Survey of Plastic Tube Digesters in Kenya

A Field Assessment Survey of the Performance of Plastic Tube Digesters in Kenya

STUDY REPORT

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Francis Xavier Ochieng

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Study undertaken by	Francis Xavier Ochieng Director, Energie Konsult Ltd, P. O. Box 7764 – 00200, Nairobi, Kenya Tel: +254-714-693299/+254-20-3203802 E-mail: xavierfo@yahoo.com; xvrfrank@gmail.com www.energiekonsult.com

Prepared for	Regional Energy Advisory Platform (East Africa) - REAP (EA) GIZ-REAP; Utumishi Cooperative House, 5th Floor Mamlaka Road, off Nyerere Road, P. O Box 41607-00100, GPO; Nairobi, Kenya Email: gerard.hendriksen@giz.de

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Francis Xavier Ochieng,
C.E.O Energie Konsult Ltd,
P. O. Box 7764 – 00200, Nairobi, Kenya
www.energiekonsult.com

Acknowledgements

The German International Cooperation (GIZ) is through the Energizing Development Programme (EnDev) funding the installation of 15,000 biogas digesters before December 2010 in Rwanda (Renwick et al (2007). In achieving this target, an optimal cost effective biogas digester has to be adopted. It is within this framework that an assessment of Plastic Tube Digesters was undertaken. Essentially, the study sought to ascertain the truth of the performance of digester types in the field (i.e. practice) and also ground truth the claims of practitioners in terms of scope and applicability of the technology.

This output informs the basis on which decisions regarding the adoption, modification or non-adoption of the tubular biogas digesters could be made. More importantly it lays the truth regarding the industry practices and what can be done about it.

This research would not have been possible without Dedan N. Ndungu of Modeline Electrical and Mechanical engineers, who took the time to take me through the various sites, many of which I had no contact information. In addition, it is worth noting that Dedan also provided a video of some of the sites he has installed these PTDs. The first part of the video gives not only the technical information about the digesters, its costs, sizes and installation, but also provides information on the users views on the use of the digester and the benefits they accrued. His contact information can be obtained from page 20.

In addition we gratefully acknowledge the support of Gerard Hendriksen and GIZ-REAP for their invaluable contribution in supporting and reviewing this report. Last but not least we thank Samuel Nene of Pioneer Technologies for providing that very invaluable initial contact list and availing the time to give the consultant more in-depth understanding of the tubular digesters.

Lastly we do acknowledge that the views expressed in this report are entirely the responsibility of the author and may not be the official views of GIZ or its affiliated partner agencies. Thus any comments, contributions and clarifications should be addressed to the author. It is our hope that the work will enrich the ongoing discussions among practitioners, policy makers and academia and welcome any feedback and comments.

Francis Xavier Ochieng,

C.E.O Energie Konsult Ltd,

P. O. Box 7764 – 00200, Nairobi, Kenya

www.energiekonsult.com

Executive Summary

This report documents the results of a field survey of Plastic tubular digesters (PTD) in Kenya. Using a precision level (e) of 17% a total of 39 biogas digesters installed by Pioneer Technologies and other local companies visited. Of these 30 were found to be working, 6 were not working, and of the last three, one had been abandoned and two decommissioned. The two decommissioned Plastic Tube Digesters had been installed at Jomo Kenyatta University of Agriculture and Technology for experimental purposes, whose objectives have since been achieved, and the operation of the PTDs' stopped. In addition visits were also made to two other sites where PTDs had initially been installed. Unfortunately, they had been removed and masonry fixed dome digester installed.

The survey findings indicate that 77% of the users in the sample were satisfied with the PTD. Some however did express disappointment due to the challenges they face. These included low gas pressure during the morning and evening cooking periods, low/insufficient gas production as energy needs increased and lastly insufficient farmer training on how to feed and maintain the biogas digesters.

These challenges are mainly user management problems e.g. what should be fed into the digester and at what frequency. Further, the issue of low gas production in the morning and evening is more of how well the digester is insulated from the elements of weather i.e. sun, rain and wind which can be resolved by training. The use of UV treated double layer plastic did not seem to be a problem only in as far as the plastic tube was not pierced.

The survey noted that the opportunity cost of not using firewood, and the utilisation of animal waste for energy, seems to be the main motivator for the uptake of PTDs. In addition, household cooking and general sanitation of the farm were also mentioned as some of the key motivating factors for installing a tubular biogas digester.

The study brings to fore the importance of user management of the plastic tube digester in ensuring its optimal operation and survival. Thus if the Plastic Tube Digesters are to be replicated elsewhere, priority should be given to extension services and user maintenance. Of additional research importance is the Optimisation of gas production by correct retention time, research into the effects of adding cattle urine, toilet waste, or using other locally available material as well as recycling of slurry. In addition, the success of the biogas project is dependent on the farmers' ability to pay for the digesters and this can be achieved by establishing an efficient credit system.

It is thus realized that with proper maintenance and user education including proper extension services these PTDs can last over 7 years, making them quite sustainable as a source of cooking fuel. This means that under certain proper regulated environment (user practices and management), PTDs can work quite successfully.

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1. About the Field Assessment

1.1 Introduction and Background to the Field Study

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH is through the Energizing Development Programme (EnDev) funding the installation of up to 5,000 biogas digesters in Rwanda. This is undertaken within the framework of the National Domestic Biogas Programme (NDBP). The NDBP aims at installing at least 5,000 biogas units by December 2011 [Rwanda (2009), EJS (2010)], and targets rural households in Rwanda that have 2–3 cows.

However, for many of the rural households the cost of a digester, about € 1,000, is still high despite a € 350 subsidy and a bank credit. Thus, according to the November 2009 project review mission, there was a recommendation that an assessment of cost reduction opportunities be undertaken. Based on GIZ experience in some South American Countries, the possibility of alternative biogas technology other than the fixed dome is now being considered.

The Plastic Tube Digesters (PTDs) as experienced by GIZ in the aforementioned countries provides such an option. Within the Eastern Africa region experience exists in form of Pioneer Technologies who claim that they have installed about 300 PTDs in Kenya since the year 2006. However, there have been no independent surveys that have been undertaken to verify these claims

Initial studies to verify these claims were undertaken by the consultant under the auspices of the Institute of Energy and Environmental Technology (IEET) of Jomo Kenyatta University of Agriculture and Technology (JKUAT). The Consultant together with his team tested the technical performance of two PTDs' from Pioneer Technologies PTDs at IEET field lab. The tests revealed a good technical performance (that is technical operation, gas production, efficiency) , but were however not conclusive due to shorter testing time period and ground water seepage into the surrounding soil in the vicinity of the digester, giving the surrounding soil lower temperature which in turn affected the temperatures inside the digester tube.

Subsequently, the GIZ PTDs study furthers the scope of work done by the Institute and provides an even greater sample space to draw scientifically valid lessons which can be used to deal with the challenge facing NDBP of which this study seeks to solve. It will however be noted that the study used a sample of 39 PTDs out of a total of 136, and sought to identify how many were installed by Pioneer technologies and how many are still working. This study did not however, take into consideration, the technical aspects e.g. the operations, gas production, and efficiency etc of the PTDs surveyed.

1.2 Study Problem

NDBP is interested in assessing the potential of the PTD technology as a possible option for farming households in Rwanda. While there are claims that Pioneer Technologies has installed over 300 PTDs in Kenya, no independent surveys have been done to verify these claims.

In addition, information on Kenya's experience with PTDs is required to asses if and how they can be used to aid in the NBDP's decision making process on whether to introduce the PTDs in Rwanda.

1.3 Justification/Significance of the Study

The study will collect data and other relevant information to enable the NDBP to make sound judgement on whether or not to pursue the introduction of PTDs in Rwanda. In addition the study will verify the claims made by Pioneer Technologies that it has installed about 300 PTDs in Kenya out of which about 90% are operational. The significance of a positive or negative verification of this claim will provide lessons on technology adoption, adaptation and fuel further research in the area of PTDs.

2. Aim, Scope and Expected Deliverables of the Study

2.1 Aim of the Study

The main aim/objective of the assignment was identify the Plastic Tube Digesters (PTDs) installed by Pioneer Technologies in Kenya and to determine how many are working as well as to gather relevant information pertaining to PTDs to be submitted to the Rwanda biogas program.

2.2 Specific Objectives

The study will seek to attain the following:

1. Compilation of a list of PTDs installed by Pioneer Technologies in Kenya. The list will contain the contact details and other pertinent information e.g. status, digester specifications and performance.
2. Visits 39 randomly selected PTDs from the pioneer database to assess their performance and obtain additional technical details.
3. Creation and verification of a database of PTDs installed in Kenya.
4. Draft a report indicating the status of PTDs installed by Pioneer Technologies in Kenya and lessons learnt from experience in using them. This report will be based on the findings of the above objectives

2.3 Scope of the Study

The study being limited both in time and depth of assessment was confined to the general assessment of 39 randomly selected Plastic Tube Digesters. The aim was to give a general picture on the performance of these digesters.

2.4 Expected Deliverables of the Study

Two main deliverables to be provided by this study are:

1. A report detailing the status of PTDs installed by Pioneer Technologies Limited in Kenya highlighting the experiences of the users.
2. A verified data base of PTDs installed in Kenya

3. Structure and Methodology of the Study

The study essentially utilised stratified random sampling to identify about 29% of the total installed PTDs. This translated to about 39 PTDs out of the total 136 PTDs to sample and visit. From the

original list obtained from Pioneer Technologies (Appendix 3), a corrected and reformatted list, which includes location or counties (AG, 2010), was developed.

The need for including counties is based on the demands of the stratified random sampling wherein, in determining the sample size, the data was stratified/divided in accordance with administrative divisions i.e. Counties. Appendix 6 is the unverified results of this correction and stratification while Appendix 5 shows the 39 PTDs physically visited. The final verified database of installed PTDs (Appendix 5.3) after removal for double entries is 135 of which the IEET-JKUAT site has two PTDs'. This results in a total digester database of 136 PTDs.

3.1 Determination of the Sample Size and Digesters to Visit

3.1.1 General Overview

Determination of the number of digesters to visit (sample size, n) out of the total number of digesters (expected population size, N) though complex, was simplified using a number of scientifically proven statistical techniques, which unfortunately ended up giving a slightly different size from the pre-determined sample size given in the Terms of Reference (ToR).

In determining the size of the sample a number of factors are considered, these include: purpose of the study, population size, risk of selecting a "bad" sample and the allowable sampling error. In studies involving a lot of variables and/or high precision demands, then more stringent sample determinations are utilised. In simple quick scoping studies like this one, simple formulas can be applied.

It is however, the question of the population size that tends to seriously impact on the determination of the sample size. Various methods have evolved for determining N (Israel, u.d, Bartlett et. al. 2001). For our purpose an initial population size of 300 was given.

In terms of reducing the risk of selecting a "bad" sample - where a bad sample in this case would refer to selecting only the working digesters or the ones that are not working -the constituents of the sample had to be selected randomly, both in time and space. It also meant that different geo-administrative locations had to be visited. In addition, the telephone contacts that were provided in the Pioneer List were called randomly and whoever agreed to meet us, irrespective of status of digesters, or even its existence/presence was visited. No preference was given to whether the digester was installed by the main study client (i.e. Pioneer Technologies Ltd) or not.

Lastly an acceptable/allowable margin of error, which is also known as the level of precision (e) has to be defined. This is the range at which the true value of the population is estimated to be. Generally researchers increase this value when a higher margin of error is acceptable or decrease it when a higher degree of precision is needed. For this study a higher e value than the normal one of ± 5% was utilised this was due to the uncertainty of the true population (or number) of the PTDs in the field. Further discussion on this is given in appendix 5.6.

It is thus for the above reasons that the initial suggested sample size of 30 PTDs was increased to 39. This allowed us to be able to cover between true populations of between 30 to over 300 installed PTDs.

3.1.2 Digester Sampling and Survey Methodology

The study was undertaken using a stratified sampling methodology, based on geo-administrative units referred to as counties. Whereas other sample methods could have been used to determine the sample size (Bartlett et. al. 2001), the Terms of Reference (ToR) had already a pre-determined minimum sample size of 30 digesters, which was increased to 39, based on statistical analysis (see Annex 7). Thus, the sampling of digesters in Appendix 5 resulted in the following selection of sites (Table 1) based on a stratified sampling approach.

Table 1: Selection of digester sites based on pre-determined sample size (Author)

County	Household location Type	Number of digesters	% of digesters in population	Sample size / county	Sample done
Embu	Rural	3	2%	1	0
Kajiado	Rural	3	2%	1	2
Kiambu	Rural	82	60%	24	24
Kisumu	Rural	5	4%	1	5
Machakos	Rural	7	5%	2	1
Meru	Rural	2	1%	1	0
Muranga	Rural	7	5%	2	3
Nairobi	Urban/Peri-urban	9	7%	3	4
Nakuru	Urban/Peri-urban	9	7%	3	0
Nyeri	Rural	3	2%	1	0
Taita Taveta	Rural	2	1%	1	0
Uasin Gishu	Rural	4	3%	1	0
Total		136	100%	39	39

Realizing that the household location types were similar in certain areas, sampling of the counties was done on the basis of whether they are in rural areas or urban/peri-urban areas. Which allowed the research to concentrate only on certain parts of the country and not transverse the whole country. The premise for this is that the waste being used is cow dung and the biogas is used mainly for cooking. In cases where the different wastes would have been used and/or the end product – in this case biogas had more than the envisaged usage of cooking and lighting, then a more rigorous sample space based on user waste generation habits and biogas usage characteristic would have been necessary, resulting in the need to visit all possible counties in the country.

Subsequently the results of this geo-administrative sampling based on counties to be visited are shown (Table 2). It meant in principle that site visits would be made of Kajiado, Kisumu, Kiambu, Machakos, Muranga and Nairobi Counties.

Table 2: Selection of final sites to visit based on household location type (Author)

Household location Type	Number of digesters	% of digesters in population	Sample size / county	Sample done
Total Rural	118	87%	102	23
Total Urban/Peri-urban	18	13%	2	4
Total	136	100%	105	27

Based thus on the selected sites above, questionnaires were developed (Appendices 1 and 2) and from guidance of a former engineer from Pioneer technologies and the tools indicated in the appendices above, the sites were visited in accordance with the indicated work plan (Table 3). The latitude and longitude of each site was then recorded by use of E-Trex Garmin handheld Geographical Positioning System (GPS).

3.2 PTD Study Revised Work Plan

In meeting the objectives of the assignment, the following work plan (Table 3) was utilised. It is worth noting that names of the localities to be visited are also correlated to the aforementioned counties (Table 1).

Table 3: PTD performance study – Revised work plan (Author)

	Localities to be visited	Tues, 23rd Nov	Wed, 24th Nov	Thur 25th Nov	Frid, 26th Nov	Sat, 27th Nov	Sun, 28th Nov	Mon, 29th Nov	Tue, 30th Nov	Mon, 1ST Dec
Site Visits	Kajiado, Nairobi City									
	Kiambu, Machakos									
	Kiambu, Muranga									
	Nairobi City, Kiambu									
	Miwani									
Data analysis										
Draft report writing, data base creation										
Receipt of comments										
Submission of final report and cleaned data base										

3.3 Challenges and Limitations of the Field Survey

1. Distribution and accessing the digesters: The biggest challenge in the study was not only in identifying the digesters but also in accessing them. The original list obtained from Pioneer technologies lacked contact details of most PTD owners. Therefore, the consultant had to hire the

services of an individual who used to install PTDs for pioneer technologies Ltd. to help him identify the sites. This was both expensive and difficult since there were areas, which could not be accessed by the vehicle. The distance between the various sites was also huge, and meant traversing huge distances while carrying out the survey.

2. Things not covered in the performance assessment: The performance assessment of the PTDs didn't cover the more technical aspects such as gas composition or the digester temperature. But it is assumed that these are in within the acceptable ranges based on the fact that the gas is actually burning on the stove and is almost odourless. Other aspects not covered in the survey include size of the households, their incomes and even household energy expenditure before and after installation of the biogas systems.
3. Time frame constraints: The study was constrained by time not because of poor planning but mainly due to unexpected events e.g. there was a delay in obtaining the initial contact list as well as getting an interview with Pioneer Technologies as it took almost 4.5 weeks before these could be accomplished, leaving only 1.5 weeks for the survey.

4. Results of the Field Survey

4.1 Synopsis of Results

Whereas, the sample space is statistically verifiable as being a representation of the total National population, it is worth pointing out that the inferred results in this study refer to the 136 PTDs'. Extrapolation of these results to National levels will require a more comprehensive survey of at least all possible counties across Kenya.

Further to the above, it should be pointed out that this was a so called "quick and dirty" survey, whose main aim was to quickly assess whether the PTDs installed by Pioneer Technologies Ltd are working.

The results indicate that due to improper book keeping, Pioneer Technologies Ltd could only provide a list of 117 digesters, which was not comprehensive enough in terms of contact details of the purchasers and the exact locations of the PTDs installed. In addition, the list also had duplicate names and inconsistency (The initial list in its original form is attached in Appendix 3). From this list and using an expert in PTD, a new revised, verified and corrected list was made with a total of 136 PTDs. Extrapolating the sample survey data to this population meant that 77% of this 136 PTDs are in working condition. It is difficult to ascertain whether Pioneer technologies have actually installed 300 PTDs as they claim.

4.2 Number of Digesters Installed

Based on the findings of the field survey, the database of Plastic Tube Digesters was updated and now has a total of 136 PTDs. From the sample size of 39 PTDs visited, 20 were installed by Pioneer, while the remaining 19 were installed by other companies and individuals.[1]

1. While in the initial contact Pioneer had claimed to have installed 300 units, their data bank only has 117 units. In explaining this, Pioneer indicated that in the earlier years, not much work went in maintaining a client database. Which in a way implies that user support depending largely on Pioneer technicians who installed the

Subsequently based on the statistical analysis indicated in Figure 1, the following is the current situation of the installed digesters as per the new database.

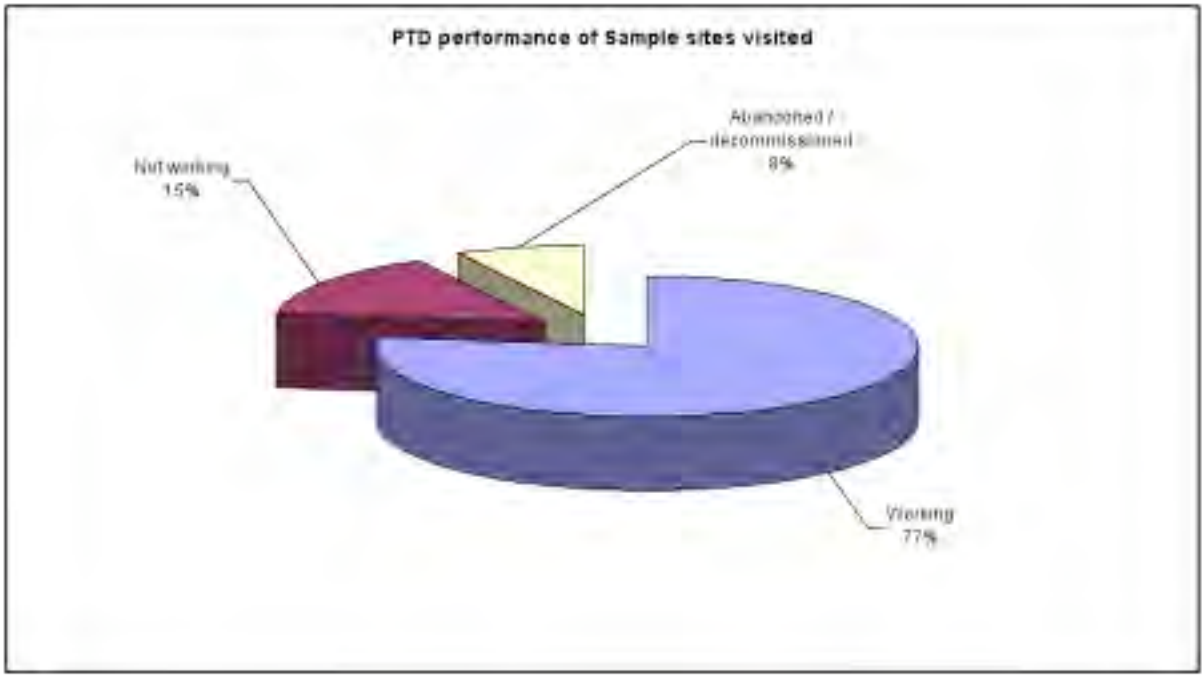


Figure 1: Performance of installed PTDs in sample and in total population (Author)

Figure 1 indicates that 77% of the sampled digesters working. This can be inferred to mean that about 105 PTDs are in working condition, while 21 (15%) are not working. The remaining ten (8%) were either abandoned or decommissioned. However, some PTD owners did express slight dissatisfaction with the working PTDs due to its inability to be used for lighting. Also the low gas pressure during the morning and evening periods,[2] which made cooking take longer than expected, was an issue of concern to some users. The low gas pressure in PTDs is normally caused by temperature changes in the vicinity of the digester.

For plastic tube digesters, the tube is normally placed at 1 meter (at most) from the ground surface. Hence, changes in ambient soil temperature affect gas production.[3] IEET-JKUAT is thus considering in this quarter to study the use of elevated/raised Biogas digester to see how this can lead to constant gas production. This is corroborated by studies from the University of Adelaide - http://www.adelaide.edu.au/biogas/anaerobic_digestion/model/chenmod.ppt - indicating a reduction in methane production and an increase in retention time, as the temperature inside the digester which was being measured by temperature probes was varied from between 10°C to 55°C in respect to either increased warming of the digester wall from the surrounding).

PTDs, and who when they left the company would also leave with this information.

2. From initial IEET – JKUAT field study experiences and GIZ studies (ISAT/GIZ, u.d.), it was noted that microbial process of producing biogas is very sensitive to changes in temperature.

3. The temperature fluctuations between day and night are no great problem for plants built underground, since the temperature of the earth below a depth of one meter is practically constant. households with larger sized fixed dome digesters tended to have a more constant digester temperature leading to uniform gas production since the surrounding soil temperature did not unduly affect the microbial activity inside the digester due to the stonewall.

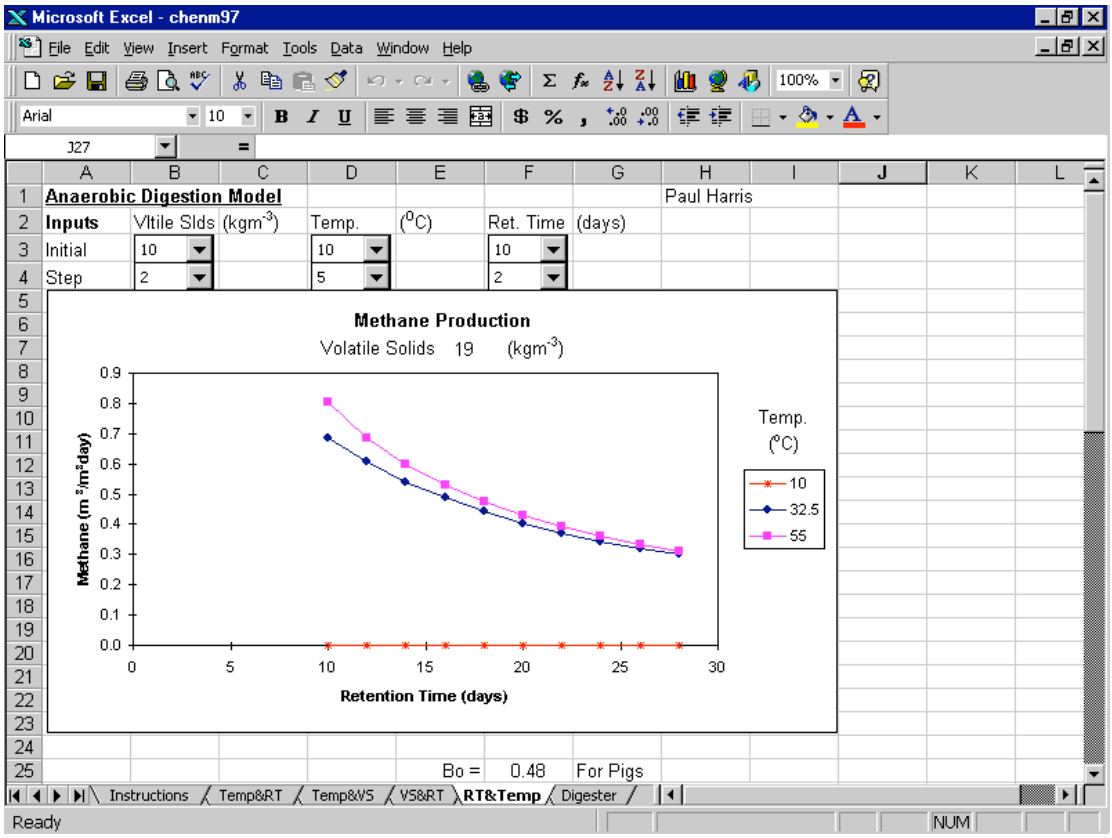


Figure 2: Effect of temperature on methane production in a biogas digester fed with cattle manure

4.3 Digester Material

From discussions with Pioneer Technologies Ltd, the material that is commonly used for their PTDs is Butyl rubber liners. These liners are UV resistant and have a 20-year lifespan. Some other types of these liners contain toxic ingredients that may leach into the digestion chamber thereby killing the digestive bacteria. The ones used by Pioneer technologies are inert in nature. Two forms of these liners exist, based on the thickness. The 40-50 microns are normally thick and are hard to fold at corners and curves but the 300 microns is quite easy to work with.

The current 4th generation of PTDs (Picture 1) from Pioneer Technologies ltd consists mainly of a double layer UV treated polythene material with Glass reinforced Fibre (GRF) and carbon black. The digester has thickness gauge of about 300 micron and an estimated lifespan of about 5-15 years.

Picture 1: A fourth generation biogas digester

4.4 PTD Costs

4.4.1 Costs from Pioneer

The determination of the digester size and available gas storage volume (Table 4) provide us with the types of 4th generation PTDs currently available in the Kenyan Market. These are the standard and large types.

Table 4: Determination of available gas storage volume for a biogas digester

Digester length L (m)	Digester diameter D	Total Digester volume V ($3.14*L*(D/2)^2$) (m^3)	Available gas storage volume (10-30% V) (m^3)
10	1.5	18	6
10	2.5	49	16

1. Standard type (length: 10m, diameter: 1.5 m, total gas volume: 6 m^3), with a daily gas production of = 2.4 m^3/day and costing about KES 42,000 (ca. US$ 525[4])
2. Large type (length: 10m, diameter: 2.5 m, total gas volume: 16 m^3), with a daily gas production of 3.2 m^3/day and costing about KES 65,000 (ca. US$ 812)

The aforementioned costs generally include transportation to most parts of Kenya, the stove, gas pipes, biogas digester bag and installation costs. It does not include the cost of digging the trench where the digester will lie in.

4.4.2 Costs of PTD from the Field Study

The results from the field however indicate different costs from those given by Pioneer Technologies.

4. Exchange rate being 1 USD = KES 80

From the study it was noted that the cost ranged between US$ 250 and US$ 562. Two main reasons are attributed to this discrepancy: First a number of the PTDs in the sample were not installed by Pioneer as such, but by a one Dedan Ndungu before he joined Pioneer in 2006 and also by other companies (see Section 5.1 for a list of companies involved in PTD installations).

Secondly, a trend analysis over the years (Fig 3) shows a slow increase in the general prices of both PTD sizes, which maybe attributed to increased cost of raw materials. For Pioneer's competitors (the aforementioned companies) it was found based on 2009–2010 figures, that for the Standard type it costs about US$ 488, while the large sized costs about US$ 563, making them 7% and 31% cheaper than Pioneer's respectively.

Figure 3: Trend analysis of PTD prices and installations over the years (Author)

Analysis of Figure 3 shows that generally 64% of digesters are of standard size while 36% are the large sized type. It is postulated that the choice for more standard sized digesters is based on its comparatively lower price. However, Fig 4 shows an increase in prices of both standard PTDs (35.7%) and large sized PTDs (55.6%). The increase in digester prices can be attributed to the general increase in input material costs, transport and labour charges. Nevertheless, as farmers come to experience the advantages of bio-digesters and/or as the number of cows they keep increase, the tendency of farmers to move from standard sized PTD, to large sized ones and/or masonry based fixed or floating type bio digesters increases.[5]

4.4.3 Cost of PTDs in Terms of Number of Cows Required

From the updated guidebook on biogas development, the following can be derived (Table 5):

5. During the site visits, the consultant came across 2 sites that initially had PTDs but were decommissioned and replaced with fixed dome biogas digesters The owners had decommissioned the 2 units due to increased demand for gas (especially for lighting) and also as a way of maintaining sanitation and reducing bad odours from cow dung due to the large numbers of zero-grazing cows.

Table 5: Averaged dung requirements for gas production for PTDs

Type of dung	Gas production per kg dung and m^3/day	Average gas production per Kg of dung (m^3)	Dung required (kg) for 2.4 m^3 (Standard digester)	Dung required (kg) for 3.2 m^3 (Standard Digester)
Cattle (cows & buffaloes)	0.023 - 0.040	0.0315	76.19	101.59
Pig	0.040 - 0.059	0.0495	48.48	64.65
Poultry/chicken	0.065 - 0.116	0.0905	26.52	35.36
Human	0.020 - 0.028	0.024	100.00	133.33

Based on the above, the number of cows required can then be determined as follows (Table 6).

Table 6: Number of cows required per PTD

				Number of cows required for twice a week feeding	
Cow type	Daily manure production (kg)	Total solids	Slurry (litres)	Standard sized digester	Large sized digester
Dairy cow	68	47.6	130	1 - 2	2
Indigenous cow	30	21	40-60	4	5

The standard type can work with one dairy cow, whilst the large type may require between 1–2 dairy cows. In the event of local indigenous cows the number of the cows will range from 3–5 depending on the size of the cow, the quantity of dung it removes and the frequency of dung removal.

4.5 Farm Layout and Digester Inlet Feeding Design

The general farm layout with respect to the design characteristics and placement of the PTDs was on average similar. For most parts, 1–3 cows were kept in an enclosure with a cement floor (zero-grazing unit) and their dung taken to the digester either via the cemented drainage canals or manual collection using buckets. At the digester site, two approaches were used for feeding the digesters:

1. Either a rectangular trench was dug where fresh dung was placed. Whenever the digester was to be fed, a bucket would be used to collect the dung from trench and fed into the digester directly.
2. A second more advanced approach involved a masonry modification of the above. The inlet pipe of the digester was enclosed within a 40–60 cm high square masonry tank that is divided into two chambers A and B (Figure 4). The inlet pipe being at the bottom. The two tanks share an inner wall, which has a gate that allows the contents of chamber A to flow into chamber B. Both chambers are sized in such a manner as to have a total volume of 160 litres (80 litres for each chamber). When the slurry (dung mixed with water) has moved from Chamber A into B, the gate is closed. Fresh dung is then periodically added into chamber A and mixed with water (until it reaches the required 80 litres slurry volume). It is allowed to sit there until the next feeding session. During the next feeding session, the gate is opened again and the slurry flows into chamber B. This approach ensures proper mixing of water and dung, and also proper volume

feeding into the digester.

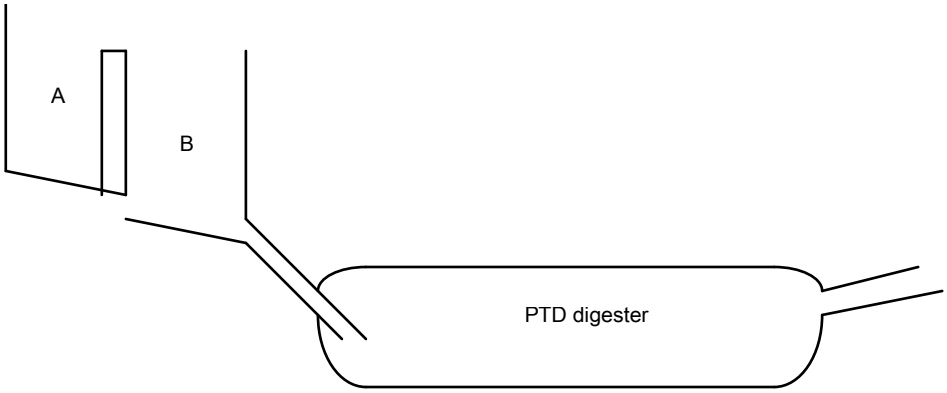


Figure 4: PTD inlet feeding approach

The advantage of this process is that the slurry while in chamber A can actually begin the microbial breakdown of the organic matter, enabling it to easily mix with the decomposing slurry in the digester.

Picture 2: Digester inlet with no trench

Picture 3: Digester inlet with a trench

4.6 Digester Performance

Results of the survey can be summarised from four main factors which in totality ascertain the performance of the PTDs. These are:

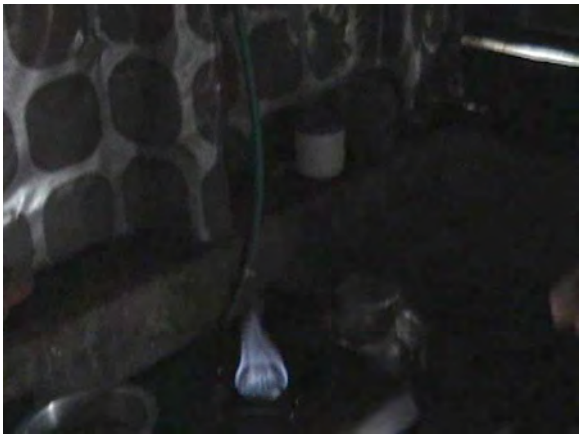
1. Digestion process
    - 39 digesters of the sample size indicated that their digester was producing gas regularly an indication of normal digestion process in the digester. Of these 39 digesters, 2 sites had problems with the digester bag. In both cases the digester bag had developed hole(s) due to piercing. At one site, the owner had repaired it using a bicycle repair kit - normally used to repair punctures in the elastic inner tube of the bicycle tyre. For the other site, the owner had tried using Super Glue™ but gas leakage was still experienced. This had an effect on gas production and the digestion process but the digester is still working to date.
2. State of the digester bag (the PTD itself)
    - Six digesters were not working as the digester bags had been burst/torn or thick scum forming

due to infrequent or inappropriate feeding material. There was one case of a digester that not in use but upon inspection it was realised that the connecting gas transfer pipes from the digester to the kitchen was detached.

- The remaining 30 digesters out of the sample of 39 PTDs had the digester bags still working, some since 2004.
- It was also observed that over 60% from the sample had a digester bag whose outside appearance was clean and in most case shaded from direct sunlight.

3. State and performance of the cooking equipment
    - For all those receiving gas from the digester, all had their cooking stove working and producing sufficient heat for a long period to allow satisfactory cooking.
    - The data analysis revealed that the number of cooking hours ranged from 2 to about 6 per day, the average being about 5 hours daily. Based on the general eating habits of rural and urban populace in Kenya, this meant 1 hour in the morning, 2 hours during lunch time and 2 hours during the evening period. However for meals requiring longer cooking hours like “Githeri” – a mixture of beans and maize, which incidentally is very common among the rural populations in central parts of Kenya, the hours would probably change with 3 to 4 hours being utilised to cook it during mid-day, when incidentally there was more biogas production.
    - There was however a concern that during the morning and late evening gas production is low, limiting the cooking duration and heat intensity. However during mid-day on sunny days, the gas production is quite high. This is indicative of a problem with temperature that allows the digestion bacteria to function. A possible solution to this would be the availability of a gas storage bag. None of the sampled households had one. Alternative approaches would be in terms of digester bag installation, by maybe installing it deeper than 1 meter into the ground. IEET-JKUAT will soon be researching on the use of elevated / raised digester bag for areas with high water table (i.e. swampy areas).

Picture 4: Biogas flame burning in the air above stove



Picture 5: Biogas stove and gas pipe connections

4. State and performance of gas transmission pipes and water traps

- None of the digesters in the sample had a water trap to capture the condensate coming out of the digester. However, the gas transmission pipe were sloping from the Kitchen area back to the digester, hence allowing the condensate to flow back to the digester. All the gas transmission pipes were in good working condition.
- An analysis of the digester performance after the year of installation indicates that of the 20 PTDs' installed in the last 3 years (2008 – 2010), only 2 were not working while 1 had been abandoned (Table 7).

Table 7: Digester performance after the year of installation

	CURRENT PTD STATUS (DECEMBER 2010)				
Installation year	**Number working**	**Number not working**	**Decommissioned**	**Abandoned**	**Total Digesters**
2010	2				**2**
2009	5				**5**
2008	10	2		1	**13**
2007	5	3	2		**10**
2006	5				**5**
2005	2				**2**
2004		1			**1**
2003					
2002	1				**1**
Total Digesters	**30**	**6**	**2**	**1**	**39**

Based on Table 7 it is noted that of 19 digesters installed between 2002 and 2007, 4 were not working and 2 had been decommissioned. Further, it is realized that 68% of the digesters from the previous time period of 2005-2007 were working as the period 2008 – 2010 started. These 68% included a mix of 3rd and 4th generation PTDs. Of these 2 stopped working in 2008 and 1 was abandoned in 2008. The implication being that by 2010 of the working 29 PTDs, 22 were installed between 2005 and 2008 and are still working.

It is worth noting that those digesters that were functioning well were mainly due to the user

management. In cases of the failed digester and/or abandoned digesters, the reasons for their failure were mainly poor user management. For instance in Miwani, a rural setting in Kisumu County, four of the five digesters sampled within this area had failed. The reasons for their failure was mainly to do with user management: over/or under-feeding, no protective fence hence animals had stepped on the digester and in one case, the owner had totally stopped feeding the digester citing the lack of cow dung as he was sourcing it from a neighbouring farm. The only one that was functioning in this area is well maintained.

4.7 Biogas Applications

In all cases (100%) biogas was being used for cooking (Picture 6), and in some cases even baking using a modified biogas baking oven.

Picture 6: Biogas cook stove, with the feed inlet pipe being shown (Author)

Some of the respondents expressed interest in the utilisation of biogas for lighting. However, due to the low gas pressure especially at night,[6] it was not possible. None of the sampled sites had biogas based lighting systems nor more than one biogas cook stove.

Many of the sampled owners/users were happy with the benefits that the system was giving, especially in terms of savings in the use of charcoal and firewood. They were however not aware or did not mentioned other attendant benefits e.g. reduction of indoor air pollution and the simple convenience and cleanliness of the gas.

An additional advantage of using biogas is the utilisation of the slurry. In all the sites visited where the biogas was in good working condition, the slurry obtained was mainly used as an organic fertilizer and soil conditioner and farmers mentioned that the digester acts as a sanitizer as it decomposes the cow dung which when in huge quantities would lead to foul smelling air.

6. Like in the cases of Uganda (Pandey et.al., 2007:51), the low gas pressure normally meant that lighting is not feasible when using a PTD nor is it possible to have many biogas cook stoves connected to one PTD, since it had a corresponding increase in the amount of time spent cooking due to decreased gas pressure.

Picture 7: PTD outlet discharging slurry to pit

Picture 8: PTD slurry pit

Many of those interviewed indicated that the slurry makes very good fertilizer. However it was not widely known is that the watery part of the slurry is also high in nutrients and can also yield similar results.

4.8 How Do Households Find Out About PTDs

Users indicate a number of ways in which they came to know about the PTDs (Fig 5).

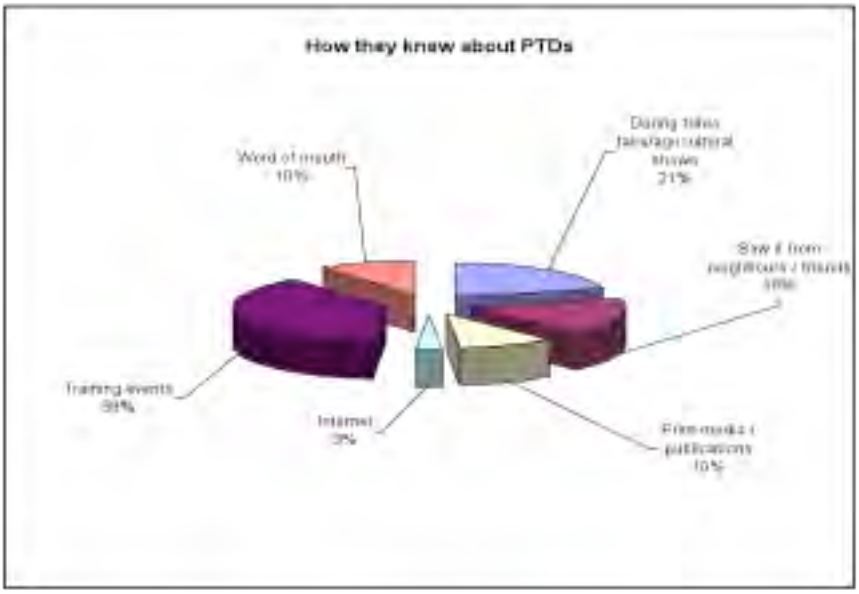


Figure 5: How they knew about PTDs

A huge percentage of them knew about PTDs through training events (38%), agricultural fairs (21%) and from the seeing it working at their friends and neighbours (18%). Getting information through the print media and word of mouth was not very common as only 10% of respondents confirmed to get information through the source.

4.9 PTD Payback Period

In determining the payback period, two comparative approaches were used. One where payback period is based on charcoal for urban and Peri-urban areas and secondly one where the payback period is based on firewood for rural areas.

4.9.1 Payback Period Based on Charcoal Use

It is estimated that the biogas digester can pay for themselves between 15 to 43 months, depending on the type of fuel the digester is replacing, its cost (or what one would pay for it, if bought) fuel use, and based on the assumption that the bio digesters could be used instead of charcoal for 54% or more of the household cooking.

The determination of the payback period for the PTD is calculated as:

Cost of investment/savings per month

Or Cost of investment/2.31 times the price of a sack of charcoal per month

The calculation assumes that a household of about 5 people will use an equivalent of 15.1 kg of charcoal per week, which translates to about 0.54 of a sack of charcoal, leading to 64.7 kg per month (about 2.31 sacks of charcoal). A sack of charcoal is about 28 kg.

In our case based on the average digester cost of KES 45,040, the payback period based on the current prices of a sack of charcoal going for KES 900. The payback period translates to about 16.25 months and is calculated as follows:

PTD payback period = Cost of investment/(2.31 * price of a sack of charcoal/month)

= KES 45,040/(2.31 * KES 1,200/month)

= KES 45,040/(KES 2,772/month) = 16.25 Months ~ 17 months

It is however noted that the lower the price of charcoal the longer the payback.

4.9.2 Payback Period for PTDs and Fixed Dome Digesters Based on Other Biomass Fuels

In Kenya and many other rural East African Countries, use of fuel wood and biomass residues like maize cobs is quite common. A comparative analysis was thus done on the payback period not only for the PTD but also the fixed dome “Chinese Design” biogas digester based on different biomass fuels (Table 8). The assumptions underlying Table 8 is based partly on Table 9 and also on studies done. For instance the Biogas (2008) provides a generic cost for 6 m³ fixed dome digester used in the calculation since it does not exist in Kenya. This was achieved by reducing the costs of the normal 8m³ and 12m³ digesters.

Generally, from the PTD comparative analysis (Table 8), the PTD has a slightly shorter payback period as compared to the fixed dome of similar size. The only challenge as has been identified from the field is the temperature fluctuations hence subsequent gas production fluctuations. This is attributed to the exposure of the digester bag to the elements, while the fixed is normally fully enclosed within the ground affording it constant temperature for microbial activity.

It terms of lifespan, Butyl rubber with Glass reinforced fibre and blackened with carbon has an expected lifespan of about 20 years mainly due to its resistance to UV light and resistance to acid. Thus the 4th generation PTD made of Butyl rubber is expected to last more or less the same 20 year period as a fixed dome digester.

Table 8: Payback period of different digesters based on different biomass fuels (Author, FAO (2001))

	Masonry (Fixed dome) - "Chinese design"	Plastic Tubular
Cost (KES)[7] (installations, materials, accessories)	68,720.00	45,040.00
Cost (US$) (installations, materials, accessories)	859.00 (Source: Biogas, 2008)	563.00 (In Kenya)
Lifetime	20 years or more	When polythene is used the lifetime is less than 5 years, but when butyl rubber is used the lifetime is comparatively longer (greater than 10 years)
Digester Size (M^3)	~ 6	~ 6
Biogas production (M^3/day)	~ 3	~ 3
Payback period with Charcoal (months)	25	16
Payback period with Firewood (bought) in Months	43	28
Payback period with Biomass residue (maize cobs etc) in months	65	43

Table 9: Assumptions for a household of five people (Author, Karanja & Kiruiro (2003))

Assumptions for a household of 5 people				
Fuel type	**Unit costs (KES)**	**Usage per month/unit**	**Fuel use per month (KES)**	**Fuel use per month (US$)**
Charcoal (2.31 times the price of a sack of charcoal)	1,200	2.31	2,772	34.65
Firewood (how much would be spent if bought)	400	4	1,600	20.00
Biomass residue (how much would be spent if bought)	150	7	1,050	13.13

4.10 Benefits of Digester Systems to the Users

The main benefits indicated by the farmers/users being accrued from the biogas digesters were:

1. 90% of the respondents indicated that the PTD helped them to save in the use of paraffin, charcoal and fuel wood, allowing the money so used to be channelled to other things like education, obtaining more cows etc..
2. About 10% of the survey sample indicated the benefits obtained by the simple convenience and cleanliness of the gas.
3. Of the 30 working digesters visited, all of them indicated the benefits from using the slurry as an

7. Exchange rate (1 US$ is equal to KES): 80

organic fertilizer and soil conditioner.

4. It was noted that in some rural areas and also Peri-urban areas some users had installed biogas PTDs as way of environmental sanitation.

4.11 Extension Services

Of the sampled, 96.7% had experienced some form of contact with the PTD installer after its installation. This took the form of telephone support (38%) or site visits (62%). The frequency of the extension occurred ever since the installation was done (29%), or whenever they have a problem (61%) or between 0 to 3 months after installation and nothing since then (10%).

It was further noted in all cases (100%) the farmers were given either face to face training or a manual (user guide) or both the training and manual that describes the workings of a biogas digester. The manual also explains how and when the digester should be fed. Most of the problems arising with the biogas digester were mainly centred on low pressure and low gas production.

All companies seem to provide a one off face-to-face training, issuance of a user manual that is followed up by one or two site visits after the installation. Thereafter, little or no telephone support is provided by the companies. This probably explains the high rate of PTDs failure.

4.12 PTD Sustainability

Generally, all the companies seek to install the 4th generation PTDs hence ensuring similar quality. However, the sustainability of the PTDs was noted to be significantly reduced due to poor user management of the gas pipes. More specifically, infrequent feeding, over-feeding and under-feeding were the causes of low pressure and/or low gas production. In a bid to deal with the hardened scum formed due digester feeding issues, 3% of the users had attempted to agitate the tube by stepping on it. The end result being that the tube burst. Others agitate it by shaking the tube manually which is a bit better.

It is thus realized that with proper maintenance and user education, including proper extension services, PTDs can last over seven years, making them sustainable. However, it should be noted that no current results exist on the life span of the 4th generation PTD and/or if it more efficient than a masonry ones.

4.13 PTD and Ownership Findings

It was noted that the users who had bought the digester with the own money, took better care of them as compared to those who had obtained their digester either through subsidy or through donations or through charitable organisations.

Therefore, a mix of farmer’s contribution and subsidy or a total loan programme approach may be recommended to allow for ownership development. Additionally, ownership issues are a sub-set of the how well the farmer has been trained to use the digester including the attendant extension services. However, of the sufficiently trained farmers who received regularly extension services (97%) took better care of their digesters.

4.14 Second-hand PTDs

Two of the 39 sites surveyed had switched from plastic tubular digesters to the masonry kind. The main reasons for switching were the increased demand for biogas i.e. for lighting and cooking as well as the persistent low pressure in the PTD early in the morning and late in the evening. Users who upgraded from the PTD to the masonry type digesters donated the PTDs to their relatives. In the case where the farmers upgraded to masonry digester, they gave the PTD to one of the donated their digester to their relatives to use.

5. Lessons Learnt and Challenges Experienced

5.1 Lessons Learnt

1. Companies installing PTDs in Kenya: It was noted that a number of companies that deal in PTDs exist in Kenya. Based on the initial database figures provided by Pioneer Technologies of having installed 117 biogas digesters, and realizing that of the sampled 39 PTDs visited 20 (85%) were installed by Pioneer, and 19 by other companies. This is indicative of the scale at which different players are installing PTDs in Kenya. Some of these companies are as outlined in the table below.

Table 10: Current and potential companies installing Plastic Tube Digesters in Kenya[8] (Author)

1. Dedan N Ndungu Modeline Electrical and Mechanical Engineers Tel: +254-(0)723 389642 Email: modelinetechnologies@yahoo.com	2. Samuel N. Nene Pioneer Technologies Limited P. O. Box 32910 – 00600, Nairobi, Kenya Tel: +254-(0)20 253442 Mobile: +254-(0)722 552505 Email: pioneerteknik@yahoo.co.uk
3. E. K. Kahiga Biens Limited, P. O. Box 57859 Nairobi Tel: +254-(0)778030 / +254-(0)737521242 Email: ekahiga@yahoo.com	4. Kinoti Skylink innovators, P. O. Box 64459 - 00620 Nairobi, Kenya http://skylinkinnovators.blogspot.com Email: skylinkinnovations@gmail.com Skylink have not yet started but aims to do so soon.

2. Installation methodology: Simple approaches have been devised to allow for proper feeding. This has taken the form of either a masonry tank or rectangular trench. In other cases, recycled 200

8. The 4th company, Sky link Innovators is one of the top five East African energy SMEs in the Access to Clean Energy Challenge and a winner of the GVEP-I Ashden Award . Skylink also has received financial training and expect further funding in 2011 for piloting a plastic biogas digester from Mexico from the Access to clean Energy Challenge promoters. However, it was noted that due to the rather cut-throat competition, none was willing to give information or even acknowledge the existence of the other competitor, thus the study was unable to get more information of other competitors.

litres oil drums were used to store the fresh cow dung before it is transferred to the digester.

3. Failure of PTDs: The main cause of failure of the PTDs is mainly centred on user maintenance and poor or inadequate extension services. By user management the main causes of problems were under-feeding, over-feeding the digester, inappropriate slurry mix (wrong ratio of water to cow dung) and lastly general protection of the digester with regard to a protective fence and roof.
4. PTD lifespan: In assessing the lifespan of the PTDs, it was realized that some of the ones installed in 2003 are still performing quite well. In this case the PTDs were actually 7 years old at the time of the study. This indicates that PTDs when well taken care of can last much longer than the 2 years given in literature. However the exact life span is still unclear.
5. Digester drawbacks: Though quite a number of the consumers were satisfied with the PTD, a number of them expressed disappointment that the digester could not meet their lighting needs and further that the fluctuation in gas production especially during morning and late evenings was very inconvenient, as it meant longer cooking hours.
6. Savings made: PTDs can enable savings of about KES 2,772 (US$ 34.65) monthly in avoided cost of buying 2.31 sacks of charcoal. Savings are also subsequently made in reduced deforestation due to acquisition of firewood. In addition savings are made in terms of avoided costs of buying the fuel source are made for fuel wood (US$ 20) and US$ 13.13 for biomass residues like maize cobs.

5.2 Challenges/Weaknesses of PTDs

1. Gas production in the digester varied depending on the ambient temperature. As has already been mentioned, during the early morning and late evening hours, the gas production is normally low, due to the reduced microbial activity due to the subsequent drop in temperatures. This was mainly the case in the central parts of Kenya while areas with high temperatures like Kisumu and Kajiado County this problem was not being experienced. Therefore, there is need for further research as to how this particular challenge can be overcome.
2. Though the 4th generation Plastic Tubular Digester bag is more robust than its predecessor, when pierced or torn it becomes a challenge to repair it, especially when the tear or hole is big. User management through protection of the digester site and proper feeding rates are highly recommended as a way of minimizing this.
3. In all the sites visited, the PTD was only used for cooking. Thus, there is need for further studies on how gas pressure fluctuation due temperature variance can be stabilized.
4. Users of PTDs were not well versed with the full use of slurry especially the highly nutritious fluid part as fertilizer and soil conditioner, nor that can it be sold as fertilizer. Though this was not related directly to the key issues the survey was to assess, it nonetheless came out clearly as a key finding. Utilisation of the slurry could provide the PTD owners with some form of livelihood interventions in form of alternative fertiliser and hence save money.
5. It was evident that no sustainable user support mechanism (technical back-up) exists from the installer. Thus, there is need for building sufficient capacity at the various regions and frequent

refresher trainings should be carried out for both current and potential users.

6. Recommendations

6.1 Framework for PTD Installation and Operation Manual

From the study, it was noted that Pioneer technologies normally give an operation manual to its user. A review of the manual by the consultant revealed that it is not well organized and is lacking, especially in its discussions about Installation, feeding frequency and contact details of the nearest installer or extension officer.

It is therefore recommended, that for instance, a 12 paged, double sided A5 user guide or operational manual, in the event PTDs are to be installed elsewhere, be developed. The manual should cover the following issues:

1. The process occurring inside a biogas digester – use of diagrams and photographs is highly recommended (about 2 pages).
2. A brief description including a measurement based schematic/cross-sectional diagram of the Plastic tubular digester (about 1 page).
3. A brief description – supported by diagrams - of the layout and installation of the plastic tubular digester (2 to 3 pages).
4. How to feed the biogas digester, including feeding frequency and use of simplified formulas for retention time, daily feeding capacity and frequency, and expected gas amount (about 1 page).
5. Digester feeding, digester repair, digester agitation in case of scum formation etc (4 pages).
6. Frequently asked questions (trouble shooting) (2 pages).
7. Contact details of local installer, local extension officer and/or artisan who can repair the digester (back cover).

The same information can also be summarized and produced as a poster and pasted near the digester.

6.2 Recommendations for Successful PTD Use

Based on the results of the study, it is realised that for the successful dissemination of PTD in Kenya, the following issues will have to be addressed.

1. Proper user support programmes and maintenance training.
2. Developing capacity to locally manufacture materials for PTD construction.
3. Developing friendly financing mechanisms for those who want to invest in PTDs.
4. Exploring the possibility of incorporating the gas storage bag in the design of the PTD.

6.3 Recommendations for Further Scientific Research and Field Studies

It is also recommended that further scientific research and field studies be done with respect to:

1. Determination of the life span of the Plastic Tube Digester, including the best kinds of cost effective materials to be used in manufacture and repair of tubular digesters. Of particular interest

in such a research is the ultra-violet light protection mechanism of the tube, its thermal capacity (ability to retain or lose heat) and its thickness which is important in terms of light piercing of the digester

2. Efficiency benchmarking:
    - Determining the quality and quantity of gas produced by both a PTD and masonry type digester like fixed dome and/or floating drum
    - Determining, on a comparative basis, the performance of the digester (PTD, fixed dome and floating drum) based on time of day, feeding frequency, feeding quantity, feeding type, effect of temperature fluctuations on gas production etc
3. Investigating cost-effective, easily adaptable and locally available approaches to repairing a
    - Torn/burst plastic digester bag
    - Pierced plastic digester bag
4. Development and piloting of a PTD value chain and also of a sustainable PTD market delivery model. This will specifically target the problems experienced in relation to
    - User support
    - Extension services

6.4 Recommendations for Better Market Delivery Models

1. Supporting on a local scale, an industry or a number of Small and Medium Enterprises (SMEs) to mass produce UV protected thick double layered PTD tubes.
2. Support of local skills upgrading in biogas installation and repair.
3. Support industry in availing affordable PTD repair kits.
4. Government support in extension services for small scale farmers owning PTDs.
5. Local industry support for biogas equipment and accessories. These would include gas valves and biogas stoves.

6.5 User Recommendations

1. Development of a PTD user manual (Section 6.1) and wide distribution to users in a language they can understand.
2. During this nascent development stage of the PTDs, a need exists for regular user support visits from government extension officers and installers. This is especially important to sites that are far away from urban centres e.g. Miwani (Kisumu county). As the industry matures, then such visits can reduce in scale and frequency.
3. Protection of the PTD against animals, children and other harm.
4. Farmer training on type of feeding material and feeding frequency of the digester.
5. Development and dissemination of a video on PTD installation, operation (feeding, cleaning, troubleshooting etc), repair and gas use.

6.6 Recommendations to Policy Makers

1. Undertake study on effect of subsidies on user management of PTDs.
2. Determination and piloting of best financing mechanism of PTDs for poor households in the context of ownership creation and sustainability.
3. Scaling up of the whole program region-wide.

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Appendix

Appendix 1: Institutional Questionnaire

Questionnaire with Pioneer Technologies:

Aim:

1. Understand the history of the company and its staffing level including branches and/or outposts
2. Distributors/retailers and suppliers of their products or manufacturing material
3. Understand their scope of activities (installation areas, costs / area, what they do (activities)
4. Understand the technology and its processes
5. Understand the challenges they are experiencing
6. Obtain a database of all their installed plants including names of clients, their contact details, location of installation, date of installation, frequency of monitoring & evaluation, Cost of installation at that time,
7. Their extension processes

Interviewee _____ Tel _____

Contacts _____ Position _____

Main issue	Sub-issues	Responses
Company	Contacts Branches Staffing levels Branches /outputs History (when it started, people involved, growth record)	
Delivery network	Distributors Retailers Suppliers of the materials / material availability	
Scope of activities	Installation areas (provinces, districts, locations) Installation costs (stratified per installation area) Number of installed PTDs & area of installation (geo-referencing?) Any other activities they are involved in	

Technology	Who manufactures it How it works Operation parameters (PH, Temp, etc) Feedstock type Lifespan Average gas production / day Manufacturing costs and energy	
Challenges	Production Transportation Installation User operation & Education Extension (user) support Policy Others	
Extension processes	Who does extension? What kind of extension? (Education, O&M, marketing etc) Who pays for it?	
Database compilation	Location of installation Geo-reference Names of client Contacts (postal, mobile, e-mail) Installation date Cost of installation at that time Frequency of M&E, Repair works + costs Performance of PTD (gas production, feedstock availability	

PTD type	Size & cost	Retention time & days before it starts working, Temperature issues,	Gas volume

Appendix 2: User Questionnaire

Plastic Tube Digester Questionnaire with Users

Preamble:

The Government of Rwanda is intending to install about 5,000 biogas digesters for small households having 1-3 cows. For this reason, they are assessing the performance of different types of biogas digesters within the region.

For this reason, they have obtained permission from Pioneer Technologies to undertake a quick assessment of the digesters installed by them in order to obtain an understanding of how the digesters are performing in real life. We thus kindly request a few minutes of your time in responding to this questionnaire and if possible allowing our interviewer to access your digester, gas storage bag, gas piping and gas cooking stove.

Questions	**Responses**
1. Location of the digester (Geo-reference if possible)	Physical/administrative location …… …….. Latitude …… Longitude …….
2. Name owner and contact details	…… …… …… …… …….
3. Date of installation	……..
4. Costs of installation	…….
5. Time to construct the digesters	…… ……
6. Time between construction date and the start of the gas production/use	…… …… …….
7. What is the feeding material?	…… …… ……..
8. What is the gas used for?	Cooking Lighting Operating dual fuel engines (for water pumping, electricity generation and/or running agro-machinery) Other uses:
9. Average hours of cooking and/ or light per day	…… ……

10. Operating condition of the digester, Gas bag and cooking equipment	Digester condition & performance Gas bag condition & performance Cooking equipment condition & performance Gas pipes conditions & performance Water trap condition & performance Digester Size Feeding frequency Number of cows …….
11. Farmers' opinion on the performance of the digester	…… ……
12. If out of order, what are the reasons	Digester busted along the seam – settings interfered with No gas production – overfeeding, wrong feeding material Low pressure Stove not lighting – condensate, pressure, gas production issues Protection of digesters from animals and children Lack of interest from user – delegation of digester maintenance to farm helper etc, Others: - …… …… ……..
13. After sales services provided	After sale service provided: Yes No After sale service provider After sale provider is Pioneer Other after sale provider (state name and contact details) …… …… In what form Telephone support Site visits Others …… …… How frequent 0 – 3 months after installation Whenever their is a problem Ever since installation of digester Other frequency ……..

14. How did the farmer hear about PTDs?	Saw it from neighbours / friends During trade fairs / agricultural shows Training events Internet, Audio-visual Media Print media, publications Word of mouth Others ……..
15. Did he see it from neighbours/ friends before purchasing the unit?	Yes No
16. Does he use the slurry? For what for what purpose? Benefits compared to dung?	Yes No As organic fertilizer Feeding fish food supplement for pigs and chicken In mushroom cultivation Earthworm cultivation In hydroponics (growing plants in a nutrient rich solution) Others: …… …… ……

Any other comments / Observations / photos / maps etc
……
……
……
……
……

Appendix 3: Initial PTD List from Pioneer Technologies Limited

No.	DATE OF INSTALATION (dd.mm.yy)	CLIENT NAME	CONTACT	LOCATION
1	22.10.06	Shem Njiraini	733719001	Githunguri
2	23.10.06	Job Mwangi	722288907	Mwiki
3	19.09.06	Luka Kinyanjui	735499043	Kinoo
4	15.11.06	Mr Wanjehia	733528830	Mangu,Gatukuyu
5	21.10.06	Mama Leah	722513825	Ruai
6	15.11.06	Mrs Kimathi		Thika sports club
7	10.11.065	Nehaemiah		Kisumu
8	23.11.06	Mr karanja	722376389	Gikuni
9	13.11.06	Mrs Karanja	721717154	Kiserian
10	23.11.06	Anthony Mugwanja		Thika sports club
11	14.11.06	Hinga		Mangu,Gatukuyu
12	06.12.06	Land o lakes		Mukurwini
13	06.12.06	Land o lakes		Nakuru
14	20.11.06	Nehemiah int		Kisumu
15	20.11.06	Mayor Kericho-Isaiah Rono		Kericho
16	05.12.06	Mrs Matu	Thika Delmonte	
17	18.12.06	Mr Wanjohi Josephat	722623606	Ngong
18	20.12.06	Kiteto Joy	722958019	Voi
19	20.12.06	Elizabeth Mwhihaki	721339460	Kibiciku
20	20.12.06	Gichuhi Mwaniki	Kimende	
21	15.01.07	George Ngugi	722856040	Limuru
22	10.01.07	Jane Nganga		Limuru
23	02.02.07	Joram Njenga	724596606	Kibiciku
24	05.02.07	Joyce	723480488	Ndeiya
25	02.02.07	Lilian	Meru	
26	07.02.07	Mirium	Meru	
27	10.02.07	Mr Kamau	Wangige	
28	13.02.07	Nahashon Kariuki	Ruku	
29	12.02.07	Nehemiah - oira O	kisumu	
30	12.02.07	Nehemiah - j.Omtata	kisumu	
31	12.02.07	Nehemiah int	Kisumu	
32	12.02.07	Nehemiah int- GERORGE	kisumu	
33	13.02.07	Land o lakes Nakuru Kabarak	Kabarak	
34	27.02.07	Koigi MwANgi	Chumgamali	
35	13.02.07	Land o lakes	Kericho	
36	13.02.07	Land o lakes - Kiarii	Githunguri	
37	26.03.07	Land o lakes	Rongai	
38	26.03.07	Land o lakes	Cura wangige	
39	03.04.07	Mr mwaura	Cura wangige	

40	05.04.07	George Tharao Njugia	Kimende	
41	04.04.07	Mrs Nyaga	Thome	
42	24.04.07	Benote	Nakuru	
43	24.04.07	Kingshop	Nakuru	
44	24.04.07	Pokea Farm	Nakuru	
45	04.05.07	Cosmas Munyeke	Machakos	
46	30.04.07	Wakulima Dairy members		
47		Mrs Thairu	Mukurweini	
48		Mr karanja metal	Mukurweini	
49		wahumuira	Mukurweini	
50		Penina njeri Kago	Mukurweini	
51		kim chair	Mukurweini	
52		Best dairies	Mukurweini	
53		kwamunga	Mukurweini	
54		Githioro	Mukurweini	
55		Njenga kim	Mukurweini	
56		Method w	Mukurweini	
57		Hosea mangy	Mukurweini	
58		Tire	Mukurweini	
59		Peter mania	Mukurweini	
60		macharia gaitho	Mukurweini	
61	26.04.07	Njoroge Nguru	Kimende	
62		Ngurugi thiaka	Kimende	
63		Wanjiku kibe	Kimende	
64		Mr koigi	Kimende	
65		Wamai	Bahati	
66		Baba Njenga	Bahati	
67		Pastor wangombe	Bahati	
68		Cidar lodge	Bahati	
69	18.04.07	WANJEMA	Nakuru	
70	07.05.07	Mr. R. Muthui	Nakuru	
71	07.05.07	Mr mutual	Nakuru	
72	08.05.07	Mr karaoke	Nakuru	
73	11.06.07	Evans Karanja	Gikuni wangige	
74	12.06.07	Daniel kilonzo MULI	Tala	
75	13.06.07	Pastor Afwayi	733393528	Njiru
76	14.06.07	Peris kabaria	Tim nganga	
77	20.06.07	Kariuki	Ravine nakuru	
78	21.06.07	Naomi Wangari goko	wendani kahawa	
79	03.07.07	Job Mwangi	mwiki	
80	23.07.07	Bernad Ngige	kahawa	
81	16.07.07	Ann wachinga	Kiambu	
82	16.07.07	Paul kuria	midrange mbiri	

83	23.07.07	Isaac kogi	muranga kangari	
84	26.07.07	Nuthiamwathi	Naivasha	
85	20.08.07	Paul wachira	722722697	Limuru
86	10.07.07	Roy Ngure	kahawa	
87	19.09.07	Daniel mbugua	722263523	wangige
88	15.09.07	Endarasha school for orphans	Nyeri endarasha	
89	20.11.07	James njenga kaguora	limuruGichagi	
90	01.12.07	NYS TUMAINI	OLO-KALAO	
91	01.12.07	Ngugi mwaura	722868550	ndenderu
92	04.12.07	Alice kihara	githiga	
93	10.12.07	Joseph mwangi	722211874	Nazareth
94	04.12.07	Kigali teachers	embu town	
95	13.12.07	Ithururu dairy farmers	nyeri	
96	14.12.07	Dr mwatu	machakos	
97	13.08.07	bogus	githunguri	
98	15.08.07	prof. keriko	Juja JKUAT	
99	16.08.07	Joyce	Muranga	
100	31.08.07	Susan mbiti	wamunyu	
101	02.10.078	Nicholas muindi	Machakos	
102	19.09.07	Jikaze	wiyumiririe	
103	19.07.07	Daniel ikoro	Wangige	
104	17.12.07	kamwende	722735026	embu
105	14.01.08	Boniface mwaniki	embukanja	
106	14.12.07	David mbuguanduati	Githunguringewa	
107	21.01.08	John kiarii	722706820	Githunguri
108	19.02.08	Njukimunano	karura	
109	19.02.08	Land o lakes - grace makau	Nyeri	
110	19.02.08	Land o lakes - kamau	Kimende	
111	05.02.08	Land o lakes - mwororo	Machakos	
112	08.04.08	Land o lakes- mutukus	Machakos	
113	08.04.08	Land o lakes - samuelbalazi	Machakos	
114	12.04.08	karanja	jabini	
115	13.04.08	Njoroge k	jabini	
116	13.04.08	P.Mwai	GITHIGA	
117	13.04.08	Baldo	Ndaragwa	

Appendix 4: Verified Database of Installed PTDs

No.	Installation date	Client name	Contact	Location	County	In survey sample or organization supporting user	Company
1	Dec-2007	Kamwende	+254-(0)-722-735 026	embu	Embu		Pioneer Technologies Limited
2	Jan-2008	Boniface mwaniki		embu kanja	Embu		Pioneer Technologies Limited
3	Dec-2007	Kigali teachers		embu town	Embu		Pioneer Technologies Limited
4	Nov-2006	Mrs Karanja	+254-(0)-721-717 154	Kiserian	Kajiado		Pioneer Technologies Limited
5	Aug-2008	Patrick Munyi	+254-(0)721-214 007	Kiserian-St. Patrick	Kajiado	In Survey sample	Pioneer Technologies Limited
6	Dec-2006	Mr Wanjohi Josephat	+254-(0)-722-623 606	Ngong	Kajiado		Pioneer Technologies Limited
7	Apr-2007	Baba Njenga		Bahati	Kiambu		Pioneer Technologies Limited
8	Apr-2007	Cedar Lodge		Bahati	Kiambu	Cedar Lodge	Pioneer Technologies Limited
9	Apr-2007	Pastor wangonbe		Bahati	Kiambu		Pioneer Technologies Limited
10	Apr-2007	Wamai		Bahati	Kiambu		Pioneer Technologies Limited
11	Mar-2007	Client		Cura wangige	Kiambu	Land O' Lakes	Pioneer Technologies Limited
12	Apr-2007	Mr mwaura		Cura wangige	Kiambu		Pioneer Technologies Limited
13	Nov-2006	Mr Karanja	+254-(0)-722-376 389	Gikuni	Kiambu		Pioneer Technologies Limited
14	Jun-2007	Evans Karanja		Gikuni wangige	Kiambu		Pioneer Technologies Limited
15	Dec-2007	Alice kihara		githiga	Kiambu		Pioneer Technologies Limited
16	Apr-2008	P. Mwai		githiga	Kiambu		Pioneer Technologies Limited
17	Feb-2007	Client		Githunguri	Kiambu	Land O' Lakes	Pioneer Technologies Limited
18	Jan-2008	John kiarii	+254-(0)-722-706 820	Githunguri	Kiambu		Pioneer Technologies Limited
19	Aug-2007	Mr and Mrs Mbugua		githungur i	Kiambu		Pioneer Technologies Limited

20	Oct-2006	Shem Njiraini	+254-(0)-733-719 001	Githungu ri	Kiambu		Pioneer Technologies Limited
21	Dec-2007	David mbugua nduati		Githungu ri ngewa	Kiambu		Pioneer Technologies Limited
22	Aug-2007	IEET-JKUAT	+254-(0)-726-811 416	Juja	Kiambu	IEET-JKUAT (In survey Sample)	Pioneer Technologies Limited
23	May-2009	Bernard Kinyanjui	+254-(0)722-348 496	Kagwe	Kiambu	In Survey sample	Modeline Electrical and Mechanical Engineers
24	Aug-2008	Kennedy Kamau	+254-(0)721-351 995	Kagwe	Kiambu	In Survey sample	Modeline Electrical and Mechanical Engineers
25	Apr-2009	Margret Kungu	+254-(0)725-654 130	Kagwe	Kiambu	In Survey sample	Modeline Electrical and Mechanical Engineers
26	Jul-2007	Bernad Ngige		kahawa	Kiambu		Pioneer Technologies Limited
27	Jul-2007	Roy Ngure		kahawa	Kiambu		Pioneer Technologies Limited
28	Feb-2008	John Kimani	+254-(0)723-287 878	Kamburu	Kiambu	In Survey sample	Pioneer Technologies Limited
29	Jul-2007	Francis Kamilichui	+254-(0)722-796 859	Kamiti	Kiambu	In Survey sample	Pioneer Technologies Limited
30	Feb-2008	David Njoroge	+254-(0)722-807 638	Kamuthi	Kiambu	In Survey sample	Pioneer Technologies Limited
31	Aug-2007	Francis Njehia	+254-(0)723-161 820	Kamuthi area	Kiambu	In Survey sample	Pioneer Technologies Limited
32	Aug-2007	Ngugi mwaura	+254-(0)722-686 550	Karura	Kiambu	In Survey sample	Pioneer Technologies Limited
33	Feb-2008	Njuki munano		karura	Kiambu		Pioneer Technologies Limited
34	Jul-2007	Ann wachinga		Kiambu	Kiambu		Pioneer Technologies Limited
35	Dec-2006	Elizabeth Mwhihaki	+254(0)721-3 39460	Kibiciku	Kiambu		Pioneer Technologies Limited
36	Feb-2007	Joram Njenga	+254-(0)-724-596 606	Kibiciku	Kiambu		Pioneer Technologies Limited
37	Jul-2009	Esau Kinyanjui	+254-(0)722-795 081	Kimende	Kiambu	In Survey sample	Modeline Electrical and Mechanical Engineers
38	Apr-2007	George Tharao Njugia		Kimende	Kiambu		Modeline Electrical and Mechanical Engineers

39	Dec-2006	Gichuhi Mwaniki		Kimende	Kiambu		Modeline Electrical and Mechanical Engineers
40	Jun-2008	Joseph Mirengo	+254-(0)722-376 806	Kimende	Kiambu	In Survey sample	Modeline Electrical and Mechanical Engineers
41	Feb-2008	Kamau		Kimende	Kiambu	Land O' Lakes	Pioneer Technologies Limited
42	Apr-2007	Mr koigi		Kimende	Kiambu		Modeline Electrical and Mechanical Engineers
43	Apr-2007	Nguru githiaka		Kimende	Kiambu		Modeline Electrical and Mechanical Engineers
44	Apr-2007	Njoroge Nguru		Kimende	Kiambu		Modeline Electrical and Mechanical Engineers
45	Apr-2007	Wanjiklu kibe		Kimende	Kiambu		Modeline Electrical and Mechanical Engineers
46	Feb-2006	Luka Kinyanjui	+254-(0)712-333 611	Kinoo-Muthiga	Kiambu	In Survey sample	Pioneer Technologies Limited
47	May-2002	Moses Koigi	+254-(0)720-472 477	Lari	Kiambu	In Survey sample	Pioneer Technologies Limited
48	Jan-2007	George Ngugi	+254-(0)-722-856 040	Limuru	Kiambu		Pioneer Technologies Limited
49	Aug-2007	James Njenga Kaguora	+254-(0)722-265 319	Limuru	Kiambu	In Survey sample	Pioneer Technologies Limited
50	Jan-2007	Jane Nganga		Limuru	Kiambu		Pioneer Technologies Limited
51	Sep-2006	Kabunyi	+254-(0)722-782 691	Limuru	Kiambu	In Survey sample	Pioneer Technologies Limited
52	Aug-2007	Paul wachira	+254-(0)-722-722 697	Limuru	Kiambu		Pioneer Technologies Limited
53	Sep-2009	David Karanja	+254-(0)720-827 638	Magina	Kiambu	In Survey sample	Pioneer Technologies Limited
54	May-2008	James Thuo	+254-(0)720-684 910	Magina	Kiambu	In Survey sample	Pioneer Technologies Limited
55	Oct-2008	Kuselu Mwangi	+254-(0)751-834 022	Magina	Kiambu	In Survey sample	Modeline Electrical and Mechanical Engineers
56	Sep-2005	Moses Gichoya	+254-(0)720-297 313	Magina	Kiambu	In Survey sample	Pioneer Technologies Limited

57	Nov-2006	Hinga		Mangu,Gatukuyu	Kiambu		Pioneer Technologies Limited
58	Nov-2006	Mr Wanjehia	+254-(0)-733-528 830	Mangu,Gatukuyu	Kiambu		Pioneer Technologies Limited
59	Dec-2006	Client		Mukuruweni	Kiambu	Land O' Lakes	Pioneer Technologies Limited
60	Apr-2007	Best dairies		Mukurweini	Kiambu	Wakulima Dairy members	Pioneer Technologies Limited
61	Apr-2007	Githioro		Mukurweini	Kiambu	Wakulima Dairy members	Pioneer Technologies Limited
62	Apr-2007	Hosea mwangi		Mukurweini	Kiambu	Wakulima Dairy members	Pioneer Technologies Limited
63	Apr-2007	Kwamunga		Mukurweini	Kiambu	Wakulima Dairy members	Pioneer Technologies Limited
64	Apr-2007	Macharia gaitho		Mukurweini	Kiambu	Wakulima Dairy members	Pioneer Technologies Limited
65	Apr-2007	Mr karanja metal		Mukurweini	Kiambu	Wakulima Dairy members	Pioneer Technologies Limited
66	Apr-2007	Mrs Thairu		Mukurweini	Kiambu	Wakulima Dairy members	Pioneer Technologies Limited
67	Apr-2007	Mutho w		Mukurweini	Kiambu	Wakulima Dairy members	Pioneer Technologies Limited
68	Apr-2007	Njenga kim		Mukurweini	Kiambu	Wakulima Dairy members	Pioneer Technologies Limited
69	Apr-2007	Penina njeri Kago		Mukurweini	Kiambu	Wakulima Dairy members	Pioneer Technologies Limited
70	Apr-2007	Peter maina		Mukurweini	Kiambu	Wakulima Dairy members	Pioneer Technologies Limited
71	Apr-2007	Tiiri		Mukurweini	Kiambu	Wakulima Dairy members	Pioneer Technologies Limited
72	Apr-2007	wahu muira		Mukurweini	Kiambu	Wakulima Dairy members	Pioneer Technologies Limited
73	Dec-2007	Joseph mwangi	+254-(0)-722-211 874	Nazareth	Kiambu		Pioneer Technologies Limited
74	Jul-2009	J. W. Gatumbi	+254-(0)724-881 203	Ndakaini	Kiambu	In Survey sample	Pioneer Technologies Limited

75	Dec-2008	Winfred K. Njuri	+254-(0)723-317 156	Ndakaini	Kiambu	In Survey sample	Pioneer Technologies Limited
76	Apr-2008	Baldo		Ndaragwa	Kiambu		Pioneer Technologies Limited
77	Jun-2007	Pastor Afwayi	+254-(0)-733-393 528	Njiru	Kiambu		Pioneer Technologies Limited
78	Nov-2006	Anthony Mugwanja		Thika sports club	Kiambu		Modeline Electrical and Mechanical Engineers
79	Nov-2006	Mrs Kimathi		Thika sports club	Kiambu		Modeline Electrical and Mechanical Engineers
80	Dec-2006	Mrs Matu		Thika-Delmonte	Kiambu		Modeline Electrical and Mechanical Engineers
81	Jun-2006	Esther Nyaga	+254-(0)722-742 052	Thome	Kiambu	In Survey sample	Pioneer Technologies Limited
82	Apr-2007	Mrs Nyaga		Thome	Kiambu		Pioneer Technologies Limited
83	Jun-2007	Peris kabaria		Tinganga	Kiambu		Pioneer Technologies Limited
84	May-2008	Peter Mwangi Kihara	+254-(0)736-451 398	Tinganga	Kiambu	In Survey sample	Pioneer Technologies Limited
85	Aug-2007	Susan mbiti		wamunyu	Kiambu		Pioneer Technologies Limited
86	Sep-2007	Self		wiyumiriri e	Kiambu	Jikaze	Pioneer Technologies Limited
87	May-2007	Kiratu	No phone	Zambezi	Kiambu	In Survey sample	Pioneer Technologies Limited
88	Aug-2008	Client (abandoned homestead)	No phone / contacts available, Information obtained from Nehemiah International Miwani center	Miwani	Kisumu	Nehemiah International Miwani Center (in survey sample)	Pioneer Technologies Limited
89	Feb-2008	David Isure	+254-(0)-726-697 272	Miwani	Kisumu	Nehemiah International Miwani Center (in survey sample)	Pioneer Technologies Limited
90	Oct-2008	Joseph Oroko	+254-(0)-721-489 293	Miwani	Kisumu	Nehemiah International Miwani Center (in survey sample)	Pioneer Technologies Limited

91	Nov-2007	Meshack Lwenya	+254-(0)-723-798 620	Miwani	Kisumu	Nehemiah International Miwani Center (in survey sample)	Pioneer Technologies Limited
92	Jan-2008	Washington Ogolla	No phone	Miwani	Kisumu	Nehemiah International Miwani Center (in survey sample)	Pioneer Technologies Limited
93	May-2007	Cosmas Munyeke		Machakos	Machakos		Pioneer Technologies Limited
94	Dec-2007	Dr. mwatu		machakos	Machakos		Pioneer Technologies Limited
95	Apr-2008	Mr. Mutuku		Machakos	Machakos	Land O' Lakes	Pioneer Technologies Limited
96	Feb-2008	mwororo		Machakos	Machakos	Land O' Lakes	Pioneer Technologies Limited
97	Oct-2007	Nicholas muindi		Machakos	Machakos		Pioneer Technologies Limited
98	Apr-2008	samuel balazi		Machakos	Machakos	Land O' Lakes	Pioneer Technologies Limited
99	Jun-2007	Daniel kilonzo Muli		Tala	Machakos		Pioneer Technologies Limited
100	Feb-2007	Lilian		Meru	Meru		Pioneer Technologies Limited
101	Feb-2007	Miriam		Meru	Meru		Pioneer Technologies Limited
102	Jul-2007	Isaac Kogi		muranga kangari	Murang a		Pioneer Technologies Limited
103	Jul-2007	Paul kuria		muranga mbiri	Murang a		Pioneer Technologies Limited
104	Feb-2007	Joyce	+254-(0)-723-480 488	Ndeiya, Muranga	Murang a		Pioneer Technologies Limited
105	May-2010	Ester Karanja	+254-(0)720-556 159	Njabini	Murang a	In Survey sample	Pioneer Technologies Limited
106	Apr-2008	Karanja		Njabini	Murang a		Pioneer Technologies Limited
107	Apr-2008	Njoroge k		Njabini	Murang a		Pioneer Technologies Limited
108	Jan-2010	Stephen Thiongo	+254-(0)711-433 791	Njabini	Murang a	In Survey sample	Pioneer Technologies Limited
109	Jul-2007	Job Mwangi	+254-(0)722-288 907	Mwiki	Nairobi	In Survey sample	Pioneer Technologies Limited

110	Oct-2006	Mama Leah	+254-(0)-722-513 825	Ruai	Nairobi		Pioneer Technologies Limited
111	Jul-2007	Daniel ikoro		Wangige	Nairobi		Pioneer Technologies Limited
112	Oct-2006	Daniiel Mbugua Njuguna	+254-(0)722-263 523	Wangige	Nairobi	In Survey sample	Pioneer Technologies Limited
113	Apr-2005	Evan Njuge Karanja	+254-(0)723-996 788	Wangige	Nairobi	In Survey sample	Pioneer Technologies Limited
114	Feb-2007	Mr Kamau		Wangige	Nairobi		Pioneer Technologies Limited
115	May-2006	Stella Kimani	+254-(0)722-651 036	Wangige-Muthumu Academy	Nairobi	In Survey sample	Pioneer Technologies Limited
116	Oct-2006	Nahashon Kariuki Njoroge	+254-(0)721-594 333	Wangige-Ruku area	Nairobi	In Survey sample	Pioneer Technologies Limited
117	Jun-2007	Naomi Wangari goko		wendani kahawa	Nairobi		Pioneer Technologies Limited
118	Jul-2007	Nuthia mwathi		Naivasha	Nakuru		Pioneer Technologies Limited
119	Apr-2007	Benote		Nakuru	Nakuru		Pioneer Technologies Limited
120	Dec-2006	Client		Nakuru	Nakuru	Land O' Lakes	Pioneer Technologies Limited
121	Apr-2007	Kingshop		Nakuru	Nakuru		Pioneer Technologies Limited
122	May-2007	Mr. Muthui		Nakuru	Nakuru		Pioneer Technologies Limited
123	Apr-2007	Pokea Farm		Nakuru	Nakuru		Pioneer Technologies Limited
124	Apr-2007	Wanjema		Nakuru	Nakuru		Pioneer Technologies Limited
125	Jun-2007	Kariuki		Ravine Nakuru	Nakuru		Pioneer Technologies Limited
126	Mar-2007	Client		Rongai	Nakuru	Land O' Lakes	Pioneer Technologies Limited
127	Feb-2008	Grace Makau		Nyeri	Nyeri	Land O' Lakes	Pioneer Technologies Limited
128	Dec-2007	Self		nyeri	Nyeri	Ithururu dairy farmers	Pioneer Technologies Limited
129	Sep-2007	Endarasha School for Orphans		Nyeri endarasha	Nyeri	Endarasha school for orphans	Pioneer Technologies Limited
130	Feb-2007	Koigi Mwangi		Chumga mali	Taita Taveta		Pioneer Technologies Limited

131	Dec-2006	Kiteto Joy	+254-(0)-722-958 019	Voi	Taita Taveta		Pioneer Technologies Limited
132	Feb-2007	Client		Kabarak	Uasin Gishu	Land O' Lakes	Pioneer Technologies Limited
133	Feb-2007	Client		Kericho	Uasin Gishu	Land O' Lakes	Pioneer Technologies Limited
134	Nov-2006	Isaiah Rono		Kericho	Uasin Gishu	Mayor-Kericho Municipal council	Pioneer Technologies Limited
135	Dec-2007	Self		Ol-Kalao	Uasin Gishu	National Youth Services-Tumaini	Pioneer Technologies Limited

Appendix 5: PTD Database of Visited Sites

No.	First Name	Address	Physical-location	County	Latitude	Longitude	Mobile Phone	installation-date	Digester performance Status	Installation Costs	Digester-size
1	Patrick Munyi	P. O. Box 205 - 00206	Kiserian- St. Patrick	Kajiado	01° 26' 045.50" S	36° 40' 029.50" S	+254-(0)721-214 007	Aug-2008	Working	38,000	Standard (L=10m, Dia=1.5m, Vol=6m³), Gas =2.4 m³/d
2	Neighbour to Mr Patrick Munyi		Kiserian- St. Patrick	Kajiado	01° 26' 045.50" S	36° 40' 029.50" S	-	Nov-2007	Not Working - gas pipe disconnected	38,000	
3	Esther Nyaga	P. O. Box 936 - 0068	Thome	Nairobi City	01° 12' 040.20" S	36° 52' 003.20" S	+254-(0)722-742 052	Jun-06	Working,	40,000	
4	Job Mwangi		Mwiki	Machakos	01° 13' 041.20" S	36° 56' 007.70" S	+254-(0)722-288 907	Jul-2007	Working	38,000	Large (L=10m, Dia=2.6m, Vol=16m³), Gas =3.2 m³/d
5	Francis Kamilichui	P. O. Box 65727 - 00607	Kamiti	Kiambu	01° 10' 055.50" S	36° 53' 027.80" S	+254-(0)722-796 859	Jul-2007	Working	40,000	

6	Esau Kinyanjui		Kimende	Kiambu	00° 58' 021.70" S	36° 36' 042.30" S	+254-(0)722-795 081	Jul-2009	Working	37,000	Standard (L=10m, Dia=1.5m, Vol=6m³), Gas =2.4 m³/d
7	David Karanja		Maginа	Kiambu	00° 59' 046.20" S	36° 38' 005.00" S	+254-(0)720-827 638	Sep-2009	Working	39,000	
8	Kuselu Mwangi		Maginа	Kiambu	00° 56' 056.80" S	36° 37' 038.50" S	+254-(0)751-834 022	Oct-2008	Working	40,000	Large (L=10m, Dia=2.6m, Vol=16m³), Gas =3.2 m³/d
9	Moses Gichoya	P. O. Box 36	Maginа	Kiambu	00° 57' 011.80" S	36° 37' 025.90" S	+254-(0)720-297 313	Sep-2005	Working	36,000	
10	James Thuo		Maginа	Kiambu	00° 58' 015.10" S	36° 37' 025.90" S	+254-(0)720-684 910	May-2008	Working	40,000	
11	James Njenga	P. O. Box 339	Limuru	Kiambu	01° 07' 008.10" S	36° 38' 007.10" S	+254-(0)722-265 319	Aug-2007	Working	38,000	
12	Ester Karanja		Njabini	Muranga	00° 44' 002.70" S	36° 39' 055.70" S	+254-(0)720-556 159	May-2010	Working	45,000	
13	Stephen Thiongo		Njabini	Muranga	00° 44' 002.70" S	36° 39' 055.70" S	+254-(0)711-433 791	Jan-2010	Working	45,000	

14	Luka Kinyanjui	P. O. Box 4104 - 00100	Kinoo-Muthiga	Kiambu	01° 14' 042.60" S	36° 44' 044.20" S	+254-(0)712-333 611	Feb-2004	Not working - Digester busted because someone had stepped on digester to increase gas pressure	25,000	Standard (L=10m, Dia=1.5m, Vol=6m³), Gas =2.4 m³/d
15	Nyahashon Kariuki Njoroge	P. O. Box 44246 - 00100	Wangige-Ruku area	Kiambu	01° 12' 010.40" S	36° 41' 030.30" S	+254-(0)721-594 333	Oct-2006	Working	36,000	Standard (L=10m, Dia=1.5m, Vol=6m³), Gas =2.4 m³/d
16	Stella Kimani		Wangige-Muthumu Academy	Kiambu	01° 12' 059.80" S	36° 42' 018.20" S	+254-(0)722-651 036	May-2006	Working	32,000	
17	Daniiel Mbugua Njuguna	P. O. Box 142	Wangige	Kiambu	01° 12' 055.50" S	36° 42' 044.70" S	+254-(0)722-263 523	Oct-2006	Working	36,000	
18	Evan Njuge Karanja		Wangige	Kiambu	01° 41' 053.20" S	36° 41' 053.20" S	+254-(0)723-996 788	Apr-2005	Working	32,000	

19	Ngugi		Karura	Nairobi City	01° 11' 015.00" S	36° 43' 005.40" S	+254-(0)722-686 550	Aug-2007	Working	35,000	
20	Peter Mwangi Kihara		Tinganga	Kiambu	01° 07' 030.90" S	36° 49' 000.50" S	+254-(0)736-451 398	May-2008	Working	32,000	
21	J. W. Gatumbi	P. O. Box 85	Ndakaini	Kiambu	00° 49' 046.20" S	36° 51' 042.30" S	+254-(0)724-881 203	Jul-2009	Working	38,000	
22	Winfred K. Njuri	P. O. Box 244	Ndakaini	Kiambu	00° 49' 036.00" S	36° 51' 058.50" S	+254-(0)723-317 156	Dec-2008	Working	38,000	
23	Francis Njehia		Kamuthi area	Nairobi City	01° 18' 036.90" S	36° 38' 037.10" S	+254-(0)723-161 820	Aug-2007	Not working - due to user management	38,000	
24	Joseph Mirengo		Kimende	Kiambu	01° 00' 033.60" S	36° 42' 029.70" S	+254-(0)722-376 806	Jun-2008	Working	36,400	
25	David Njoroge		Kamuthi	Nairobi City	01° 11' 043.90" S	36° 54' 037.10" S	+254-(0)722-807 638	Feb-2008	Working	36,400	
26	John Kimani		Kamburu	Kiambu	01° 01' 045.40" S	36° 44' 052.10" S	+254-(0)723-287 878	Feb-2008	Working	37,000	
27	Kennedy Kamau	P. O. Box 35	Kagwe	Kiambu	01° 00' 012.70" S	36° 45' 015.40" S	+254-(0)721-351 995	Aug-2008	Working	36,000	
28	Margret Kungu	P. O. Box 56	Kagwe	Kiambu	01° 00' 028.10" S	36° 54' 007.00" S	+254-(0)725-654 130	Apr-2009	Working	35,000	
29	Bernard Kinyanjui		Kagwe	Kiambu	01° 00' 033.60" S	36° 42' 029.70" S	+254-(0)722-348 496	May-2009	Working	38,000	Large (L=10m, Dia=2.6m, Vol=16m³), Gas=3.2 m³/d

30	Kabunyi		Limuru	Kiambu	01° 21' 051.90" S	36° 41' 044.40" S	+254-(0)722-782 691	Sep-2006	Working	35,700	Standard (L=10m, Dia=1.5m, Vol=6m³), Gas =2.4 m³/d
31	Moses Koigi		Lari	Muranga	01° 00' 021.60" S	36° 45' 023.20" S	+254-(0)720-472 477	May-2002	Working	20,000	Large (L=10m, Dia=2.6m, Vol=16m³), Gas =3.2 m³/d
32	Kiratu		Zambezi	Kiambu	01° 12' 051.90" S	36° 39' 042.90" S		May-2007	Working	36,400	
33	Washington Ogolla	P. O. Box 100	Kisumu	Kisumu	0.8° 11' 64.6" S	34° 42' 9.4" E		Jan – 208	Not working-digester bag busted	35,000	Standard (L=10m, Dia=1.5m, Vol=6m³), Gas =2.4 m³/d
34	David Isure		Kisumu	Kisumu	O.6° 3' 1.5" S	34° 54' 9.2" E	+254-(0)726-697 272	Feb – 2008		35,000	
35	Meshack Lwenya		Kisumu	Kisumu	0.7° 8' 4.5' S	34° 56' 9.2" E	+254-(0)723-798 620	Sept – 2007		35,000	
36	Joseph Oruko	P. O. Box 057 - 002841	Kisumu	Kisumu	0.6° 14' 3.5' S	34° 48' 11.2" E	+254-(0)721-489 293	Oct – 2008	Working	35,000	
37	Abandoned homestead		Miwani	Kisumu	0.6° 9' 4.5" S	34° 56' 11.2" E	-	Aug – 2008	Abandoned	35,000	

38	IEET-JKUAT (Two PTDs')	P. O. Box 62000 - 00100	Juja	Kiambu	01° 05'S	37° 00' E	+254-(0)67-52711	Aug-07	De-commissioned	40,000	

Note:

1. Information regarding digester number 2 was gathered mainly from the neighbour (digester number 1). We were unable to get the owner to obtain his full contacts details. Nonetheless the digester was shown to be not working due to the gas pipes having become disconnected.
2. Information regarding digester number 37 was obtained from Nehemiah International, Miwani Center. They are the ones who sponsored the digester and gave pertinent details like installation date, costs of installation, the installer etc. Upon visiting the site it was found that the no one lived in the homestead, but information on performance was acquired by a visual inspection of the digester
3. The total number of digesters is 39, however the total sites visited are 38. This is attributed to the fact that IEET-JKUAT site had two digesters installed side by side.

Appendix 6: Unverified Database of Installed PTDs

INDEX-No.	INSTALLATION DATE	CLIENT NAME	CONTACT	LOCATION	ORGANISATION
1	13.11.06	Mrs Karanja	+254-(0)-721-717 154	Kiserian	
2	10.12.07	Joseph mwangi	+254-(0)-722-211 874	Nazareth	
3	19.09.07	Daniel mbugua	+254-(0)-722-263 523	wangige	
4	23.10.06	Job Mwangi	+254-(0)-722-288 907	Mwiki	
5	23.11.06	Mr karanja	+254-(0)-722-376 389	Gikuni	
6	21.10.06	Mama Leah	+254-(0)-722-513 825	Ruai	
7	18.12.06	Mr Wanjohi Josephat	+254-(0)-722-623 606	Ngong	
8	21.01.08	John kiarii	+254-(0)-722-706 820	Githunguri	
9	20.08.07	Paul wachira	+254-(0)-722-722 697	Limuru	
10	17.12.07	kamwende	+254-(0)-722-735 026	embu	
11	15.01.07	George Ngugi	+254-(0)-722-856 040	Limuru	
12	01.12.07	Ngugi mwaura	+254-(0)-722-868 550	ndenderu	
13	20.12.06	Kiteto Joy	+254-(0)-722-958 019	Voi	
14	05.02.07	Joyce	+254-(0)-723-480 488	Ndeiya	
15	02.02.07	Joram Njenga	+254-(0)-724-596 606	Kibiciku	
16	15.08.07	IEET – JKUAT (Two sites)	+254-(0)-726-811 416	Juja	IEET-JKUAT
17	13.06.07	Pastor Afwayi	+254-(0)-733-393 528	Njiru	
18	15.11.06	Mr Wanjehia	+254-(0)-733-528 830	Mangu,Gatukuyu	
19	22.10.06	Shem Njiraini	+254-(0)-733-719 001	Githunguri	
20	19.09.06	Luka Kinyanjui	+254-(0)-735-499 043	Kinoo	
21	May-2007	Kiratu		Zambezi	In Survey sample
22	Jan-2010	Stephen Thiongo	+254-(0)711-433 791	Njabini	In Survey sample
23	Feb-2004	Luka Kinyanjui	+254-(0)712-333 611	Kinoo-Muthiga	In Survey sample

24	Sep-2005	Moses Gichoya	+254-(0)720-297 313	Magina	In Survey sample
25	May-2002	Moses Koigi	+254-(0)720-472 477	Lari	In Survey sample
26	May-2010	Ester Karanja	+254-(0)720-556 159	Njabini	In Survey sample
27	May-2008	James Thuo	+254-(0)720-684 910	Magina	In Survey sample
28	Sep-2009	David Karanja	+254-(0)720-827 638	Magina	In Survey sample
29	Aug-2008	Patrick Munyi	+254-(0)721-214 007	Kiserian- St. Patrick	In Survey sample
30	20.12.06	Elizabeth Mwhihaki	+254(0)721-339 460	Kibiciku	
31	Aug-2008	Kennedy Kamau	+254-(0)721-351 995	Kagwe	In Survey sample
32	Oct-2006	Nyahashon Kariuki Njoroge	+254-(0)721-594 333	Wangige-Ruku area	In Survey sample
33	Oct-2006	Daniiel Mbugua Njuguna	+254-(0)722-263 523	Wangige	In Survey sample
34	Aug-2007	James Njenga	+254-(0)722-265 319	Limuru	In Survey sample
35	Jul-2007	Job Mwangi	+254-(0)722-288 907	Mwiki	In Survey sample
36	May-2009	Bernard Kinyanjui	+254-(0)722-348 496	Kagwe	In Survey sample
37	Jun-2008	Joseph Mirengo	+254-(0)722-376 806	Kimende	In Survey sample
38	May-2006	Stella Kimani	+254-(0)722-651 036	Wangige-Muthumu Academy	In Survey sample
39	Aug-2007	Ngugi	+254-(0)722-686 550	Karura	In Survey sample
40	jun-2006	Esther Nyaga	+254-(0)722-742 052	Thome	In Survey sample
41	Sep-2006	Kabunyi	+254-(0)722-782 691	Limuru	In Survey sample
42	Jul-2009	Esau Kinyanjui	+254-(0)722-795 081	Kimende	In Survey sample
43	Jul-2007	Francis Kamilichui	+254-(0)722-796 859	Kamiti	In Survey sample
44	Feb-2008	David Njoroge	+254-(0)722-807 638	Kamuthi	In Survey sample
45	Aug-2007	Francis Njehia	+254-(0)723-161 820	Kamuthi area	In Survey sample
46	Feb-2008	John Kimani	+254-(0)723-287 878	Kamburu	In Survey sample
47	Dec-2008	Winfred K. Njuri	+254-(0)723-317 156	Ndakaini	In Survey sample
48	Apr-2005	Evan Njuge Karanja	+254-(0)723-996 788	Wangige	In Survey sample

49	Jul-2009	J. W. Gatumbi	+254-(0)724-881 203	Ndakaini	In Survey sample
50	Apr-2009	Margret Kungu	+254-(0)725-654 130	Kagwe	In Survey sample
51	May-2008	Peter Mwangi Kihara	+254-(0)736-451 398	Tinganga	In Survey sample
52	Oct-2008	Kuselu Mwangi	+254-(0)751-834 022	Magina	In Survey sample
53	04.12.07	Alice kihara		githiga	
54	16.07.07	Ann wachinga		Kiambu	
55	23.11.06	Anthony Mugwanja		Thika sports club	
56	26.04.07	Baba Njenga		Bahati	
57	13.04.08	Baldo		Ndaragwa	
58	24.04.07	Benote		Nakuru	
59	23.07.07	Bernad Ngige		kahawa	
60	30.04.07	Best dairies		Mukurweini	Wakulima Dairy members
61	14.01.08	Boniface mwaniki		embu kanja	
62	26.04.07	Cidar lodge		Bahati,	Cedar Lodge
63	06.12.06	Client		Nakuru	Land O' Lakes
64	10.11.065	Client		Kisumu	Nehemiah International Miwani Center
65	12.02.07	Client		Kisumu	Nehemiah International Miwani Center
66	13.02.07	Client		Githunguri	Land O' Lakes
67	13.02.07	Client		Kabarak	Land O' Lakes
68	13.02.07	Client		Kericho	Land O' Lakes
69	20.11.06	Client		Kisumu	Nehemiah International Miwani Center
70	26.03.07	Client		Cura wangige	Land O' Lakes
71	26.03.07	Client		Rongai	Land O' Lakes
72	6.12.06	Client		Mukurwini	Land O' Lakes
73	04.05.07	Cosmas Munyeke		Machakos	
74	12.06.07	Daniel kilonzo Muli		Tala	
75	19.07.07	Daniel ikoro		Wangige	
76	14.012.07	David mbugua nduati		Githunguri ngewa	
77	14.12.07	Dr. mwatu		machakos	
78	11.06.07	Evans Karanja		Gikuni wangige	
79	12.02.07	George		Kisumu	Nehemiah International Miwani Center
80	05.04.07	George Tharao Njugia		Kimende	
81	20.12.06	Gichuhi Mwaniki		Kimende	

82	30.04.07	Githioro		Mukurweini	Wakulima Dairy members
83	19.02.08	grace makau		Nyeri	Land O' Lakes
84	14.11.06	Hinga		Mangu,Gatukuyu	
85	30.04.07	Hosea mwangi		Mukurweini	Wakulima Dairy members
86	23.07.07	Isaac kogi		muranga kangari	
87	20.11.06	Isaiah Rono (Self)		Kericho	Mayor-Kericho Municipal council
88	12.02.07	J. Omtata		Kisumu	Nehemiah International Miwani Center
89	20.11.07	James njenga kaguora		limuru Gichagi	
90	10.01.07	Jane Nganga		Limuru	
91	03.07.07	Job Mwangi		mwiki	
92	16.08.07	Joyce		Muranga	
93	19.02.08	kamau		Kimende	Land O' Lakes
94	12.04.08	karanja		jabini	
95	20.06.07	Kariuki		Ravine nkr	
96	04.12.07	Kigali teachers		embu town	
97	30.04.07	kim chair		Mukurweini	Wakulima Dairy members
98	24.04.07	Kingshop		Nakuru	
99	27.02.07	Koigi Mwangi		Chumga mali	
100	30.04.07	kwamunga		Mukurweini	Wakulima Dairy members
101	02.02.07	Lilian		Meru	
102	30.04.07	macharia gaitho		Mukurweini	Wakulima Dairy members
103	13.08.07	mbuguas		githunguri	
104	07.02.07	Mirium		Meru	
105	10.02.07	Mr Kamau		Wangige	
106	30.04.07	mr karanja metal		Mukurweini	Wakulima Dairy members
107	08.05.07	Mr kariuki		Nakuru	
108	26.04.07	Mr koigi		Kimende	
109	07.05.07	Mr muthui		Nakuru	
110	03.04.07	Mr mwaura		Cura wangige	
111	07.05.07	Mr. Muthui		Nakuru	
112	15.11.06	Mrs Kimathi		Thika sports club	
113	05.12.06	Mrs Matu		Thika Delmonte	
114	04.04.07	Mrs Nyaga		Thome	
115	30.04.07	Mrs Thairu		Mukurweini	Wakulima Dairy members
116	30.04.07	Mutho w		Mukurweini	Wakulima Dairy members

117	08.04.08	mutukus		Machakos	Land O' Lakes
118	05.02.08	mwororo		Machakos	Land O' Lakes
119	13.02.07	Nahashon Kariuki		Ruku	
120	21.06.07	Naomi Wangari goko		wendani kahawa	
121	26.04.07	Nguru githiaka		Kimende	
122	02.10.078	Nicholas muindi		Machakos	
123	30.04.07	Njenga kim		Mukurweini	Wakulima Dairy members
124	13.04.08	Njoroge k		jabini	
125	26.04.07	Njoroge Nguru		Kimende	
126	19.02.08	Njuki munano		karura	
127	26.07.07	Nuthia mwathi		Naivasha	
128	12.02.07	Oira O.		Kisumu	Nehemiah International Miwani Center
129	13.04.08	P.MWAI		GITHIGA	
130	26.04.07	Pastor wangonbe		Bahati	
131	16.07.07	Paul kuria		muranga mbiri	
132	30.04.07	Penina njeri Kago		Mukurweini	Wakulima Dairy members
133	14.06.07	Peris kabaria		Tinganga	
134	30.04.07	Peter maina		Mukurweini	Wakulima Dairy members
135	24.04.07	Pokea Farm		Nakuru	
136	10.07.07	Roy Ngure		kahawa	
137	08.04.08	samuel balazi		Machakos	Land O' Lakes
138	01.12.07	Self		OLO-KALAO	National Youth Services-Tumaini
139	13.12.07	Self		nyerii	Ithururu dairy farmers
140	15.09.07	Self		Nyeri endarasha	Endarasha school for orphans
141	19.09.07	Self		wiyumiririe	Jikaze
142	31.08.07	Susan mbiti		wamunyu	
143	30.04.07	Tiiri		Mukurweini	Wakulima Dairy members
144	30.04.07	wahu muira		Mukurweini	Wakulima Dairy members
145	26.04.07	Wamai		Bahati	
146	18.04.07	Wanjema		Nakuru	
147	26.04.07	Wanjiklu kibe		Kimende	

Appendix 7: Statistical Determination of the Sample Size

This study is based on the realisation that the total population of PTDs installed countrywide in Kenya is unknown. Consequently, certain assumptions based on scientifically accepted statistical approaches have to be utilised. In the case of survey research, this normally means use of random samples that are generally assumed to cover the whole population. The determination of sample size based on scientific approaches cannot be underscored. This is mainly done to avoid to common errors in survey research (Bartlett et. al. 2001)

Subsequently, Yamane (Israel, u.d) provides such a formula for calculating the sample size (Eqn 1):

Eqn 1: Simplified formula for determining sample size (Israel, u.d)

$$n = \frac{N}{1 + N(e)^2}$$

The following table was derived.

Table 11: Sample size at 95% confidence level with a degree of variability P of 0.5 (Author)

	Sample size (n) at a Desired Precision level (e) of									
Expected population (N)	**30%**	**20%**	**17.0%**	**15.0%**	**12%**	**10%**	**8%**	**5%**	**3%**	**1%**
30	8	14	16	18	21	23	25	28	29	**30**
40	9	15	19	21	25	29	32	36	39	40
50	9	17	20	24	29	33	38	44	48	50
60	9	18	22	26	32	38	43	52	57	60
70	10	18	23	27	35	41	48	60	66	70
80	10	19	24	29	37	44	53	67	75	79
90	10	20	25	30	39	47	57	73	83	89
100	10	20	26	31	41	50	61	80	92	99
116	**10**	**21**	**27**	**32**	**43**	**54**	**67**	**90**	**105**	**115**
118	10	21	27	32	44	54	67	91	107	117
20	10	21	27	32	44	55	68	92	108	119
121	10	21	27	33	44	55	68	93	109	120
130	10	21	27	33	45	57	71	98	116	128
150	10	21	28	34	47	60	77	109	132	148
180	10	22	29	36	50	64	84	124	155	177
210	11	22	**30**	37	52	68	90	138	177	206
240	11	23	**30**	38	54	71	95	150	197	234
270	11	23	31	38	55	73	99	161	217	263
300	**11**	**23**	**31**	**39**	**56**	**75**	**103**	**171**	**236**	**291**
330	11	23	31	39	57	77	106	181	254	319
500	11	24	32	41	61	83	119	222	345	476
600	11	24	33	41	62	86	124	240	390	566
700	11	24	33	42	63	88	128	255	429	654

800	11	24	33	42	64	89	131	267	465	741
900	11	24	33	42	64	90	133	277	497	826
1,000	11	24	33	43	65	91	135	286	526	909
2,000	11	25	**34**	43	67	95	145	333	714	1667
4,000	11	25	**34**	44	68	98	150	364	870	2857
5,000	11	25	**34**	44	68	98	152	370	909	3333
10,000	11	25	**34**	44	69	99	154	385	1000	5000
100,000	11	25	35	44	69	100	156	398	1099	9091
300,000	11	25	35	44	69	100	156	399	1107	9677
1,000,000	11	25	35	44	69	100	156	400	1110	9901

From Table 11 It is noted that the higher the number of PTDs expected to be actually installed (N), the higher the sample size (**n**) needs to be. Subsequently based on the initially pre-determined sample size of 30, only two options are open to us in terms of the precision level (**e**): Either we assume **e** is 1% and hence **N** is 30 or we take a higher value of **e** and subsequently have a wider choice of **N**.

For this studies purpose an **e** value of 17% was chosen. This was based on a two point criteria: First, that we have an **e** that can cover as wide a range of known and unknown Population (**N**), and secondly to have a sample size (n) that is as near as possible to that given in the ToR. A much bigger sample space will mean more time and resources (money, transport etc) to undertake the survey than was initially agreed upon or allowed by the contract. Subsequently an **e** value of 17% allowed the study to be able to choose a sample size that covers not only the final list given to us by Pioneer Technologies of 116 installed PTDs but more importantly to also cover their initial claim of 300 installed PTDs. In addition it allows us to have a sample size that can cover a possible potential of exceptionally high numbers of installed PTDs – since no census of the number of installed PTDs has been done or is known.

It is thus for the above reasons that the initial suggested sample size of 30 PTDs was increased to 34. This allowed us to be able to cover a potential number of between 30 to over 300 installed PTDs.