HOUSEHOLD AND INSTITUTIONAL BIOGAS FROM URBAN ORGANIC WASTE IN NAIROBI

TECHNICAL AND ECONOMIC POTENTIAL - INITIAL RESULTS

GREENTECH INTERNATIONAL

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Background

- Organic waste in Nairobi is at least 50% of a total of approximate 3000 tonnes generated daily (2009).
- From an inventory of solid waste categories/quantities in Nairobi, a LEI/WUR-supported pilot project was initiated with local partners in Kenya.
- For energy generation from organic waste in this pilot project, an small-scale anaerobic digestion technology was identified: the ARTI Compact Biogas System.
- Two household and one institutional size ARTI digesters were installed and are being tested in Nairobi.

Objectives of the pilot biogas project

Overall objective:

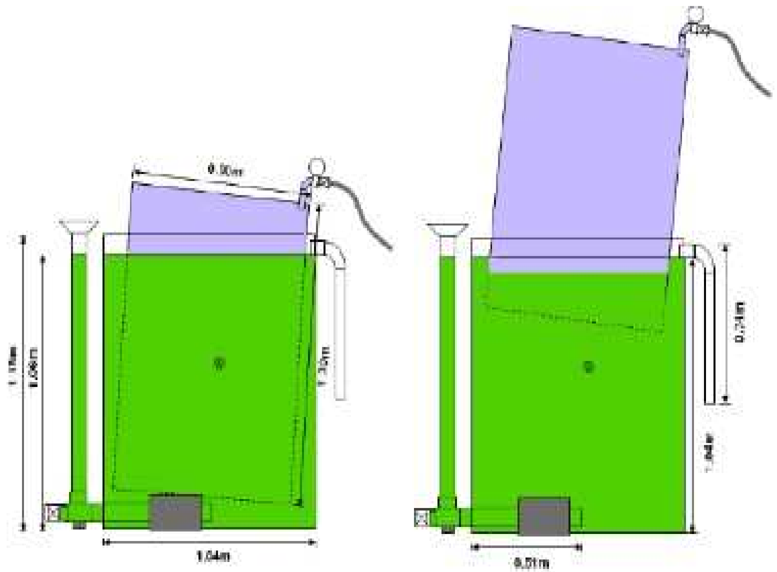
- Evaluate whether compact biogas systems are appropriate as part of an urban waste management strategy in Kenya and whether an economically sustainable model for their dissemination can be realized.

Objectives of the pilot biogas project

Specific objectives:

- 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

- Two cut-down standard high-density polyethylene water tanks and standard plumber piping.
- larger is the digester while the smaller one is the floating gas holder
- System was designed in India

Technical performance assessment

System installation (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

Technical performance assessment

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

Technical performance assessment

Feeding

- Twice daily (morning and evening)
- Feedstock - mainly organic kitchen waste consisting of miscellaneous food leftovers, peelings and discarded pieces of fruits
- Effluent is reinserted into digester with daily feedstock and excess used in gardens.

Technical performance assessment

Monitoring

- Begun in May 2010

Methodology

- Data collection forms (type of feedstock and cook time)
- Periodic inspections with interviews once in two weeks
- Equipment measurement (gas holder height measurements, temperature data logger)

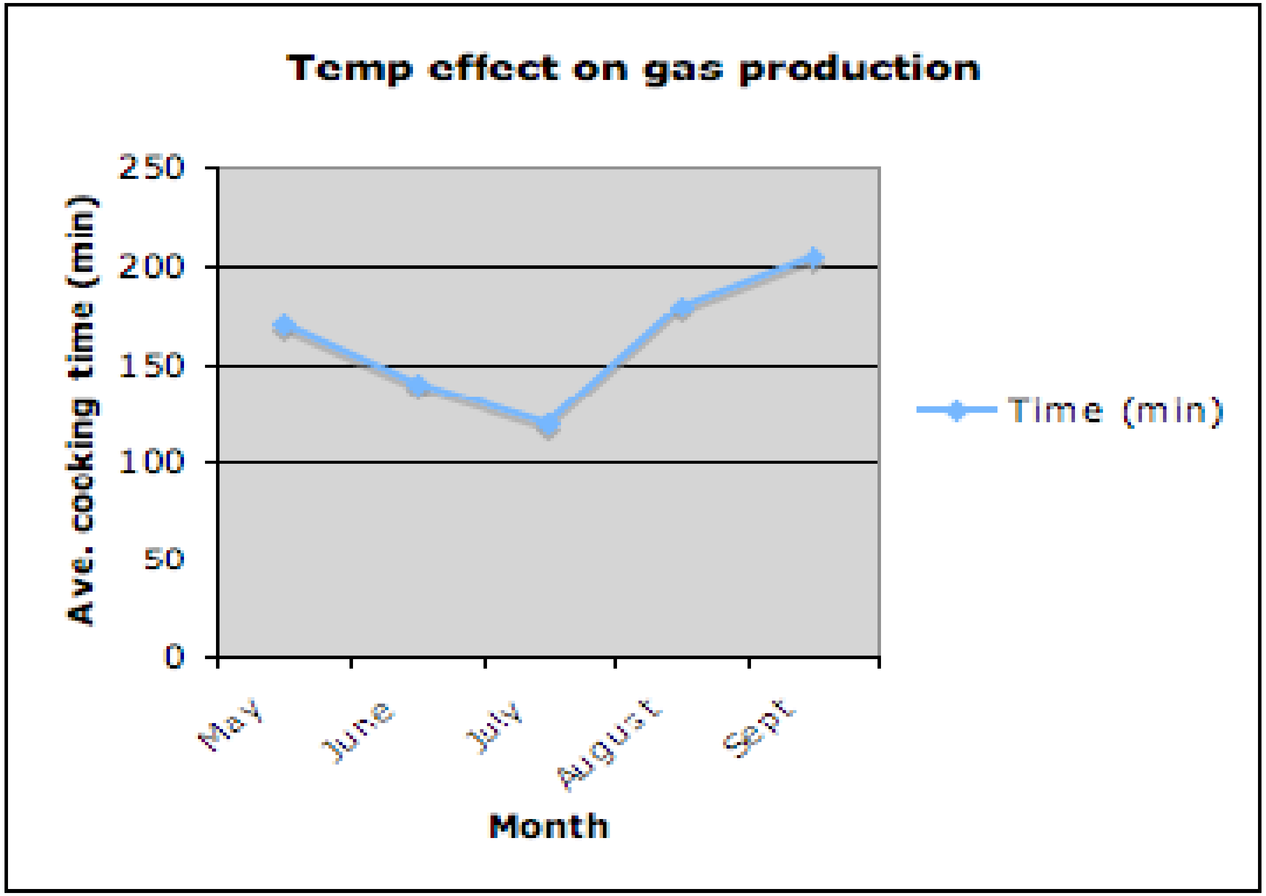
Technical potential - Initial results

Institutional unit inputs and outputs

Quantity of feedstock	Mon, Tues, Wed and Fri - about 60 litres of potato starch residues and peeling. Thurs – an additional meal served and waste food was used as feedstock. Additional meals (during special occasions and functions), food residues were fed into the digester.
Type of feedstock	Potato starch, vegetable peelings and waste cooked food
Structure of feedstock	Diluted with water, liquid state
Av. 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

Technical potential - Initial results

Institutional unit



Results

Household unit 1 (Westlands) inputs and outputs

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

Results

Household unit 2 (Kileleshwa) inputs and outputs

Quantity of feedstock	3-4 kg of kitchen waste per day
Type	Kitchen waste, vegetable peelings, other fruit and vegetable waste
Structure	Ground into porridge consistency using and electric motor
Ave. cooking time available from biogas using one 2.5-4 L/min burner	90 minutes / day (May, August, Sept) 180 minutes / week (cold season – June, July)

Results

Comparing household units

- 1 takes longer to produce gas compared to 2 due to structure of feedstock.

Temperature influence

- Cold weather (July and August) affected gas production
- Institutional unit was not vulnerable to temperature drops

Problems encountered during implementation

- Cold temperature effects on units' performance (insulation was an option but lack of time and resources)
- Temporary movement of institutional unit due to construction in Sept so not operational but expected to be by end Nov.
- Temporary movement also affected internal digester temperature data collection.

Technical Analysis

- *System reliability and appropriateness* - ARTI CBS is robust in structural stability, long lasting, materials for installation are locally available. Trained technician required for serious maintenance
- *Climatic conditions* - Low temperatures affect stability in gas production.
- *System operations* - Household 1 drops of water inside the stove preventing continuous burning. Institutional unit - Inlet pipe blockage
- Gas escape from space between digester and gas holder
- Visual appearance of the ARTI units is not attractive but functional

Economic potential - Initial results

Biogas impact on the use of LPG at the institution

2009 vs. 2010

Month	Year	LPG consumption (L)	No. of functions held	LPG savings (L) with biogas
May	2009	1924	5	-755
	2010	2679	8	
June	2009	2249	10	117
	2010	2132	10	
July	2009	2314	12	403
	2010	1911	9	
August	2009	2288	10	-292
	2010	2580	13	

Cost Savings

- June - tentative direct comparison, but maybe misleading as LPG usage in other months is not uniform.
- Assuming June comparison is valid, biogas use decreases the use of LPG, a cost saving of approx. KES 9,000 (EUR 77) was achieved.

Basis:

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

Cost of ARTI system

Item	Cost in EUR (Domestic size)	Cost in EUR (Institutional size)
Parts	110	183
Stove	54	99
Foundation	73	141
Tanks	171	600
Labour	607	1241
Total	**1,015**	**2,237**

Average price of fixed dome digester

Ave. price of fixed dome digesters in Kenya 2007,2009*

Domestic size digester		*Institution size digester*	
Size (m3)	Price (EUR)	Size (m3)	Price (EUR)
8*	435	16*	1338
9	514		
10*	492	31*	2286
12*	594		
14	1269	54*	3902
16*	743		
16	1372	84*	5018

Advantages and Disadvantages of ARTI Technology

Advantages

- Materials can be sourced locally
- System is mobile and modular
- Design is simple and easy to fabricate
- System doesn’t require much space

Disadvantages

- Sensitive to temperature fluctuations and poor performance in cold weather
- Waste/feedstock may not always be available
- Aesthetic issues with adoption in urban areas

Economic Potential

"Cash for gas" idea

- Model where entity pays for and maintains ownership of biogas units once installed and client pays for the gas delivered.
- Way to break the barrier of upfront investment costs
- A lease-to-own / installment payment structure could also be considered, with a small (token) upfront deposit by the client.
- If cost of gas delivered is less than the price of cooking fuel used and reliable digesters, assumption is model would be attractive to certain market.

NB: Operation risk of the digester remains with the entity

Market Analysis

- As of November 2010, the market potential (size) of the ARTI CBS and the “Gas-for-cash” business idea are unknown
- Currently, there is no major competing biogas technology on the Kenyan market that specifically targets (urban) organic waste as a feedstock. However Kentainers has started to produce floating drum similar to ARTI design.

Cooking fuels economic baseline

Results of student researcher:

- Annual expenditure in peri urban Nairobi (wood, charcoal, LPG) = KES 25,000 (EUR 215) and KES 16,000 (EUR 137) in semi rural areas of Northern Mt Kenya with a range of KES 0 - 78,000 (EUR 0 - 670). *(results only indicative, random sampling was not used)*
- Range coincides with that of Gichohi 2009 report which is between KES 14,000 (EUR 120) - KES 80,000 (EUR 690)

Cooking fuels economic baseline

- Ave. annual income levels for users already adopted biogas = KES 500,000 (EUR 4,300)in peri urban Nairobi vs potential users who had not adopted biogas = below KES 200,000 (EUR 1,715) in the semi-rural areas round northern Mt. Kenya.
- Those already adopted biogas spent KES 30,000 (EUR 260) - KES 60,000 (EUR 520) on cooking fuel. *This may indicate cost level at which potential users perceive switch to biogas to be competitive.*
- For institutions (Jai Jalaram temple) cost of LPG for cooking exceeds KES 100,000 (EUR 850)/Month
- RETAP estimates for boarding school Ave. KES 70,000 (EUR 600) - KES 105,000 (EUR 900).

Simple Pay Back Period

	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 385 (based on mid-range of peri-urban users who have already adopted biogas)	EUR 10,200 (using the temple from the pilot study as an example)	EUR 750 (using mid-range of RETAP findings)
Monthly cooking fuel expenses	EUR 32	EUR 850	EUR 62
Monthly savings with ARTI biogas	EUR 10 (assuming one biogas unit replaces 33% of cooking energy needs)	EUR 42 (assuming one biogas unit replaces 5% of cooking energy needs)	EUR 20 (assuming one biogas unit replaces 33% of cooking energy needs)
Payback period	*8.5 years*	*4.4 years*	*9.3 years*

Suitability of the "gas for cash" idea

Focus Group Discussions (peri urban Nairobi and northern Mt Kenya, 2010)

- Monthly payments for gas were perceived as a type of credit, more flexible and less threatening than a loan from a bank
- A key condition for interest was ownership of the biogas system should be handed over after a certain period of time (*lease-to-own model*).
- Potential users willing to feed the digesters but expected that a reduction in charges as they were also contributing to the biogas production.

Business model innovation

Barriers to implementation from the potential biogas company point of view from interviews with existing biogas companies, 2010:

- Higher risk endured by the company/entity.
- Need for initial capital that is unavailable currently.
- Inability to plan and execute project in a way that guarantees profitability while managing risks.

Key findings

- Technical performance of ARTI CBS test units in Nairobi is satisfactory
- Outdoor air temperature during cold seasons affect biogas production.
- Institutional size digesters may offer short PBP than household unit thus more immediately economically viable.
- 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.
- Upfront costs and business risks may be too high to entice a company to implement the “Gas-for-cash” idea, although this has not yet been properly evaluated.

THANK YOU!

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