Final report on household and institutional biogas from urban organic waste in Nairobi

Technical performance & economic potential

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KEY FINDINGS

The key findings of the ARTI biogas pilot project in Nairobi, which ran from March to November 2010, can be summarized follows:

1. *Satisfactory technical performance*: the ARTI compact biogas test units installed in Nairobi operated as designed. Cooking gas was produced from urban organic waste with no major system problems.

2. *Air temperature significantly affects system performance*: during the cold season (June, July) in Nairobi, colder weather seriously curtails biogas production in the above ground, un-insulated ARTI digesters (2 hours per day versus 3-4 hours for the institutional unit).

3. *Institutional size units more economical than household units*: institutional size units may offer a shorter payback period (2-4 years versus 5-9 years) and thus be more immediately commercially viable, especially where LPG cooking fuel is replaced.

4. *Consumers positive about "gas-for-cash" biogas business idea*: initial indications are that existing and potential biogas users in peri-urban and semi-rural areas of Kenya would be willing to participate in the "gas-for-cash" concept.

5. *"Gas-for-cash" idea perceived as too risky for uptake by existing biogas companies*: upfront costs and business risks may still be too high to entice a company to implement the "gas-for-cash" idea.

This report has been prepared by Carbon Africa Limited of Nairobi, with substantial inputs from Ms. Bijal Shah of GreenTech International Limited of Nairobi. The report is based on findings from the May to September 2010 monitoring of the technical performance of three small-scale biogas systems installed in Nairobi in March 2010 and on a preliminary review of economic potential by two students from the Free University of Amsterdam. The project is undertaken by Carbon Africa, GreenTech International and Joint Environmental Techniques (JET) Tanzania, with financial and technical support from LEI/Wageningen UR and ALTERRA/Wageningen UR using funding from the Ministry of Economic Affairs, Agriculture and Innovation of the Netherlands.

BACKGROUND

The organic fraction of municipal solid waste in Nairobi, Kenya is estimated to be at least 50% of the total daily waste of approximately 3,000 tonnes generated in the city.[i] [ii] [iii] A similar ratio is likely the case in Kenya and East Africa's other large urban centers. Given the large quantities involved, there are significant perceived opportunities in segregating and using the organic waste stream as a renewable resource – for animal feed, for compost/fertilizer and/or for energy generation.

In January 2010, following an earlier inventory of solid waste categories/quantities in Nairobi, a LEI/WUR-supported pilot project was initiated with local partners in Kenya to help assess the latter two possibilities. The pilot was as a practical contribution to the wider Nairobi solid waste management planning currently underway under the auspices of the City Council of Nairobi, UNEP and JICA.

Currently there are around ten to twelve existing biogas companies and NGOs in Kenya. Of these, only a small number are operating successfully on a commercial basis. Most the projects receive technical support or subsidies from donors and have not yet succeeded in expanding the biogas market sufficiently.

While a combination of fixed-dome, floating-drum and plastic tubular technologies are being promoted, the large majority of these target rural domestic and institutional users. Livestock dung is the primary feedstock, though examples using other agricultural residues and human manure do exist. Approximately 2,000 biogas units of all types have been installed to date in Kenya.[iv]

For the investigation of energy generation from organic waste in this pilot project, a small-scale anaerobic digestion technology was identified: the ARTI compact biogas system. The Appropriate Rural Technology Institute (ARTI) of India, an NGO based in Pune, Maharashtra State, developed this system in 2003. The ARTI technology[v] uses municipal organic and market green waste as a feedstock. The technology is modular, easy to install, relatively low cost and is made from local materials.

Approximately 60 of the ARTI compact biogas digesters are operational in Tanzania, where in 2009 the technical performance of the system was evaluated by a student from the Zurich University of Applied Sciences.[vi] The student's review indicated fairly good system performance but certain maintenance procedures that needed to be improved upon.

For the pilot project in Nairobi, two household and one institutional size ARTI digesters were installed and tested. Basic system monitoring began in May 2010 and the results in this report are presented based on data up to September 2010.

A preliminary analysis of the economic possibilities and interest in new business models for the scale-up of biogas in Kenya was also conducted by two students from the Free University of Amsterdam and incorporated in this report.

This report gives an overview of the technical performance for the ARTI compact biogas system in Nairobi and of the potential economic savings therein, and provides a preliminary analysis of the "gas for cash" business concept in Kenya. However, further evaluation is likely required before the ARTI systems and the "gas for cash" business model could be successfully rolled out on a commercial basis in Nairobi.

OBJECTIVE OF THE BIOGAS PILOT PROJECT

The overall objective of the pilot project was to evaluate whether compact biogas systems are appropriate as part of an urban waste management strategy in Kenya and whether an economically sustainable model for their dissemination can be realized.

Specific project objectives were:

- A technical assessment of the performance of the ARTI technology in Nairobi
- A market analysis for the technology and its economic potential
- Identification of a business model that would counter for the high upfront investment cost that is a barrier to the dissemination of the technology

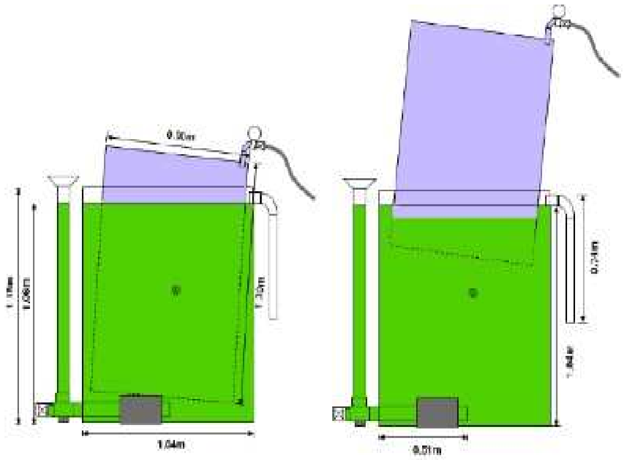
TECHNICAL PERFORMANCE ASSESSMENT

Technology

The ARTI compact biogas system is made from two cut-down standard high-density polyethylene water tanks and standard plumber piping.

The larger tank acts as the digester while the smaller one is inverted and telescoped into the digester and serves as a floating gas holder, which raises proportional to gas produced and acts as storage space for the biogas.

Figure 1: Schematic of ARTI floating drum biogas system



The gas can directly be used for cooking on an adjustable gas stove whereas the liquid effluent can be applied as nutrient fertilizer.

At the household level, the ARTI digesters require two square meters of space, and at the institutional level approximately 2.5 square meters of level flat ground or floor for the base.

More information regarding the ARTI technology is available on the ARTI India website.[vii]

System installation

One institutional size digester and two household size digesters were installed in relatively upmarket areas of Nairobi at the end of March 2010 as follows:

Table 1: Location and size of pilot ARTI biogas units

Location	**Type**	**Digester size**	**Gas holder size**
Westlands	Institutional	5,000 L	4,500 L
Westlands	Household	1,500 L	1,000 L
Kileleshwa	Household	1,500 L	1,000 L

Installation of ARTI compact biogas systems units was carried out from 14 - 20 March 2010 by JET Tanzania technicians, who have experience with the implementation of approximately 60 ARTI systems in Tanzania. The plastic tanks were delivered on site by the manufacturer, Kentainers, some key components were brought in from Tanzania and the rest were purchased at local hardware shops in Nairobi. Unit locations at the different sites were chosen based on availability of sunlight (to maintain adequate temperature inside the digester), easy flow of gas from the units and proximity to the kitchen where stoves would be located.

In order to speed up the initial production of gas, cow dung slurry from an existing (fixed dome) biogas unit on a farm in Ruai (eastern Nairobi) was procured and transported to each installation location and mixed with water in the following quantities:

Table 2: Initial substrate mix to start the digestion process

Institutional size unit - 1000 L porridge - 3000 L cow dung slurry - 1000 L water	
Household unit 1 (*Westlands*) - 400 L cow dung slurry - 1000 L water - 1 kg flour -	
Household unit 2 (Kileleshwa) - 1000 L cow dung slurry - 500 L water - 1 kg of maize flour	

It is not known if the difference in starter slurry mix between the two household units had an influence on initial gas production. No apparent difference was noted during installation and commissioning, although this is in part because the host households were asked to release the initial gas twice before using the systems for cooking.

Feeding

Feeding of all the units was done twice daily, once in the mornings and once in the evening. The feedstock used was mainly organic kitchen waste consisting of miscellaneous food leftovers, peelings and discarded pieces of fruits and vegetables.

Responsible persons at each location were taught how to dilute the feedstock, normally with food or grey wastewater, in order to reduce the size of food waste particles. This has two purposes: (i) it helps avoid clogging of the 3-inch in-let pipe and (ii) the increased surface area of the feedstock allows for improved bacterial digestion.

Monitoring

System monitoring was begun in May 2010 and the results of up to September 2010 are presented in this report. Monitoring was undertaken through (a) on-site measurements, (b) data collection forms and (c) periodic inspections and interviews with persons responsible. A simple and low-tech approach to monitoring was taken due to resource constraints.

<u>Equipment measurements</u>
Only the institutional unit was equipped with an internal temperature data logger, although the data from this was not available during the pilot project (see below). Gas volumes were extrapolated manually by measuring difference in gasholder height before and after use. The household units were not equipped with a thermometer. Data was compiled on at least a monthly basis.

<u>Data forms</u>
Responsible persons at each location were provided with forms and instructions for filling them out. This was meant to be done on a daily basis although it was not always the case due to attention other matters. For the feedstock, three aspects were monitored, namely the (a) type, (b) quantity and (c) structure of the input materials. Daily gas production was measured by keeping records of the time spent cooking using the biogas as well as marking the gas holder height before and after cooking.

An example of the data form with the type of information collected is presented here.

Table 3: Sample data form for biogas unit hosts to complete

Date	Morning feed (type)	Quantity (kg)	Evening Feed (type)	Quantity (kg)	Who fed	Cooking time		Gasholder Height	
						Start	End	Before cooking	After cooking

PH levels were not been measured due to time constraints while gas pressure monitoring in the absence of a proper gas meter was not been possible. Likewise, effluent from the system was not analyzed but information on the composition and quality of such is already available.[viii]

Periodic inspections and interviews
Approximately once every two weeks each of the biogas digester sites were visited, usually by GreenTech International, to collect and compile data. During the visit the units were also inspected and their performance discussed with the persons responsible to learn more about the quality, quantity and dilution of the daily feedstock, duration of daily gas use, utilization of effluent, operator experiences and the perception of performance. At the same time, outside temperature, cloud cover and precipitation were also noted.

The parameters chosen are considered to be those most important for digester performance under the simple and low-tech monitoring regime used in the project.

Results

Given that the pilot project encompasses three digester systems and that only a basic monitoring system was put in place, the results of the study should be considered as indicative in nature. However, they do reveal some important findings.

A summary of the results of the system performance monitoring from May to September 2010 is presented in the tables below.

Table 4: Institutional unit inputs and outputs

Quantity of feedstock	Mon, Tues, Wed and Fri - about 60 litres of potato starch residues and peeling is used per day, from the one daily meal prepared by the temple for poor people Thurs – an additional meal is served on Thursdays and the extra waste food was used as feedstock. When other additional meals were prepared (during special occasions and functions), all food residues were also fed into the digester.
Type of feedstock	Potato starch, vegetable peelings and waste cooked food
Structure of feedstock	Diluted with water, liquid state
Average cooking time available from biogas using one 18 L/min burner	May - 170 minutes / day June - 140 minutes / day (cold season) July - 120 minutes / day (cold season) August – 180 minutes / day September – 205 minutes / day

Table 5: Household unit 1 (Westlands) inputs and outputs

Quantity of feedstock	2-4 kg of kitchen waste per day
Type of feedstock	Kitchen waste, mostly peelings and bi-monthly starch waste from potatoes and lentils
Structure of feedstock	Hand chopped to pieces smaller than one centimetre square
Average cooking time available from biogas using a 2.5-4 L/min burner	60 minutes / day (May, August, Sept) 180 minutes / week (cold season – June, July)

Table 6: Household unit 2 (Kileleshwa) inputs and outputs

Quantity of feedstock	3-4 kg of kitchen waste per day
Type	Kitchen waste, mostly vegetable peelings and other fruit and vegetable waste

Structure	Ground into porridge consistency using and electric motor
Average cooking time available from biogas using a 2.5-4 L/min burner	90 minutes / day (May, August, Sept) 180 minutes / week (cold season – June, July)

Comparison of the two household systems

It was noticed that household unit 1 (Westlands) takes longer to produce gas once the feedstock was inserted as compared to household unit 2 (Kileleshwa). As both units were well placed to receive a similar amount of sunlight, it is assumed that the main reason for this was the structure of the feedstock. This was due to the relatively small size of the feedstock input material in the latter unit, which is ground into a porridge consistency, hence facilitating bacteria digestion.

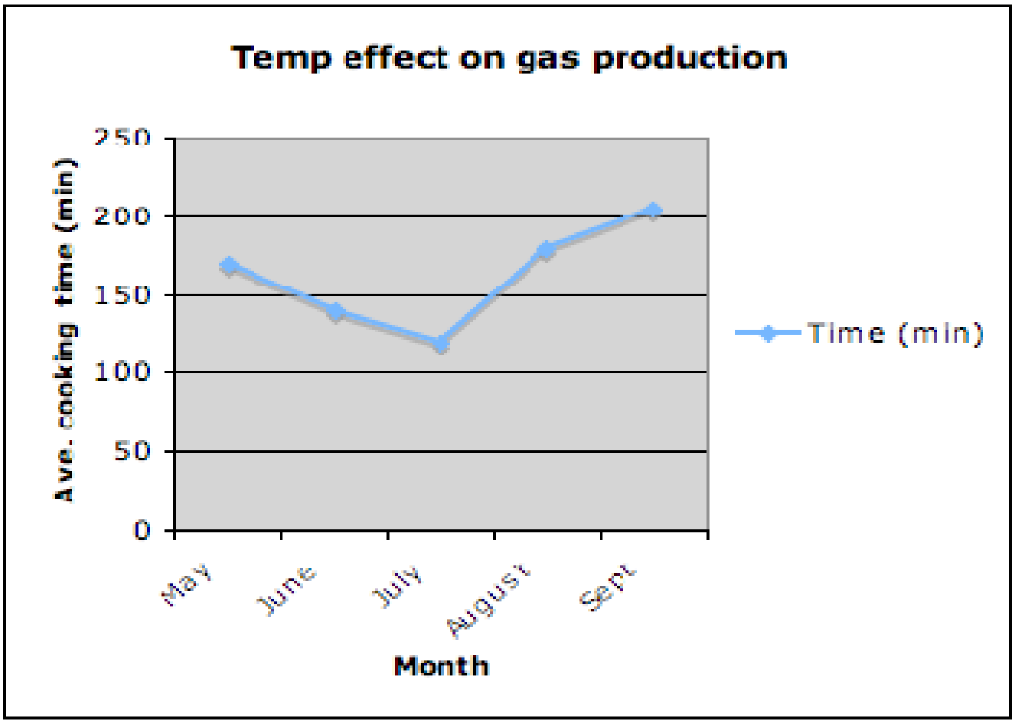
Influence of temperature

The cold weather in Nairobi (coldest in June, July and August) significantly affected gas production. Low temperatures especially at night hindered anaerobic digestion, which was further compounded by a lack of sunshine during the day. Adequate digester temperatures were not maintained in the household units, reducing the availability of gas in both until the households were only able to use the gas for two days a week at approximately 1.5 hours per day.

Tellingly, the institutional unit was not as vulnerable to the drop in temperatures as the household units. Even during the cold season, the institution was still able to utilize the gas for approximately two or more hours each day of the week. This is likely due to the larger size of the unit, which permitted better heat retention for bacterial digestion.

Internal temperature data for the institutional size unit was not analyzed as the data logger installed in the unit was affected when the unit was moved due to construction.

Figure 2: Effect of outside temperature on gas production



Problems encountered during implementation

A number of general problems arose during the implementation and assessment of the project to date. These are useful to point out so they can be avoided in the future, and are as follows:

1. Availability of the starter slurry. The identified location was further away than anticipated and it became more of a logistical challenge to transport the starter material.
2. It was realized early on that colder temperatures were seriously affecting the performance of the household units. The project coordinators discussed the option of insulating one of the units to see if it would make a difference, but time and resource did not permit this.
3. Due to construction which began around 16 September 2010 at the site of the institutional unit, it was drained of slurry and temporarily moved. A new foundation has been built but more starter slurry will need to be sourced before the unit is re-activated. The one positive aspect of this episode is that the mobility of an above ground biogas digester is shown.
4. The above also affected internal digester temperature data collection. Slurry/water ingress disturbed the temperature data logger recordings and hence no internal digester temperature readings were made.
5. During re-location of the institutional unit prior to construction, the emergency outlet pipe was damaged. This was repairable locally.

Technical analysis

<u>System reliability and appropriateness</u>
If installed and operated properly, the ARTI Compact biogas system is robust in terms of structural stability. No leakages of slurry were reported, and the accompanying equipment (pipes, valves) functioned well. The longevity of the polyethylene tanks is expected to be more than 20 years. All materials necessary for installation of the compact biogas system were locally available. However, a trained technician is required in the case of any serious maintenance or repair issues.

<u>Climatic conditions</u>
As was observed above, low temperatures significantly affected stability in gas production from the units. The household size units performed quite poorly during the cold months, with biogas use being limited to twice a week. The institutional size unit was not as vulnerable to the drop in temperatures, but a reduction in gas output was still evident. The relatively warmer average temperatures in cities such as Mombasa and Kisumu could be expected to mitigate this issue, as the digesters in Dar es Salaam have not to date experienced any known significant temperature-related performance reduction. Insulation of the units is also an option, although this will increase costs and the effectiveness of such has not been tested.

<u>System operations</u>
The biogas unit at household 1 (Westlands) experienced some early technical problems. Initially, the cooking stove provided did not sustain a continuous burn even when there was enough supply of gas. All connections were checked for loose fittings and leaks and none were found. Drops of water were discovered inside the stove itself after about 2.5 months of operations. Clearing these helped to solve the problem. Although the water moisture recurred from time to

time, the household members were able to clear the system on their own. Another relevant factor may be that the digester at household unit 1 (Westlands) is on a balcony and the stove is on a level below, meaning that the gas has travel approximately 4m downwards while with the household 2 unit (Kileleshwa) the digester and stove are both on level ground. However, the reason for the build-up of moisture was not entirely clear as both household units have a moisture release valve in the gas piping system.

The institutional unit and the household 1 unit (Westlands) experienced several incidents of inlet pipe blockage. These events were due to insufficient reduction in size or dilution of feedstock material and the persons responsible neglecting to flush the feedstock through with slurry after insertion.

A weakness of the system design, which contributes to its simplicity and ease of assembly, is that the space between the digester tank and the telescoping gasholder allows an un-quantified amount of biogas to escape. This potentially reduces the efficiency of the ARTI system.

Aesthetics

The visual appearance of the ARTI units is not attractive but functional. This may turn off a certain market segment of potential urban users. Odour on the other hand was found to be a relatively minor issue, with no complaints reported after the smell of the initial starter slurry dissipated. One issue of concern may be the flies attracted to the digesters due to the gaps between the two plastic tanks though during the pilot this is of less concern as each unit is located a fair distance away from the main cooking and areas of habitation. The 2009 study by the Zurich University of Applied Sciences student in Dar es Salaam found that the insects attracted to the system did not present a significant risk of disease transmission.[ix]

Cost savings

The institution and two households normally use LPG for cooking. The institutional host had historical data on fuel consumption for cooking that they were able to make available. The households, however, had not kept previous records on quantities of LPG used. Hence this brief analysis of cost savings is based on the institutional unit only.

The table below compares LPG usage for the institution for the months May, June, July and August 2009 and 2010, although not enough data was collected to enable any certain conclusions

Table 7: Biogas impact on the use of LPG at the institution (2009 vs. 2010)

Month	Year	LPG consumption (L)	LPG cost (average of EUR 0.70/L)	Number of functions held	LPG savings (L) with biogas
May	2009	1924	1347	5	-755
	2010	2679	1875	8	
June	2009	2249	1574	10	117
	2010	2132	1492	10	
July	2009	2314	1620	12	403
	2010	1911	1338	9	
August	2009	2288	1602	10	-292
	2010	2580	1756	13	

As can be seen above, only the month of June can possibly be used for tentative direct comparison as the same number of functions (which affect food waste levels) was held in the month in both 2009 and 2010. The comparison may be misleading, however, as data from the other three months shows that the amount of LPG consumed per function is not necessarily uniform. It is also likely that the amount of food consumed per function, and hence amount of food residue feedstock available, may also not always be consistent. Thus further evaluation would be required before an assessment with an acceptable degree of certainty can be made.

On the assumption that the June comparison is valid, and that the use of biogas did directly result in a decrease in the use of LPG, a cost savings of approximately KES 9,000 (EUR 77) was achieved for the month. This is based on:

- LPG price of KES 153 / kg[x]
- 1 kg of LPG = 1.985 L of LPG
- Cost per L of LPG = KES 77.1

It should also be noted again that June, July and August are the cold months in Nairobi, resulting in lower biogas production.

ARTI system costs

For the installation and commissioning of the pilot ARTI compact biogas systems in Nairobi, the total costs came to EUR 1,015 for the household size unit (2.5 m3) and EUR 2,237 for the institutional size unit (9.5 m3). The breakdown is as follows:

Domestic size digester
(2.5 m3)

Item	**Cost (EUR)**
Parts	110
Stove	54
Foundation	73
Tanks	171
Labour	607
Total	*1015*

Institutional size digester
(9.5 m3)

Item	**Cost (EUR)**
Parts	183
Stove	99
Foundation	141
Tanks	600
Labour	1214
Total	*2237*

Labour was the most significant cost item due in part for the requirement for the technicians to come from Tanzania. It is expected that these costs could be reduced significantly once local trained technicians are available.

The cost for the procurement, fabrication, installation and commissioning of the ARTI biogas digester during the pilot project in Nairobi can be compared with average fixed-dome biogas digester costs in Kenya from 2007[xi] and 2009[xii] studies. However, while the below prices from the 2007 study (with asterisks *) include materials and some labour costs, it is not clear to what extent they incorporate donor subsidies and they likely exclude transport, piping and appliance (e.g. cooking stove) costs. The prices from the 2009 study (no asterisks) are considered to be all-inclusive.

Table 8: Average price of fixed dome digesters in Kenya (2007, 2009)

Domestic size digester

Size (m3)	Price (USD)	Price (EUR)
8*	574	435
9	714	514
10*	649	492
12*	784	594
14	1762	1269
16*	980	743
16	1905	1372

Institutional size digester

Size (m3)	Price (USD)	Price (EUR)
16*	1765	1338
31*	3015	2286
54*	5147	3902
84*	6618	5018

Advantages and disadvantages of the ARTI technology

Advantages
- All materials for system fabrication can be sourced locally
- The system is mobile and modular
- The design is simple, easy to fabricate, does not involve digging or construction and does not have any mechanical parts that may need repair
- The system itself does not require much space (2 – 2.5 m2 of level ground)

Disadvantages
- The above-ground system is sensitive to fluctuations in temperature and performs poorly in cold weather
- The waste feedstock may not always be available in sufficient quantities to produce the desired level of gas and in some cases requires some processing (chopping, dilution) to help speed up gas production
- There may be aesthetic issues with adoption of the technology in urban areas

ECONOMIC POTENTIAL

"Gas-for-cash" idea

Generally one of the biggest barriers to the uptake of biogas digesters, even with subsidies, sponsors and micro-finance loans, is the upfront investment costs. One potential way to break this barrier is for a private entity, NGO or consortium to develop a "gas for cash" business model wherein the entity pays for and maintains ownership of the biogas units once installed and the client (household, institution) only pays for the gas delivered. A lease-to-own / installment payment structure could also be considered, with a small (token) upfront deposit by the client. If the monthly cost of the biogas delivered is significantly less than the price of LPG, fuelwood or charcoal, and the digesters perform reliably, it is anticipated that such a model would be attractive to a certain market segment. It is also important to note that under this model the operational risk for the digester remains with the entity and not the customer.

In order to assess the viability of the "gas-for-cash" idea, the pilot project attempted a brief assessment of economic potential to gauge the interest and "willingness-to-pay" of target household and institutional potential biogas users. Market surveys were not undertaken as part of the pilot project and would be a useful next step in under taking a proper economic assessment.

Market analysis

Two masters students from the Free University of Amsterdam were hosted in Nairobi by Carbon Africa from May to August 2010. The students did not focus their research purely on the "gas-for"cash" business idea, but more broadly looked at related aspects of biogas in Kenya. Some of the results of their research[xiii] [xiv] are, nevertheless, relevant for the assessing the "gas-for-cash" idea. Existing studies[xv] that give some indication of potential market size for biogas in general in Kenya were reviewed but as they focus mostly on rural systems using cow dung as the feedstock, they were not analyzed in this report.

At present, there is no major competing biogas technology on the Kenyan market that specifically targets (urban) organic waste as a feedstock. However, local water tank manufacturing company Kentainers has started to produce a polyethylene floating-drum above ground system very similar in design to the ARTI technology and a somewhat similar system of Chinese origin has started to be marketed by at least one biogas digester provider in Nairobi.

Cooking fuel economic baseline

The research of the first student hosted by Carbon Africa relied on the results of Focus Group Discussions with biogas and non-biogas users in semi-rural and peri-urban areas of Nairobi and northern Mt. Kenya. A total of 95 individuals took part, separated into groups of men and women. While the results of the research are instructive, random sampling was not used to select the Focus Group Discussion participants, so the data cannot necessarily be extrapolated to the general population. The research found an average annual cooking fuel (wood, charcoal and/or LPG) expenditure of KES 25,000 (EUR 215) in the peri-urban areas of Nairobi and KES 16,000 (EUR 137) in semi-rural areas of northern Mt. Kenya, with a range of KES 0 to KES 78,000 (EUR 670).[xvi]

Interestingly, in interviewing existing biogas users, the student found that those who had already adopted the technology had prior annual average cooking fuel expenditures of around KES 30,000 (EUR 260) to KES 60,000 (EUR 520),[xvii] giving some indication of at what cost level potential users perceive a switch to biogas to be competitive (keeping in mind the other factors involved in biogas adoption). This is also apparent in the average annual income levels of those users who had already adopted biogas (KES 500,000 or EUR 4,300) in the peri-urban areas of Nairobi versus those potential users who had not adopted biogas (below KES 200,000 or EUR 1,715) in the semi-rural areas around northern Mt. Kenya.[xviii] This information is useful for any future "gas-for-cash" market surveys and to anticipate the market potential for biogas energy from organic waste in urban and semi-urban areas of Kenya.

This range of yearly household cooking fuel expenditures coincide well with those of a 2009 report,[xix] in which a Kenyan household's cooking energy costs were found to range between KES 14,000 (EUR 120) and KES 80,000 (EUR 690) annually, depending on district.

In the case of institutions, as can been seen from the case of the Jai Jalaram Satsang Mandal Temple in Westlands included in this study, *monthly* LPG costs for cooking well exceeds KES 100,000 (EUR 850).

For more general figures, the Renewable Energy Technology Assistance Programme (RETAP) estimates that the typical boarding school in Kenya consumes approximately 200 – 300 tonnes of fuelwood per year for cooking at an average cost of KES 350 (EUR 3) per tonne.[xx] This means that an average boarding school may spend between KES 70,000 (EUR 600) and KES 105,000 (EUR 900) per annum on cooking fuel – which this report considers to be an underestimate.

Simple payback period

Based on the actual ARTI technology installation and commissioning costs taken from this pilot project and the above household and institutional cooking energy expenditure estimates, the following simple payback calculation (Simple payback = biogas unit cost / annual fuel cost savings) is provided:

Table 9: Basic simple payback period calculation

	Urban household 2.5 m3 ARTI unit	*Urban institution 9.5 m3 ARTI unit*	*Rural school 9.5 m3 ARTI unit*
Upfront ARTI system cost	EUR 1,015	EUR 2,237	EUR 2,237
Annual cooking fuel expenses	EUR 580 (based on mid-range of peri-urban users who have already adopted biogas)	EUR 16,000 (using the temple from the pilot study as an example)	EUR 750 (using mid-range of RETAP findings in main report)
Monthly cooking fuel expenses	EUR 48	EUR 1333	EUR 62
Monthly savings with ARTI biogas	EUR 16 (assuming one biogas unit replaces 33% of cooking energy needs)	EUR 67 (assuming one biogas unit replaces 5% of cooking energy needs)	EUR 20 (assuming one biogas unit replaces 33% of cooking energy needs)
Payback period	*5.3 years*	*2.9 years*	*9.3 years*

The above estimates are considered to be conservative, as it has been mentioned previously that it is likely possible to reduce substantially the labour costs associated with the installation of the ARTI biogas digesters. In addition, the above has not considered any potential income from carbon credits that could be in the range of EUR 10 – 20 per year depending on the size of the biogas digester and the type of cooking fuel that is displaced. And lastly in the case of the institutions, the estimated annual cooking energy expenditures are thought be below what is actually the case.

However, maintenance costs and the need for periodic replacement of parts are not included in the above analysis.

Under a "gas-for-cash" business model, the simple payback period is the amount of time required before the entity owning the units would begin to make a profit. Based on the conservative payback scenario above, it is clear that a company would face a substantial risk investing in such at the household or rural school level. An investment at the urban institutional level may already make economic sense.

However, if the upfront cost of the ARTI biogas system could be reduced by 50% (as is likely possible) and if the carbon credits were included in the equation, the payback period of institutional systems installed in urban and peri-urban areas to replace LPG cooking fuel may drop below two years, hinting at economic viability.

These payback periods are contrasted with that found in a 2007 report,[xxi] which estimates a three-year payback (albeit under an optimistic scenario including low upfront investment costs, no maintenance costs and some carbon credit revenue) for biogas digesters in Kenya.

Qualitatively, the 2010 Masters Thesis report indicates that some potential biogas users are aware that in the long-term biogas is cheaper than other cooking fuels and that cost savings would occur after the payback period but that the barrier of the upfront cost is critical,[xxii] which is something that the "gas-for-cash" idea would be designed to overcome.

Suitability of the "gas-for-cash" idea

During the Focus Group Discussions conducted by the first student in the peri-urban areas of Nairobi and semi-rural areas of northern Mt. Kenya, the "gas-for-cash" concept was presented to existing biogas users and potential household consumers and discussed.

According to the student's report, the idea was welcomed and most participants indicated their willingness to participate in such a scheme. Key feedback received[xxiii] was as follows:

- The proposed monthly payments for gas were perceived as a type of "credit," although more flexible and less threatening than that of a loan from a bank.

- A key condition for participants' interest in the "gas-for-cash" idea is that ownership of the biogas system should be handed over after a certain period of time, which should be agreed between the biogas service company and the user (lease-to-own model).

- Potential users were willing to feed the digesters but expected that there might be a reduction in charges for the gas due to the fact that they were also contributing to the biogas production.

The second student hosted at Carbon Africa's study focused on business model innovation for the scale-up of biogas use in Kenya. This involved semi-structured interviews with a number of existing biogas companies, biogas supporters and other stakeholders. The "gas-for-cash" idea was discussed briefly with the following conclusion:

> Often mentioned issues with [the "gas-for-cash" model] was the bigger risk endured by the [biogas provider service] company, the need for initial capital that is unavailable currently and the inability to plan and execute the projects in a way that guarantees profitability while managing risks... Unanimously interviewees agree that these business model innovations are beyond their current expertise and capital capacity and doubted their success in principle.[xxiv]

Thus the preliminary conclusion is that while potential biogas users would welcome the "gas-for-cash" business model, existing biogas companies in Kenya are either unable or unwilling to take up the challenge.

ENDNOTES

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[xviii] *Ibid.*, p. 23.

[xix] Gichohi 2009, p. 9.

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[xxi] ETC Group 2007, p. 56.

[xxii] Jonusauskaitè 2010, pp. 30-31.

[xxiii] Jonusauskaitè 2010, pp. 38-39.

[xxiv] Rangelov 2010, pp. 44-45.