most treatment processes, there will be some emissions from anaerobic digestion. Air emissions are low due to the enclosed nature of the process, though combustion of the biogas will produce some nitrogen oxides. However, emissions from anaerobic digesters are generally lower than other forms of waste disposal.

The health risk from the solid and liquid residue from the AD plant should be low as long as source-separated waste is being used - i.e. no chemical contaminants are entering the system from other waste- (DEFRA, 2004).

2.11 Studies of biogas units around the world

Understanding the factors that affect the success or failure of operation of biogas units has motivated several studies that have been carried out around the world. In most of the studies the success or failure were based on the economic benefits arising from operating biogas units.

A study was conducted in Hungary and Germany that examined whether small farms will benefit from participating in biogas production. Large industrial biogas plants ranging into the megawatt-scale dominate in Hungary, while in Germany, farm-scale biogas units continue to prevail. They concluded that despite the stronger focus of both tariff systems on small biogas plants since 2007, investments in small scale biogas agricultural units are no longer economically attractive for farms smaller than 5 ha. This is mainly due to the high fixed investment costs and rising prices of biogas feedstock. The key explanatory factors for different production scales in Germany and Hungary are the farm size distribution and the motivation behind national support schemes. (Buchenrieder, et al., 2009)

One research studied the impact of single versus multiple policy options on the economic feasibility of biogas energy production for Swine and dairy operations in Nova Scotia. This study concluded that combinations of multiple policies that included cost-share and green energy credit incentive schemes generated the most improvement in financial feasibility of on-farm biogas energy production, for both swine and dairy operations.

Without incentive schemes, on-farm biogas energy production was not economically feasible across the farm size ranges studied, except for 600- and 800-sow operations. Among single policy schemes investigated, green energy credit policy schemes generated the highest financial returns, compared to cost-share and low-interest loan schemes (Brown, et al., 2007).

In Germany, a study has evaluated energy efficiency management strategies of different biogas systems, including single and co-digestion of multiple feedstock, different biogas utilization pathways, and waste-stream in Germany. The method of Primary Energy Input to Output (PEIO) ratio was used to evaluate the energy balance and figure out the energy efficiency, hence, the potential sustainability. Results of their study showed that energy input was highly influenced by the characteristics of feedstock used. For example, agricultural waste, in most part, did not require pre-treatment. Energy crop feedstock required pre-treatment in order to meet stipulated hygiene standards. Energy balance depended on biogas yield, the utilization efficiency, and energy value of intended fossil fuel substitution. (Pöschl, et al., 2010)

An economic assessment of biogas to electricity generation was performed in small pig farms with and without the H_2S removal prior to biogas utilization. The main findings of the evaluation are that the payback period for the system without H_2S removal was about 4 years. With H_2S removal, the payback period was twice that of the case without H_2S removal. For both treated and untreated biogas, the governmental subsidy was the important factor determining the economics of the biogas-to-electricity systems. Without subsidy, the payback period increased to almost 7 years and about 11 years for the case of untreated and treated biogas, respectively, at the reference electricity price at Thiland (0.06 Euro/kWh). (Pipatmanomai, et al., 2009)

2.12 Summry

Biogas technology has become widely used around the world due to its environmental, social and economical benefits. So, a lot of studies were directed toward studying the anaerobic digestion of organic matter to produce biogas. Several system classifications and types of organic matter input were used in the biogas systems. The system can be either wet or dry, batch or continuous and single step or multi step. The digester material can be either animal manure mixed with solid waste or solid waste alone.

There are many factors that influence the process of organic matter digestion in the biogas unit. Some of these factors are related to:

The surrounding environment – temperature-.

Digestate characteristics – C/N ratio, dilution, pH and toxicity-.

Operational conditions –loading rate, mixing and retention time.

Since the biogas yield is affected by these factors; in this research study, the biogas yield from a biogas unit was measured taking these factors under consideration.

Using biogas technology has advantages that can be classified according to the scale of biogas technology usage. That is, if biogas technology is implemented at micro level the following advantages are noticed:

The production of energy at low cost.

A crop yield increase in agriculture by the production of bio fertilizer.

An increase in the quality of agricultural production due to using the organic fertilizer instead of the manufactured fertilizers for producing ecologically pure products.

The improvement of social conditions of rural population.

Creating a solution for organic waste disposal in areas were municipal services are not covered.

Whereas at the macro level, the following advantages become more obvious:

The conservation of tree and forest reserves and a reduction in soil erosion.

Poverty reduction of the rural population.

Reduction in importing fuel and fertilizers.

Provision of skills enhancement and employment for rural areas.

The success or failure of biogas projects were based on the social acceptance to the system and the economic benefits arising from operating biogas units. This fact has motivated the researcher to conduct a socio – financial evaluation of using biogas technology in rural Palestinian communities.

Most of the Palestinian energy needs are met by importing oil products from Israeli companies. The prices are high and usually not affected by international market prices especially when the international prices drop (Al Sadi, 2010). Al Sadi stated that the theoretical amount of biogas that could be produced in north of Palestine is 8,640,000 kg/year based on the 115,200 ton of waste that Zahret Al-Finjan landfill receives at an annual rate (Al Sadi, 2010)

Each country has different circumstances, infrastructure and fiscal arrangements that affect the relative and absolute costs of various waste management options (IEA Bioenergy, 2011). So, the success or failure of any biogas system depend largely on the country or region where it is conducted. The value of this research study is that it shows the feasibility of biogas technology in the Palestinan communities in particular, taking into account the cost of constructing and operating biogas units and the social trends toward this technology.

Chapter Three

Research Methodology

To achieve the objectives of this research study, firstly research needs and objectives were defined. Data collection was conducted depending on literature review, questionnaire and field experiments. The collected data were analyzed and processed using Excel software. This leads to setup of the socio-economic evaluation of small biogas digesters in rural Palestinian communities.

3.1 Social Survey

3.1.1 Study Society

The society of the study is the Palestinian rural families in West Bank.

3.1.2 Survey Objectives

The following objectives were intended from the questionnaire:

To gather data about the methods used by rural family in dealing with their wastewater, household waste, animal waste and agricultural waste.

To investigate the level of knowledge about biogas technology.

To determine the acceptance and willingness to use biogas technology.

To determine the most preferred management and financial options regarding biogas technology.

3.1.3 Sample

200 copies of the questionnaire (in Arabic language, see appendix I) were distributed on 200 families who live at different Palestinian rural areas. The questionnaire were distributed and gathered in workshops aimed at introducing and promoting the concept of biogas technology among Palestinian people (the workshops was led by Prof. Dr Marwan Haddad – head of WESI at An-Najah University- and funded by the American Consulate at Jerusalem). The questionnaire domains and questions were explained to the participants for removing any misunderstanding. The participants answered the questionnaire before the beginning of the workshops to ensure the impartiality and neutrality of the answers. Then, the filled questionnaires were collected and the obtained data were organized and statistically analyzed.

3.1.4 Questionnaire content

The design of the questionnaire was based on the experiences of similar researches in Palestine and other countries, taking into account the special situation of this research study.

The questionnaire is divided into six main domains: general information, participants knowledge about biogas, participants acceptance and willingness to use biogas technology, participants utilizing preferability of biogas and the organic fertilizer, management aspects and financial aspects.

3.1.4.1 First domain: general information

In this domain, the participant is required to answer some general questions regarding him and his family. In some of the questions the participant chooses the answer that fits his condition from the listed choices (statements from 1-12 and 14) , these questions collects data about name of village/ city, gender, age, number of family members, housing, work type, educational level, average family income, garden availability, garden type, animals raising and frequency of cleaning animals farm.

In other questions (statements 13 and 19) the participant is required to fill tables regarding: Animals type and numbers, area of each planting type and the irrigation method used.

In one question (statement 16) the participant is required to write the distance between his house and the nearest waste disposal site.

The remaining questions (questions 15, 17, 18, 20) consist of several statements for each. These questions are regarding: Methods of dealing with animal manure (statements 15.a – 15.e), methods of dealing with household waste (statements 17.a – 15.f), methods of dealing with wastewater (statements 18.a – 18.d) and methods of dealing with agricultural waste (statements 20.a – 20.g). For each statement there were four possible choices: All, most, some and none. And the participant was asked to write X in front of the choice that applies. The choices were scored as indicated in Table 2 below to simplify statistical analysis of the data.

Table 2: Scoring the questionnaire choices

Choice	**All**	**Most**	**Some**	**None**
Score	3	2	1	0

3.1.4.2 Second domain: participants knowledge and understanding

This domain was designed to obtain data about the level of the participants previous knowledge about biogas. It consists of 8 multiple choice questions.

In three questions (statement 1, 2 and 3) the participant is asked to circle the answer that best fits his condition. While in the remaining questions (statements from 4–8) the participant is asked to circle the suitable option (strongly agree, agree, no opinion, disagree, strongly disagree) that agrees with his belief.

Some of the questionnaire statements were classified according to their positivity or negativity in order to simplify statistical analysis of the data. The options scores if the direction of statement is positive or negative are shown in Table 3 below.

Statements 4, 5, 6, 7 and 8 of the second domain are considered positive.

Table 3: Scoring the questionnaire choices

	Statement direction	strongly agree	agree	no opinion	disagree	strongly disagree
Score	**Negative**	1	2	3	4	5
	Positive	5	4	3	2	1

3.1.4.3 Third domain: participants acceptance and willingness to use biogas technology

This domain was designed to investigate the participant acceptance, willing and opinion toward biogas technology. It consists of 9 multiple choice questions. In 8 of them (statement 1 and from 3-9) the participant is asked to circle the suitable option (strongly agree, agree, no opinion, disagree, strongly disagree) that agrees with his belief as in domain two. While the remaining question (statement 2) the participant chooses between 3 choices.

The options for statements 1 and 3-9 were scored according to Table 3 to simplify statistical analysis of the data. Statements 1, 3 and 5 are positive, while statements 4, 6, 7, 8 and 9 are negative.

3.1.4.4 Fourth domain: participants utilizing preferability of biogas and the organic fertilizer

This domain aims at collecting data about the participants direction of the way they prefer to utilize biogas and the resulting organic fertilizer. It consists of 4 multiple choice questions. The first question (statement 1) consists of 4 choices.

While the remaining other questions (statements 2-4) the participant is asked to circle the suitable option (strongly agree, agree, no opinion, disagree, strongly disagree) that agrees with his belief. The options were scored according to Table 3 to simplify statistical analysis of the data. Statements 2-4 are positive.

3.1.4.5 Fifth domain: unit management aspects

This domain investigates the participants opinion toward management aspects of the biogas technology. This includes participants opinion on whether the biogas technology should be managed individually, through private company, the government or joint stock company. This domain consists of 6 multiple choice questions. The first question (statement 1) consists of two choices.

While the remaining other questions (statements 2-6) the participant is asked to circle the suitable option (strongly agree, agree, no opinion, disagree, strongly disagree) that agrees with his belief. The options were scored according to Table 3 to simplify statistical analysis of the data.

3.1.4.6 Sixth domain: financial aspects

The sixth domain is the last domain. It is mainly concerned with the participants recommendation of the best financial management of biogas technology income. It consists of 5 multiple choice question. The first and last question (statements 1 and 5) consists of three choices.

While the remaining other questions (statements 2-4) the participant is asked to circle the suitable option (strongly agree, agree, no opinion, disagree, strongly disagree) that agrees with his belief. The options were scored according to Table 3 to simplify statistical analysis of the data.

3.1.5 Statistical Analysis

3.1.5.1 Data processing

The data processing stage consisted of the following operations:

Editing and coding before data entry: All questionnaires were edited and coded.

Data entry: At this stage, data was entered into the computer using a data entry template written in Microsoft Excel software. The data entry template was prepared to satisfy a number of requirements such as:

To prevent the duplication of the questionnaires during data entry.

The ability to transfer captured data to another format for data analysis using other statistical analytic systems such as SPSS.

3.1.5.2 Calculation and the estimation

The following softwares were used to perform statistical analyses on the questionnaire data:

Microsoft Office excel.

Statistical Package for the Social Sciences software (SPSS).

SAS software.

The critical percent for evaluating the positivity or negativity of the questionnaire results is considered 60%.

The following formulas were used in questionnaire analysis:

$$\text{Average reply}=\frac{\sum \text{number of replies on a choice} \times \text{ score of the choice}}{\text{total number of replies on the statement}}$$

$$\text{Percent of reply}=\frac{\text{average reply}}{\text{maximum score}}\times 100\%$$

3.2 Experimental Setup

Biogas unit preparation

A floating tank biogas unit was prepared. Figure 2 is an illustration of the used biogas unit. The unit consists of two PVC black tanks of sizes 1000 L and 1500 L. The 1500 L tank is the digestion tank. The 1000 L tank is the gas collection tank.

Preparing the 1500 L tank (the digestion tank): The top of the tank was cut, two holes were drilled at the tanks sides, one at the bottom and one at the top. Then holes adapters were connected. The holes are used as digestate outlets. 2” tube was attached to the inside of the tank and reaches to the bottom (this is the feeding tube).

Preparing the 1000L tank (the gas collector tank): This tank is smaller in diameter than the digestion tank. At the top of the tank, several big holes were made. 1/4” hole was cut in the bottom of this tank (this hole is the gas outlet) and fitting were added.

Putting small stones at the bottom of the digestion tank: those small stones serve as adequate surface for bacteria growth (White, et al., 1995).

Placing the digestion tank on a metal base: The metal base was designed with a holder to carry the waste shredder.

Placing the gas collector tank inside the digestion tank: The gas collector tank was placed upside down inside the digestion tank having the gas outlet hole directed upwards.

Placing the waste shredder in its holder: The waste shredder is originally a garbage disposer powered by electricity and is used to shred waste.

The gas collector tank will move downward and upward as long as biogas is generated. The height that the gas collector at a certain moment indicate the gas quantity formed.

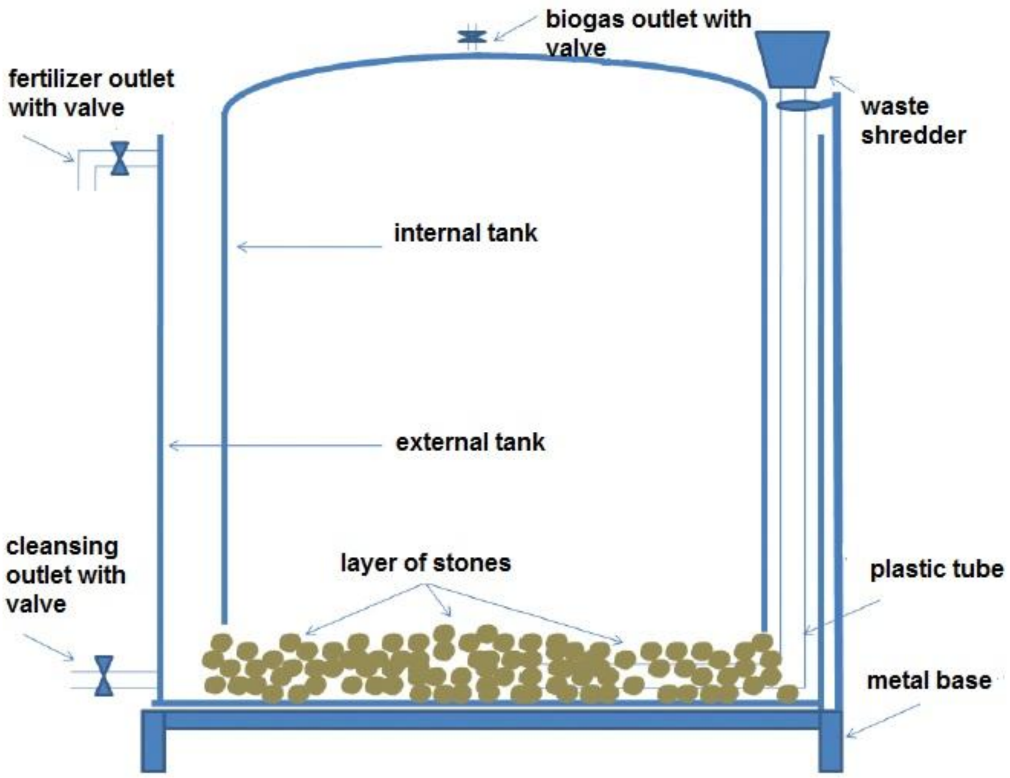

Figure 2: An illustration of the biogas unit

Figure 3: Setting up the biogas unit.

Figure 4: Starting to operate the biogas unit.

The unit was prepared at Royal factory in Hebron and the pluming work was performed at An-Najah National University.

An air compressor was used to collect and store the gas after it was formed.

An electronic balance was used to weigh the biogas stored in the compressor.

Figure 5: Weighing the compressor using the electronic balance

The biogas unit was connected to the air compressor using 1/4” gas tube.

It is important to notice that the biogas unit was placed inside a greenhouse located at Hebron city where the experiment was performed.

Figure 6: The biogas unit inside the greenhouse

3.3 Experiment Program and field work

Half of the biogas unit was filled with cow manure and water on 1:1 ratio. And no waste was added for 30 days to stabilize the unit. During this period the unit generated biogas and it was emptied several times.

3.3.1 Experiment stages and input waste preparation

The experiment was divided into four stages. Each stage has distinct waste type. Table 4 shows the waste mixture used at each stage. The purpose of these stages is to quantify the continued biogas generation from operating the biogas digester using different mixtures.

Table 4: Experimental stages

Stage number	Waste added		Water added (kg / day)	Addition period (day)
	Type	Quantity (kg / day)		
1	Cow manure	6	12	16
	Food residues	6		
2	Cow manure	12	12	16
3	Sheep manure	12	12	16
4	Poultry manure	12	12	16

Waste was mixed with water before feeding it to the biogas unit on a 1:1 ratio. 12 kg of the used waste type was added to the unit daily for 14 days.

3.3.2 Gas collection and weighing

As the waste digests, the biogas forms and rises up. Most of the generated biogas ends up in the upper tank (the gas collector tank). In order to weigh the biogas, an air compressor was used. The biogas was collected using the air compressor four times a day and weighted using digital balance. Temperature of the digestate and the surrounding air was recorded daily.

3.3.3 Temperature measurements

The surrounding temperature was measured using thermometer fixed on the greenhouse, while the digestate temperature was measured by taking a small sample of the digestate from the bottom outlet and measuring the temperature immediately using a thermometer.

3.3.4 Biogas versus Liquefied Petroleum Gas (LPG) flaring

An experiment was conducted in order to estimate a conversion factor between the family requirements of biogas if it replaced LPG.

The idea used is to compare the weight of biogas and LPG that are required to generate a flame for the same period of time.

Two samples were used during this step:

A sample of biogas was collected using the gas compressor and then weighted.

A sample of LPG brought from a pressurized gas cylinder.

Both samples were flared for an hour and a half at the same pressure. Then the remaining gas of each sample was weighted and recorded. The amount of biogas and LPG required to produce similar flame for the same period of time was calculated.

3.4 Experiment site

The experiment was performed in Hebron city, West Bank. The biogas unit was placed at the earth's. surface level inside a greenhouse.

3.5 Lab analysis

A biogas sample was taken from the biogas generated from each stage. The samples were supposed to be tested to measure their methane content using

GC (Gas Chromotography) present at Poison Control and Chemical /Biological Analysis Center at An-Najah University. The results were found incomplete due to technical specifications and of the analytical equipment. Accordingly, an assumption for methane content was made based on previous studies and literature (biogas is 60% by volume methane (White, et al., 1995)) in order to theoretically estimate the mass content of methane in biogas.

Chapter Four

Results and Discussion

4.1 Socio-economic Survey Results and Discussion

To simplify results analysis and getting out conclusions for the questionnaire, the obtained data is arranged according to the questionnaire domains.

4.1.1 First domain

The results indicate that the sample was composed of 70% males. The average age of the participants was 36.7years with standard deviation of 16. Almost 85% live in separate houses while the remaining live in apartments. It is of great importance in terms of biogas technology for a family to live separately, because living in apartments may not give enough space for placing and operating biogas units, unless operating the biogas unit is meant to be a joint process between the building members.

29% of the participants work in the agricultural sector, the percentage of work sectors of the participants is shown in Figure 7.

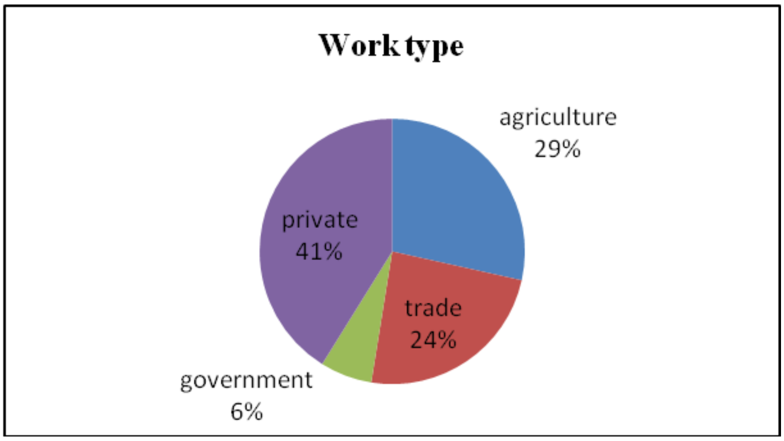

Figure 7: Work sectors of the participants

It is expected that the biogas technology will be most effective for people working in agriculture, especially if they raise animals. This is because this category of people is more likely to have the required input material, enough space and can use the output soil fertilizer in their farms. As previously indicated, 29% of the participants only work in agricultural sector. But 57% of the participants raise animals near their houses (i.e. the animal manure is a potential input of the digester). More than 72% of the participants own home garden (i.e. enough space for placing the digester is more likely to be available and the output fertilizer can be used in the garden).

Answers to statement 14 (Figure 8) indicate that almost 70% of the participants clean the animal waste in less than 7 days. This behavior is considered positive. Continuous animal waste cleaning indicates the ability of feeding the biogas digester, if constructed, with the required waste input.

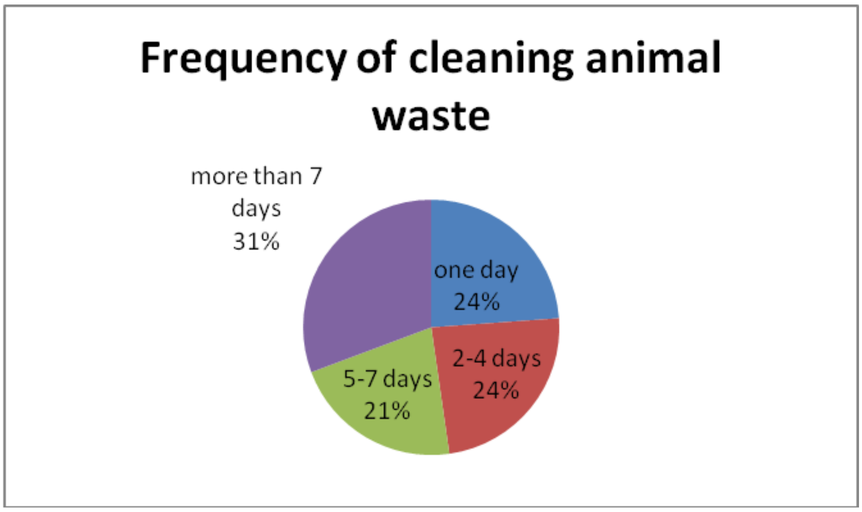

Figure 8: Frequency of cleaning animal waste

Table 5, Table 6, Table7 and Table 8 show the methods followed by participants for dealing with their wastes associated with the averages, percentages and rank.

The averages and percentages are calculated in order to rank the methods of dealing with waste by rural families - rank 1 - to the most followed way.

Table 5 shows the average, percentage and rank corresponding to the participants answers to the methods used for dealing with animal waste.

The most followed method is using the waste as fertilizer to their plants. Using animal waste to fertilizer crops is an eco friendly solution and provide nutrients for the plants, but it should be treated first. Using raw manure without treatment as a fertilizer to plants has negative health effects, and is even prohibited by some legislation around the world such as the US legislation for organic production which prohibits using raw manure without composting or treatment. So, it is of great importance to treat animal waste before using it to fertilize the land.

The next ranked method is leaving animal waste on its place. This method is unacceptable due to the negative impacts on health of the surrounding people and on the environment. This option creates nuisance and spreads disease vectors.

The remaining methods ordered according to their ranks are disposing in waste containers, selling to fertilizer factories and producing biogas.

Producing biogas from waste had the lowest rank with a very small percentage.

Table 5: Methods of dealing with animal waste:

	Method	Average *	Percentage	Rank
a.	Selling it to fertilizers factories	0.36	12.0%	4
b.	Using it as a fertilizer to my plants	1.99	66.3%	1
c.	Producing biogas from it	0.19	6.4%	5
d.	Disposing it in waste containers	0.40	13.5%	3
e.	Leaving it in place	0.41	13.7%	2

*** maximum range and score is 3**

Table 6 shows the average, percentage and rank corresponding to the participants answers to the methods used for dealing with household waste.

The method that took rank 1 of household waste disposal is disposal in public containers. This means that most household waste will end up in solid waste landfills. Using other eco-friendly alternatives of dealing with household waste such as biogas production technology reduces the amount of waste that is diverted to landfills and reduces the cost of disposal.

The second and third ranked household waste disposal methods are disposal in a nearby land and waste burning. These methods have a lot of environmental, economical and health adverse effects. They should be stopped and prohibited.

The remaining two methods are feeding the organic waste to animals and waste fermentation to produce biogas and/ or organic fertilizer. These methods are considered environmentally friendly and should be promoted and encouraged to increase their percentage.

Table 6: Methods of dealing with household waste

	Method	**Average ***	**Percentage**	**Rank**
a.	Burning the waste	0.55	18.3%	3
b.	Disposal in public containers	2.18	72.8%	1
c.	Feeding organic waste to the animals	0.52	17.5%	4
d.	Fermenting household organic waste to obtain biogas and / or organic fertilizer	0.3	9.9%	5
e.	Disposal in a nearby land	0.56	18.7%	2

***maximum range and score is 3**

Table **7**Tabel 7 shows the average, percentage and rank corresponding to the participants answers to the methods used for dealing with wastewater.

The two most popular methods of disposing wastewater are draining off to the absorption pit and draining off through wastewater networks.

Table 7: Methods of dealing with wastewater

	Method	Average *	Percentage	Rank
a.	Drained off through wastewater network	1.16	38.5%	2
b.	Drained off to the absorption pit	1.64	54.7%	1
c.	Drained off through open canal	0.19	6.3%	4
d.	Using it to irrigate plants	0.43	14.5%	3

***maximum range and score is 3**

Table 8 shows the average, percentage and rank corresponding to the participants answers to the methods used for dealing with agricultural waste.

The two most popular methods of dealing with agricultural waste are using it to feed animals and leaving it on the land or in its borders.

Table 8: Methods of dealing with agricultural waste

	Method	Average *	Percentage	Rank
a.	Burn it in the farm	0.5	16.8%	4
b.	Use it as animal feed	1.08	36.1%	1
c.	Left it at the land or its borders	0.82	27.4%	2
d.	Burn it to get energy	0.43	14.2%	5
e.	Gather the straw in the form of molds	0.52	17.4%	3
f.	Fermenting the plant remains to obtain biogas and / or organic fertilizer	0.39	13.0%	6

***maximum range and score is 3**

4.1.2 Second domain

The result of the first statement in this domain shows that only 20% of the participants have not previously heard about biogas. This reflects that the level of biogas technology popularity is significant and the concept of producing biogas from waste is already available to Palestinian communities. Figure 9 below is a chart that translates the results for statement 2 (i.e. where did the participant hear about biogas). As obvious that 43% heard about biogas from school or universities, 28% through the media, 24% through workshops and finally 5% through the internet. This reflects the importance of such places in increasing Palestinian people knowledge about this important technology. The largest percentage was through schools and universities, so it is important to ensure that the school teachers are well informed about biogas technology aspects in order to transfer their knowledge to the students. The media also have a great role in spreading any concept to people, so it is important to plan and perform campaigns that promote such eco-friendly projects. The small percentage was for the internet, although the internet is considered one of the most important tools nowadays in spreading any information. This may be due to several reasons, some of the participants may not have permanent access to the internet or they do not use internet for the purpose of gaining such knowledge.

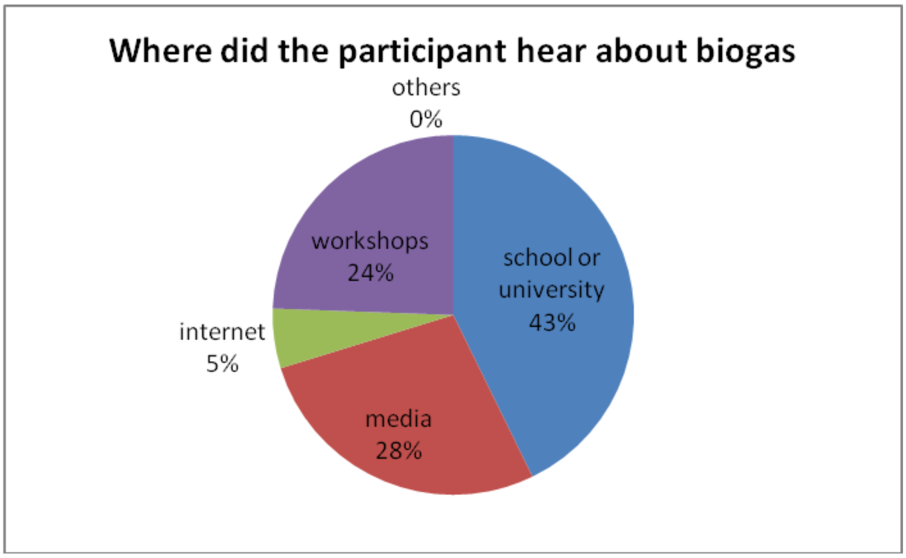

Figure 9: The way that the participants hear about biogas

Figure 10 shows the results of the participants answer to statement 3 (their belief about the origin of biogas). 78% thinks that biogas is produced from organic waste digestion, while the remaining 22% think that it is produced from petroleum, burning organic waste or had no opinion. The result of this statement and the previous one can lead us to conclude that knowledge about biogas technology is already available, but still it needs more spreading, promoting and correction of information to the targeted people.

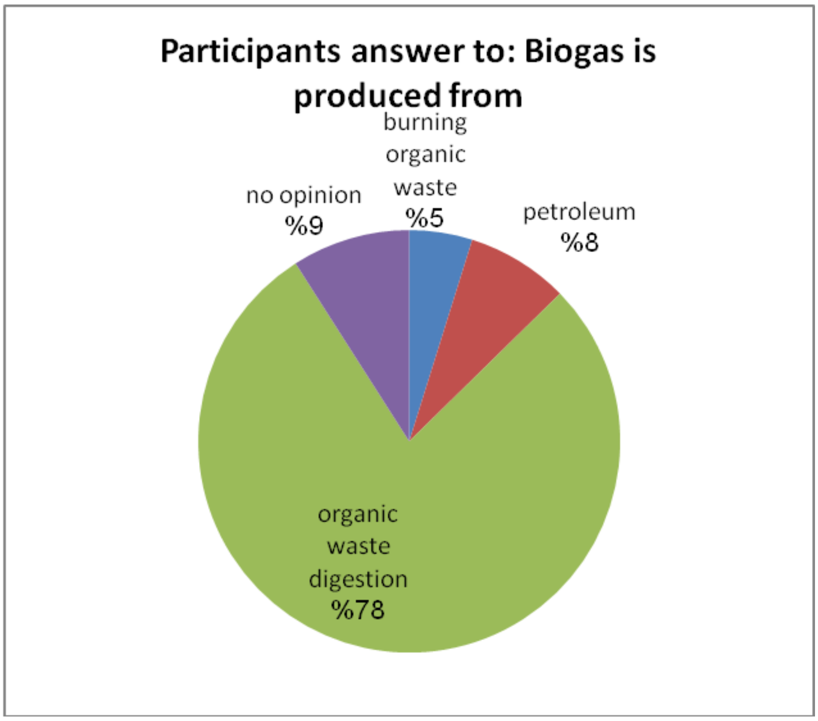

Figure 10: Participants belief about the origin of biogas

In order to simplify the study of this domain, the results were summarized in Tabel 9 below:

Table 9: Analysis of second domain

# statement	Statement	Direction of statement	Average*	Percentage	Result
4	Using biogas technology reduces the final waste volume.	+ve	4.30	86.1%	+ve
5	The primary cost of construction a biogas unit is high	+ve	3.50	70.1%	+ve
6	The digestion of organic waste through biogas technology produces solid and liquid output.	+ve	3.75	75.0%	+ve
7	The digestion of organic waste produces a fertilizer for plants.	+ve	4.14	82.8%	+ve
8	Using biogas technology had positive impacts on the environment.	+ve	4.25	84.9%	+ve
Average			**3.99**	**79.8%**	**+ve**

*** Max. Range and score is 5.**

All the statements had positive results indicating that participants knowledge about biogas technology is good.

In order to test whether there are significant differences between participants knowledge about biogas and some variables (like gender, age, housing, etc) the following research question was used:

Is there a statistically significant difference at level (0.05) in participant's knowledge and understanding according to the following variables (gender, age, number of family members, housing, work type, educational level, average family income, home garden availability, raising animals near the house, cleaning animals’ farm, and distance between the house and the nearest household waste disposal site)?

To validate this question (T. test) was used to identify differences in participant's knowledge about biogas according to the following variables (gender, housing, home garden availability, raising animals near the house), as shown in Table 10.

Table 10: The result of (T. test) to identify differences in knowledge about biogas

Variables		Mean	Std. D	Df	t	Sig. (2-ailed)
Gender	male	4.02	0.50	166	1.06	0.29
	female	3.94	0.37			
Housing	separate house	4.00	0.45	154	0.54	0.59
	apartment	3.94	0.50			
Home garden availability	Yes	3.96	0.45	168	-1.27	0.20
	No	4.07	0.50			
Raising animals near the house	Yes	4.02	0.50	159	0.49	0.63
	No	3.99	0.41			

The previous table indicates that there are no statistically significant differences at the significance level (α = 0.05) in participant's knowledge about biogas according to the following variables (gender, housing, home garden availability, raising animals near the house), the value of statistical significance respectively (0.29, 0.59, 0.20, 0.63), which are larger than (0.05). ANOVA test was used to identify differences in participant's knowledge about biogas according to the following variables (age, number of family members, work type, educational level, average family income, cleaning animals' farm, distance between the house and the nearest household waste disposal site) , as shown in Tabel 11.

Table 11: The result of (ANOVA. test) about differences in participant's knowledge about biogas

Variables		Sum of Squares	Df	Mean Square	F	Sig.
Age	Between Groups	12.57	51	0.25	1.52	0.04
	Within Groups	15.22	94	0.16		
	Total	27.80	145			
Number of family members	Between Groups	4.00	17	0.24	1.10	0.36
	Within Groups	32.56	152	0.21		
	Total	36.55	169			
Work type	Between Groups	0.78	4	0.20	0.90	0.46
	Within Groups	35.77	165	0.22		
	Total	36.55	169			
Educational level	Between Groups	1.08	5	0.22	0.99	0.43
	Within Groups	35.23	161	0.22		
	Total	36.31	166			
Average family income	Between Groups	0.72	4	0.18	0.81	0.52
	Within Groups	35.59	162	0.22		
	Total	36.31	166			

Cleaning animals' farm	Between Groups	0.79	4	0.20	0.91	0.46
	Within Groups	35.77	165	0.22		
	Total	36.55	169			
Distance between the house and household waste disposal site	Between Groups	5.64	24	0.23	1.10	0.35
	Within Groups	30.92	145	0.21		
	Total	36.55	169			

The previous table indicates that there are no statistically significant differences at the significance level (α = 0.05) in participant's knowledge about biogas according to the following variables (number of family members, work type, educational level, average family income, cleaning animals' farm, distance between the house and the nearest household waste disposal site), The value of statistical significance respectively are (0.36, 0.46, 0.43, 0.52, 0.46, 0.35), which are larger than (0.05).

And the previous table indicates that there is statistically significant difference at the significance level (α = 0.05) in participant's knowledge about biogas according to age, and this value of statistical significance is (0.04), this value is less than (0.05). Younger participants seem to have better knowledge about the biogas.

4.1.3 Third domain

This domain investigates the acceptance and willing to use biogas technology. In order to simplify the study of this domain, the results were summarized in Table 12 below.

Table 12: Analysis of third domain

# statement	Statement	Direction of statement	Average*	Percentage	Result
1	like to buy and use biogas unit for the house or farm.	+ve	4.18	83.6%	+ve
3	will use biogas technology if it will have financial profit on the family.	+ve	4.29	85.8%	+ve
4	there are other alternatives better than biogas technology to treat organic waste	-ve	2.91	58.2%	-ve
5	Do not mind the separation of organic waste (kitchen and garden waste) from other household waste.	+ve	4.11	82.2%	+ve
6	operating a biogas unit in the house or farm will require a lot time and effort.	-ve	2.83	56.5%	-ve

7	have fears regarding the quality of the fertilizer quality resulting from biogas unit.	-ve	3.08	61.5%	+ve
8	have fears regarding my ability to fix it by my own in case any damage occurs.	-ve	3.64	52.8%	-ve
9	have fears regarding the unavailability of appropriate expertise capable of following up the unit and its maintenance.	-ve	2.59	51.8%	-ve
Average			3.33	66.5%	+ve

*** maximum range and score is 5**

The results of this domain indicate that most farmers are willing to use biogas technology in their farms or homes if it has a financial profit, but they also think that operating a biogas unit in the house or farm will require a lot of time and effort.

Most participants have fears regarding their ability to fix the biogas unit in case any damage occurred, in addition to their fears from the unavailability of appropriate expertise capable of following up the unit and its maintenance.

Most of the participants are willing to use biogas technology if its initial construction cost is compensated within 1 year of operation. This requires developing a biogas digester design that is considered cost efficient.

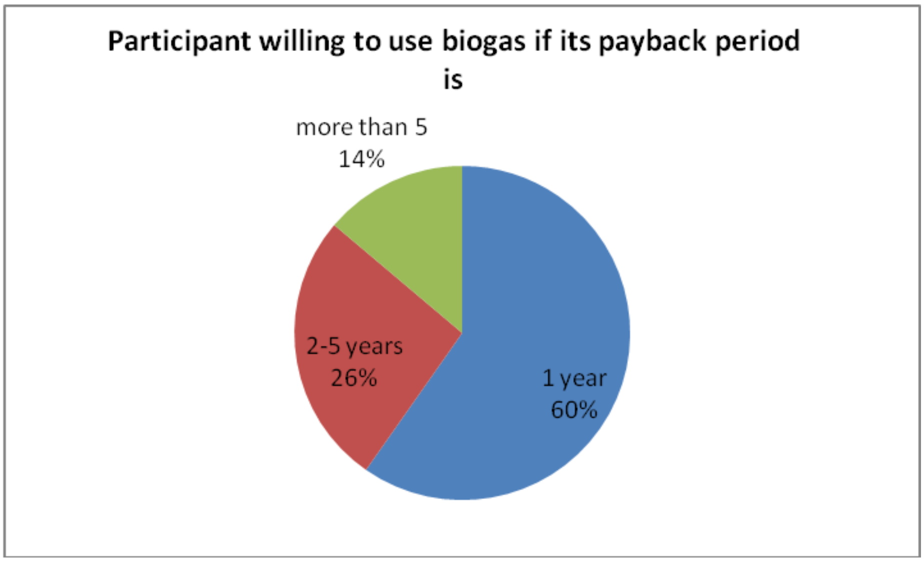

Figure 11: Payback period condition for biogas – willing to use

The overall result of this domain is positive indicating acceptance and willing to use biogas technology but with some insurances such as providing support and help in terms of unit maintenance and operation.

In order to test whether there are significant differences between participants acceptance and willing to use biogas technology and some variables (like gender, age, housing, etc) the following research question was used:

Is there a statistically significant difference at level (0.05) in participants acceptance and willing to use biogas technology according to the following variables (gender, age, number of family members, housing, work type, educational level, average family income, home garden availability, raising animals near the house, cleaning animals' farm, and distance between the house and the nearest household waste disposal site)?

To validate this question (T. test) was used to identify differences in participant's knowledge about participants acceptance and willing to use biogas technology according to the following variables (gender, housing, home garden availability, raising animals near the house), as shown in Table 13.

Table 13: The results of (T. test) to identify differences in participants acceptance and willing to use biogas technology.

Variables		Mean	Std. D	df	t	Sig. (2-ailed)
Gender	male	3.37	0.60	165	0.92	0.36
	Female	3.29	0.47			
Housing	separate house	3.37	0.55	154	0.68	0.50
	apartment	3.28	0.58			
Home garden availability	Yes	3.34	0.51	167	-0.05	0.96
	No	3.35	0.69			
Raising animals near the house	Yes	3.35	0.60	159	0.18	0.86
	No	3.33	0.53			

The previous table indicates that there is no statistically significant differences at the significance level ($\alpha = 0.05$) in participants acceptance and willing to use biogas technology according to the following variables (gender, housing, home garden availability, raising animals near the house), the value of statistical significances are respectively (0.36, 0.50, 0.96, 0.86), which are larger than (0.05).

ANOVA test was used to identify differences in participants acceptance and willing to use biogas technology according to the following variables (age, number of family members, work type, educational level, average family income, cleaning animals’ farm, distance between my house and the nearest household waste disposal site), as shown in Table 14.

Table 14: The results of (ANOVA test) about differences in participants acceptance and willing to use biogas technology.

Variables		Sum of Squares	df	Mean Square	F	Sig.
Age	Between Groups	14.47	52	0.28	0.94	0.60
	Within Groups	27.66	93	0.30		
	Total	42.13	145			
Number of family members	Between Groups	8.37	17	0.49	1.67	0.06
	Within Groups	44.62	151	0.30		
	Total	53.00	168			
Work type	Between Groups	1.16	4	0.29	0.92	0.46
	Within Groups	51.84	164	0.32		
	Total	53.00	168			
Educational level	Between Groups	0.92	5	0.18	0.57	0.72
	Within Groups	51.97	160	0.32		
	Total	52.89	165			
Average family income	Between Groups	0.16	4	0.04	0.12	0.98
	Within Groups	52.73	161	0.33		
	Total	52.89	165			
Cleaning animals' farm	Between Groups	0.40	4	0.10	0.31	0.87
	Within Groups	52.60	164	0.32		
	Total	53.00	168			
Distance between the house and household waste disposal site	Between Groups	8.53	24	0.36	1.15	0.30
	Within Groups	44.47	144	0.31		
	Total	53.00	168			

The previous table indicates that there are no statistically significant differences at the significance level (α = 0.05) in participants acceptance and willing to use biogas technology according to the following variables (age, number of family members , work type, educational level, average family income, cleaning animals’ farm, distance between the house and the nearest household waste disposal site). The value of statistical significances are respectively (0.60,0.06, 0.46, 0.72, 0.98, 0.87, 0.30), which are larger than (0.05).

4.1.4 Fourth domain

Results show that most of the participants prefer to use biogas in cooking (68%) which is considered one of the easiest and simplest ways to use biogas. Figure 12 below shows the distribution of the participants opinion toward the preferred use of biogas.

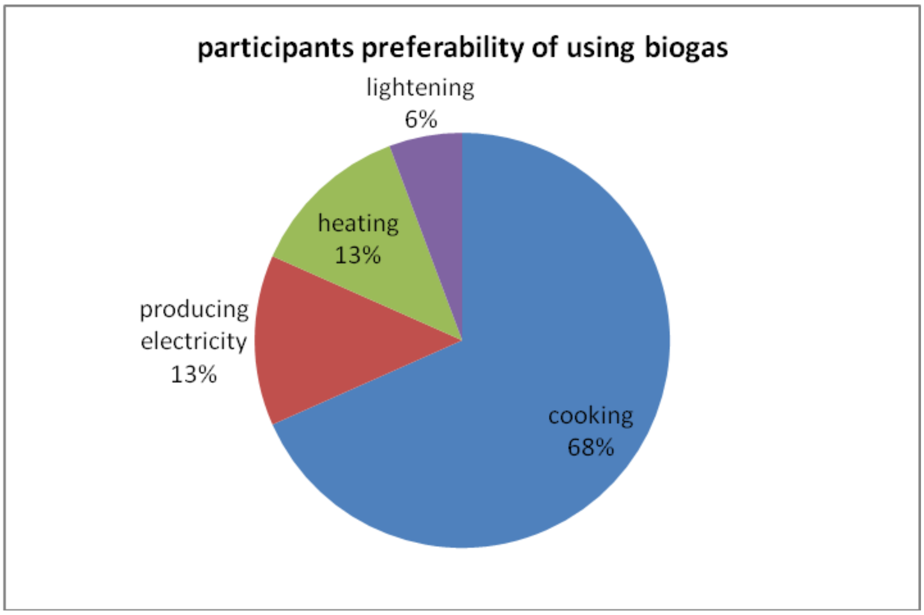

Figure 12: Participants preferability of using biogas.

Table 15: Analysis of fourth domain

# statement	Statement	Direction of statement	Average*	Percentage	Average
2	Would like to use the fertilizer resulting from biogas technology at the farm or garden.	+ve	4.21	84.2%	+ve
3	Using biogas is preferred on the house level.	+ve	4.21	84.3%	+ve
4	Using biogas is environmentally and economically feasible.	+ve	14.32	86.4%	+ve
	Average		**4.25**	**85.0%**	**+ve**

In order to test whether there are significant differences between utilizing preferability and some variables (like gender, age, housing, etc) the following research question was used:

Is there a statistically significant difference at level (0.05) in utilizing preferability according to the following variables (gender, age, number of family members, housing, work type, educational level, average family income, home garden availability, raising animals near the house, cleaning animals' farm, and distance between the house and the nearest household waste disposal site)?

To validate this question (T. test) was used to identify differences in utilizing preferability according to the following variables (Gender, Housing, Home garden availability, Raising animals near the house), as shown in Table 16.

Table 16: Results of (T. test) to identify differences in utilizing preferability

Variables		Mean	Std. D	Df	T	Sig. (2-ailed)
Gender	Male	4.32	0.51	159	2.53	0.01
	Female	4.10	0.47			
Housing	separate house	4.24	0.48	148	0.43	0.67
	apartment	4.19	0.59			
Home garden availability	Yes	4.26	0.49	161	0.65	0.52
	No	4.21	0.54			
Raising animals near the house	Yes	4.27	0.50	153	0.36	0.72
	No	4.24	0.51			

The previous table indicates that there are no statistically significant differences at the significance level (α = 0.05) in utilizing preferability according to the following variables (housing, home garden availability, raising animals near the house), The value of statistical significances are respectively (0.67, 0.52, 0.72), which are larger than (0.05).

And the previous table indicates that there is statistically significant difference at the significance level (α = 0.05) in utilizing preferability according the variable gender, and this value is of statistical significance (0.01), which is less than (0.05).

ANOVA test was used to identify differences in utilizing preferability according to the following variables (age, number of family members, work type, educational level, average family income, cleaning animals' farm, distance between my house and the nearest household waste disposal site) , as shown in Table 17.

Table 17: The result of (ANOVA. test) about differences in utilizing preferability.

Variables		Sum of Squares	df	Mean Square	F	Sig.
Age	Between Groups	15.48	50	0.31	1.61	0.02
	Within Groups	17.31	90	0.19		
	Total	32.80	140			
Number of family members	Between Groups	4.54	17	0.27	1.06	0.40
	Within Groups	36.53	145	0.25		
	Total	41.08	162			
Work type	Between Groups	0.52	4	0.13	0.51	0.73
	Within Groups	40.55	158	0.26		
	Total	41.08	162			
Educational level	Between Groups	1.95	5	0.39	1.56	0.17
	Within Groups	38.32	154	0.25		
	Total	40.27	159			
Average family income	Between Groups	0.36	4	0.09	0.35	0.84
	Within Groups	39.91	155	0.26		
	Total	40.27	159			
Cleaning animals' farm	Between Groups	1.84	4	0.46	1.85	0.12
	Within Groups	39.24	158	0.25		
	Total	41.08	162			
Distance between my house and household waste disposal site	Between Groups	4.86	24	0.20	0.77	0.77
	Within Groups	36.22	138	0.26		
	Total	41.08	162			

The previous table indicates that there are no statistically significant differences at the significance level (α = 0.05) in utilizing preferability according to the following variables (number of family members, work type, educational level, average family income, cleaning animals' farm, distance between my house and the nearest household waste disposal site), The value of statistical significances are respectively (0.40,0.73, 0.17, 0.84, 0.12, 0.77), which are larger than (0.05).

And The previous table indicates that there is statistically significant difference at the significance level (α = 0.05) in utilizing preferability according to age, and this value is of statistical significance (0.02), this value is less than (0.05).

4.1.5 Fifth domain

The results indicate that almost 41% of the participants prefer the biogas technology to be managed individually, while the remaining 59% prefer it to be jointly. Each management choice has its own advantages and disadvantages. Table 18 below shows the analysis of this domain, the average and percentage of each statement is calculated in order to compare the result of statements 2, 4, 5 and 6. Each statement is then ranked to order them according to the most preferred management options. The least percentage took rank 1.

Table 18: Analysis of fifth domain

# statement	Statement	Average*	Percentage	Rank
2	Would like to use biogas unit in my house and by house management only.	2.31	46.3%	1
3	If biogas unit management is joint, I would like to participate in a management committee regarding it.	2.03	40.5%	-
4	Recommend the biogas technology to be managed by private company.	2.57	51.4%	3
5	recommend the biogas technology to be managed by the government or its local representatives.	2.50	50%	2
6	recommend the biogas technology to be managed by joint stock company.	2.60	52%	4

Results of the statements answers to this domain are so close to each other, but generally the most preferred management of biogas technology is by house management only.

4.1.6 Sixth domain

The results indicate that 70% of the participants don't know the family income from using biogas technology.

Table 19: Analysis of sixth domain.

# statement	Statement	Average*	Percentage	Rank
2	recommend the income of biogas technology to be distributed on the village inhabitance.	2.21	44.2%	3
3	recommend the income of biogas technology to be distributed on the village inhabitance according to their participation level.	2.08	41.5%	2
4	recommend that the government participate in biogas technology establishment cost.	1.93	38.6%	1

As the previous table shows, the participants prefer the government to participate in the establishment cost. Worldwide, studies have shown that the most successful biogas projects are those subsidized by the government or other NGOs. But the people who will benefit from the biogas should have some financial stake in the construction or they may not have a sufficient sense of ownership to maintain the plant.

4.2 Experimental Results and Discussion.

In order to simplify the analysis of the experimental results, each of the phases were studied separately then the results of all the phases are compared to the other.

4.2.1 Phase 1 results: Cow manure mixed with household waste.

At this phase a quantity of 6 kg of cow manure was mixed with 6 kg of household waste (food residues) and 12 kg of water then added daily at the early morning (at 7:00 AM). The biogas was collected almost 4 times a day. The collection was 3 times at daytime and 1 time at night, this is because it was noticed that the generation rate is higher during the day than at night (this maybe due to the appropriate temperature when the sun is present).

Appendix II have the detailed biogas quantities produced. The average biogas production rate during 16 days was 1184.7 gm/day with 65.6 standard deviation.

Figure 13 below illustrates the biogas quantity produced by time at this phase.

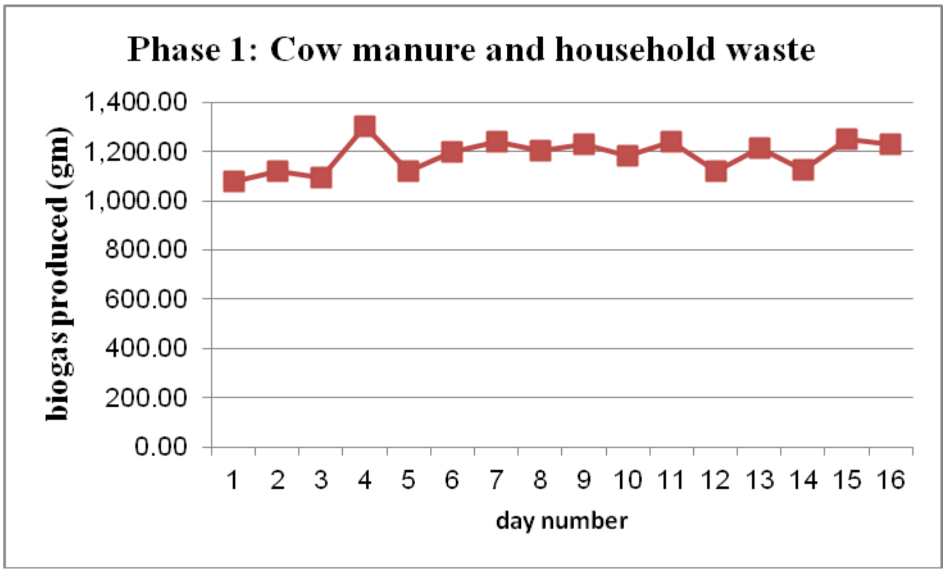

Figure 13: Biogas quantity produced by time at phase 1

The biogas production during this phase ranged from 1080-1300 gm/day. With the minimum production at days the first and third days. The maximum production was at day number 4. But in general the biogas production can be considered almost stable with slight fluctuations. The fluctuations are best explained due to the temperature fluctuations as it is known that biogas production rate is affected by the temperature.

The total quantity of biogas produced during this phase is 18.955 kg (almost 19 kg).

Based on daily feeding rate of the biogas digester, taking cow manure and household waste as the waste input, the average kilograms of biogas produced per kilograms of waste added is calculated:

Biogas in kg / kg of mixed waste = 19 / 192 = 0.099 kg biogas per kg waste. This is almost 10% of the waste is converted into biogas.

4.2.2 Phase 2 results: Cow manure.

At this phase a quantity of 12 kg of cow manure and 12 kg of water where mixed and added daily. The biogas was collected almost 4 times a day. The collection was 3 times at daytime and 1 time at night.

Appendix II have the detailed biogas quantities produced. The average biogas production rate during 16 days was 1414.1 gm/day with a 120.8 standard deviation.

Figure 14 below illustrates the biogas quantity produced by time at this phase.

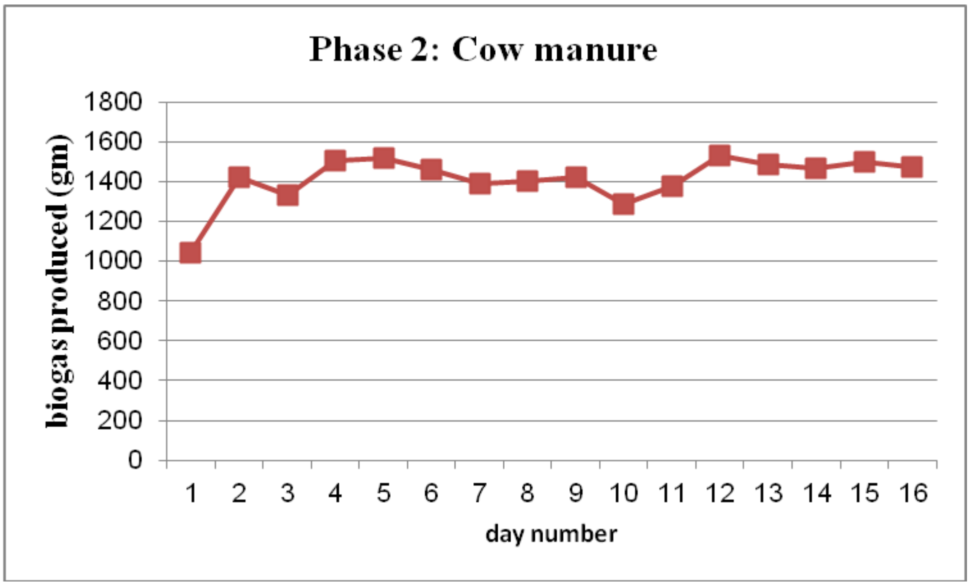

Figure 14: Biogas quantity produced by time at phase 2

The biogas production during this phase ranged from 1040-1520 gm/day. With the minimum production at day number 1 and the maximum at day number 5.

The total quantity of biogas produced during this phase is almost 22.6 kg biogas.

Based on daily feeding rate of the biogas digester, taking cow manure and household waste as the waste input, the average kilograms of biogas produced per kilograms of waste added is calculated:

Biogas in kg / kg of mixed waste = 22.6 / 192 = 0.117 kg biogas per kg waste. This is almost 11% of the waste is converted into biogas.

4.2.3 Phase 3 results: Sheep manure.

At this phase a quantity of 12 kg of sheep manure and 12 kg of water where mixed and added daily. The biogas was collected almost 4 times a day. The collection was 3 times at daytime and 1 time at night.

Appendix II have the detailed biogas quantities produced. The average biogas production rate during 16 days was 1433.8 gm/day with a 105.2 standard deviation.

Figure 15 below illustrates the biogas quantity produced by time at this phase.

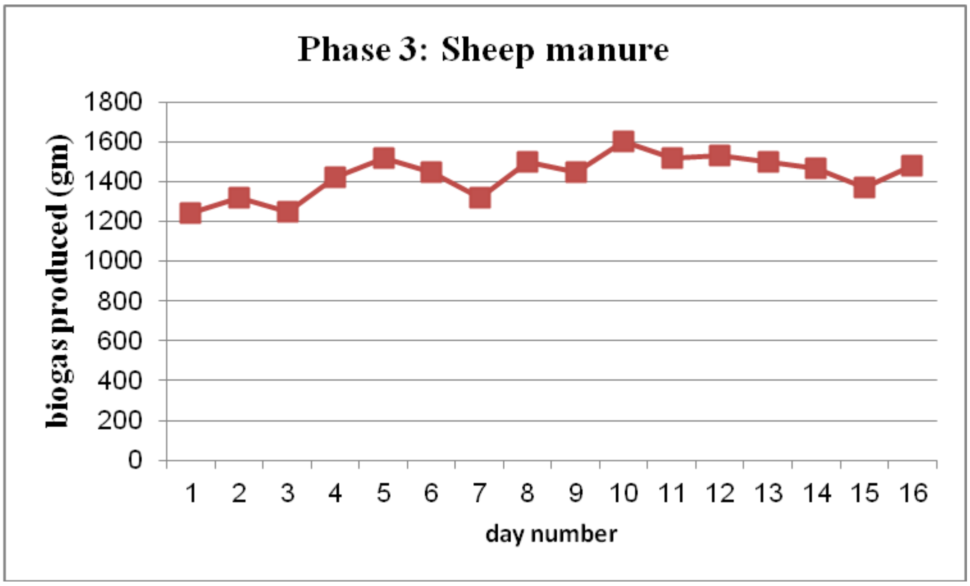

Figure 15: Biogas quantity produced per time at phase 3

The biogas production during this phase ranged from 1240-1600 gm/day. With the minimum production at day number 1 and the maximum at day number 10.

The total quantity of biogas produced during this phase is almost 22.9 kg biogas.

Based on daily feeding rate of the biogas digester, taking cow manure and household waste as the waste input, the average kilograms of biogas produced per kilograms of waste added is calculated:

Biogas in kg / kg of mixed waste = 22.9 / 192 = 0.119 kg biogas per kg waste. This is almost 12% of the waste is converted into biogas.

4.2.4 Phase 4 results: poultry manure.

At this phase a quantity of 12 kg of sheep manure and 12 kg of water where mixed and added daily. The biogas was collected almost 4 times a day. The collection was 3 times at daytime and 1 time at night.

Appendix II have the detailed biogas quantities produced. The average biogas production rate during 16 days was 1298.1 gm/day with a 90.6 standard deviation.

Figure 16 below illustrates the biogas quantity produced by time at this phase.

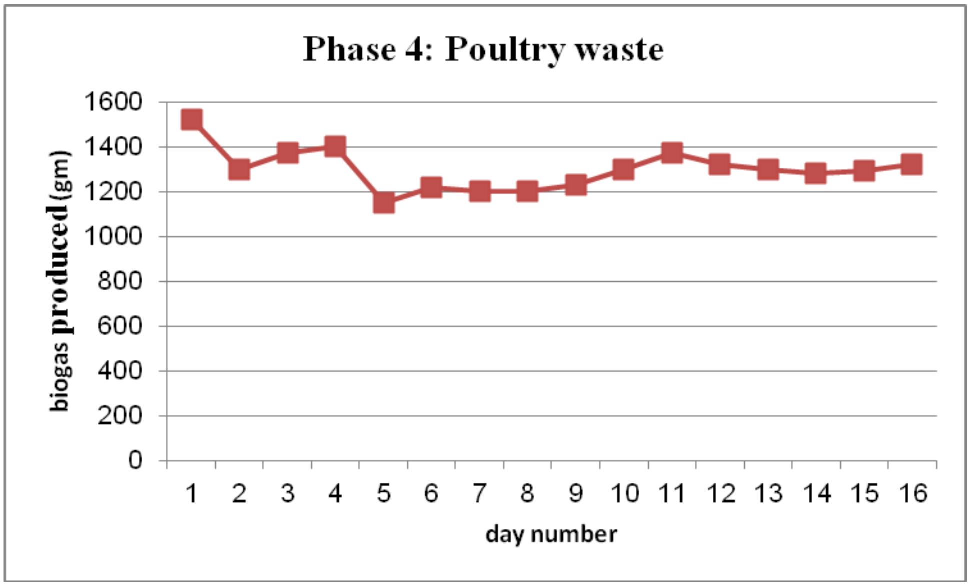

Figure 16: Biogas quantity produced by time at phase 4

The biogas production during this phase ranged from 1520-1150 gm/day. With the minimum production at day number 5 and the maximum at day number 1.

The total quantity of biogas produced during this phase is 20.8 kg.

Based on daily feeding rate of the biogas digester, taking cow manure and household waste as the waste input, the average kilograms of biogas produced per kilograms of waste added is calculated:

Biogas in kg / kg of mixed waste = 20.8 / 192 = 0.108 kg biogas per kg waste. This is almost 11% of the waste is converted into biogas.

4.2.5 Comparison between biogas productions at all phases

The biogas produced from the digestion of each waste type is different from the others. Table 20 below summarizes the average biogas quantity produced from different waste mixtures through the experiment period.

Table 20: Average biogas quantity produced from different waste mixtures

Phase #	Waste added	Average biogas produced (gm/day)	Standard deviation
1	Mixed cow manure and food residues	1187.7	65.6
2	Cow manure	1414.1	120.8
3	Sheep manure	1433.8	105.2
4	Poultry manure	1298.1	90.6

Table 21 below compares between the total biogas produced from each phase and their ranks. It is apparent that phase 3 (sheep manure) produced the largest biogas quantity during the experiment followed by phase 2 (cow manure), phase 4 (poultry manure) and phase 1 (mixed cow and food residues) respectively.

Table 21: Detailed biogas quantities produced from different waste mixtures

	Biogas quantity produced (gm/day)			
day number	**Phase1 (mixed cow + food)**	**phase 2 (cow)**	**phase 3 (sheep)**	**phase4 (poultry)**
1	1080	1040	1240	1520
2	1120	1425	1320	1300
3	1095	1330	1250	1370
4	1300	1505	1420	1400
5	1120	1520	1520	1150
6	1200	1460	1450	1220
7	1240	1390	1320	1200
8	1205	1400	1500	1200
9	1230	1425	1450	1230
10	1185	1290	1600	1300
11	1240	1380	1520	1370
12	1120	1530	1530	1320
13	1215	1485	1500	1300
14	1125	1470	1470	1280
15	1250	1500	1370	1290
16	1230	1475	1480	1320
Total (gm)	18955	22625	22940	20770
Approx Total (kg)	19.0	22.6	22.9	20.8
Rank	4	2	1	3

The figure below (Figure 17) compares between the biogas produced from different waste mixtures via time.

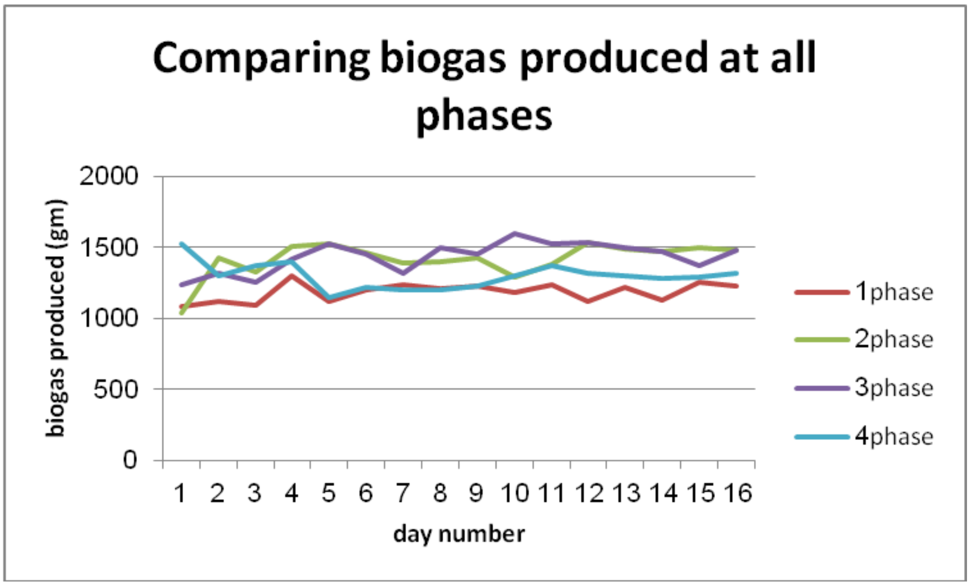

Figure 17: Comparing biogas produced at all phases

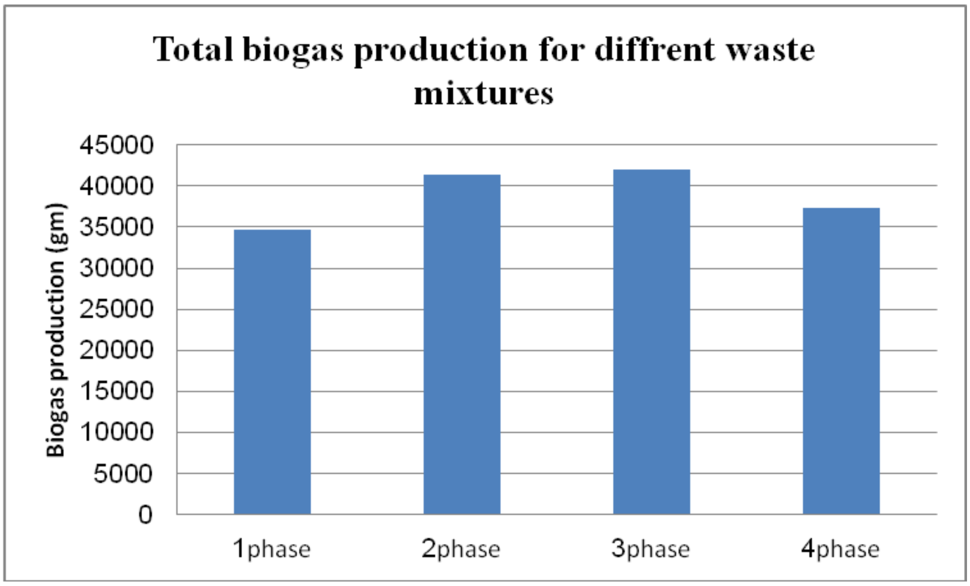

Figure 18: Total biogas production for different waste mixtures

SAS software was used to estimate the least square means of biogas production from the four waste mixtures and to plot measured versus predicted biogas production.

ANCOVA test was used to estimate the least squares means (adjusted means) of gas production from four waste types. Table 22 shows the results. (see Appendix II for the complete analysis).

Table 22: ANCOVA test results.

Waste type	**Least squares means (LSMEANS)**
Phase 1	1310.9 [a]
Phase 2	1349.2[a]
Phase 3	1344.3[a]
Phase 4	1326.2[a]

In Table 22 the means that are in the same column with similar superscripts are not significantly different ($P > 0.05$) using Tukey-Kramer adjustment for multiple comparisons.

The results indicate that there is no statistically significant differences at the significance level ($\alpha = 0.05$) in biogas production for the different waste mixtures.

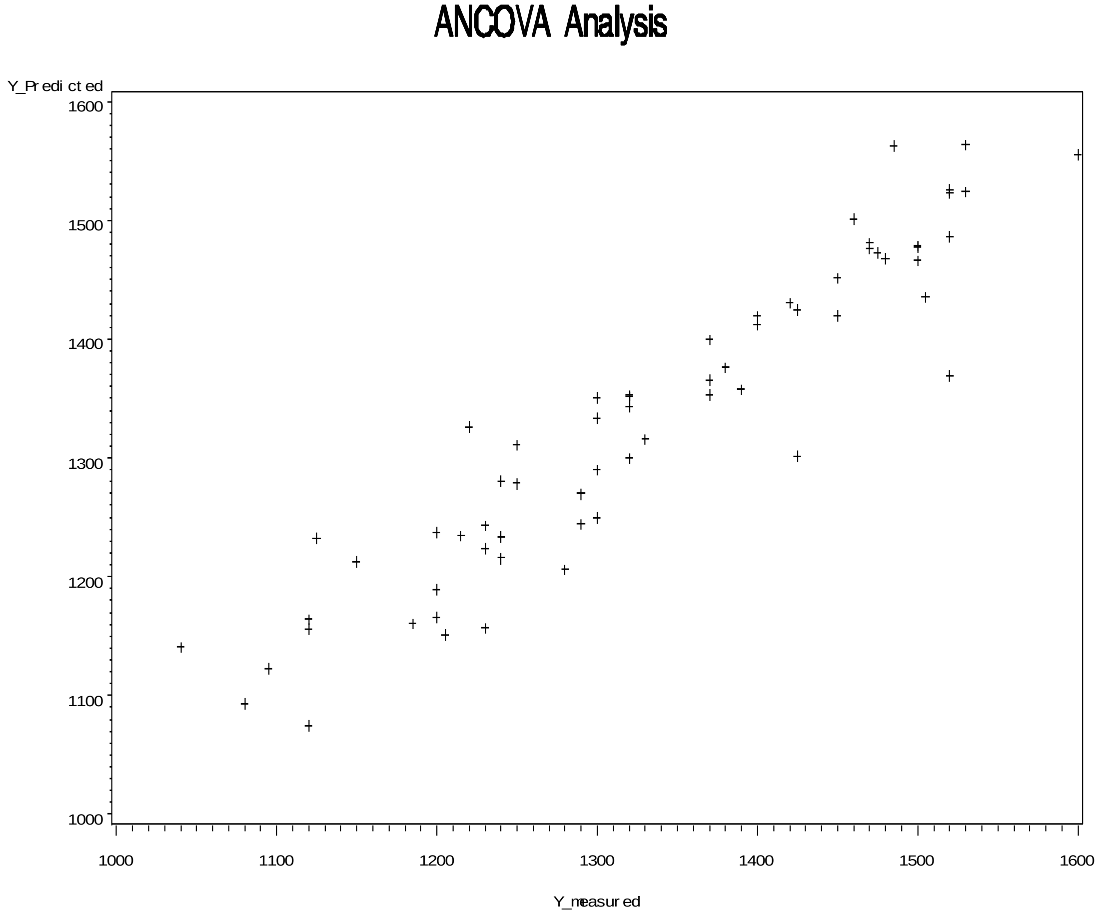

Figure 19: Plot of predicted biogas production vs. measured biogas values (ANCOVA analysis model)

In order to clarify the relationship between biogas production from the four mixtures and the temperature and time statistically, nonlinear procedure of SAS was used. The nonlinear analyses were based on the following model:

$Y = C*(Time)^{X1} * (Temp)^{X2}$, where Y is gas emission

Estimates and standard error (SE) are summarized in

Table **23** below. (Detailed analyses are in Appendix IV).

Table 23: Nonlinear analyses results.

	C		X1		X2	
	Estimate	**SE**	**Estimate**	**SE**	**Estimate**	**SE**
Phase 1	10.57	13.39	-0.00116	0.0156	1.3829	0.3761
Phase 2	1.1198	1.544	0.0256	0.0165	2.0345	0.3995
Phase 3	0.0537	0.0473	0.0369	0.00648	2.898	0.2534
Phase 4	1.2488	2.7576	0.00594	0.0214	2.007	0.631

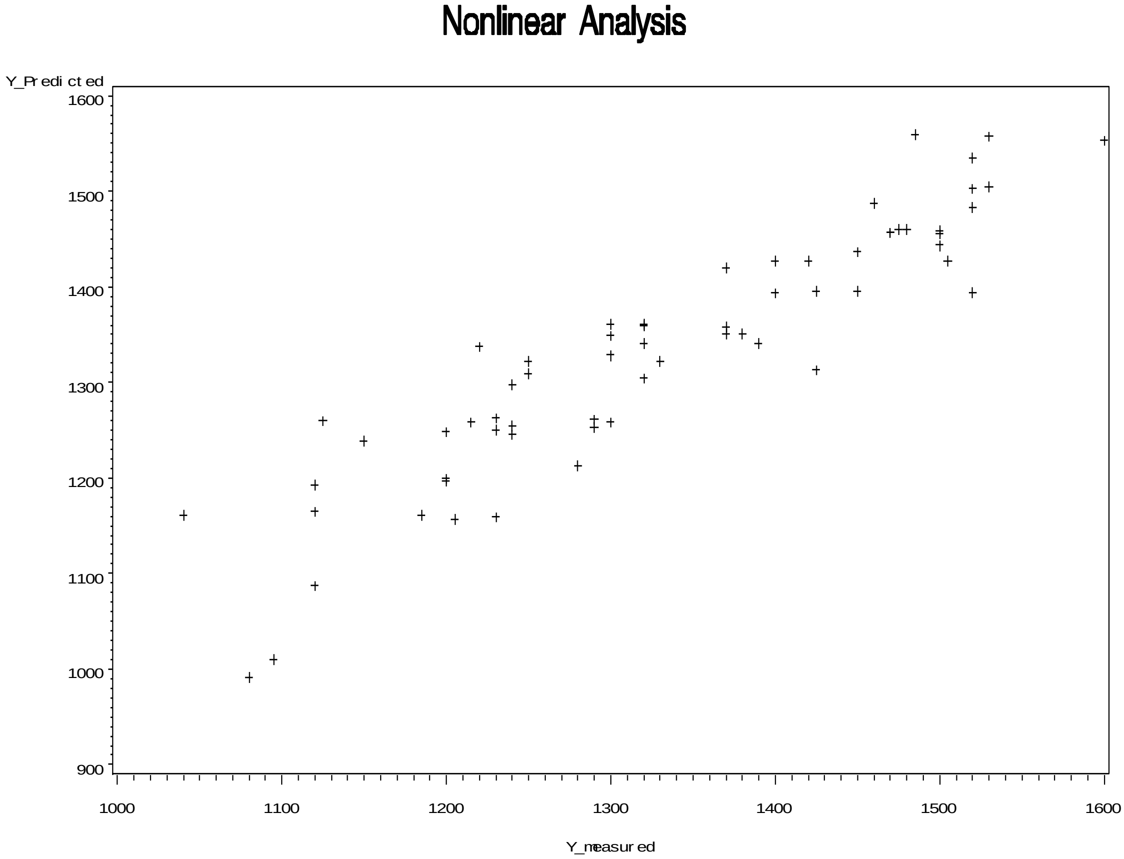

Figure 20: Plot of predicted biogas production vs. measured biogas values (Nonlinear analysis model).

4.2.6 Biogas versus Liquefied Petroleum Gas (LPG).

Cooking stoves can be designed to operate on various types of fuels, these fuels are:

Solid fuels: for example wood and animal dung.

Liquid fuels: for example kerosene and alcohol.

Gaseous fuels: for example natural gas, LPG and biogas. (Center for Energy Studies, 2001)

The fuels under this research study are biogas versus LPG because in Palestine, LPG is the main fuel used for cooking. It is supplied to the homes through pressurized cylinders.

The overall efficiency of any stove depends on various factors or conditions:

Environmental conditions, such as wind, temperature, pressure

Shape, specific heat capacity and weight of vessel.

Burner size of stove and size of bottom face of cooking vessel.

Energy content of fuel and quality of fuel. (Center for Energy Studies, 2001)

LPG is composed primarily of propane and butane, while biogas contains methane. LPG, vaporised and at atmospheric pressure, has a higher calorific value (44 MJ/kg) than biogas (32-36 MJ/kg) (Mukunda, 2009), which means that LPG cannot simply be substituted for biogas.

Taking the average of the heat value of biogas, the ratio between the heat content of LPG to the heat content of methane is: (44 MJ/kg LPG) / (34 MJ/kg biogas) = 1.3.

An experiment was conducted in order to estimate a conversion factor between the family requirements of biogas if it replaced LPG.

The results indicate that the biogas weight required for producing continuous flame – strong enough to cook rice – for one and a half hour is 280 gm. While the weight of LPG required for producing the same continuous flame for the same period of time is 120 gm.

The conversion factor= (LPG weight / biogas weight) * 1.3

= (280/120) * 1.3 = 2.99 ; approximated to 3.

This means that if a family needs 12 kg bottle of LPG every month, their biogas requirements= 3 *12 = 36 kg biogas.

So, the 12 kg bottle of LPG is equivalent to 36 kg of biogas.

4.2.7 Biogas coverage ratio for the needs of the family.

According to the experimental results discussed in the previous sections, operating the biogas unit at the same conditions carried out in this study produces 19-23 kg of biogas. As estimated in the previous section, the 12kg bottle of LPG is equivalent to 36 kg of biogas.

Assuming that the family needs 1 bottle (12 kg) of LPG to cover their energy needs, the lowest and highest biogas coverage ratio for the needs of the family are:

The lowest coverage ratio = 19/30 = 63%

The highest coverage ratio = 23/30 = 76%

Average coverage ratio is 69.5%.

4.2.8 Theoretical estimation of methane content by weight in biogas.

Methane content of biogas should be estimated. In order to do so, several samples of the produced biogas from each waste mixture were gathered then analyzed using gas chromatography. Unfortunately, the results were irrational due to several possible reasons, among which is the unavailability of lab technician experienced in gas analysis.

An assumption was made to overcome this problem; Biogas is generally composed of 60% methane by volume. Since all the measurements taken were based on weight of the produced biogas, the weight percentage of methane in biogas can be calculated:

Calculate the mass fractions of CH_4 and CO_2:

The molecular weight of methane is:

1 (C) x 12 g/mol + 4 (H) x 1 g/mol = 16 g/mol

The molecular weight of carbon dioxide is:

1 (C) x 12 g/mol + 2 (O) x 16 g/mol = 44 g/mol

Calculate the mass quantities of CH_4 and CO_2:

From the ideal gas law, we know that mole fractions are essentially the same as volume fractions. Using this approximation, we can calculate the mass fraction of methane from the volume fraction and the molecular weights (assuming that biogas is 60% by volume methane):

$$\frac{\text{methane mass}}{\text{biogas mass}} = \frac{CH_4 \text{ mass}}{CH_4 \text{ mass} + CO_2 \text{ mass}}$$

$$= \frac{0.6\ \text{mol}_{CH4}/\text{mol}_{biogas} \times 16\ \text{g}_{CH4}/\text{mol}_{CH4}}{0.6\ \text{mol}_{CH4}/\text{mol}_{biogas} \times 16\ \text{g}_{CH4}/\text{mol}_{CH4} + 0.4\ \text{mol}_{CO2}/\text{mol}_{biogas} \times 44\ \text{g}_{CO2}/\text{mol}_{CO2}}$$

$$= \frac{9.6}{27.2} = 0.35 \frac{\text{g } CH_4}{\text{g biogas}}$$

Thus, biogas is assumed to be 35% by weight methane.

Chapter Five

Financial Evaluation of a Biogas Digester

There are many economic considerations in biogas production projects arising from the initial investment, operation and maintenance, and use of the by-products.

The financial analysis for constructing family biogas unit is based on the design of the biogas unit used in this research study and on a waste feeding rate of 12 kg/day. Figure 21 below shows the unit used containing all the components.

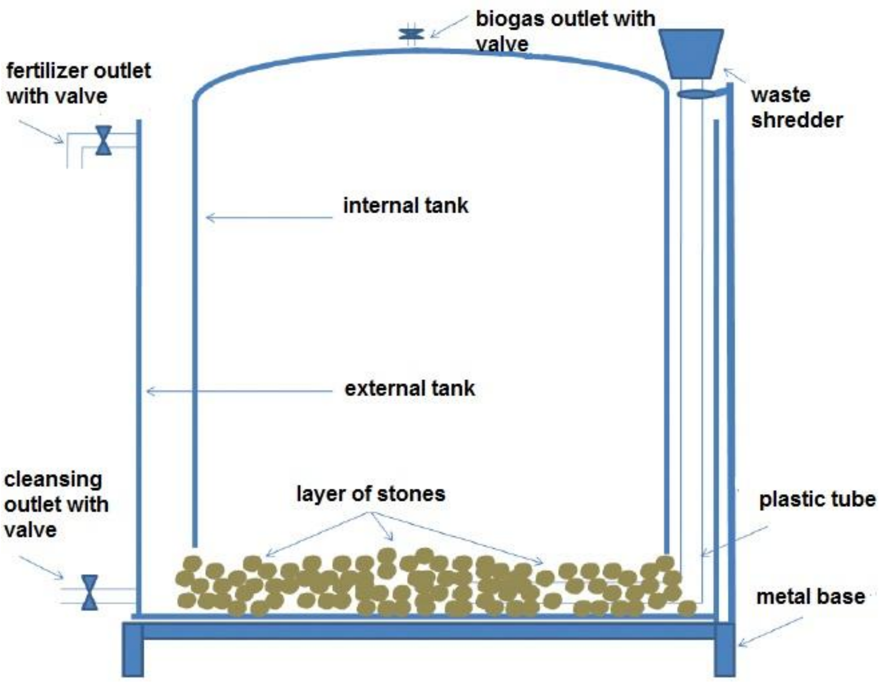

Figure 21: The proposed biogas plant design.

5.1 Initial investment

After consulting some experienced people in the market prices of the material required in addition to the personal experience gained by the researcher, the cost for constructing the used biogas unit may be estimated as follows:

Table 24: Requirements and cost for constructing family biogas unit.

Requirements	Cost (NIS)
1500 L tank	420
1000 L tank	370
Gas and fertilizer valves and connectors	200
Metal base	180
Plastic pipes	80
Miscellaneous	50
Total	1300

As shown in the previous table, the initial investment to construct a floating tank biogas unit is 1300 NIS. The electric waste shredder was not included in estimating the cost of a biogas unit, this is because from the researcher experience it was concluded that using electric waste shredder is not practical to deal with and it requires electricity source to operate.

5.2 Monthly Running cost

The monthly running cost for operating the family biogas plant may come from replacing some of the used gas transporting pipes, replacing some valves or hiring a laborer to fix or clean the unit. In addition to that, the price of using water in the digester in the case of using clean water instead of waste water.

The cost of hiring a laborer or fixing the biogas unit is approximated to 120 NIS/year; that is 10 NIS/month.

The water needed to operate the biogas unit in similar waste addition rate as this study is 12 kg/day; that is 0.012 m^3/day. According to Palestinian Central Bureau of Statistics PCBS, the price of 1 m^3 of water is 4-5 NIS. (PCBS, 2013)

So, water monthly cost = water used per day* 30 day * water price per m^3.

Monthly water cost= 0.012 m^3/day * 30 days * 5NIS/m^3 = 1.8 NIS

To approximate the calculations 1.8 NIS is assumed approximately 2 NIS.

Total monthly running cost = 10 NIS + 2 NIS = 12 NIS.

5.3 Biogas and organic fertilizer profit

The biogas unit produces both biogas and organic fertilizer. The economic benefits from biogas are difficult to define. Biogas as a fuel cannot be sold on the open market, so its value must be defined in terms of other fuel, in this research study biogas is assumed to replace LPG since it is the main cooking fuel in Palestine. The profit from biogas and the organic ferilizer can be estimated as follows:

Biogas profit: Based on the experiment results, the biogas produced is sufficient to provide for the family needs of cooking fuel; this means it is sufficient to replace the LPG that is usually used for cooking. An average Palestinian family needs one 12 kg-bottle of LPG per month. The price of LPG in West Bank- Palestine fluctuates due to some political reasons. But on average the price of 12kg bottle is 65 NIS.

So, the biogas profit = 65 NIS/month.

Fertilizer profit: the biogas unit produces organic fertilizer. The fertilizer produced can save the family the cost of buying fertilizers from the market for their farm or garden and can sell the surplus to neighboring farmers.

According to (El-Jaber, 1993) as cited by (Hassan, 2004) the organic matter contains from 65-90% volatile solids and 30-60% of the volatile solids (depending on the type of the organic matter) is converted by anaerobic digestion into biogas. If the averages for the previous percentages (77.5% and 45% respectively) are taken for calculations then:

The amount of organic waste (introduced into the digester) that is converted into biogas

= monthly loaded organic waste weight X 77.5% X 45%.

In the case of adding 12 kg organic waste per day, the amount of organic waste that is converted to biogas monthly

= 12 kg/day * 30 days * 77.5% * 45% = 125.6 kg biogas / waste

Then; the amount of organic matter that is left as a fertilizer each month

= amount added monthly – converted amount into biogas

=12 kg/day * 30 day – 125.6 kg = 234.4 kg.

That is, almost 234 kg of fertilizer is produced per month from the biogas unit.

According to Palestinian ministry of agriculture, the cheapest fertilizer available at Palestinian markets is ammoniac which cost to consumer 62 NIS for the 25 kg bag. Assuming that the fertilizer produced can be sold at 10% of ammoniac price, this assumption is made because the produced fertilizer is in a liquid form and is not processed enough to gain a higher price, then the produced fertilizer is salable at:

62 NIS/ (25 kg) * 10% = 0.25 NIS/kg

So, the fertilizer profit = 234 kg/month * 0.25 NIS/kg = 58.5 NIS/month.

5.4 Total profit

The total monthly profit from running the biogas digester is the sum of biogas profit and fertilizer profit subtracting the running cost. But to be more realistic, some people may not sell the produced fertilizer. So, two cases are made to find out the total profit from each, the cases are:

The first case: assumes selling the fertilizer in addition to using the biogas.

The second case: assumes using biogas only without selling the fertilizer.

In the first case (selling the fertilizer in addition to using biogas) the total monthly profit = Biogas profit + fertilizer profit – running cost

= 65 NIS + 58.5 NIS – 12 NIS = 111.5 NIS

In the second case (using biogas only without seling the fertilizer) the total monthly profit = Biogas profit – running cost

= 65 NIS – 12 NIS = 53 NIS

5.5 The simple payback period

The simple payback period is calculated for the two cases mentioned in the previous section.

The simple payback period = initial investment / monthly profit

In the first case (selling the fertilizer in addition to using biogas) the simple payback period = 1300 / 11.5 = 11.6 months, approximated to 1 year.

While in the second case (using biogas only without selling the fertilizer) the simple payback period = 1300 / 53 = 24.5 months, approximated to 2 years.

This means that the Palestinian family will get back their initial investment of constructing a floating tank biogas unit within 1-2 years. This time period is considered reasonable.

Hassan and Al Sadi reported a close payback period for constructing family sized biogas units in Palestine; they both reported 1.8 years as the payback period (Hassan, 2004) (Al Sadi, 2010).

Chapter Six

Main Findings and Recommendations

6.1 Main Findings

The following are the main findings of this research study:

There is a relatively good knowledge about biogas in the Palestinian communities, since 80% of the surveyed people have previously heard about biogas and 78% of them knew that biogas is produced through the digestion of organic waste.

Positive trends are detected toward knowledge, acceptance and willing to use biogas technology in the rural Palestinian communities.

Results indicated that 68% of the surveyed population prefer to use biogas as fuel for cooking – in case they adopted the technology-.

Results indicated that 60% of the surveyed population prefer to use biogas if the payback period is within 1 year; it is concluded through the economic evaluation that the payback period is 1-2 years. This is considered reasonable and acceptable.

The biogas quantity produced from the four waste mixtures is 1.18-1.43 kg/day, which represents a financial added value to rural families.

The weight of biogas requirement is almost 3 times more than the requirement of LPG, which indicates that the 12 kg bottle of LPG is equivalent to 36 kg of biogas.

The initial investment to construct a floating tank biogas unit is 1300 NIS, the monthly running cost is 12 NIS. The simple payback period is 1 year if the fertilizer is sold in the market and 2 years if the fertilizer is not sold. This time period is considered reasonable.

Using positive results obtained in this study, biogas technology should be encouraged and promoted in rural Palestinian communities due to several reasons:

The most followed method of disposing animal waste is through fertilizing the plants; the adoption of biogas technology does not only provide energy source, but also produces organic fertilizer for plants.

Using biogas technology reduces the amount of waste that is diverted to landfills, abandoned or burned. Thus; reduces the cost of waste disposal, save landfill space and reduces environmental and health subsequences arising from inappropriate disposal.

6.2 Recommendations

Promotion and dissemination of the benefits of biogas should be carried out and target the rural areas where feedstock is available.

Subsidies (from government or NGOs) should be provided for rural families to help in constructing biogas plants, keeping in mind that those who will use the biogas should have some financial stake in the construction or they may not have a sufficient sense of ownership to maintain the plant.

Encourage the private sector investment in biogas technology because this will support sustainability.

Each biogas project should be economically and socially studied to ensure its success and continuity.

Government should adopt green energy incentives scheme to ensure the success of small scale biogas projects.

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Appendix I

In the name of God the Merciful

An-Najah National University

Faculty of Graduate Studies

Questionnaire

Peace be upon you and God's mercy and blessings

This questionnaire is designed to gather information about the knowledge of the Palestinian community concerning biogas technology, and their acceptance and willing to use biogas technology at the household level. It also aims to gather information concerning your opinion in the methods used to dispose household, animal and agricultural waste and its effects on the surrounding environment at the study society.

Biogas is produced from the digestion of organic animal, plant, human and some industrial waste in the absence of oxygen. This is performed in a special chamber working under specified conditions. The produced biogas can be used as a source of fuel (cooking fuel, electricity production, running vehicles , etc).

In addition to biogas, this process produced organic fertilizer that can be used to improve the production of agricultural crops.

The data that is collected will be kept confidential and will be used to scientific research purposes only. So, please fill the required data truthfully and objectively.

Thank you for your kind cooperation

Supervisor: Prof.Dr Marwan Haddad

Researcher: Dania Maraka

Date:

First domain: General information

1. Name of village/ city:					
2. Gender:	a. male	b. female			
3. Age:					
4. Number of family members:					
5. Housing:	a. separate house	b. apartment			
6. Work type	a. agricultural sector	b. trade sector	c. government sector		d. Private sector
7. Educational level:	a. uneducated	b. elementary	c. preparatory	d. secondary	e. university graduate
8. Average family income (in shekels)	a. less than 1000	b. 1000 - 2000	c. 2000 - 3500		d. more than 3500
9. Health insurance availability	a. yes	b. no			
10. Home garden availability	a. yes	b. no			
11. Home garden type? (choose all that apply)	a. flowers	b. vegetables	c. fruit trees		d. non fruit trees
12. Raising animals near the house?	a. yes	b. no			

13. If your previous answer is yes, please fill the following table:

Type	Number
Poultry and rabbits	
Birds	
Sheep	
Cows	
Else (determine): ………….	

14. Cleaning animals' farm once every: a. day b. 2-4 days c. 5-7 days d. more than 7 days

15. Methods of dealing with animal manure (put X in front of the choice that applies):

	Method	All	Most	Some	None
a.	Selling it to fertilizers factories				
b.	Using it as a fertilizer to my plants				
c.	Producing biogas from it				
d.	Disposing it in waste containers				
e.	Leaving it in place				

16. Distance between my house and the nearest household waste disposal site is about … m.

17. Methods of dealing with household waste (put X in front of the choice that applies):

	Method	All	Most	Some	None
a.	Burning the waste				
b.	Disposal in public containers				
c.	Feeding organic waste to the animals				
d.	Fermenting household organic waste to obtain biogas and / or organic fertilizer				
e.	Disposal in a nearby land				
f.	Other (determine): ...				

18. Methods of dealing with wastewater (put X in front of the choice that applies):

	Method	All	Most	Some	None
a.	Drained off through wastewater network				
b.	Drained off to the absorption pit				
c.	Drained off through open canal				
d.	Using it to irrigate plants				

19. If you work in the agricultural sector, fill the following table:

Planting type		Area (donum)	Irrigation type		
			Drip irrigation	Sprinkler irrigation	Surface irrigation (the traditional way)
Greenhouse					
Outside planting	Trees				
	Vegetables				

20. Methods of dealing with agricultural waste (put X in front of the choice that applies):

	Method	all	most	Some	none
a.	Burn it in the farm				
b.	Use it as animal feed				
c.	Left it at the land or its borders				
d.	Burn it to get energy				
e.	Gather the straw in the form of molds				
f.	Fermenting the plant remains to obtain biogas and / or organic fertilizer				
g.	Else (determine):…..				

Second domain: participants knowledge about biogas

Have you ever heard about biogas?				
a. yes	b. no			
If your previous answer is yes, where did you hear about biogas?				
a. school or university	b. media	c. internet	d. workshops	e. else (determine….)
What do you think biogas is produced from?				
a. burning organic waste	b. petroleum	c. organic waste digestion	d. no opinion	
I think that using biogas technology reduces the final waste volume.				
a. strongly	b. agree	c. no opinion	d. disagree	e. strongly

agree				disagree
I think that the primary cost of construction a biogas unit is high				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree
I think that the digestion of organic waste through biogas technology produces solid and liquid output.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree
I think that the digestion of organic waste produces a fertilizer for plants.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree
I think that using biogas technology had positive impacts on the environment.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree

Third domain: participants acceptance and willing to use biogas technology

I'd like to buy and use biogas unit in my house or farm.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree
I will use biogas technology if its initial construction cost is compensated in:				
a. 1 year	b. 2-5 years	c. more than 5 years		
I will use biogas technology if it will have financial profit on my family.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree
I think there are other alternatives better than biogas technology to treat organic waste.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree
I don't mind the separation of organic waste (kitchen and garden waste) from other household waste.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree
I think that operating a biogas unit in the house or farm will require a lot time and effort.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree
I have fears regarding the quality of the fertilizer quality resulting from biogas unit.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree

If I own a biogas unit, I have fears regarding my ability to fix it by my own in case any damage occurs.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree
If I own a biogas unit, I have fears regarding the unavailability of appropriate expertise capable of following up the unit and its maintenance.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree

Fourth domain: participants utilizing preferability of biogas and the organic fertilizer

I prefer to utilize the energy resulting from biogas in:			
a. providing gas for cooking	b. generate electricity to operate a device (ex: refrigerator)	c. house heating	d. house lightening

I would like to use the fertilizer resulting from biogas technology at my farm or garden.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree
3. Using biogas is preferred on my house level.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree
4. Using biogas is environmentally and economically feasible.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree

Fifth domain: management aspects

I think the process of biogas unit management should be:				
a. individual	b. joint			
I would like to use biogas unit in my house and by house management only.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree
If biogas unit management is joint, I would like to participate in a management committee regarding it.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree
I recommend the biogas technology to be managed by private company.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree
I recommend the biogas technology to be managed by the government or its local representatives.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree
I recommend the biogas technology to be managed by joint stock company.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree

Sixth domain: financial aspects

Do you know the family's income resulting from using biogas technology?				
a. yes	b. no	c. no opinion		
I recommend the income of biogas technology to be distributed on the village inhabitance equally.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree
I recommend the income of biogas technology to be distributed on the village inhabitance according to their participation level.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree
I recommend that the government participate in biogas technology establishment cost.				
a. strongly agree	b. agree	c. no opinion	d. disagree	e. strongly disagree
What do you recommend to regain the biogas establishment cost out of the following?				
a. produce biogas and sell it collectively. b. put fees on the inhabitants to contribute in the biogas technology, aiming at reducing waste and preserving the environment. c. reduce waste fees to those who participate in operating biogas technology.				

بسم الله الرحمن الرحيم
جامعة النجاح الوطنية
كلية الدراسات العليا
استبيان

السلام عليكم ورحمة الله وبركاته...

يهدف هذا الاستبيان إلى معرفة مدى وعي ومعرفة المجتمع الفلسطيني بتقنية الغاز الحيوي ومدى تقبلهم ورغبتهم في استخدام تقنية الغاز الحيوي للاستخدام المنزلي أو على مستوى المنزل، كما ويهدف إلى جمع المعلومات المتعلقة برأيكم حول الطرق المتبعة في التخلص من النفايات المنزلية والحيوانية والزراعية وتأثيراتها على البيئة المحيطة في مناطق الدراسة.

ينتج الغاز الحيوي عند تخمر المخلفات العضوية الحيوانية والنباتية والبشرية وبعض المخلفات الصناعية بمعزل عن الأكسجين، ويتم ذلك في حجرة خاصة تعمل تحت ظروف محددة. يمكن استخدام الغاز الناتج كمصدر للطاقة (غاز للطبخ، توليد الكهرباء، تسيير المركبات وغيرها). بالإضافة للغاز الحيوي ينتج عن هذه العملية سماد عضوي يمكن استخدامه لتحسين إنتاج المحاصيل الزراعية.

إن ما سيتم جمعه من معلومات سيحاط بالسرية التامة وسيستخدم لأغراض البحث العلمي فقط، لذلك نرجو منكم تعبئة المعلومات المطلوبة بصدق وموضوعية.

شاكرين لكم حسن تعاونكم

المشرف: البروفسور مروان حداد.

الباحثة: دانيا مرقة.

التاريخ:

المحور الأول: معلومات عامة

المدينة: /اسم القرية					
الجنس:	أ. ذكر	ب. أنثى			
العمر:					
عدد أفراد العائلة:					
طبيعة السكن:	أ. منفصل	ب. شقة بعمارة			
نوع العمل:	أ. قطاع زراعي	ب. قطاع تجاري	ج. قطاع حكومي	د. قطاع خاص	
المستوى التعليمي:	أ. غير متعلم	ب. ابتدائي	ج. إعدادي	د. ثانوي	هـ. جامعي
متوسط دخل الأسرة الشهري (بالشيكل):	أ. أقل من 1000	ب. 1000 – 2000	ج. 2000 – 3500	د. أعلى من 3500	
توفر تأمين صحي للعائلة	أ. نعم	ب. لا			
توفر حديقة منزلية:	أ. نعم	ب. لا			
ما طبيعة الحديقة؟ (اختر كل ما ينطبق)	أ.أزهار	ب. خضروات	ج. أشجار مثمرة	د. نباتات زينة	
تربية حيوانات حول المنزل	أ. نعم	ب. لا			

إذا كانت إجابتك السابقة نعم، املأ الجدول التالي:

النوع	**العدد**
دواجن وأرانب	
طيور	
أغنام	
أبقار	
أخرى (حدد):	

تنظيف مزرعة الحيوانات

مرة واحد كل:

أ. يوم **ب. 2-4 أيام** **ج. 5-7 أيام** **د. أكثر من 7 أيام**

طرق التعامل مع مخلفات الحيوانات: (ضع إشارة X أمام الخيار الذي ينطبق)

	الطريقة	**جميعه**	**معظمه**	**بعضه**	**لا شيء**
أ.	بيعه لمصانع الأسمدة				
ب.	استخدامه كسماد لمزروعاتي				
ج.	تخميره لانتاج الغاز الحيوي				
د.	القاءه في حاويات النفايات				
و.	تركه بالمكان				

المسافة ما بين منزلي وأقرب مكان للتخلص من النفايات المنزلية هو ....م تقريبا.

طرق التعامل مع المخلفات المنزلية: (ضع إشارة X أمام الخيار الذي ينطبق)

	الطريقة	**جميعها**	**معظمها**	**بعضها**	**لا شيء**
أ.	حرق النفايات				
ب.	التخلص منها في الحاويات العامة				
ج.	إطعام النفايات العضوية للحيوانات				
د.	تخمير النفايات المنزلية العضوية للحصول على الغاز الحيوي و/أو السماد العضوي				
و.	إلقائها في أرض قريبة				
هـ	أخرى (حدد):				

طرق التعامل مع المياه العادمة (المجاري): (ضع إشارة X أمام الخيار الذي ينطبق)

	الطريقة	**جميعها**	**معظمها**	**بعضها**	**لا شيء**
أ.	تصريفها في شبكة الصرف الصحي				
ب.	تصريفها في حفرة امتصاصية				
ج.	تصريفها من خلال قناة مفتوحة				
د.	استخدمها لري المزروعات				

إذا كنت تعمل بالقطاع الزراعي، املأ الجدول التالي:

نوع الزراعة		**المساحة (دونم)**	**نوع الري**			
			الري بالتنقيط	الري بالرشاشات	الري بالقنوات (الأسلوب التقليدي)	الزراعة بعلية (مياه الامطار)
دفيئات بلاستيكية						
زراعة خارجية	أشجار					
	خضروات					
	حبوب					

طرق التعامل مع المخلفات الزراعية: (ضع إشارة X أمام الخيار الذي ينطبق)

	الطريقة	**جميعها**	**معظمها**	**بعضها**	**لا شيء**
أ.	تحرق في المزرعة				
ب.	تستخدم كطعام للحيوانات مباشرة				
ج.	تترك في الأرض أو على حدودها				
د.	تحرق للحصول على الطاقة				
و.	يجمع القش على شكل قوالب				
هـ.	تخمر البقايا النباتية للحصول على سماد أو غاز حيوي				
ي.	أخرى (حدد):				

المحور الثاني: مدى معرفة المشارك حول الغاز الحيوي

هل سمعت عن الغاز الحيوي مسبقا؟				
أ. نعم	ب. لا			
إذا كانت إجابتك السابقة نعم، من أين سمعت عن الغاز الحيوي؟				
أ. المدرسة أو الجامعة	ب. وسائل الإعلام	ج. الانترنت	د. ورشات عمل	هـ. أخرى (حدد):.....
باعتقادك، عن ماذا ينتج الغاز الحيوي؟				
أ. حرق النفايات العضوية	ب. البترول	ج. تحلل النفايات العضوية	د. لا رأي لي	
أعتقد أن استخدام تقنية الغاز الحيوي تقلل من حجم النفايات النهائي.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة
أعتقد أن التكلفة الأولية لإنشاء وحدة غاز حيوي مرتفعة.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة
باعتقادي،ينتج عن تحلل النفايات العضوية عبر تقنية الغاز الحيوي مخلفات سائلة وصلبة.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة
باعتقادي، ينتج عن تحلل النفايات العضوية سماد للنباتات.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة
أعتقد أن استخدام تقنية الغاز الحيوي له آثار ايجابية على البيئة؟				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة

المحور الثالث: مدى تقبل المشارك لتقنية الغاز الحيوي ورغبته في استخدامها:

لدي الاستعداد لشراء وحدة غاز حيوي واستخدامها في منزلي أو مزرعتي.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة
سأستخدم تقنية الغاز الحيوي إذا كانت تكلفة إنشاءها الأولية تعوض خلال:				
ب. سنة	ب. 2-5 سنوات	ج. أكثر من 5 سنوات		
أعتقد أن تقنية الغاز الحيوي ستعود بالنفع المادي على أسرتي.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة
أعتقد أن هناك بدائل أخرى أفضل من تقنية الغاز الحيوي لمعالجة النفايات العضوية.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة
لا أمانع فصل النفايات العضوية (نفايات المطبخ والحديقة) عن باقي نفايات المنزل.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة
أعتقد أن تشغيل وحدة غاز حيوي في المنزل أو المزرعة سيتطلب الكثير من الوقت والجهد.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة
لدي مخاوف حول تدني نوعية السماد الناتج من استخدام تقنية الغاز الحيوي.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة
في حال اقتنائي وحدة غاز حيوي، أخشى من عدم قدرتي على صيانتها في حال حدوث عطل.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة
في حال اقتنائي وحدة غاز حيوي، أخشى من عدم توفر خبرات ملائمة قادرة على متابعة عمل الوحدة وصيانتها.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة

المحور الرابع: توجه المشترك لاستخدام الغاز الحيوي والسماد العضوي الناتج:

أفضّل استخدام الطاقة الناتجة من الغاز الحيوي في:			
أ. تزويد غاز الطبخ	ب. توليد الكهرباء لتشغيل جهاز في المنزل (كالثلاجة)	ج. تدفئة المنزل	د. إنارة المنزل

أود استخدام السماد الناتج عن تقنية الغاز الحيوي في حديقة منزلي أو مزرعتي:				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة
3. استخدام الغاز الحيوي أمر محبذ على المستوى المنزلي.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة
3. استخدام الغاز الحيوي مجدي اقتصاديا وبيئيا.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة

المحور الخامس: النواحي الإدارية:

أعتقد أن إدارة تقنية الغاز الحيوي عملية:		
أ. فردية	ب. جماعية	

أؤيد استخدام تقنية الغاز الحيوي في المنزل وبإدارة منزلية فقط.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة
لو كانت إدارة تقنية الغاز الحيوي جماعية، أود المشاركة في لجنة إدارة بهذا الخصوص.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة
أوصي بأن تكون إدارة استخدام تقنية الغاز الحيوي من خلال شركة خاصة.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة
أوصي بأن تكون إدارة استخدام تقنية الغاز الحيوي من خلال الحكومة أو من يمثلها محليا.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة
أوصي بأن تكون إدارة استخدام تقنية الغاز الحيوي من خلال شركة مساهمة.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة

المحور السادس: النواحي المالية:

هل تعرف مقدار مدخول الأسرة من استخدام تقنية الغاز الحيوي؟		
أ. نعم	ب. لا	ج. لا رأي لي

أوصي بأن تكون عوائد تقنية الغاز الحيوي توزع على سكان القرية بالتساوي.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة
أوصي بأن تكون عوائد تقنية الغاز الحيوي توزع على المشاركين بالتقنية حسب نسب المشاركة.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة
أوصي بأن تساهم الحكومة في تكلفة إنشاء تقنية الغاز الحيوي.				
أ. أوافق بشدة	ب. أوافق	ج. لا رأي لي	د. أرفض	هـ. أرفض بشدة

ما هي الإجراءات التي توصي بها لاستعادة تكلفة تقنية الغاز الحيوي؟
أ. إنتاج الغاز وبيعه جماعيا. **ب. وضع رسوم/ ضرائب على السكان للمساهمة في تقنية الغاز الحيوي بهدف تقليل المخلفات والحفاظ على البيئة.** **ج. تخفيض ضرائب النفايات لمن يشارك في تشغيل تقنية الغاز الحيوي.**

Appendix II

Table 25: Phase 1 experiment results.

Phase 1: mixed cow manure and food residues			
date	day number	biogas produced (gm)	Digestate temperature
13-Jul	1	1080	28.5
14-Jul	2	1120	29.5
15-Jul	3	1095	28.5
16-Jul	4	1300	32
17-Jul	5	1120	30.5
18-Jul	6	1200	30.5
19-Jul	7	1240	31
20-Jul	8	1205	30
21-Jul	9	1230	30
22-Jul	10	1185	30
23-Jul	11	1240	31
24-Jul	12	1120	30
25-Jul	13	1215	31
26-Jul	14	1125	31
27-Jul	15	1250	31.5
28-Jul	16	1230	31

Table 26: Phase 2 experiment results

Phase 2: cow manure			
Date	Day number	Biogas produced (gm)	Digestate temperature
31-Jul	1	1040	30.5
1-Aug	2	1425	32
2-Aug	3	1330	32
3-Aug	4	1505	33
4-Aug	5	1520	34
5-Aug	6	1460	33.5
6-Aug	7	1390	32
7-Aug	8	1400	32.5
8-Aug	9	1425	32.5
9-Aug	10	1290	31
10-Aug	11	1380	32
11-Aug	12	1530	34
12-Aug	13	1485	34
13-Aug	14	1470	33
14-Aug	15	1500	33
15-Aug	16	1475	33

Table 27: Phase 3 experiment results

Phase 3: Sheep manure			
Date	Day number	Biogas produced (gm)	Digestate temperature
18-Aug	1	1240	32
19-Aug	2	1320	32.5
20-Aug	3	1250	32
21-Aug	4	1420	33
22-Aug	5	1520	33.5
23-Aug	6	1450	33
24-Aug	7	1320	32
25-Aug	8	1500	33
26-Aug	9	1450	32.5
27-Aug	10	1600	34
28-Aug	11	1520	33.5
29-Aug	12	1530	33.5
30-Aug	13	1500	33
31-Aug	14	1470	33
1-Sep	15	1370	32
2-Sep	16	1480	33

Table 28: Phase 4 experiment result

Phase 4: poultry manure			
Date	Day number	Biogas produced (gm)	Digestate temperature
5-Sep	1	1520	33
6-Sep	2	1300	32.5
7-Sep	3	1370	33
8-Sep	4	1400	33
9-Sep	5	1150	31
10-Sep	6	1220	32
11-Sep	7	1200	3.5
12-Sep	8	1200	31
13-Sep	9	1230	31
14-Sep	10	1300	32
15-Sep	11	1370	32
16-Sep	12	1320	31.5
17-Sep	13	1300	31
18-Sep	14	1280	30.5
19-Sep	15	1290	31
20-Sep	16	1320	32

Appendix III

ANCOVA Analysis 1

The GLM Procedure

Class Level Information

Class	Levels	Values
TRT	4	1 2 3 4

Number of observations 64

ANCOVA Analysis 2

The GLM Procedure

Dependent Variable: gas

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	1070881.423	133860.178	52.36	<.0001
Error	55	140617.015	2556.673		
Corrected Total	63	1211498.438			

R-Square	Coeff Var	Root MSE	gas Mean
0.883931	3.794193	50.56355	1332.656

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TRT	3	638945.3125	212981.7708	83.30	<.0001
time	1	57395.0184	57395.0184	22.45	<.0001
time*time	1	10339.5002	10339.5002	4.04	0.0492
temp	1	320391.7376	320391.7376	125.32	<.0001
temp*temp	1	28979.6971	28979.6971	11.33	0.0014
temp*temp*temp	1	14830.1571	14830.1571	5.80	0.0194

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TRT	3	6541.71559	2180.57186	0.85	0.4711
time	1	20157.33205	20157.33205	7.88	0.0069
time*time	1	10972.09631	10972.09631	4.29	0.0430

temp	1	16068.25208	16068.25208	6.28	0.0152
temp*temp	1	15526.27343	15526.27343	6.07	0.0169
temp*temp*temp	1	14830.15712	14830.15712	5.80	0.0194

Parameter		Estimate	Standard Error	t Value	Pr > |t|
Intercept		162251.5410 B	63493.41805	2.56	0.0134
TRT	1	-15.2587 B	21.58356	-0.71	0.4826
TRT	2	22.9581 B	19.58958	1.17	0.2463
TRT	3	18.0826 B	20.51380	0.88	0.3819
TRT	4	0.0000 B	.	.	.
time		17.8664	6.36295	2.81	0.0069
time*time		-0.7370	0.35577	-2.07	0.0430
temp		-15267.0787	6089.88677	-2.51	0.0152
temp*temp		479.0511	194.39532	2.46	0.0169
temp*temp*temp		-4.9746	2.06549	-2.41	0.0194

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.

ANCOVA Analysis 3

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Tukey-Kramer

TRT	gas LSMEAN	LSMEAN Number
1	1310.95203	1
2	1349.16885	2
3	1344.29334	3
4	1326.21078	4

Least Squares Means for effect TRT
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: gas

i/j	1	2	3	4
1		0.4290	0.6058	0.8939
2	0.4290		0.9933	0.6469
3	0.6058	0.9933		0.8144
4	0.8939	0.6469	0.8144	

Measured and predicted values of gas emission based on the ANCOVA analysis model

ANCOVA Analysis 4

Obs	TRT	Y_measured	Y_Predicted	residual
1	1	1080	1093.31	-13.307
2	1	1120	1074.69	45.309
3	1	1095	1123.14	-28.144
4	1	1300	1290.10	9.900
5	1	1120	1156.14	-36.139
6	1	1200	1165.90	34.102
7	1	1240	1215.62	24.382
8	1	1205	1151.50	53.503
9	1	1230	1156.83	73.165
10	1	1185	1160.70	24.302
11	1	1240	1234.02	5.981
12	1	1120	1164.00	-44.002
13	1	1215	1234.38	-19.376
14	1	1125	1232.34	-107.343
15	1	1250	1278.48	-28.478
16	1	1230	1223.86	6.145
17	2	1040	1140.58	-100.578
18	2	1425	1301.43	123.572
19	2	1330	1315.61	14.391
20	2	1505	1435.05	69.945
21	2	1520	1526.16	-6.158
22	2	1460	1501.21	-41.206
23	2	1390	1357.59	32.406
24	2	1400	1419.27	-19.268
25	2	1425	1424.61	0.395
26	2	1290	1269.85	20.153
27	2	1380	1376.00	4.005
28	2	1530	1563.52	-33.519
29	2	1485	1562.96	-77.960
30	2	1470	1481.06	-11.057
31	2	1500	1477.55	22.450
32	2	1475	1472.57	2.431
33	3	1240	1280.90	-40.897
34	3	1320	1351.41	-31.415
35	3	1250	1310.73	-60.734
36	3	1420	1430.18	-10.179
37	3	1520	1486.57	33.428
38	3	1450	1451.17	-1.172
39	3	1320	1352.72	-32.719
40	3	1500	1466.27	33.731
41	3	1450	1419.73	30.270
42	3	1600	1555.34	44.661
43	3	1520	1523.02	-3.017
44	3	1530	1523.93	6.068
45	3	1500	1478.21	21.785
46	3	1470	1476.18	-6.182
47	3	1370	1365.94	4.064
48	3	1480	1467.69	12.306

49	4	1520	1369.55	150.447
50	4	1300	1333.33	-33.332
51	4	1370	1399.39	-29.389
52	4	1400	1412.10	-12.097
53	4	1150	1212.83	-62.833
54	4	1220	1326.35	-106.351
55	4	1200	1189.44	10.558
56	4	1200	1237.69	-37.688

ANCOVA Analysis 5

Obs	TRT	Y_measured	Y_Predicted	residual
57	4	1230	1243.03	-13.0257
58	4	1300	1350.65	-50.6481
59	4	1370	1353.04	16.9627
60	4	1320	1299.84	20.1650
61	4	1300	1249.63	50.3655
62	4	1280	1206.17	73.8334
63	4	1290	1244.09	45.9053
64	4	1320	1342.87	-22.8729

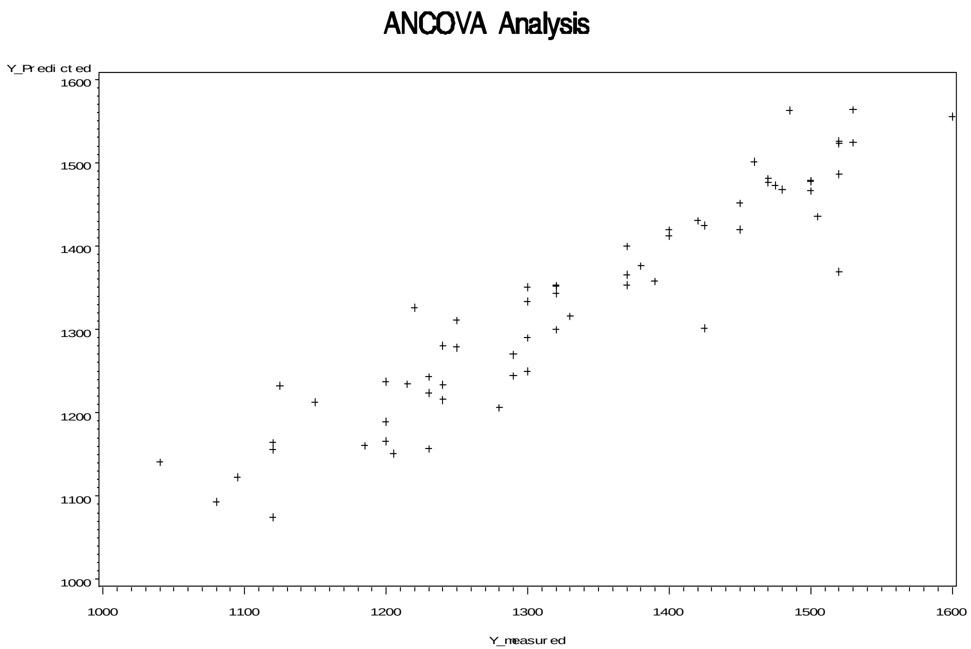

Figure 22: Plot of predicted biogas production vs. measured biogas values (ANCOVA analysis model)

Appendix IV

The nonliniar analyses were based on the following model:

$Y = C*(Time)^{X1} * (Temp)^{X2}$, where Y is gas emission

ALL DATA

Nonlinear Analysis 6

The NLIN Procedure
Dependent Variable gas
Method: Gauss-Newton
Iterative Phase

Iter	c	X1	X2	Sum of Squares
0	10.0000	2.0000	2.0000	1.034E14
1	0.0624	1.9973	2.0005	3.064E9
2	0.0626	1.5648	2.0731	3.6123E8
3	0.1132	0.7502	2.2478	19948900
4	0.2792	-0.1042	2.3763	15183770
5	0.4459	0.0742	2.2669	385774
6	0.4098	0.0151	2.3260	189226
7	0.4128	0.0167	2.3237	188349
8	0.4127	0.0167	2.3238	188349

NOTE: Convergence criterion met.

Estimation Summary

Method	Gauss-Newton
Iterations	8
R	1.577E-6
PPC(c)	4.354E-6
RPC(c)	0.000281
Object	3.271E-7
Objective	188348.6
Observations Read	64
Observations Used	64
Observations Missing	0

NOTE: An intercept was not specified for this model.

Source	DF	Sum of Squares	Mean Square	Approx F Value	Pr > F
Model	3	1.1469E8	38228467	12381.0	<.0001
Error	61	188349	3087.7		
Uncorrected Total	64	1.1487E8			

Parameter	Estimate	Approx Std Error	Approximate 95% Confidence Limits	
c	0.4127	0.1921	0.0286	0.7969
X1	0.0167	0.00708	0.00251	0.0308
X2	2.3238	0.1346	2.0547	2.5929

Nonlinear Analysis 7

The NLIN Procedure

Approximate Correlation Matrix

	c	X1	X2
c	1.0000000	0.0837981	-0.9995010
X1	0.0837981	1.0000000	-0.1132192
X2	-0.9995010	-0.1132192	1.0000000

Measured and predicted values of gas emission based on the NLIN analysis model

Nonlinear Analysis 8

Obs	TRT	Y_measured	Y_Predicted	RESIDUAL
1	1	1080	991.74	88.261
2	1	1120	1086.97	33.025
3	1	1095	1010.07	84.930
4	1	1300	1328.41	-28.411
5	1	1120	1192.61	-72.606
6	1	1200	1196.24	3.764
7	1	1240	1245.50	-5.498
8	1	1205	1156.69	48.307
9	1	1230	1158.97	71.033
10	1	1185	1161.00	23.996
11	1	1240	1254.92	-14.919
12	1	1120	1164.54	-44.539
13	1	1215	1258.42	-43.419
14	1	1125	1259.97	-134.974
15	1	1250	1309.21	-59.209
16	1	1230	1262.78	-32.782
17	2	1040	1161.03	-121.032
18	2	1425	1313.15	111.851
19	2	1330	1322.06	7.945
20	2	1505	1426.88	78.120
21	2	1520	1535.08	-15.079
22	2	1460	1487.65	-27.645
23	2	1390	1340.86	49.138
24	2	1400	1393.15	6.850
25	2	1425	1395.89	29.112
26	2	1290	1252.93	37.074
27	2	1380	1351.00	28.996
28	2	1530	1557.65	-27.648
29	2	1485	1559.73	-74.728
30	2	1470	1456.99	13.006
31	2	1500	1458.67	41.330
32	2	1475	1460.24	14.759
33	3	1240	1298.06	-58.062

34	3	1320	1361.32	-41.322
35	3	1250	1322.06	-72.055
36	3	1420	1426.88	-6.880
37	3	1520	1483.13	36.870
38	3	1450	1436.56	13.442
39	3	1320	1340.86	-20.862
40	3	1500	1443.46	56.536
41	3	1450	1395.89	54.112
42	3	1600	1552.92	47.079
43	3	1520	1502.75	17.246
44	3	1530	1504.94	25.065
45	3	1500	1455.19	44.805
46	3	1470	1456.99	13.006
47	3	1370	1358.01	11.992
48	3	1480	1460.24	19.759
49	4	1520	1394.28	125.719
50	4	1300	1361.32	-61.322
51	4	1370	1420.05	-50.053
52	4	1400	1426.88	-26.880
53	4	1150	1238.53	-88.531
54	4	1220	1337.42	-117.421
55	4	1200	1199.31	0.686
56	4	1200	1248.27	-48.274

Nonlinear Analysis 9

Obs	TRT	Y_measured	Y_Predicted	RESIDUAL
57	4	1230	1250.73	-20.7276
58	4	1300	1348.86	-48.8590
59	4	1370	1351.00	18.9961
60	4	1320	1304.35	15.6527
61	4	1300	1258.42	41.5814
62	4	1280	1213.25	66.7467
63	4	1290	1261.42	28.5757
64	4	1320	1359.47	-39.4695

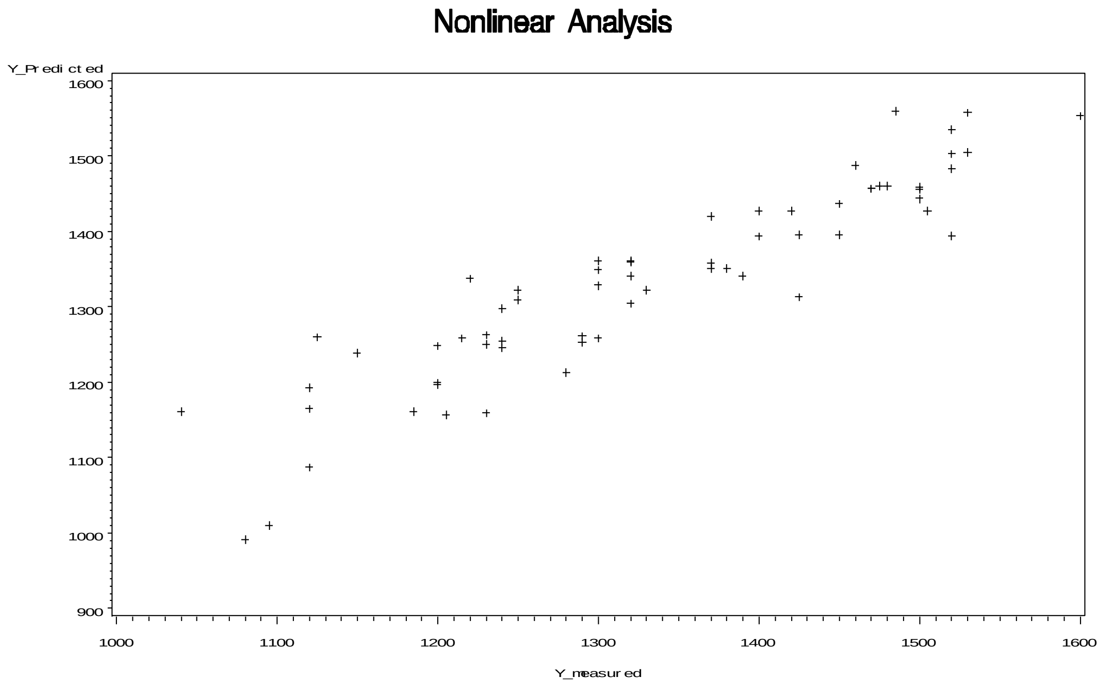

Figure 23: Plot of predicted biogas production vs. measured biogas values (Nonlinear analysis model)

TRT1 10

The NLIN Procedure

Dependent Variable gas

Method: Gauss-Newton

Iterative Phase

Iter	c	X1	X2	Sum of Squares
0	20.0000	0.4100	2.0000	3.024E10
1	2.7761	0.3972	1.9755	3.0887E8
2	3.0242	0.2973	1.7843	29624602
3	5.5403	0.1378	1.4880	242989
4	7.9954	0.0637	1.4038	200498
5	10.4835	0.00165	1.3699	73421.4
6	10.5786	-0.00127	1.3830	24485.3
7	10.5759	-0.00115	1.3829	24478.8
8	10.5762	-0.00116	1.3829	24478.8

NOTE: Convergence criterion met.

Estimation Summary

Method	Gauss-Newton
Iterations	8
Subiterations	1
Average Subiterations	0.125
R	1.398E-7
PPC(X1)	6.559E-6
RPC(X1)	0.000441
Object	5.53E-10
Objective	24478.75
Observations Read	16
Observations Used	16
Observations Missing	0

NOTE: An intercept was not specified for this model.

Source	DF	Sum of Squares	Mean Square	Approx F Value	Pr > F
Model	3	22495746	7498582	3982.29	<.0001
Error	13	24478.8	1883.0		
Uncorrected Total	16	22520225			

Parameter	Estimate	Approx Std Error	Approximate 95% Confidence Limits	
c	10.5762	13.3934	-18.3584	39.5109
X1	-0.00116	0.0156	-0.0348	0.0325
X2	1.3829	0.3761	0.5704	2.1953

The NLIN Procedure

Approximate Correlation Matrix

	c	X1	X2
c	1.0000000	0.5895544	-0.9997902
X1	0.5895544	1.0000000	-0.6049445
X2	-0.9997902	-0.6049445	1.0000000

TRT2 12

The NLIN Procedure
Dependent Variable gas
Method: Gauss-Newton

Iterative Phase

Iter	c	X1	X2	Sum of Squares
0	20.0000	2.0000	2.0000	1.163E14
1	0.0901	1.9986	1.9998	1.9526E9
2	0.0903	1.6960	1.9647	2.3675E8
3	0.1429	1.0514	2.0545	17489165
4	0.3946	0.1216	2.1002	6968388
5	0.8389	0.0283	1.9552	5961643
6	1.0362	0.0244	2.0738	156062
7	1.1108	0.0255	2.0366	44970.5
8	1.1198	0.0256	2.0345	44948.5
9	1.1198	0.0256	2.0345	44948.5

NOTE: Convergence criterion met.

Estimation Summary

Method	Gauss-Newton
Iterations	9
Subiterations	1
Average Subiterations	0.111111
R	3.253E-7
PPC(c)	1.391E-6
RPC(c)	0.000061
Object	7.319E-7
Objective	44948.51
Observations Read	16
Observations Used	16

Observations Missing 0

NOTE: An intercept was not specified for this model.

Source	DF	Sum of Squares	Mean Square	Approx F Value	Pr > F
Model	3	32167076	10722359	3101.12	<.0001
Error	13	44948.5	3457.6		
Uncorrected Total	16	32212025			

Parameter	Estimate	Approx Std Error	Approximate 95% Confidence Limits	
c	1.1198	1.5441	-2.2160	4.4556
X1	0.0256	0.0165	-0.0100	0.0613
X2	2.0345	0.3995	1.1713	2.8976

The NLIN Procedure
Approximate Correlation Matrix

	c	X1	X2
c	1.0000000	0.4499417	-0.9997505
X1	0.4499417	1.0000000	-0.4686391
X2	-0.9997505	-0.4686391	1.0000000

TRT3 14

The NLIN Procedure
Dependent Variable gas
Method: Gauss-Newton
Iterative Phase

Iter	c	X1	X2	Sum of Squares
0	20.0000	2.0000	2.0000	1.141E14
1	0.2560	1.9986	1.9975	1.708E10
2	0.2589	1.8860	1.8011	2.2077E9
3	0.6424	1.6063	1.3237	59502426
4	5.5222	0.5625	-0.2556	32721898
5	4.3681	0.5341	-0.1643	32714333
6	3.2181	0.5015	-0.0518	32708739
7	2.1492	0.4642	0.0870	32708586
8	1.6958	0.4429	0.1733	32701984
9	1.2559	0.4182	0.2784	32696966
10	0.8558	0.3898	0.4064	32695990
11	0.6879	0.3736	0.4845	32688761
12	0.5246	0.3546	0.5787	32682126
13	0.3745	0.3328	0.6919	32677492
14	0.2458	0.3079	0.8276	32677227
15	0.1952	0.2937	0.9089	32668042

16	0.1477	0.2774	1.0054	32658779
17	0.1054	0.2589	1.1191	32650199
18	0.0704	0.2380	1.2517	32643278
19	0.0437	0.2150	1.4049	32638883
20	0.0251	0.1900	1.5797	32636826
21	0.0135	0.1635	1.7748	32633523
22	0.00713	0.1366	1.9843	32617562
23	0.00405	0.1114	2.1926	32565993
24	0.00144	0.0697	2.5568	32483424
25	0.00112	-0.00693	3.3211	27745144
26	0.00279	0.0208	3.0476	27691394
27	0.0130	0.0626	2.6596	26143577
28	0.0177	-0.00770	3.2863	1041304
29	0.0260	0.0108	3.1221	18598.0
30	0.0307	0.0172	3.0666	17460.8
31	0.0334	0.0204	3.0395	17381.8
32	0.0354	0.0224	3.0221	16470.1
33	0.0385	0.0255	2.9958	16107.5
34	0.0422	0.0288	2.9674	15412.0
35	0.0457	0.0316	2.9438	13341.3
36	0.0512	0.0356	2.9096	10933.1
37	0.0535	0.0368	2.8987	7769.7
38	0.0537	0.0369	2.8980	7699.8
39	0.0537	0.0369	2.8980	7699.8

NOTE: Convergence criterion met.

Estimation Summary

Method	Gauss-Newton
Iterations	39
Subiterations	64

TRT3 15

The NLIN Procedure

Estimation Summary

Average Subiterations	1.641026
R	1.811E-6
PPC(c)	1.718E-7
RPC(c)	0.000058
Object	1.22E-6
Objective	7699.835
Observations Read	16
Observations Used	16
Observations Missing	0

NOTE: An intercept was not specified for this model.

Source	DF	Sum of Squares	Mean Square	Approx F Value	Pr > F
Model	3	33048500	11016167	18599.1	<.0001
Error	13	7699.8	592.3		
Uncorrected Total	16	33056200			

Parameter	Estimate	Approx Std Error	Approximate 95% Confidence Limits	
c	0.0537	0.0473	-0.0485	0.1559
X1	0.0369	0.00648	0.0229	0.0509
X2	2.8980	0.2534	2.3506	3.4455

Approximate Correlation Matrix

	c	X1	X2
c	1.0000000	0.3887700	-0.9998985
X1	0.3887700	1.0000000	-0.4010988
X2	-0.9998985	-0.4010988	1.0000000

TRT4 16

The NLIN Procedure

Dependent Variable gas

Method: Gauss-Newton

Iterative Phase

Iter	c	X1	X2	Sum of Squares
0	20.0000	0.4000	2.0000	3.203E10
1	0.5263	0.3878	2.0082	1771202
2	0.5638	-0.0608	2.2875	240132
3	0.7789	-0.0313	2.1542	105382
4	0.9535	-0.0146	2.0846	100168
5	1.1712	0.00201	2.0189	76975.0
6	1.2452	0.00577	2.0068	54903.0
7	1.2487	0.00594	2.0066	54738.5
8	1.2488	0.00594	2.0066	54738.5

NOTE: Convergence criterion met.

Estimation Summary

Method	Gauss-Newton
Iterations	8
Subiterations	2
Average Subiterations	0.25
R	4.53E-6

PPC(X1)	0.000042
RPC(X1)	0.001113
Object	9.79E-8
Objective	54738.49
Observations Read	16
Observations Used	16
Observations Missing	0

NOTE: An intercept was not specified for this model.

Source	DF	Sum of Squares	Mean Square	Approx F Value	Pr > F
Model	3	27030562	9010187	2139.86	<.0001
Error	13	54738.5	4210.7		
Uncorrected Total	16	27085300			

Parameter	Estimate	Approx Std Error	Approximate 95% Confidence Limits	
c	1.2488	2.7576	-4.7086	7.2061
X1	0.00594	0.0214	-0.0402	0.0521
X2	2.0066	0.6307	0.6441	3.3691

The NLIN Procedure

Approximate Correlation Matrix

	c	X1	X2
c	1.0000000	-0.6834661	-0.9998948
X1	-0.6834661	1.0000000	0.6736624
X2	-0.9998948	0.6736624	1.0000000

جامعة النجاح الوطنية

كلية الدراسات العليا

التقييم الاجتماعي الاقتصادي وجدوى استخدام وحدات غاز حيوي في ريف فلسطين

إعداد

دانيا محمد فايز محمد سعيد مرقة

إشراف

أ.د. مروان حداد

قدمت هذه الأطروحة استكمالا لمتطلبات الحصول على درجة الماجستير في العلوم البيئية بكلية الدراسات العليا في جامعة النجاح الوطنية، نابلس.

2014

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الملخص

لقد أدت الآثار البيئية والصحية والاجتماعية المؤذية المرتبطة مع استخدام الوقود الأحفوري والكتلة الحية إلى تحسين الاهتمام المتزايد في البحث عن مصدر طاقة بديل ونظيف مثل الغاز الحيوي. الغاز الحيوي هو وقود يتم إنتاجه عبر عملية التحلل اللاهوائي للمواد العضوية.

إن أي خطة لاستخدام الطاقة الخضراء يجب أن تكون مستدامة بيئيا ومجدية اقتصاديا ومقبولة اجتماعيا. تهدف هذه الدراسة البحثية إلى تقييم الجدوى الاقتصادية والقابلية الاجتماعية لاستخدام وحدات غاز حيوي على المستوى المنزلي في فلسطين. ومن أجل تقييم القابلية الاجتماعية تم إجراء مسح اجتماعي لتقييم مستوى معرفة الفلسطيين وتقبلهم وتوجهاتهم نحو استخدام تقنية الغاز الحيوي. بالإضافة إلى ذلك تم إجراء تجارب عملية على وحدة إنتاج غاز حيوي من نوع الخزان العائم من أجل حساب كمية الغاز الحيوي الناتجة من خلطات مخلفات مختلفة، وإجراء دراسة جدوى اقتصادية.

أظهرت نتائج المسح الاجتماعي أن 80% من المشاركين قد سمعوا عن تقنية الغاز الحيوي عن طريق المدارس والجامعات على وجه الخصوص. بالإضافة لذلك فقد أظهر المشاركون توجهات إيجابية فيما يخص الوعي بتقنية الغاز الحيوي (النسبة المتوسطة 79.8%).

لقد أظهر معظم المزارعون الرغبة في استخدام تقنية الغاز الحيوي في مزارعهم او بيوتهم في حال كان لها فائدة مالية (النسبة المتوسطة 85.8%)، لكنهم أيضا يعتقدون أن تشغيل وحدة غاز حيوي في المنزل او المزرعة ستطلب الكثير من الوقت والجهد (النسبة المتوسطة 56.6%).

بشكل عام، هناك مستوى جيد من القبول والرغبة في استخدام تقنية الغاز الحيوي لكن مع بعض الضمانات مثل تقديم الدعم والمساعدة في صيانة وتشغيل الوحدة.

لقد تم تنفيذ التجربة باستخدام وحدة غاز حيوي من نوع الخزان العائم سعة 1500 لتر. لقد تم اختبار كمية الغاز الحيوي الناتجة في نظام التغذية المستمرة من أربعة خلطات مختلفة من المخلفات. نتائج التجربة تظهر أن أعلى كمية غاز حيوي ناتجة خلال فترة 16 يوم من التشغيل هي على الترتيب: مخلفات الأغنام (22.9 كغ)، ومخلفات الأبقار (22.6 كغ)، ومخلفات الدواجن (20.8كغ) وخليط من بواقي الطعام ومخلفات الأبقار (19 كغ).

تم إجراء تحليل غير خطي لإنشاء نموذج لكمية الغاز الناتجة بدلالة نوع المخلفات ودرجة الحرارة والوقت. وتم إنشاء رسم بياني لكمية الغاز الحيوي الناتجة مقابل المتوقعة.

تم عمل تجربة لحساب معامل تحويل لاحتياجات العائلة من الغاز الحيوي إذا استبدل غاز البترول المسيل. تظهر نتائج التجربة أن معامل التحويل هو 3، أي أن أسطوانة غاز البترول المسيل زنة 12كغ تعادل 36 كغ من الغاز الحيوي. هذه الكمية تغطي بمعدل 70% من متوسط احتياج العائلة الفلسطينية لغاز الطبخ.

في التقييم الاقتصادي لوحدة الغاز الحيوي، قيمة الاستثمار الأولي لإنشاء وحدة غاز حيوي من نوع الخزان العائم هي 1100 شيكل، وبلغت قيمة التشغيل الشهري 7 شيكل. وبلغت فترة الاسترداد البسيطة سنة واحدة في حال تم بيع السماد الناتج في السوق، بينما بلغت سنتان في حال لم يتم بيع السماد.

يوصى بتشجيع استخدام تقنية الغاز الحيوي المنزلية في المناطق الريفية الفلسطينية حيث تتوافر المخلفات وحيث يتم استخدام الغاز الحيوي الناتج. كما ويوصى بعمل برامج ترويجية تهدف إلى تثقيف الناس حول فوائد تقنية الغاز الحيوي في المناطق الريفية.