

# Technical performance of biogas from urban organic waste in Nairobi and economic potential of a “gas-for-cash” business model

## December 2010 – summary

From May to November 2010, an urban biogas pilot project was implemented in Nairobi, Kenya as a practical contribution to the solid waste management planning process being led by the City Council of Nairobi, JICA and UNEP. The Ministry of Economic Affairs, Agriculture and Innovation of the Netherlands partly funded the pilot project. The pilot objectives were to:

- (a) Evaluate whether compact biogas systems are appropriate as part of an urban waste management strategy in Nairobi
- (b) Provide a preliminary economic assessment of a new business model for the roll-out of biogas digesters at the household and institutional level in Kenya

The implementing partners were two Kenyan and one Tanzanian-based company, being Carbon Africa, GreenTech International and Joint Environmental Techniques.

### Urban ARTI biogas digester system performance



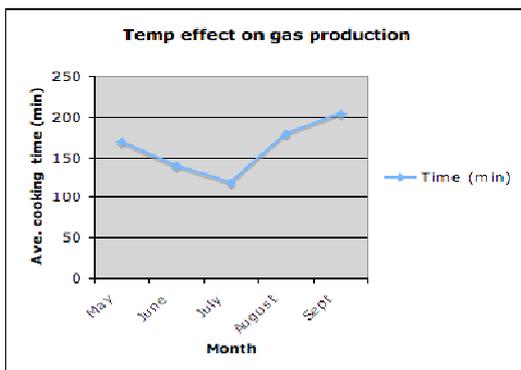
The pilot tested the technical performance of two household (2.5 m<sup>3</sup>) and one institutional (9.5 m<sup>3</sup>) sized urban ARTI biogas digesters for cooking purposes. The Appropriate Rural Technology Institute (ARTI) of India’s plastic, floating drum technology was chosen as it is modular, mobile, easy to install, relatively low cost and uses municipal organic and market green waste as a feedstock.

Unit locations were selected based on access to sunlight (to maintain digester temperatures), ease of gas piping installation and proximity to kitchens where the cooking would take place. Starter slurry from an existing biogas system was used speed up the initial digestion process, resulting in the systems producing gas within a week.

Biogas digester feeding with diluted organic waste feedstock was done daily by responsible persons at each site. Input parameters and system performance were likewise monitored every day with the use of simple methods and equipment. Data collected included feedstock type, quantity and structure as well as cooking time and gasholder height. The results of this monitoring are presented below:

<i>Unit location</i>	<b>Household 1 (Westlands)</b>	<b>Household 2 (Kileleshwa)</b>	<b>Institutional (Westlands)</b>
<i>Unit size</i>	2.5 m <sup>3</sup>	2.5 m <sup>3</sup>	9.5 m <sup>3</sup>
<i>Gas cooker burn rate</i>	2.5 – 4 L/min	2.5 – 4 L/min	18 L/min
<i>Daily feedstock quantity</i>	2-4 kg kitchen waste	3-4 kg kitchen waste	60 L potato starch & varying other food waste
<i>Feedstock type</i>	Vegetable and fruit peelings and some lentil/potato starch	Vegetable peelings and fruit and vegetable residues	Potato starch, vegetable peelings & cooked food residues from events
<i>Feedstock structure</i>	Hand chopped to small pieces	Blended into fine porridge consistency	Liquid state, diluted with water
<i>Average daily cooking time from biogas (June, July = cold season in Nairobi)</i>	- May, Aug, Sep: 60 mins - Jun, Jul: 180 mins/ week	- May, Aug, Sep: 90 mins - Jun, Jul: 180 mins/ week	- May: 170 mins - Jun: 140 mins - Jul: 120 mins - Aug: 180 mins - Sep: 205 mins

In comparing the two household units, it is noticeable that the Kileleshwa unit produces slightly more gas even though both receive a similar amount of sunlight. This is likely due to the slightly larger quantities and finer structure of the feedstock.



It is clear that the colder temperatures in Nairobi especially during the months of June and July significantly affected biogas production, especially of the household units, when gas use was reduced to twice a week. This is a serious issue that may require solutions such as insulation of the units or a focus on warmer cities such as Kisumu and Mombasa. The larger institutional unit was less vulnerable to the drop in temperatures, but its performance was still curtailed, as can be seen in the graph on the left.

ARTI compact biogas system technical advantages and disadvantages are outlined here:

#### Advantages

- System fabrication and maintenance is relatively easy (materials are locally available, simple design, no mechanical parts)
- The system is mobile, modular and does not take up much space
- The digesters are structurally sound (no slurry leaks, issues such as inlet pipe blockage and water condensation can be quickly solved)
- Longevity of the polyethylene tanks is expected to be more than 20 years
- Odour is not perceived to be an issue

#### 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
- A trained technician is required in the case of serious maintenance and repair issues
- Release of gas from the space in between the digester and telescoping gas holder may reduce system efficiency
- If located too close to a kitchen, the flies the system attracts may turn off users

#### **Economic potential of the ARTI system and a "gas-for-cash" business model**

The cost for the pilot systems in Nairobi came to EUR 1,015 for the household size and EUR 2,237 for the institutional size unit. This is compared with figures from 2007 and 2009 Kenyan studies, which focused more on the fixed dome technology in rural areas. The numbers may not be directly comparable as it is not clear to what extent the studies include donor subsidies, transport, piping and appliance costs.

	<b>Household ARTI digester (2.5 m3) EUR</b>	<b>Institutional ARTI digester (9.5 m3) EUR</b>
Parts	110	183
Stove	54	99
Foundation	73	141
Tanks	171	600
Labour	607	1214
<b>Total</b>	<b>1015</b>	<b>2237</b>

<b>2007 &amp; 2009 study digester prices</b>	<b>EUR</b>
8 m3	435
9 m3	514
10 m3	492
14 m3	1269
16 m3	1372
16 m3	1338

For the ARTI pilot systems in Nairobi, 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.

### 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 mid-2010, focus group discussions with biogas and non-biogas users were held with 96 individuals in the peri-urban areas of Nairobi and semi-rural areas of northern Mt, Kenya to help gauge the willingness to participate in the "gas-for-cash" concept. Similarly, a number of existing local biogas companies were interviewed to assess their interest in such a model. While the results are not necessarily representative, the findings are summarized here:

	<b>Peri-urban Nairobi (EUR)</b>	<b>Semi-rural Mt. Kenya (EUR)</b>
Annual average cooking fuel (charcoal, wood, LPG) expenditure	215 (range of 36 to 780)	137 (range of 0 to 600)
Annual average cooking fuel expenditure of existing biogas users prior to their adoption of biogas [ <i>gives an indication of the cost level at which users adopt biogas</i> ]	580 (range of 360 – 800)	580 (range of 40 – 600)
Annual average income	>4,300 (existing biogas users)	<1,715 (non-biogas users)

These figures coincide well with those of a separate 2009 study in Kenya. The data is useful for a basic understanding of domestic willingness-to-pay for biogas and to help anticipate the market potential of biogas energy from organic waste in urban and semi-urban areas of Kenya's large cities. In the particular case of the Westlands institution that hosted the 9.5 m<sup>3</sup> ARTI biogas digester during the pilot, namely the Jai Jalaram Satsang Mandal Temple, *monthly* LPG costs for cooking well exceed EUR 1000:

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 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 although data from the other three months shows that the amount of LPG consumed per function is not necessarily uniform. Based on this in June the biogas digester achieved a cost savings of approximately EUR 80.

Given certain assumptions, a simple payback period calculation reveals the following:

	<i>Urban household 2.5 m<sup>3</sup> ARTI unit</i>	<i>Urban institution 9.5 m<sup>3</sup> ARTI unit</i>	<i>Rural school 9.5 m<sup>3</sup> ARTI unit</i>
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)
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)
<i>Payback period</i>	<i>5.3 years</i>	<i>2.9 years</i>	<i>9.3 years</i>

The above estimates are considered to be fairly conservative as (a) as mentioned previously labour costs may be reduced and (b) carbon credits have not be included. However, maintenance and replacement part cost considerations were likewise excluded..

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, on the otherhand, already make economic sense.

#### Suitability of gas-for-cash idea

According to the focus group discussions, the "gas-for-cash" idea was welcomed and most participants indicated their willingness to participate in such. Key feedback received was:

- 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 period of time, which should be agreed between the biogas service company and the user (lease-to-own model).
- Participants were willing to feed the units but expected that there be a reduction in gas charges due to the fact that they were also contributing to the biogas production.

However, a summary of interviews with existing biogas companies in Kenya reveals a lack of interest to take up the "gas-for-cash" business model. This is due to the bigger risk ensured by the company, the need for initial capital that is also unavailable to many companies and an inability to properly plan and execute such a concept.

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.

#### **Key findings**

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 aboveground, 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.