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Development of a low cost biodigester for East Africa

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ABSTRACT:

Any family with sufficient organic waste – be it cattle manure or food scraps – can generate biogas in their own home. For households in tropical developing countries, where livestock ownership is common and ambient temperatures are ideal, the potential for domestic biogas production is particularly high. Using biogas as a fuel for cooking and lighting brings many social and environmental benefits to a household and its surroundings, explaining its large uptake in East Asia. In East Africa on the other hand biodigesters haven't caught on due to their high capital cost, and a more affordable solution is shown here.

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Biogas is formed by a group of bacteria that only work under anaerobic (oxygen-free) conditions. Therefore the essential function of a biodigester is to take organic waste, hold it in these conditions for around thirty days, and capture the biogas that bubbles out.

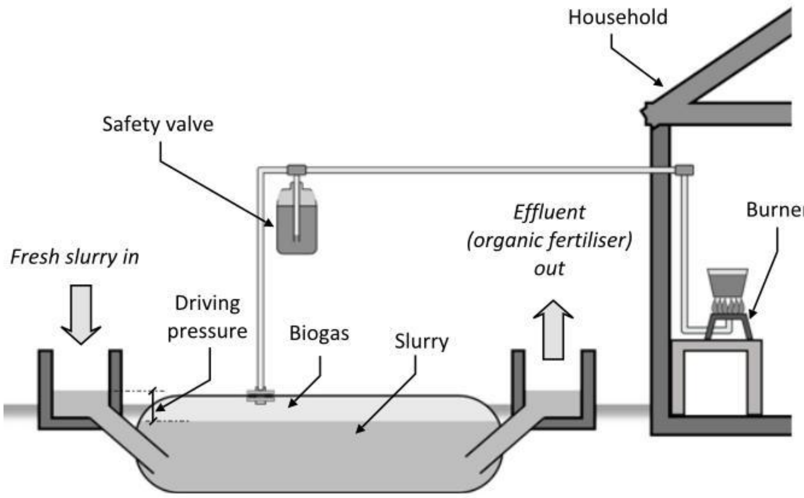

Figure 1: Sketch to show the basic workings of a simplified domestic biodigester

The essentials of biodigestion can be performed on a small scale through a number of simple designs, for example that shown in Figure 1. On this scale, a household owning three cattle can generate enough combustible biogas to carry out all their cooking.

Environmental and social sustainability

The vast majority of the developing world still use solid fuels (such as firewood and charcoal) as their main source of energy. Biogas increases social and environmental sustainability by replacing these. In industrialised countries we often see solid fuels as a sustainable and renewable source of energy, which can be burned efficiently and smokelessly in advanced burners. In many developing countries on the other hand, solid fuels are both socially and environmentally unsustainable, as exemplified in the case of Tanzania by the table below.

Solid fuels	Biogas
1. Unsustainable chopping of trees: 95% of Tanzanians use firewood or charcoal for cooking[(1)], heavily contributing to deforestation rates of 400,000 hectares per annum[(2)].	Biogas does not contribute to deforestation.
2. Indoor air pollution: Nearly 30,000 Tanzanian's die every year due to inhalation of smoke from cooking over a charcoal or firewood stove.[(1)]	Biogas burns with an odourless, smokeless flame.
3. Climate change: Using solid fuels results in anthropogenic greenhouse gas emissions of 1.9 tonnes of carbon dioxide per family per year[(3)].	Biogas is a zero-carbon source of energy.

Economic sustainability

Replacing solid fuels with biogas brings economic benefits to a developing world household. This is either in the form of savings on charcoal expenditure (in urban areas), or through the opportunity cost of time spent collecting firewood (in rural areas); as shown by the figures below for Tanzania.

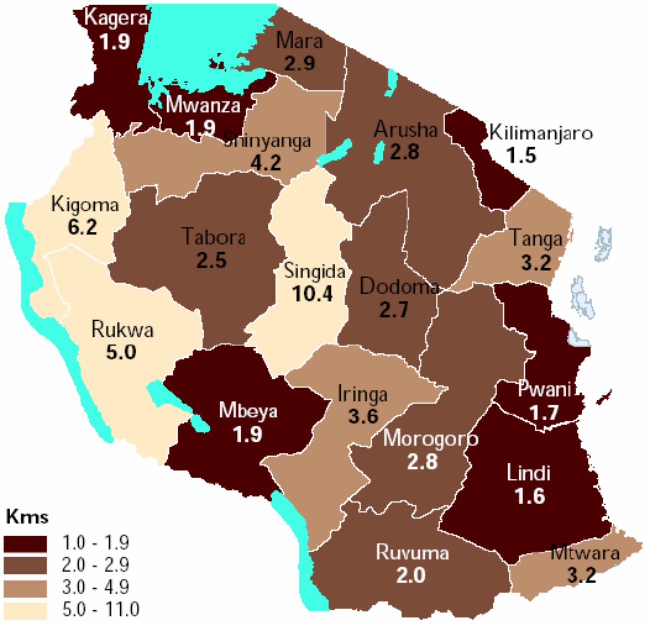

Figure 2: Mean distance walked daily by rural households to collect firewood in Tanzania, by region [7]

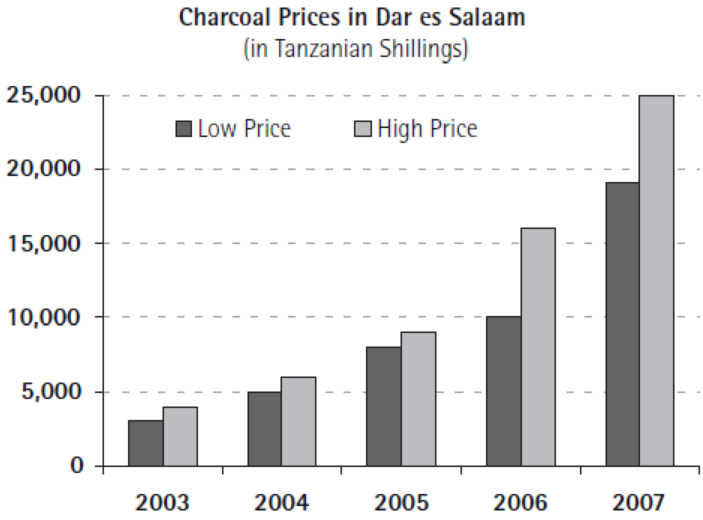

Figure 3: Trend for the cost of one bag of charcoal (approx. 1 week's worth). [10] The increase is reportedly due to increasing firewood collection distances, due to deforestation. [10] [£1 = TZS 2,000, typical currency inflation = 10%]

A typical Tanzanian biodigester has a life expectancy of at least 40 years, and pays for itself in 5-10 years[4]. Despite this economically-sensible business case, only 3,000 units have ever been installed to date in a country with a potential for 276,000 units[4]. Interviews suggest that the main reason is due to the high up-front capital cost[4]. Microfinance banks can help people to pay for this investment, but currently only 2% of the population are a member of one[5], and growth is very slow.

Efforts by the Tanzanian government to introduce the technology with help from European funding bodies have been ongoing since 1975. Unfortunately, the implementing organisation have a vested interest to promote a high-quality and expensive design, which can only be made affordable to the very richest farmers through heavy subsidies. In 1990, foreign funding for subsidies was withdrawn (due to changes in the funding body's long term strategy) causing the collapse of the programme and dereliction of installed biodigesters. Despite the demonstrated economic unsustainability of subsidising the product, the programme was restarted with a similar technology several years ago, and a heavy dependence on foreign funding bodies. The programme has now trained approximately 300 technicians that are installing units at a net rate of around 20 per month.

It may be that the only way for biogas to be truly adopted in the way it has in East Asia, is to make a step increase in the affordability of the biodigester. Like this, the sale of biodigesters can be done through a business that doesn't depend on foreign subsidies, in an economically viable and sustainable manner.

New product development

There are many designs for domestic biodigesters. The 'fixed-dome' is the design of choice for Tanzanian dissemination programmes, where the digestion chamber is built underground using bricks and mortar in an 'igloo' arrangement (see Figure 4). As shown in Figure 5, the largest proportion of its cost is in the labour costs of its installation (it needs 20-30 man-days to build) and the material costs of the digestion chamber.

Figure 2: Photo of a fixed dome biodigester before covering with earth.

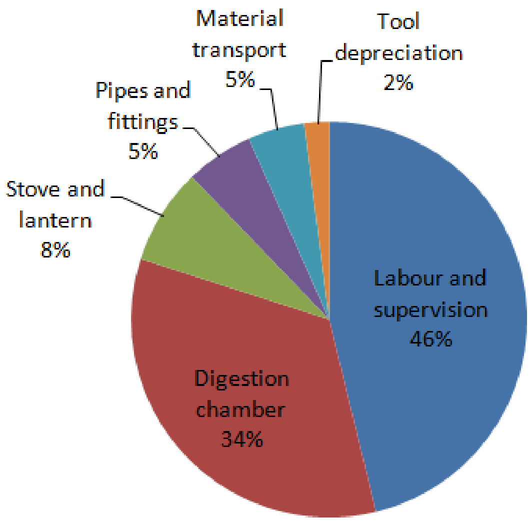

Figure 3: Relative cost of all aspects of fixed dome biodigester, created from a parts list in (4)

At Shamba Technologies Ltd we are using a different design, known as a 'flexible bag' digester. Here, the digestion chamber wall is made from a layer of inexpensive plastic film that reduces the combined material and installation cost by 80%.

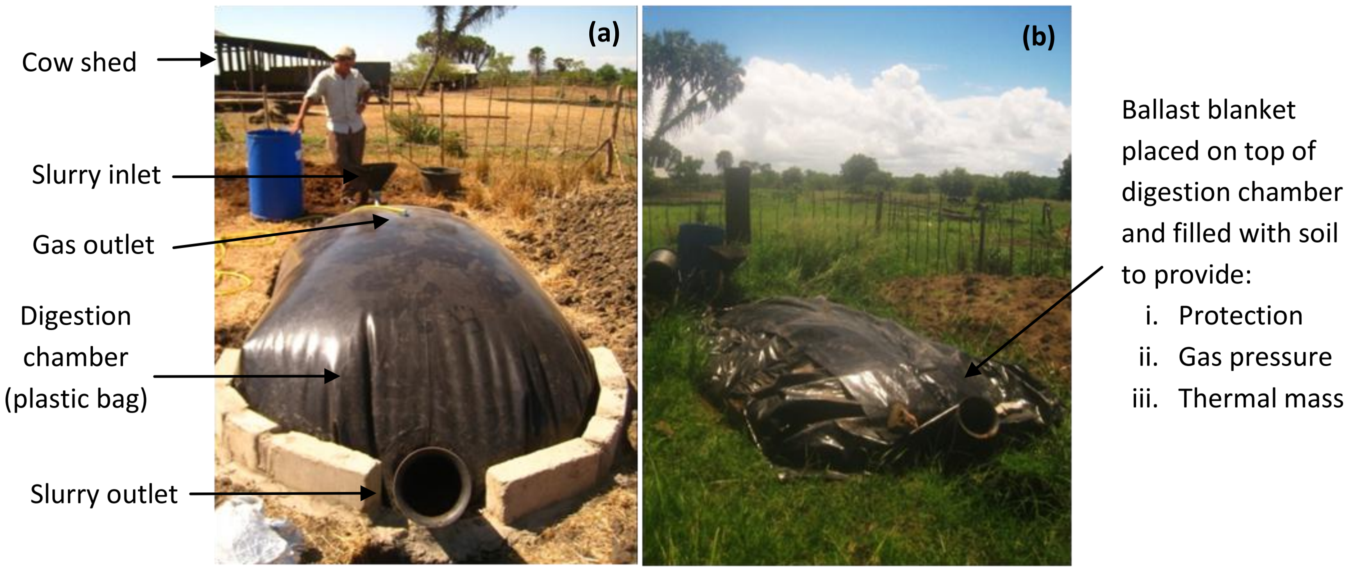

Figure 4: Photos of a prototype flexible bag digester (a) without the ballast bag and (b) and with it in place

Historically, the major disadvantages of this design have been its fragility, unacceptably short life-span, low gas pressure and low efficiency. To solve all these problems we have adopted the 'ballast blanket', an innovative feature patented by a Dutch-based company, and are currently using it to develop a product suitable for the Tanzanian market.

Engineering design

One of our challenges when developing this product is to consider the trade-off between cost and efficiency. As shown in Figure 7 the larger the biodigestion chamber, the longer the slurry can be digested. The generally accepted digestion time is around 30 days, but we currently making a compromise in favour of a less-efficient and cheaper product.

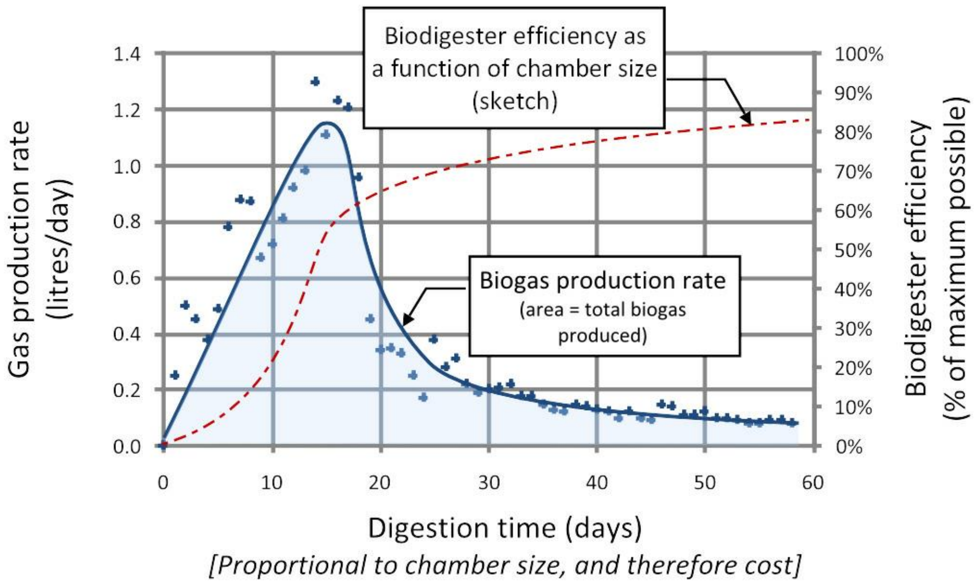

Figure 5: Biogas production for 1 litre of slurry as it moves through a biodigester, along with the cumulative biodigester efficiency at each point. Data points taken from (8).

A market-ready product will be released in Tanzania in early 2011, thus launching a dissemination programme that hopes to be environmentally, socially, and economically sustainable. Though growth will be controlled to start with, once a scalable model has been proven we plan to expand rapidly into neighbouring countries and achieve installation rates of 500-1000 units per month.

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Copies of all reference texts are available on request.