UNIVERSITY OF CAMBRIDGE
INSTITUTE FOR SUSTAINABILITY LEADERSHIP

Biogas Community and Household Pilot

Baseline Study

Dunga Beach, Kenya

December 2018

The University of Cambridge Institute for Sustainability Leadership

University of Cambridge Institute for Sustainability Leadership (CISL)

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Biogas International Ltd (BIL)

BIL is a Kenya-registered enterprise, founded in 2011, specialising in the design, manufacture and installation of biogas technologies. Its offices function as an Eco Resource Centre (ERC) where simple, affordable and appropriate technologies are designed to alleviate the typical daily challenges faced by low-income African families. More than 15 years of effort preceded the launch of the company which now offers flexi-biogas plants, biogas waste management, evapo-coolers, chick and piglet brooders, and a biogas/solar combo fruit and vegetable dryer. All its products can be assembled easily by an average local technician. For more information, see https://biogas.co.ke/.

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About this report

All views expressed are those of authors.

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Reference

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Executive summary

Worldwide, 40 per cent of the population, or 2.8 billion people, rely on solid fuels such as wood, charcoal and dung for household energy and cooking needs, causing serious health, development and environmental impacts. Households often cook inside the home, or in enclosed kitchens on poorly vented, inefficient devices. Related respiratory infections, heart disease, stroke and lung cancers are responsible for an estimated 2.2-4.3 million deaths every year. Improved biomass burning cookstoves and clean fuel sources such as biogas not only address this major health issue, but also have the ability to reduce energy poverty in rural areas, decrease forest degradation and can improve a poor household's economic situation.

Biogas is a clean fuel produced relatively simply from raw materials like manure, green waste, food waste or sewage as part of a natural process of decomposition. However, despite significant possibilities for biogas and about 50 million biogas systems worldwide, dissemination in Africa is very limited. In Kenya, 1.3 million households have potential for biogas; but only several thousand have been installed to date.

As part of addressing this major challenge, the Cambridge Institute for Sustainability Leadership (CISL) is leading a major project introducing innovative biogas technology to a peri-urban community in Kenya with the support from AstraZeneca, in partnership with Biogas International Ltd and the Centre of Development Studies in Cambridge. The 18-month pilot project covers two initiatives: the first is the installation of 50 smaller household systems that will introduce biogas systems to some of the poorer, more needy families living in the peri-urban area. The second innovation is the installation of two large community level biodigesters that will produce gas on the Dunga Beach lake shore for commercial use by fish fryers using the invasive water hyacinth plant species and local waste produce. For traditional reasons, fish fryers are female in this area, so the principal participants in the community biodigesters are women. Over the course of this pilot project we will assess economic and health improvements, employment creation, business models and potential for upscale and replication through the business models applied as part of a longitudinal research study. We will also be sensitive to gender differences throughout, in order to contribute to the limited literature on this in Kenya.

Three main research questions frame the study:

1. Does biogas provide benefits for households from both an economic and social perspective?
2. What measures can be taken to enhance uptake of the biodigesters?
3. What will ensure financial and social sustainability of community level biogas businesses?

This baseline report details information from the August-September 2018 field visit before the installation was completed in most of the households and in the community. Fifty recipient households were selected from 92 surveyed on the basis of levels of need, sustainability and ability to maintain the system, numbers of people cooking and willingness to pay towards the subsidised technology. We assessed basic household characteristics and assets, details of cooking facilities, fuel sources and costs of fuel and water for households. We also asked participants about health issues and recent costs related to these, and attitudes to the biodigester.

At the community level, we facilitated several discussions with women fish fryers and traders to understand perceived concerns, opportunities and to monitor interactions of the private implementer Biogas International Limited (BIL). This initial survey will be followed up in the months following installation in May and November 2019 to document change over time.

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1. Background and purpose

This baseline study reports on an innovative pilot project introducing biogas as cooking fuel at Dunga Beach, Lake Victoria, Kenya. It provides the first summary of data collected as part of a longitudinal study. The primary focus is household cooking and commercial women fish-fryers in a lakeside peri-urban fishing community. The project explores how a switch to clean cooking fuel can improve lives in a densely populated lakeshore community in Kenya. Here, poorer families suffer health impacts from inhaling smoke in the household and spend valuable household time and money on collecting and/or buying fuel. Smoke inhalation may impact women and children in particular, if they spend a lot of time in the household. The project takes an innovative approach to tackling smoke-related respiratory illness through the replacement of firewood and charcoal with clean, green, biogas technology. Nearly four million people die prematurely worldwide each year through toxic smoke inhalation in their homes from wood, charcoal and kerosene burning (1); an area of increasing attention for the Global Sustainable Development Goals. A novel feature of the biogas technology employed is its potential use of a local invasive weed – water hyacinth – as feedstock. Water hyacinth is a major environmental problem on Lake Victoria due to its impact on fishing, lake transport and tourism due to clogging effects and biological impacts (2, 3).

AstraZeneca (AZ) has a significant interest in non-communicable diseases (NCD) in general, and cardiac and respiratory health in Kenya in particular. In 2018 AZ teamed up with CISL, the Centre of Development Studies (CDS) in Cambridge, and Biogas International Ltd (BIL) in Kenya. The 18-month pilot project, launched in July 2018, is working on two initiatives in the community. The first is the installation of 50 household-scale biodigester systems ($8m^3$ capacity) that will introduce biogas to families living in the peri-urban area. The second is the installation of two large community level biodigesters (total $60m^3$ capacity) that will produce gas on the Dunga Beach lake shore for commercial use by women fish fryers. In this longitudinal study we will assess potential for upscale and replication, and possible impacts in several areas, including:

i) Economic development for the households involved, and women fish-fryers working at Dunga Beach as costs for fuel are reduced
ii) Health improvements to improve respiratory health and illnesses related to fuelwood collection and fuel burning in enclosed spaces in the homestead
iii) Food security improvement when the by-product of biogas generation – a powerful fertiliser known as bio-slurry – is used to fertilise vegetable gardens
iv) Job creation for servicing the biodigesters and providing feedstock

The pilot project aims to put in place the biodigesters over the course of a year in the Dunga community. The household installations are subsidised by AstraZeneca, means-tested with individual households to determine an appropriate level of subsidy/grant. The community level installations are being piloted through an inclusive business model (ie an SME created for this purpose), with the aim of developing financial sustainability and potential replicability across other areas of Lake Victoria and further afield.

A research study has been designed to work closely alongside the implementation of the pilot project before, during and after installation of the biogas systems to assess household and community perceptions, impacts and changes in lived experiences.

The high-level research questions initially developed for the study comprise:

1. Does biogas provide benefits for households from both an economic and social perspective?
2. What measures can be taken to enhance uptake of the biodigesters?
3. What will ensure financial and social sustainability of community level biogas businesses?

This report details information gathered as part of the baseline study during a field visit in August-September 2018 by researchers from CISL and CDS in close collaboration with local researchers. An additional 'light touch' visit to the communities in early 2019 will provide some information during the installation of the household biodigesters. A more in-depth mid-term evaluation will be undertaken in May-June 2019, and an end-of-project evaluation is planned for November-December 2019 (see Appendix A for full timeline). More information on our research approach is available in Appendix B.

Through this approach we aim to develop a robust analysis of the impacts at household level and community level of this biogas technology, and potential for upscaling more widely. This type of household and community energy provision in developing countries directly addresses a number of ongoing major issues in development: energy provision, equity, poverty and wellbeing. In particular, these are reflected in three global Sustainable Development Goals (SDGs):

3 – *Good Health and Wellbeing: ensure healthy lives and promote well-being for all at all ages* – our work directly addresses the causes of pollution-linked respiratory disease which kills around 4m people each year.
7 – *Affordable and Clean Energy: promoting sustainable energy for healthy homes and lives* – our work directly improves access to clean, green cooking energy, produced by households themselves with immediate health, economic, gender and food security benefits, and indirect job creation.
1 – *No poverty: Prioritising the health needs of the poor* – improved access and control over economic resources, reduced energy expenditure, job creation through scalable community scale biogas SMEs, access to saleable bio-slurry and biogas-linked service provision for income generation.
The project also is relevant for *SDG 5: Gender equality* (increasing women's income and household spending) and *15: Life on land* (creating a healthy natural environment)

2. Biogas in Kenya

2.1 Household biogas sector

Worldwide, in 2010, 40 per cent of the population, or 2.8 billion people, relied on solid fuels such as wood, charcoal and dung for households' energy and cooking needs, causing interrelated and serious health, development and environmental challenges (4) (5) (6). Households often cook inside the home, or in enclosed kitchens on poorly vented, inefficient devices. Resulting smoke in households mean that these areas frequently greatly exceed air quality guidelines for carbon monoxide and particulate matter set by the World Health Organisation (WHO). The effect of this input of toxins has been likened to an effect somewhere between active and passive smoking (7). Respiratory infections, heart disease, stroke, lung cancer and other health effects such as cataracts, burns and low birth weights for children linked to this are common, and are responsible for an estimated 2.2-4.3 million deaths annually (6).

Impacts on livelihoods are significant: women in particular spend a lot of time collecting and processing wood fuels, or a significant proportion of low household incomes to pay for them. At the same time, using solid fuels to meet the energy needs of human populations drives forest degradation and deforestation in Africa. Greenhouse gases that increase carbon emissions in the atmosphere are produced in harvesting wood fuels, making charcoal and when used for cooking. Interventions tackling this major problem include urban and rural electrification, fuel-efficient cooking stoves, and use of cleaner fuels such as biogas.

Much importance has been placed to date on improved biomass-burning cookstoves, which use fuels more efficiently and produce less smoke. However, international studies have shown that these only improve air quality incrementally, with modest health benefits (8). This has been echoed in East Africa: evidence from recent studies in western Kenya and Uganda with more efficient cookstoves found reductions in air quality levels, but nowhere near sufficient to meet WHO guidance values (5); (9).

Since the 1980s, biogas technology has been promoted as an effective, sustainable, pro-poor energy source in many developing countries, but despite being technically feasible in 18.5 million households, dissemination in Africa is still very limited (11). Biogas digester technology at household level is based on using animal or plant waste to feed digesters in a fixed dome, floating drum or a flexible 'balloon' structure (12). Biogas fuel is clean and greatly reduces particulate emissions from cooking (13). Wider benefits claimed from introduction of biogas digesters include poverty reduction due to lowered cost for household fuels, livelihoods improvements from reduced time for collecting and carrying wood fuel, and local employment opportunities in the installation, servicing and provision of feedstock/selling of bio-slurry (9). Impacts depend very much on the location and pre-existing situation of the households.

In the successful roll-out of biogas technology three main challenges remain:

1. First, questions remain about the extent to which reducing air pollutants in the household through using biogas improves health outcomes. Changes in health outcomes from these interventions are most often measured by personal reporting; studies of pollutant levels within households are technically difficult and time consuming to execute. However, some studies do examine this. A recent international systematic review of how much improved stoves and clean fuels reduce particulate matter and carbon monoxide found significant reductions when chimneys were introduced into a household alongside improved efficiency stoves, and reductions from using clean fuels, but that levels were still much higher than WHO limits (10). A focussed study in Uganda found similar: use of biogas systems in households in reality did not reduce pollutants below WHO limits, suggesting this was possibly due to use of other cooking methods in addition to biogas in households (9).

2. Second, biogas technologies have typically not been an instant success. Low adoption rates, and high disadoption rates are common. In rural households in central Uganda, adoption rates are 26 per cent of estimated potential uptake (14). Disadoption amongst those who started the technology can be startlingly high: in some studies, 80 per cent of households had discarded the technology within four years, and some after just six months. Reasons were both technical or household-specific: insufficient labour available to continue feeding the biodigester, incorrect feeding of biodigester, breakdown of equipment, problems with getting enough feedstock, and people's preferences for using traditional or other cooking methods.

3. The financial cost of the biogas technology has proven a barrier to significant uptake in poor African households (9). Biodigester equipment and installation currently costs several hundred dollars in East Africa; and is unaffordable to most as a result. People need grants, subsidies or accessible, affordable financial mechanisms for credit including micro-finance, so many initial NGO-funded programmes are not rolled out long term. An economically-sustainable business model and approach is needed, with necessary government and private involvement, that makes these technologies available to households. Given the need for clean energy, relatively little attention has been given to the important question of how to enhance the uptake of these technologies at scale (7).

2.2 Biogas industry in Kenya

With the first installation of a biogas plant in 1957, Kenya now has several thousand biodigesters supported by national and international organisations. Major public sector development programmes included German development organisation GTZ in the 1980s under the Special Energy Programme in the Ministry of Energy in the 1980s. More recently, Kenya has developed a multi stakeholder approach in biogas technology dissemination fostered through the Kenyan country programme of the African Biogas Partnership Programme (ABPP).

The ABPP programme aims to establish viable biodigester markets, contributing to the achievement of the Millennium Development Goals (MDGs) through dissemination of domestic biodigesters as a local, sustainable energy source. Starting in 2009, this programme used a Public-Private Partnership model to promote, incentivise and implement 8,000 biodigesters. Involving government, private sector, NGOs and farmer organisations and developing a systematic process, the NGO SNV provides technical assistance and support. The initial focus was to install and then improve the quality and functionality of the biodigesters. Under this programme, a raft of small private businesses has grown in Kenya to provide these technologies. However, frequent mechanical breakdown, poor installation, corrupt practices and bad functioning due to installers not training users properly initially led to low confidence and frequent disadoption (11); van Nieuwenhuizen 2018 pers. comm.). Significant effort in Phase 2 of the programme from 2013 has largely addressed these issues.
More recently, the programme's focus has been on:

- developing and monitoring minimum quality standards,
- influencing government policy to support biogas (e.g. reducing high import tariffs for biogas equipment)
- 'de-risking' the technology, generating an improved business case for companies and entrepreneurs, and
- supporting small companies to organise together to provide a larger scale, more efficient service

By 2017, 22 marketing hubs had been established linking rural organisations with local construction enterprises and finance institutions. In Kenya, while the business case for farmers has proven viable if they have access to long term finance, the business case for finance institutions is doubtful due to immature financial markets (11). At a more local level, we find a nascent sub-sector in Kenya where community initiatives arrange for the installation of larger volume biodigesters in institutions such as schools, hospitals, universities and energy user groups. At government level, Kenyan national policies seek to increase access to energy and promote the use of renewable technologies[1]. Government has discussed subsidising the biogas industry but has not put this into place yet (van Nieuwenhuizen, 2018 pers. comm).

[1] *"In keeping with the Government's Economic Recovery Strategy for Employment and Wealth Creation, the Session Paper No. 4 of 2004 on Energy was developed, spelling out the Government's aspirations towards provision of quality, adequate, sustainable, cost-effective and affordable energy services for socio-economic growth, including the use of biogas. The use of biogas as a renewable source for energy was also included in the Energy Act 2006. Paragraph 103(1) states "The Minister shall promote the development and use of renewable energy technologies, including but not limited to biomass, biodiesel, bioethanol, charcoal, fuelwood, solar, wind, tidal waves, hydropower, biogas and municipal waste" in Simgas (2015, p.10) 15. SimGas. Promoting biogas as sustainable clean cooking fuel for rural households in Kenya project – ESMF and ESMP; 2015.*

2.3 Gender and biogas in Kenya: key issues

When households rely on wood and charcoal this translates into high labour demands in the household and increased health impacts on women and girls (16). Currently there is limited reporting and awareness of gender issues in the household biogas sector as a whole in Kenya (17). Given that biogas installations involve women centrally, there is a strong need to understand impacts for women's labour and how economic and social impacts are gendered when household biogas is installed (see Table 1).

Table 1: Gender-sensitive areas for biogas sector in Kenya

Activity/sector	Gendered aspects
Obtaining fuel for household cooking	Task falls primarily on women if gathering wood and charcoal with labour inputs
Benefits of biogas adoption and use	Strongly gendered: • reduced time (if applicable) and labour impact • reduced health impacts of indoor air pollution • reduced energy costs
Barriers to adoption	Access to credit and finance may be strongly gendered if women have no collateral for credit
Uptake and adoption of biogas	Inconclusive evidence of any gendered differences on decision to adopt
Biogas promotion initiatives	Currently these rarely address and consider gender explicitly through programme functions – eg promotion, training, extension, credit, institutional partnership development, finance, Monitoring and Evaluation
Government policy	Current Kenyan energy policy are not gender-sensitive, and are not collecting gender disaggregated data

Summarised from Wilkes and van Dijk, 2017

3. Innovation in Dunga: the approach

The introduction and uptake of innovative technologies depends on their perceived benefits by the target community. This pilot project assesses the impact of biogas technology in three main areas:

1. The observed health and socio-economic benefits for households and enterprises piloting a Kenyan-originated clean fuel technology (e.g. loosening dependence on bought and foraged fuels).
2. The ability to utilise an invasive weed (water hyacinth) from Lake Victoria as feedstock for biogas (methane) production, converting an environmental problem (clogging) into a community development opportunity (18).
3. The potential for scaling up deployment of the technology through financially and socially credible business models since there are thousands of lakeside households and fishing communities which may be able to benefit from this approach if successful.

Grassroots technology applications such as clean fuels can be understood through a series of innovative characteristics. These include not only the newness of the innovation to the adoptive community, but also emphasise a number of other aspects not often examined: how these have been adapted, the types of interaction as the innovation adoption process is undertaken, the iterative and reflexive transfer, and development of new knowledge with the community, and the process of learning, scaling up and diffusion (see Figure 1, adapted from Cozzens and Sutz 2012). (19, 20) (21)

Figure 1: Characteristics of innovation

Newness	An innovation is an **idea, practice or object that is perceived as new** by an individual or other unit of adoption.
Adaptation	**Imitating or adapting from other efforts** at problem-solving, blending together.
Interaction	**How interactive the innovation** is with the people using it is very important. The degree to which an innovation fosters collective action, and potentially building links and networks for the community that will strengthen it.
Knowledge content	An innovation may bring **new knowledge and understandings** of **why** it is important to change existing processes **as well as how** to do things better (through doing, using, interaction).
Learning, scaling-up and diffusion	Learning can be kept specific to the individual innovators or can be scaled up and disseminated. The process of this is variable, innovation uptake can be designed or happen through existing social networks and 'natural' uptake, and can be assessed for its social inclusivity and effectiveness.

4. Dunga background

Dunga Beach is located on the shores of Lake Victoria, near Kisumu, the third largest city in Kenya, in a predominantly Luo community (the fourth largest ethnic group in Kenya) (see Figures 2 and 3 maps). Kisumu developed as a major trading post, founded in 1901 as the main inland terminal of the Uganda Railway Port Florence. Dunga's population is around 4,500 (22). The area has a tropical climate with significant year-round rainfall, two rainy seasons and no major dry season.

This scrubland area was informally settled in the 1950s. The layout of the area reflects this today – houses and land areas are not demarcated in the area. Land titles are not formalised, although settlers consider the houses their own and buy and sell their land. In recent years the Kisumu county government has invested in bringing clean water and standpipes to the area, as well as electricity sources. An NGO has built nearly 200 latrines to reduce open defecation that was creating significant disease outbreaks of cholera in the community. The Dunga area is accessed by an unpaved road, but a major paved road is shortly to be completed that will connect Dunga to Kisumu.

Figure 2: Dunga Beach, situated in North Eastern part of Lake Victoria in Kenya

Note that the area of Dunga beach appears light green on the Google map due to silt load from rivers.

Dunga Beach was originally developed as homesteads for fishers and their families. Today, the community hosts a set of services, including a beachfront area selling fried and raw fish, tourist trinkets and a port that enables off-loading of charcoal, fruit, grains and other products from Uganda and elsewhere. Nearby are informal motels, bars, kiosks and restaurants and the offices of the Dunga Beach Management Unit, responsible for oversight of the fishers and local businesses. The Dunga Fishermen Cooperative Society and Dunga Fish Group support fishermen with fish marketing, savings and investments.

Figure 3: Dunga Settlement

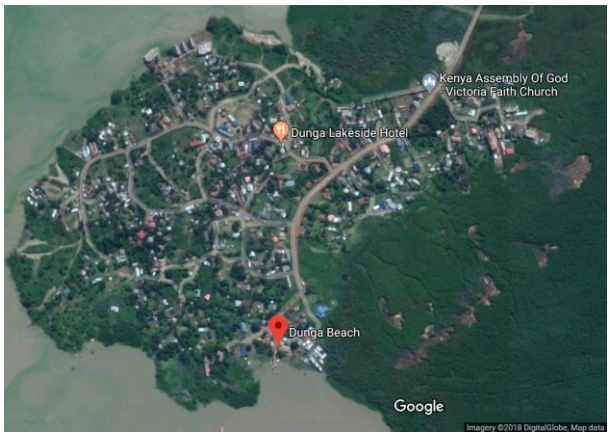


Figure 3 shows the small commercial beach front area (marked Dunga Beach) and homes for about 2000 people who have informally settled in the area since 1950. Note the wetland area east of the settlement and several areas of incursion for agriculture and papyrus extraction. The area currently does not have formal conservation area status

Fish catches have declined significantly in recent years in this area; more than 60 per cent according to some fisheries experts (23). Fishermen catch species including tilapia, Nile perch, cat fish and omena, as well as small fish (fingerlings). Overfishing and catching fish that are too young with small hole nets, is a significant issue around Lake Victoria. Along with human population pressures and climate change, fish habitats are under pressure. The periodic arrival of the huge rafts of invasive plant species, water hyacinth, that blow across the lake and strangles boating activity for weeks. This has increased fish prices and encouraged import of fish from China and elsewhere. Many small boat fishers have been forced off the lake and into tourism, vegetable selling and are often under-employed. Aquaculture and fish cages have been introduced so that farmed fish will bring in income to the community.

Luo people have strong fishing traditions, with men fishing and women collecting fish from the shores, and so. the decline in fish availability affects the whole community. Within many families, work allocations are gender based (women responsible for household duties, men for building the home and fishing). The Luo culture retains elements of strong patriarchal leadership, with authority remaining within groups of male elders who are consulted about community decisions. Absence of male circumcision within Luo culture has been blamed for the high spread of HIV and AIDS (24). HIV, despite now-available suppressive medication, is considered a stigma. In the Dunga community, many grandparents are taking care of orphaned grandchildren after the death of parents to the unspoken illness.

Figure 4: Dunga Beach, with water hyacinth in foreground
Figure 5: Fresh fish catch for sale to the public, cleaned and ready to cook
Figure 6: Fingerlings (immature fish) sold for frying

Figure 7: Shrimp off-catch sold for chicken feed

The Dunga Beach and wetland area has high biodiversity and a rich and diverse papyrus wetland ecosystem. There is a Wetland Pedagogical Centre used by school groups and tourists. Papyrus specialist birds dwell in this habitat, including some globally threatened species (e.g. Papyrus Yellow Warbler) (22).

The swamp area is a drain for incoming streams regulating floodwater volumes into Lake Victoria. It is used by some locals as a source of papyrus for thatching, mats and as raw material for baskets. The swamp has been seen as a 'wasteland of mosquito breeding', and is under pressure from human population expansion. Pollution and eutrophication are considerable threats and have caused algal blooms. Some farming takes place here, and grazing in times of drought (25) (see Figures 8 and 9). Where this happens, peatlands are drained, potentially increasing carbon emissions (22) (26).

Figure 8: Papryus wetland East of Dunga
Figure 9: Papryus wetland East of Dunga

5. Household biodigesters

5.1 Aims for household biodigesters and household selection process

This pilot project involves the trial of 50 household biodigesters in the poorer or more needy households in the Dunga Community. The aim of the first two research questions accompanying the research study is to examine the **benefits of biogas at the household level from both an economic and social perspective (RQ1 and RQ2)** during the 18 month study period, looking at possibilities for further uptake. To do so, we aim to answer four sub-questions:

RQ1.1 What is the process of implementation and management of household biodigesters? Are household biodigesters cost effective?

RQ1.2 How does biogas generation impact on household economy? What is the impact on poverty?

RQ1.3 What are the potential social impacts, especially gender relations and intra-household changes?

RQ 1.4 How will future feasibility, sustainability and uptake be ensured?

Household selection process: undertaken by BIL

The pilot household selection process was designed by Biogas International Limited (BIL) in collaboration and agreement with CISL. In July 2018 after initial discussion with local committee of the Dunga Beach Management Unit (DBMU), 'pilot' digesters were set up in four households so that others in the community could see these working and ask questions if needed (see Figure 11). This was to raise interest amongst the community 'where households need to see this for real before they believe' (BIL Dom pers. Comm, August 2018). These four were selected and suggested by members of the DBMU, who chose families open to discussion, well known to others in the community, and as representatives from the four main Luo tribes in the community (No, Kasagam, Mangala and Kamnara). There appears to be continued strong bonds within the tribes, and householders are more willing to approach those from their 'own' people.

Figure 10: Pilot Household Biogas Installations

- 10a Biogas Flexible biodigester with plastic covering for heating
- 10b Bio-slurry output from biodigester

- 10c Discussing amounts of cow dung and water for feedstock input
- 10d Gas cooker demonstration

Household digesters' components are assembled into kits for each household comprising:

1. High quality PVC sheet imported from China and welded/fabricated into bags in Nairobi
2. Micro greenhouse tunnel made of Solarig Woven Polystyrene imported from Israel and fabricated in Nairobi
3. Standard water plumbing components (pipes, valves etc) sourced from local hardware suppliers
4. LPG cooking stoves imported from China, modified by BIL to accept biogas. Larger stoves for larger digesters are made in BIL workshops in Nairobi, longer lasting.

Each system is geo-referenced and positions put on Google map.

Source: CISL 2018 Design document [27]

The selection process was undertaken by BIL for the remaining 46 biodigesters included an initial visit to 92 households in the Dunga community, facilitated by a member of the Dunga Beach Management Committee (DBMU). Families are well known within the community. At all interviews, a DBMU member accompanied the researchers – this is because houses are difficult to locate in the unplanned settlement, because trust is needed to access people in their homes, and the members of the DMBU are trusted, and because in some cases, an arrangement needed to be made in advance to ensure the householder was present: most of the women have informal business activities that they attend to during the day in addition to household responsibilities. Two DBMU members were paid for their daily services at standard per diem rates, depending on their availability. Householders had mostly been informed in advance of the possibility of biodigesters. They completed a short survey questionnaire verbally in Luo language (mother tongue in this area) with BIL staff, which was written and then processed by BIL staff, who ranked these and presented the decision to CISL.

<u>Criteria for households to be included in the pilot were:</u>

1. 'Need'considering several factors: Basic assessment of extreme asset deprivation (poor housing, food poverty, fuel poverty etc), old age, ill-health and disability, high number of dependents living in household, orphans (i.e. grandparents caring for grandchildren due to parents' death).

2. 'Sustainability and ability to maintain the system' is dependent on land availability for the unit to be installed, access to sufficient amount of cow dung and other organic matter as feedstock, and enthusiasm towards adopting this technology.

3. 'Number of people cooking' and 'commercial cooking' was included as a criterion because some households cook for commercial purposes and they have a greater number of people exposed to prolonged inhalation of wood smoke.

4. 'Willingness to pay' – BIL asked if households would be willing to pay up to USD50 (KSh 5000) for the installation This is just under one tenth of the cost of the biodigester, considered to be the maximum amount that most of the poorer households in the community would be able to pay. BIL considers that a part payment is essential in order to create a sense of value, care and ownership amongst householders.

The criteria for exclusion from the pilot study were:

1. Lack of interest from householder
2. Lack of available feedstock (and no work-around possible)
3. Modern lifestyle (wealthy) or easy regular access to LPG.

During the survey process, there was spread of information between community members about the community digesters. After initial interviews where householder expressed willingness to pay.

Business model for household biodigesters

The household biodigesters provided by BIL are expected to have the following characteristics:

1. Capacity $6m^3$ -BG5 design- for most households (or $8m^3$ -BG6 design- if expected to be a 'high use' household with over 12 residents or used for cooking from home for cooked products for sale).
2. Price of BG5 design: US$610 (KSh 6,100), including double burner biogas stove
3. Expected lifetime: 20 years plus
4. Household contribution proposed as affordable for households in this area: US$50 (8% total cost)
5. Payback period to be negotiated individually; expected several months, expected to be affordable with savings from payments for wood and charcoal and other fuels currently used.
6. Installation included in initial price; all systems to have 2 year warranty and phone assistance available from BIL. First visit by technician in case of problem unresolvable by phone is free of charge; after that a small charge is payable "to discourage dependency"
7. Possible additional uses for excess gas is to bag these and sell them (but considered a very low return business). More likely be able to make a better economic return from use of bioslurry produced as waste from the digester.

According to BIL's expected procedure, householders' training will include 1-2 hours during installation, with regular phonecalls during first two weeks after installation from BIL to ensure the systems start producing gas for first light. BIL states that 99 per cent of problems can be dealt with by phone. BIL has two staff dedicated to aftersales and follow ups, with one field officer and a coordinator in Nairobi. They state that every site will be visited after three months for follow up training and on use if fertiliser by-product.

5.2 Characteristics of respondents

The selection process for beneficiaries was deliberately slanted towards needier households in the Dunga community; as a result, one third of the 50 household respondents are aged 60 or over (36 per cent). A further two are considered 'needy', with disabilities that severely impair mobility (one due to a broken spine in an accident, another was blind). A further two were long-term ill (more than one month) and bedridden during our visit.

All but one of these survey respondents were the primary beneficiaries chosen; in one case, the live-in daughter-in-law answered questions on behalf of her frail relative. In two other cases, due to illness or frailty, we cut all non-essential questions for the respondent.

The group of respondents is well-established in this community. All stated that they own their own piece of land where their house is built[2]. Most respondents[3] (84 per cent) have lived in Dunga for 20 years or more, and several of these (5) have been resident since Dunga was first inhabited in around 1950 (60 years or more)(#INT 18,19,35). The average length of time people have stayed in Dunga is 37 years, with a minimum 4 years and maximum 69 years. Recipients' average age is 53, ranging from 26 to 84 years old.

Amongst the 50 households interviewed, there was a total of 347 inhabitants. On average there were seven people per household, with a mode of five people, but ranging from 1 to 20 people in total. The ratio of adults to under 18s was 1:1.28 on average. Adults to dependents was higher at 1:1.74 due to some older adults being economically non-productive.

Most respondents (42, or 84 per cent) were female. In some of the interviews where the main respondent was male, a female was also present and could contribute on cooking information. In this community, the household head of the family is male if present. Of the 30 households with a male household head, nearly all of these (28, or 93per cent) are married. Only two of these households have no spouse present: one male is separated from his wife who is currently living in the rural area elsewhere in Kisumu, and the other male is widowed.

Women are heads of household in 40 per cent of the sample, being mothers or grandmothers, or living alone in a dwelling. All of the 20 households with a female head are widowed, and range in age from 33 to 84 years old, with an average age of 60 years (slightly older than the average age for all respondents, which is 53).

5.3 Biodigester attitudes and feasibility

5.3.1 Understandings about biogas and biodigesters

Of the 50 households, respondents in half of these had heard about biogas before. Of these, three household members had been involved in the training with the Dunga Beach Chiela fish fryer women's group for a biodigester at the beach front: a three-day training workshop held at the county university (University of the Great Lakes). Several others had seen the installation at the beach front, or in other people's properties outside Dunga. People commented that it looked easy to use, fuel costs might be decreased, and showed some understanding about the feedstock inputs that might be used. Two said they were amazed that this could work. Only one mentioned that they knew it was very expensive to acquire.

They had heard about the biodigesters mostly through Maurice from the Dunga Beach Management Committee, though seven of the group had heard directly from others in the Dunga Community – those running the pilots.

[2] However, we heard that land titles are not available for the community, and it is an informal settlement. Whilst we were told that pieces of land change hands for money, it is unclear currently if there have been any processes towards formalisation of land tenure or if the land still officially belongs to Kisumu County government. Kisumu County have installed some basics in the community, e.g. stand pipes. However, other sanitation is not provided: an NGO installed pit latrines three years ago, which are emptied privately by houseowners paying individuals for this service.

[3] N=49 as one respondent couldn't remember how many years she had been here

After the household pilots were set up, 30 of the potential recipients had gone to see them in place (65 per cent of the 46 future recipients). Most of these had not been taught how they worked, but they could see it working, producing gas and cooking faster. None of them were put off by seeing it or said anything negative about it.

5.3.2 What do recipients perceive to be the benefits of the biodigester?

An open question was asked to the respondents about the benefits of the biodigester. Most people thought it would be cheaper, easier to cook with and would bring benefits of not being smoky (see Figure 11). Over a third also mentioned it would be quicker to cook with and save time from gathering fuel. Others mentioned benefits such as being able to multitask when cooking, being a clean energy source that would not make the food or utensils dirty, that it could be used in all weathers, or that grandchildren and children can help cook as it is safer. However, fourteen percent of respondents didn't know any benefits when asked (although when prompted later about time/money, they cited these savings).

A more specific question asked later showed that nearly three quarters of respondents expect to save money from reduced fuel costs, and around half expect to save time as a result of reduced fuel gathering needs.

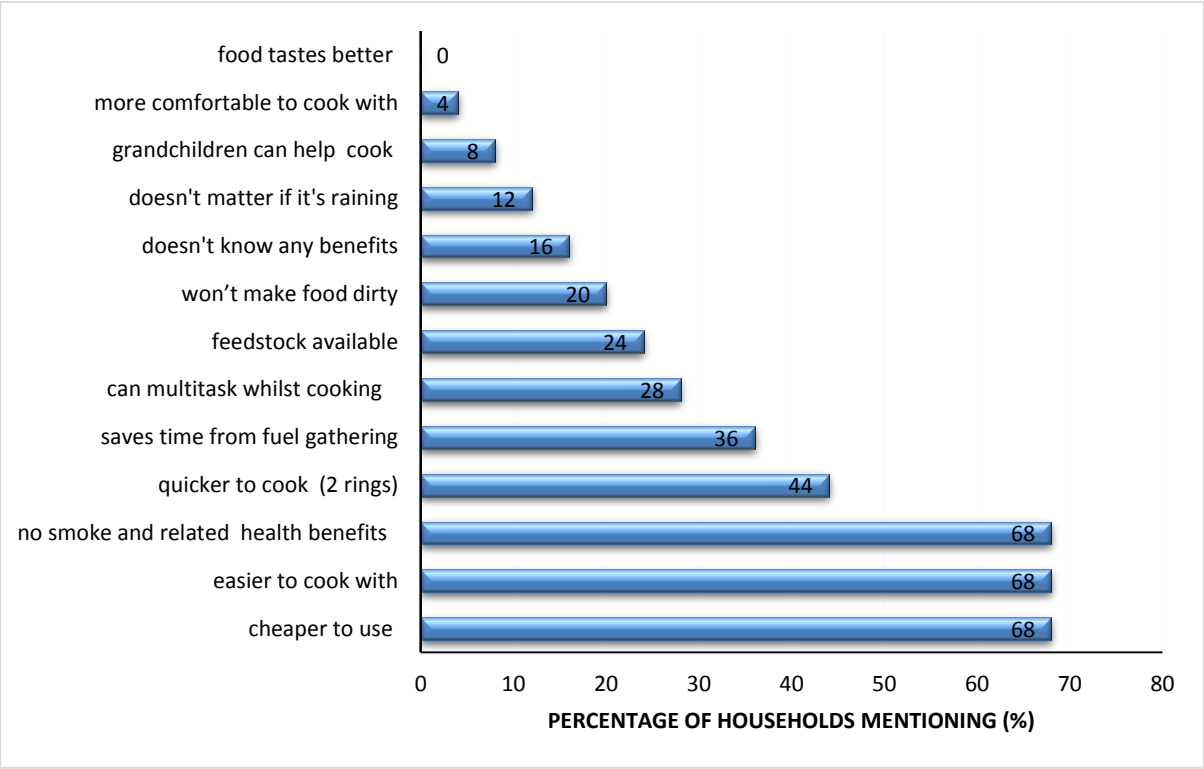
5.3.3 Deciding to get the digester

Most of the recipients were very positive about the possibility of obtaining a biodigester. Four households (9 per cent) hesitated for reasons of cost (thinking they cannot afford it, or might need to take a loan).

Of those within a shared household (married male and female adults), most discussed this with their spouse (89 per cent). Three women did not discuss this with their spouse; one of these commented that she thought it was a good thing and knew her husband would agree. Of the other respondents, one said she did discuss it with her husband but rather despondently claimed there was not much point to this as "he's a drunkard, so not much use".

In terms of decisions about whether to have the digester the women made this decision in just over half the households (52 per cent). In households with married couples, women alone made the decision to have a biogas digester in about one fifth (21 per cent) of these (six out of the 29 households) after these discussions. Both made the decision in 38 per cent of the households. In only four households the men alone made the decision, and only two of these (4 per cent) are shared with a spouse. This demonstrates that the decision about the household acceptance of a biodigester is very dependent on the input of the women, who are the primary caregivers and homemakers in this community.

Figure 11: Householders' expectations of benefits of biodigester pre-installation



5.3.4 Biodigester feasibility: feedstock and bio-slurry

Feedstock availability is a major concern in this peri-urban area, contrary to many rural biogas systems placed on farms. Of the 50 households, half of these say that they have a dependable source of feedstock for the biogas digesters – usually cow dung from their own cows or a neighbour's supply, but sometimes fish wastes or restaurant wastes from the local area. The others will need to collect cow dung from roaming cows, or use other wastes to supplement this – potentially water hyacinth from the lake if BIL are able to provide some machinery for this processing.

Bio-slurry is produced by the biodigesters. Usually in rural areas this is a useful by-product for vegetable gardens and crop fertiliser. However in this area, few households have kitchen gardens so there is no obvious use for the bio-slurry for other households, which may become an environmental hazard despite its reduced microbial load in comparison to 'raw' cow dung due to its increased liquid nature. For kitchen gardens, households would need to invest in fencing as many livestock roam freely in the area and destroy garden crops.

5.3.5 Who will maintain, repair and own the digester?

In terms of daily upkeep, most respondents see the women as solely responsible for this in their household (80 per cent), with a small proportion sharing this between the couple, or with children/grandchildren. Only three (6 per cent) households see the male as responsible (and note that two of these are males who are alone in the household) (see Table 2).

This contrasts with responsibility for repair, where nearly all respondents said they did not know who would be responsible for this, and just a few naming either the DMBU member accompanying the biogas company (who had in fact fixed a couple of initial problems on discussion with the biogas company after the initial pilots were installed), or the biogas company themselves. Respondents expect ownership of the digester to be largely female (72 per cent) with just under a fifth considering this to be joint owned, and 10 per cent considering this to be male owned.

It is worth noting that given that most of the respondents to this survey were female in the absence of the males of their households, there was no evidence of full agreement between the couple over the predominantly female ownership of this valuable, and highly subsidised piece of equipment.

Table 2: Householders' expectations of responsibilities and ownership of biodigesters

	Daily maintenance		**Repair**		**Owner**	
	#	%	#	%	#	%
Female	40	80%	0	0%	36	72%
Male	3	6%	1	2%	5	10%
Female and Children/grandchildren	2	4%	0	0%	0	0%
Male and female	3	6%	0	0%	9	18%
Don't know	0	0%	43	86%	0	0%
Maurice /DMBU	0	0%	2	4%	0	0%
Biogas company BIL	0	0%	1	2%	0	0%
Didn't answer	2	4%	3	6%	0	0%
Total	**50**	**100%**	**50**	**100%**	**50**	**100%**

5.3.6 Payments and finance

Just under half (42 per cent) of the recipients are expecting to receive full subsidy for the biodigester, with no costs to pay. This includes the over 60s, those who are disabled, and the four pilot biodigester recipients who are demonstrating and informally teaching about the biodigester to others (see Table 3). Just under half (48 per cent) said they are willing to pay the full subsidy of 5000 KSh (USD 50 / GBP 38) requested for the biodigesters. Of the remaining five householders, two said they did not discuss it during the visit by the biogas company, one that the biogas company had discussed it with their spouse and they were not aware of the decision, and the final three said they could not pay the full KSh 5000 and no firm agreement had been made.

Table 3: Subsidy and payment expected for household biodigesters

Payment	# Households	% Households
Pay KSh 5000 / USD 50	24	48%
Pay nothing	21	42%
Other	5	10%

Respondents who are due to pay the subsidised amount had briefly discussed with BIL about payment mechanisms (cash/money transfer by MPESA, a mobile phone 'electronic wallet' service allowing transfer of money) and frequency of payments (weekly/monthly/lump sum). They were led to believe that there was flexibility in payment timings and amounts. However, exact terms had not been agreed during the visits. None of the respondents said that they would have to borrow money to pay this amount. Most respondents are unaware of when the biodigesters will be installed; only one told us they expected this to be done in November/December 2018.

5.4 Household assets and livelihood

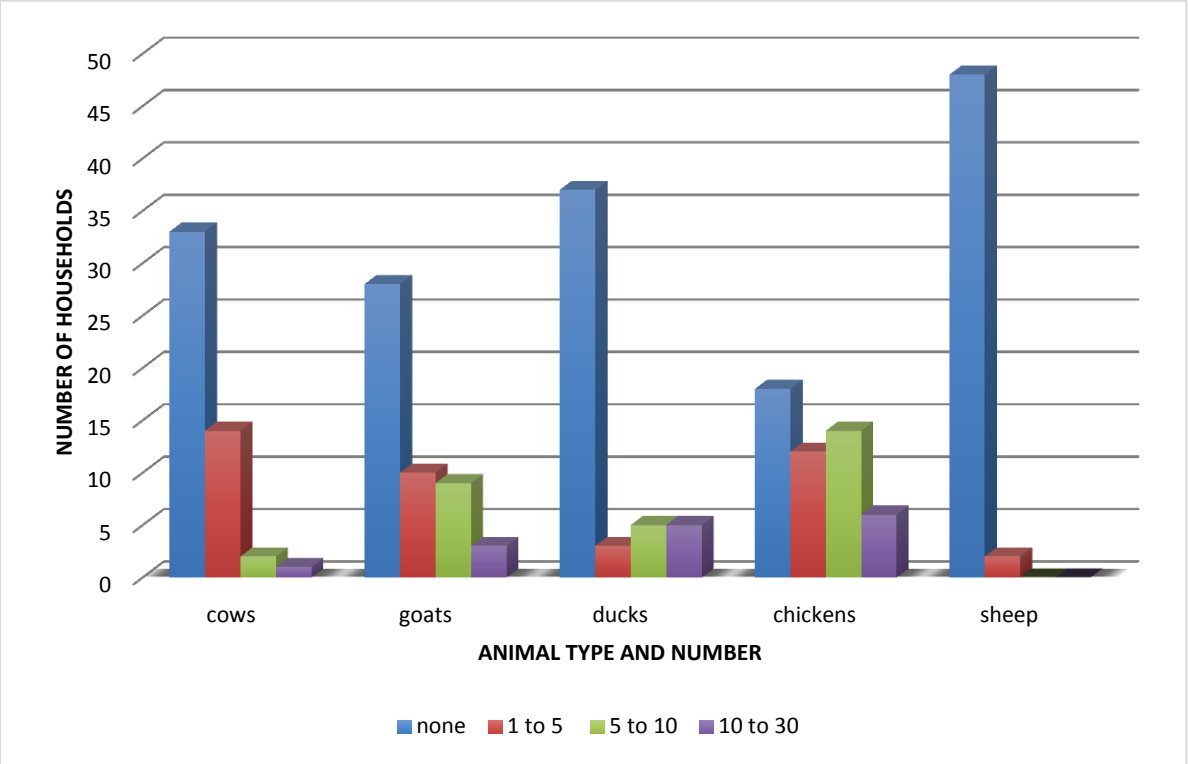
5.4.1 House dwelling

Householders live in simple wattle and mud housing for the most part (86 per cent), just over half of which have been rendered for durability. Just over 10 per cent of the houses are brick with durable flooring.

5.4.2 Livestock ownership

Most households do not own cows (66 per cent have no cows, with an average of 1.5 across the whole sample). Of those that do own them, most households have less than 5 cows (28 per cent have 1-5) (see Figure 12). One household is an outlier, with 27 cows that are kept on nearby pasture. Small livestock, including goats, ducks, chickens and some sheep are also kept in the community, with one householder breeding and keeping ducks and chickens in closed coops for sale, and three householders owning more than 10 goats. A small proportion of the householders (10-12 per cent) also keep between 10 and 30 poultry. Householders complained that many poultry have died from disease recently, and that their ducks wander onto other people's land and can be killed when scavenging in houses by stones thrown to scare them off.

Figure 12: Livestock number and type owned by household



5.4.3 Other household assets, services and credit availability

Just over a quarter of households have access to electricity. Table 4 below shows that households do not own a large number of assets; indicating relative poverty. Householders' major assets include mobile phones (90 per cent), boats (16 per cent), bike (30 per cent, motorbikes (6 per cent) and sewing machines (4 per cent). None of the householders own a car.

Table 4: Asset ownership amongst households

Asset	#	%
Boat	8	16%
Bike	15	30%
Motorbike	3	6%
Car	0	0%
Sewing machine	2	4%
Current loans	11	22%
Mobile phone	45	90%
Phone ownership average number per household	2.4	
Phones average number per adult	0.83	

Loans are currently held by just over one fifth of households with various groups including Dunga Traders, Par Mos, Sulwe Ma Nam, Oyasu, Dunga Sisters, Great Influence Self Help Group, Bet Rach Wuoth Ber, Dunga Roundabout, Stasoft, Chako Ni Chako. These range from KSh 6,000 - 34,000 (USD 59-337 / GBP 46 -259).

Just over two thirds of households belong to one or more social groups for church, savings, credit and investment. Some householders reported that they sometimes had to drop the group if they didn't have enough money to continue to participate. Two householders were disillusioned with the groups, claiming that they find them a waste of time and a drain of money, and 15 in total (nearly a third) participated in no groups. But the rest were positive about the funds raised in this way. Several used this for school fees, building their house, investing in small businesses locally (e.g. chairs to hire out). Types of group include Table Banking, Merry Go Round, Savings and Church or other Charity. These are mostly the women who participate, but sometimes men.

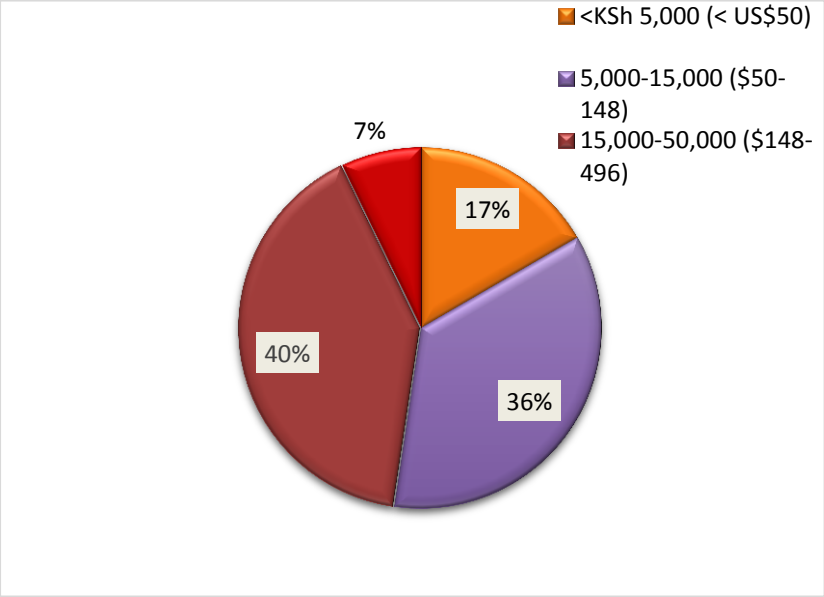
Groups named include the following: MEYO Development Group, White House, Tede Teyede, Dunga Flying Eagles group, Dunga Jiimarishe self help, Oyussi Women's group, Saint Monica Church, AIC church, Pastoral Assembly of God Church Group, ECLOP, Prowe Savings and Credit, Kisumu Action Development Disability Network, Par Mos, Great Influence Self Help Group, Chiela Women's Group, Kisumu Action Development Group, Dunga Cooperative, Dunga Beach Traders' group, STAsoft Group, Dunga Roundtable and Kamnara

5.5 Income

Income is a sensitive question for most households. Reliable income data is tricky to gather in dependable detail at community level through informal surveys, to the point where it is not often used as a proxy for wealth. In our attempt to understand data about the community, we aimed to get an understanding of the bands of wealth amongst the respondent group, to see if there was a difference between these households in terms of their material wellbeing and the impacts of the biodigester on their household over the course of the project.

Using judgement and income data (where considered reasonably reliable from fullness of answers given), from 42 households we estimated income to be in the lowest category (<USD50/month) for 17 per cent of households, and between USD50 and less than USD148 for 36 per cent of households, meaning that over half of households are earning income less than USD150 per month (see Figure 13). As this is a highly monetised community – people are not farming or bartering frequently, their cash income is a reasonably good representation of these transactions. However, other support is also important to many of the households: 60 per cent of the 50 households receiving either money or food from relatives. Ten of these (20 per cent of the sample) are also sponsored by an NGO or by a government bursary for school fees for grandchildren where parents are deceased. Therefore, cash income will not provide a full picture of an entire household's economy.

Figure 13: Approximate income ranges of respondent households
Per month, August 2018, n=42

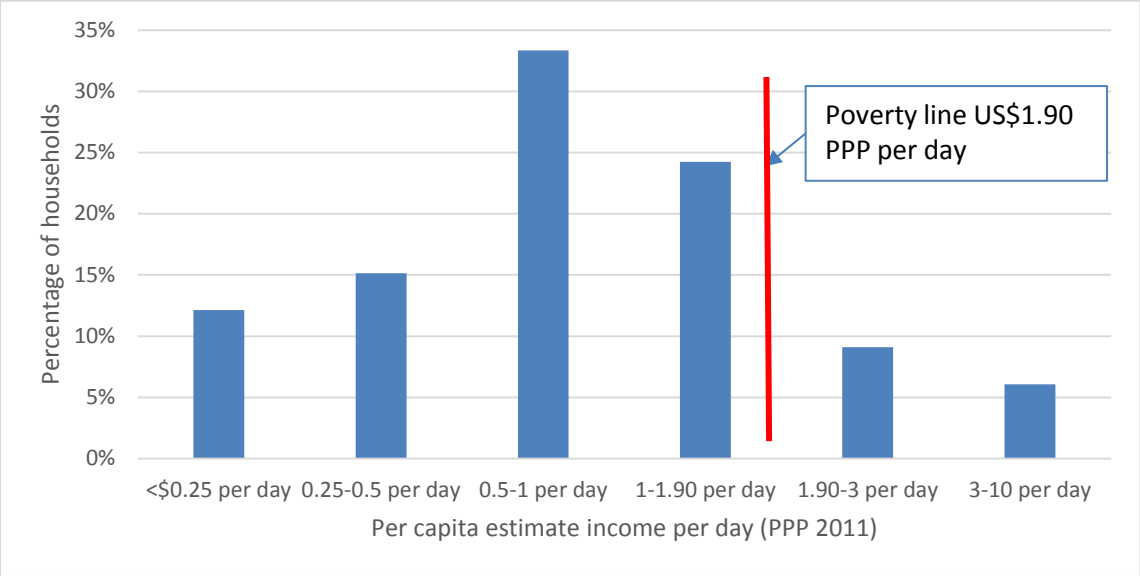


In order to calculate an approximate income per head (as households are of variable sizes) to relate this to national and international poverty lines[4], we used 33 of these data points. We considered the other households' data unreliable from answers given and didn't use this further. This means that some of the wealthier households in the sample (as we informally estimated from observation) are not included here.

The majority (85 per cent) of households are under the international poverty line for extreme poverty of USD 1.90, with 61 per cent of households under USD1/capita and 27 per cent of households under USD0.50 per capita per day (see Figure 14).

[4] We converted the September 2018 income per person to 2011 income using the CPI Consumer Products Index ratio for August 2011, then converted this using the PPP private conversion factor for 2011 in order to complete the comparison to the 2011 data used to estimate current poverty, which uses USD 1.90 as the daily per capita amount below which people are considered to be in 'absolute' or 'extreme' poverty.

Figure 14: Households' income per capita USD PPP



We must take into account that these figures do NOT include gifts received in kind from relatives of cash and food, which are very hard to calculate (and cannot be calculated reliably on one initial visit). Therefore some families will be a little better off than this, however it does give a good indication that these families are not well off. Their very limited material assets (see Table 4 above) also support this.

5.6 Cooking, fuel and water

5.6.1 Household cooking in Dunga

Householders cook a variety of foods in Dunga. Commonly, breakfast would include tea (chai) and porridge, mandazi (fried sweet bread), bread, and sometimes heavier dishes of rice, maize and beans (nyoyo). Lunch may be same as breakfast, but some households might cook ugali, small fish and eggs. Some households had a mid afternoon snack of ugali. The main meal of the day, supper, usually includes ugali, fish and fingerlings, rice, kale/cabbage and other vegetables, and occasionally chicken or beef or goat. This community is fully reliant on fish as a protein source for nutrition, and very few people in the community keep kitchen gardens – vegetables are bought in the local or main Kisumu markets. Nyoyo, a maize and bean dish, is traditional in the community and takes several hours to cook – some households buy this in from neighbours. Five of the households cook commercially, selling mandazi, fish, nyoyo and uji porridge, with two of these serving full meals of chapatti, beans, green gram, beef, samosas and vegetables cooked in their households.

Householders mostly cook with traditional 3 stones outside (84 per cent) and charcoal jikos (78 per cent) (see Figure 15). Less than one in five households own wood fuelwood fuel jikos. A few (10 per cent) use paraffin as a backup or for quick cooking of breakfast or chai, and three households (6 per cent) use the more expensive and rapid cooking fuel LPG in canisters.

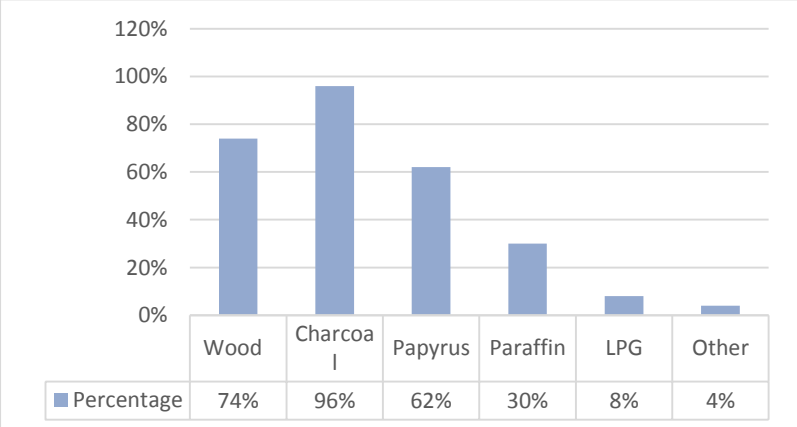
Figure 15: Cooking stoves used in Dunga
Charcoal jikos (outside and inside) and stone cooking area

5.6.2 Fuel sources

Currently householders use fuel sources for cooking that include wood (brought from Kisumu and the surrounding area, or gathered locally), charcoal (bought usually from Ugandan supplies offloaded in the Dunga Beach port), papyrus from the neighbouring wetland and LPG (gas) (see Figure 16). Most of the fuels were bought as this is a peri-urban area; however 44 per cent of householders gather wood, and 39 per cent householders gather papyrus rather than purchase it. Most households use multiple sources of fuel for the different cooking apparatus. Wood is usually used for cooking outside on a simple 3 stone structure; charcoal burners (jikos) can be moved inside in case of rain, or used outside. Some households preferred to cook inside if possible; a few also had outside shed-like structures for kitchens where they use 3 stone and jikos. These were blackened with smoke inside, like the inside of chimney breasts, and must cause huge respiration of wood and charcoal smoke when in use.

Much charcoal production in Kenya is illegal based on unlawful logging in the few remaining forests of the country (7 per cent forest cover remaining); Ugandan supplies are often smuggled in as a cheaper alternative.

Figure 16: Householders' fuel use pre-installation



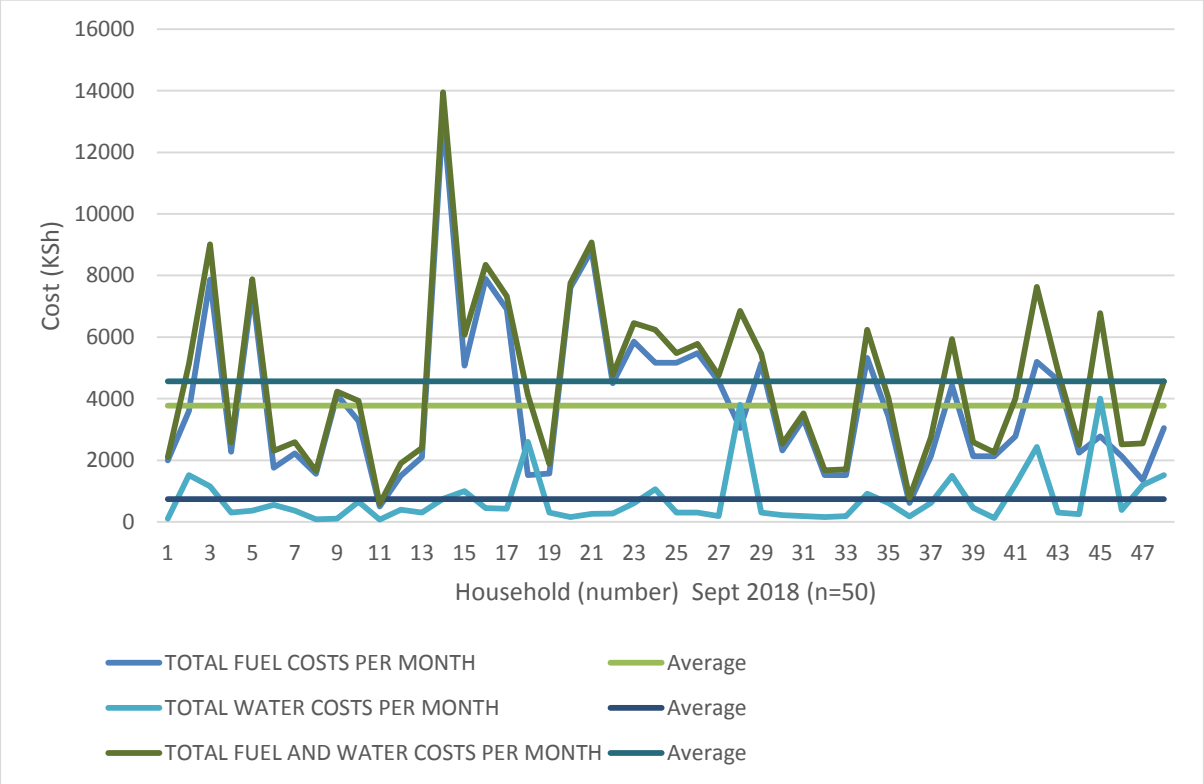
5.6.3 Water sources

Water is usually collected either from the lake or from standpipe taps in the community. Tap and lake water is used by nearly two thirds of the households (59 per cent) with tap water for drinking and lake water for washing/bathing. Thirty five per cent of households use only tap water, saying that lake water is too dirty. Three households (6 per cent) have water piped directly to the house and pay for this on a water meter. Most water is collected by the female of the household, children or grandchildren; or delivered for a fee if the householder is too infirm to collect this (seven households).

5.6.4 Costs for fuel and water

Costs for fuel and water for the household are significant, with fuel costs being significantly higher than water costs, especially where some households cook for commercial sale (see Figure 16 below). Fuel costs range from KSh 502 – 13,200 per month, average KSh 3,778. Water costs range from KSh 75-4,000 per month, average of KSh 740. Currently collecting fuel takes an average 1.3 hours per week, and water 2.9 hours per week. There is no significant correlation between cost of fuel for the household and time taken to collect it, contrary to our expectations (correlation of fuel cost and time taken correlation is -0.13). In subsequent surveys, we might expect the time taken to collect water to increase as the biodigesters require additional water, and the costs and amount of other fuel sources to reduce as the biogas provides a replacement fuel for some or the majority of fuel used.

Figure 17: Household fuel and water costs (monthly by household)

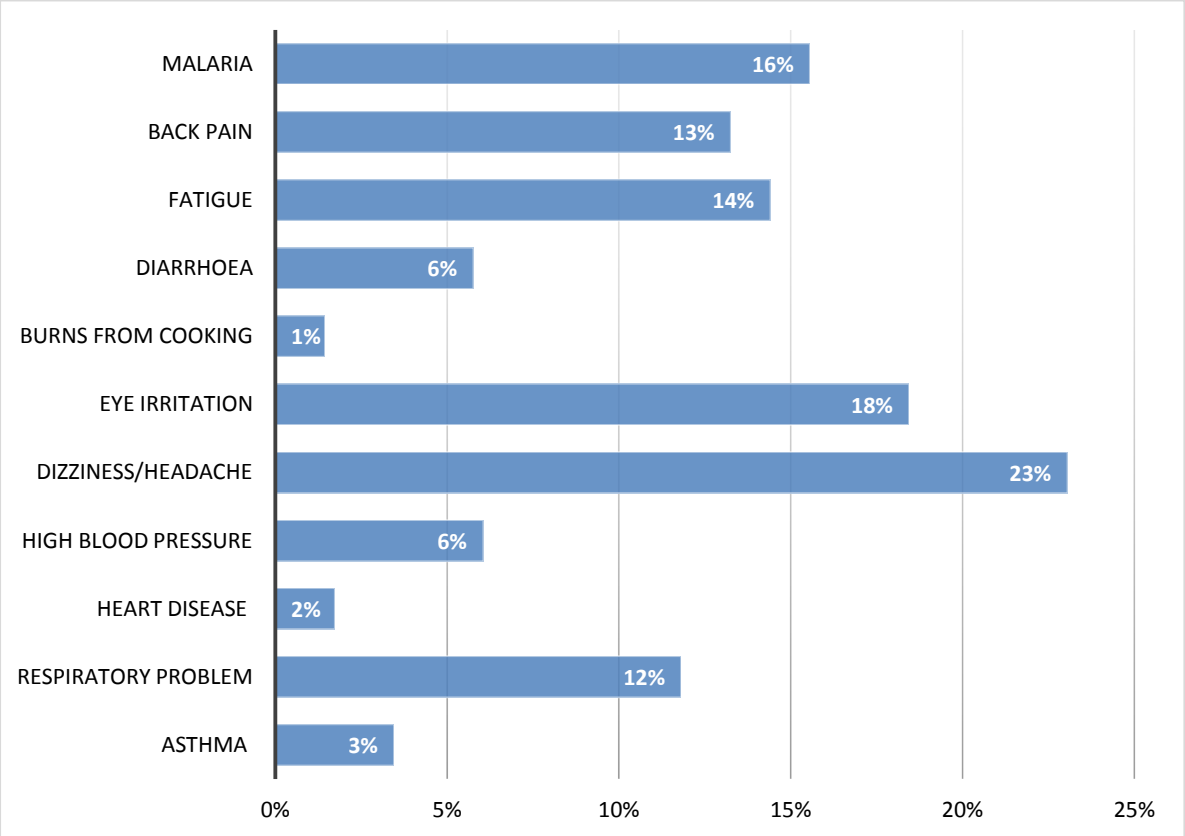


5.7 Health

5.7.1 Ailments of household members

Most (86 per cent) of household respondents say that they have health issues as a result of use of wood, charcoal and papyrus for cooking. From cooking smoke they report headache / dizziness (23 per cent), eye irritation (18 per cent), chest congestion and cough / bronchitis (12 per cent) and asthma (3 per cent). In addition to this, several report backpain from cooking or carrying fuel (13 per cent), and malaria (16 per cent) as a result of collecting papyrus reeds from the wetland areas, despite widespread availability of mosquito nets in the area (see Figure 18). High blood pressure and heart disease is reported for 2 per cent and 3 per cent of household members respectively; however these are not routinely checked in this population currently. Other illnesses reported include arthritis, knee and joint pain, chest pain, ear pain, ulcers, kidney problems and sickle cell anaemia.

Figure 18: Numbers of household members reported with illness in last three months (June to August 2018) (n=347)

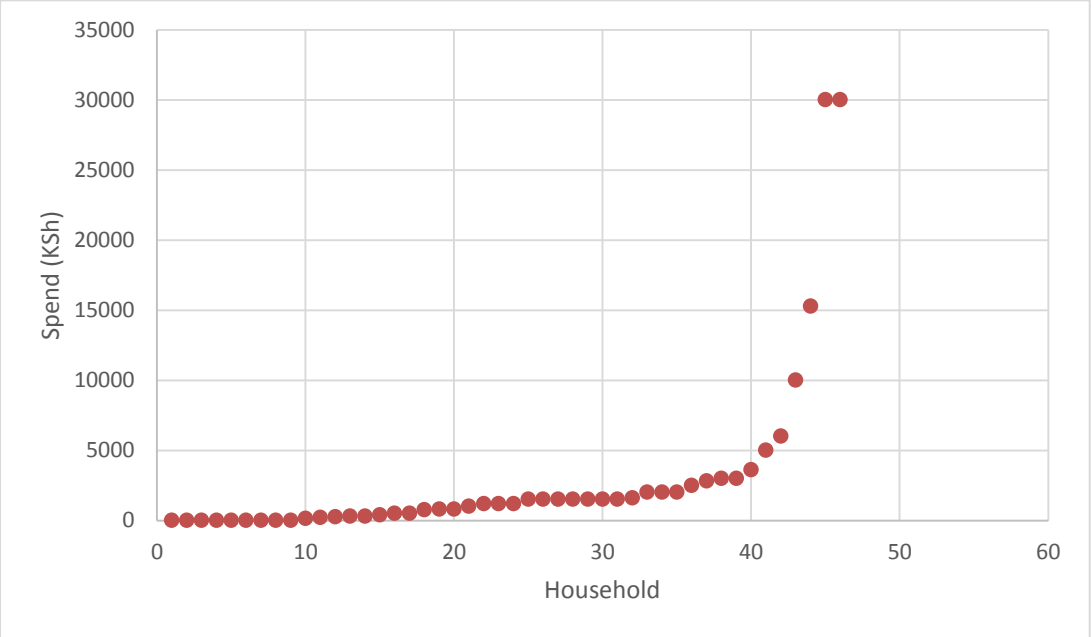


Some of these illnesses are predominantly occurring to the women in the household: 90 per cent of reported back pain is from adult women, 84 per cent of reported fatigue, 59 per cent of eye irritation, 49 per cent of dizziness/headache and 39 per cent respiratory illnesses. Whilst it is of course not possible to draw clear causal links in most cases between fuel sources and illnesses reported, some doctors of these householders have linked headaches with charcoal jiko use (carbon monoxide outputs), and many women carry heavy burdens as part of their housework: papyrus bundles, wood and water, report this causing back pain. These figures will provide data for future comparison once smokeless gas cookers are used in the households.

5.7.2 Health spend

Average spend on health in the last three months for households was KSh 3,018, with the highest amount paid KSh 300,000 (see Figure 19). The Kenyan National Health Insurance Fund (NHIF) has paid cards that allow households to obtain medical care free with monthly payment plans for families. In this community, most households say that they would like to have one of these cards, but cannot afford it; only six households have an actively paid-up card. A further six used to have a card, or have one that is inactive. The households with high spend in the last three months (KSh >10,000) reported different problems – serious leg infection, heart issues and two people with lung infections that needed scans and medications. Of these four, one has an NHIF card, which meant her household costs were KSh 10,000 and the NHIF covered the "significant" additional hospital costs.

Figure 19: Household spend in last three months on health



6.Community biodigesters: a new biogas enterprise

6.1 Aims and research questions

The community biodigesters bring a sustainable, inclusive business opportunity to Dunga Beach, providing women with clean and affordable energy for frying fish, which is sold commercially on the beach front at local markets and to passing traders. During the pilot project a key question is **what is the financial and social sustainability of community level biogas generation in this peri-urban community (RQ3)?** Gender is an important consideration throughout this research. Given that the community level biodigester will focus on women users within a male-dominated community and Dunga Beach management structure, we expect the use, participation and management of community biodigesters to have an impact on gender relations.

The longitudinal study as a whole therefore aims to investigate the following sub-questions:

- **RQ3.1 How is effective governance of the community biogas project developed?** How does a private business foster positive sustainable links within the locality? How does the community view the biodigester? How are any misunderstandings/miscommunications resolved?
- **RQ 3.2 How is the community digester implemented practically** and how are adaptations fostered and made effective within the specific locality?
- **RQ 3.3** What **social and economic** impact does this have, in particular on reduced expenditure, income generation and gender issues relating to economic and social empowerment in the community? What are the benefits and what are potential sources for conflict?
- **RQ 3.4** What is the **financial sustainability** in the longer term for these digesters? Are budgetary and output projections realistic?
- **RQ 3.5** What are the **main recommendations for businesses** wishing to bring biogas to similar communities in the future (social acceptance, affordability, capital, skills)?

The research team conducted meetings with key stakeholder groups, exploratory interviews and field observations throughout the Dunga Beach business community, including many who are not directly involved with the project. We also reviewed reports on the local history, culture and resource management to supplement interview data collected. Research methods are in Appendix B and a list of respondents is in Appendix C.

6.2 Implementation process

6.2.1 The business plan design

This project is a pilot of innovative technology and is designed to test and trial a number of variables for economic, social and practical feasibility. Critical to the success of this innovation is its adaptability to local circumstances, co-creation, acceptance and co-learning with the community. This is seen to be a mutual learning and simultaneous outreach process, as this innovation could be replicated around Lake Victoria if successful (Dominic Wanjihia, BIL pers. Comm. September 2018).

Biogas International Limited (BIL) has a strong history of technological innovation with design, manufacture and ongoing improvement of equipment so it can be tailored to individuals and groups' conditions and requirements.

The approach developed by CISL and BIL is that two 'community biodigesters' will be installed as an inclusive business opportunity for local residents and "intended to be run primarily as services businesses" (27)p.4). Each of these large biodigesters is 15m long and 2.6m wide, with a capacity of $30m^3$ (T-30 plants, also known as 'T-Rexs'): $60m^3$ in total. In this pilot the biodigesters will be owned by CISL and will be set up, run and maintained by BIL along with local staff to be identified and trained.

Led with an entrepreneurial slant from BIL, the feedstock used for the plant is intended to primarily comprise the overgrowth of water hyacinth gathered from the lake, possibly to be supplemented with food waste. BIL will train local staff to process water hyacinth in a shredder to mince the plant before it is fed to the biodigester by hand, producing biogas, fertiliser and power from conversion of biogas to electricity. Later on, BIL may add further activities such as converting plastic waste to energy and creating safe potable water using the fuel provided, depending on interest, demand and feasibility.

The gas produced by the community biodigester is expected to be piped to a bank of 'kitchenettes' constructed with five stoves set up for fish frying. The women fish fryers from the local Chiela women's fish frying group, and other women fish fryers at Dunga Beach, will be able to use this kitchenette for a small fee per day. It has to be stressed that the biodigester gas is not a 'community' project available for all people within this community; people need to be registered fish fryers with Dunga Beach, and the gas is not intended for other groups or individuals to use.

In the development of the project, set up, installation and maintenance, BIL are responsible for all community communications with entities responsible for Dunga Beach oversight (the DBMU), and the groups and individuals using them.

Budgetary considerations of the community biogas business model are as follows:

- Fuel costs: currently this intends to match existing prices for fuel for the fish fryers – assuming that women spend KSh 300 (USD 3) on fuelwood for three hours' frying, the cooking points will be provided at KSh 100 (USD 1) per hour.
- Excess gas will be used to supply a biogas generator, which will process feedstock and charge batteries in a biogas-solar vendor outlet
- Possibility to sell gas in bags to consumers for household use
- Outputs expected:
    - $60m^3$ gas per day
    - $50\text{-}60m^3$ flow per day
    - 800-1000 litres slurry fertiliser produced per day (40x 20l buckets)
- Revenue expected: USD 45 per day/ USD 990 per month:
    - Kitchenette: KSh 30,000 (USD30) per day
    - Gas in bags KSh 5,000 (USD5) per day
    - Fertiliser - initially 0: will be given away; then a cost will be up to USD0.2/l
    - Electrical power charging - USD10 for solar batteries when cloudy (automotive batteries USD2 for fishing lights/domestic); phone charging. To be priced competitively against grid electricity once prices are known
- Expenditure expected: USD 985 per month (initial)

- Core and casual staff: USD 645 per month
- Rent USD 120
- Fuel USD 50 for boat for collection of hyacinth
- Wear and tear USD50
- Consumables office products USD20

Over time, the business plan purports that: "the business model is expected to produce modest surpluses of USD250 per month" as users grow in confidence. According to the plan, this will allow for reinvestment over time after the business has broken even financially.

Once the business is in surplus, it will be registered formally. Any surpluses generated will be reinvested in expansion of the Dunga Beach facility and replication into other areas. A community enterprise could be created where local stakeholders buy shares in the biogas plant in exchange for products; or could invest in a savings cooperative to enable them to buy their own household-sized biogas plants.

If the business is unsuccessful, in consultation with CISL and AstraZeneca, BIL is expected to dismantle the pilot and relocate them elsewhere. Business accounts for the community digesters will be kept by BIL during this time, reported regularly to CISL and to AstraZeneca.

6.2.2 Implementation: Initial observations to date on process

During the research for this baseline study, only a few observations were possible in relation to the main research questions. These will be reported more fully in subsequent reviews. Two key observations during the project set up phase were

a) the dissemination of information about on project inception on local Kenyan media and on CISL and AstraZeneca websites (28-30) (31) (32) helped to raise the profile of this pilot project, and

b) some delays in accessing finance for renting land as agreed from DBMU caused concern during formal inception at Dunga in August 2018. However, once finance became available the project moved ahead smoothly.

RQ3.1 Governance

The Dunga Beach front is under the jurisdiction of the Dunga Beach Management Unit. The DMBU can rent or lease out land and are responsible for keeping it safe, healthy and clean. The fish fryers are either in the Chiela women's fish frying group or in no group. Fish fryers are mostly from Dunga – vetted by DBMU – which charges KSh 20 per day to fry fish. They check the person is Kenyan and local in order to " focus on our own community" (Maurice Misodhi, pers. comm. Sept 2018). The fish fryers provide or build their own stoves in the frying area. If they are not from here, they do not fry here; they get fish and clean them for trade elsewhere. There are 16-17 members of group, which set up in 2013. The Chiela women's group does fish frying but also has a savings group that makes small loans to members, supporting each other as a group. They own a boat, which was a gift from a Dutch visitor to the area, a fish cage, and bought chairs as an investment for hire.

RQ3.2 Practical adaptations

Fish fryers' biogas experience to date. There is a good level of knowledge about biogas here due to an unsuccessful experience with Biogas at Dunga. In 2015 there was an installation by the Great Lakes University (GLU), training 17 of the Chiela women's group, with three days' training at the

university. The installation was on the eastern side of Dunga Beach (since flooded, so they are now on the higher ground on western side) (see Figure 21). The biogas worked for a while, using cow dung and water hyacinth as the feedstock, but because one pipe was too short they could not use it for frying, only for making tea [so not working as intended]. In addition, the small burners could not hold the large frying pans. Later, in 2016, there was an accident where the National Youth Service paramilitary cut one of the pipes and they asked the GLU to repair it but this was postponed. In 2016 they moved to the new space after flooding. There was a weekly rota to feed the digester; each group member had a duty to perform. The Chiela women's group are concerned that they will have to feed the biodigester as this responsibility caused some issues. There was also another development institution, the Japan International Cooperation Agency (JICA), which set up a biogas research pilot here to work with water hyacinth; but this is now being taken to another place. The JICA pilot provided lighting and cooking for restaurants in Dunga.

Figure 20: Previous biogas installations in Dunga Beach

Currently the fish fryers spend about KSh 500 on fuel per day, and with the fish purchase, oil and fuel costs they make about KSh 200 profit per day [this may be an underestimate of their profit].

Due to their previous experience they were worried about having to manage water hyacinth feedstock and bio-slurry outputs, and whether they need to pay for the digester/ gas.

7.Considerations for ongoing research

This baseline report is necessarily descriptive in its nature, documenting the current situation of householders and community governance within this location. We have also aimed to position this work within a broader framework and outlined a set of relevant research questions for the ongoing research over the next 12 months. Two themes merit further emphasis following the discussion of households' current situation.

7.1 Innovations in Dunga community and household pilots

As discussed in Section 2, Kenya has a high potential for biogas energy generation, and the national demand for clean energy is high given the very limited availability of wood fuel and charcoal by legal means within the country. The Dunga project innovates on existing biodigester approaches in a number of ways (see Table 5). Some of these aspects are of particular interest to certain groups in the Kenyan biogas industry, and outreach and early engagement with these groups will be fruitful. In particular, the use of water hyacinth as a feedstock in this project will be of interest to Lake Victoria environmental groups; health research linked to this will be of interest to those developing further biogas finance proposals in the country, and the novel location of the biogas digesters within a peri-urban setting is likely to be of interest to many who are implementing biogas within the country. If this can be made to work, resolving potential issues of bio-slurry waste and feedstock inputs where there are relatively few cows to provide dung, this will provide a significant boost to the geographical scope for these initiatives.

Table 5: Innovation in Dunga pilots

	Community biodigester	**Household biodigesters**
Newness	Two have previously been introduced at community level (which have failed) Using water hyacinth as feedstock; innovating environmental problems to solutions	Biogas household technologies have not been brought into households in this community before
Adaptation	At community level, the flexible T rex biodigester incorporates several improvements on the traditional dome-style biodigester	The biogas company team is also developing and adapting to the specific peri-urban setting (ie bio-slurry waste) and considering additional business opportunities
Interaction	The community level biodigesters fosters collective action amongst the women fish fryers; and cooperation between the DBMU and the fish fryers. Significant interaction between the biogas company and community users is built into the process of building the digesters.	Household biodigester pilots put in place in July 2018 enabled interested potential recipients to visit and discuss them. During the main installation period a community meeting has been scheduled to foster partnership between recipients
Knowledge content	At community level, several of the Chiela fish fryer group were involved in previous training on biodigesters; this innovation will top up and expand this knowledge and introduce it to further individuals.	At household level, recipients will develop new approaches and methods. The biogas company team is also developing and adapting knowledge for the householders

	Community biodigester	Household biodigesters
Learning, scaling up and diffusion	Existing social networks of fish fryers are used to learning in this group currently; other communities around the lake may visit as Dunga is a tourist attraction; and learn and increase demand for this product Sharing information with wider biogas community as part of learning experience (through CISL, CDS and BIL)	The existing close-knit and long-term ties of the Dunga community are essential for the sharing of learning within pilot households. The expansion potential is as yet unknown. Sharing information with wider biogas community as part of learning experience (through CISL, CDS and BIL)

Later research will be able to examine how the community biodigester model works in terms of financial sustainability and how this performs against expectations as an SME. A number of adaptations are ongoing from the business plan.

7.2 Health

Alongside this research study, AstraZeneca will be setting up part of their Healthy Heart Africa Programme, and offering free peak flow lung volume readings and blood pressure screenings for hypertension to relevant people at a pop-up clinic at Dunga beach. Participants will be asked a number of questions about their household fuel sources and illnesses experienced. Data collection will be anonymous and analysed separately to this study. Some community members cannot be included in the screening: for example, the screening can only be done on over 18s. However, insights on the general health of the local population may provide a broader picture of the community than is currently available from this baseline report's limited sample.

7.3 Gender

The household and community level biogas sector may be highly gender-differentiated in terms of potential benefits, barriers to adoption, marketing and access to finance. In Kenya to date, little research has disaggregated gendered impacts specifically, which we will intend to do during this pilot. To date, initial findings show that:

- The innovation itself is inherently women-focused and benefits may initially be felt primarily by women
- Community biodigesters on Dunga Beach are under control of the (male-governed) DBMU for their location; but women will be using the fuel; later research will identify processes and any impacts of this
- The Chiela women's group has received strong support and funding to date and is an articulate presence in the community
- Household level women are sharing ownership of the biodigester in the household; but most maintenance will be done by women and children. Expected benefits (of reduced labour inputs and reduced costs of fuels) will probably accrue directly to women. Later research will investigate this
- Women do seem to be disproportionately affected by negative health impacts that are related to smoke from cooking; later research will confirm if biogas digester use improves this
- The BIL team comprises men; further research will investigate if this affects householders' abilities to interact and resolve any practical issues
- Later work will reflect back on gender relations and changes in these (social divisions of labour) and gendered aspects of impacts on health, food security and income

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Appendices

A. Project timeline
B. Research methodology
C. List of key informants
D. Household interview baseline study questionnaires (English, with Luo available on request)
E. Consent form (English, with Luo available on request)
F. Participant's information form (English, with Luo available on request)

Appendix A: Project timeline

An 18-month research project starting August 2018, and finishing December 2019.

When?	Key implementation dates	Research project dates (CISL/CDS)
May 2018	Project inception	
Aug 2018	Early August • Installation of biogas pilots in 4 households in Dunga Community Mid August • Screening further households for suitability for biogas installations •	Mid August • Baseline study Researcher mobilisation • Inception meetings 22 August - 9 September Dunga Beach Visit • Research Lead and Researcher mobilise project research team in country and initiate baseline survey **31 August Inception report FINAL**
Sept 2018	Equipment order and shipping (pending)	10 September NG to visit Astra Zeneca office in Nairobi to debrief Beth Gikonyo and Allan Mackenzie, visit Biogas International's test installations, and other biogas related key stakeholder meetings tbc End September Household surveys completed; ongoing data inputting completed; oversight of household surveys undertaken by Adoyo
Oct 2018	*Installation in households (tbc)* *Set up of Healthy Hearts Africa clinic (AZ tbc)*	October Baseline study: • Data analysis and report drafting (NG) • Reviewing (AW and JR) **30 November** Baseline survey report drafted, reviewed and finalised

When?	Key implementation dates	Research project dates (CISL/CDS)
Nov / Dec 2018	Community Installation Installation in households (tbc)	Discussion with CISL, AZ and CDS on initial findings and plan for further contract/stages Contract Research Consultant for further stages of Research Project
Jan-May 2019	• Training, oversight, maintenance (BIL) • Set up corollary business opportunities around Biogas (e.g. slurry processing) (BIL) •	Possibly attend relevant meeting/conference on Biogas (AW/Research consultant)
May/June 2019		Mid term survey fieldwork Dunga, with Adoyo (Research consultant)
June – Nov 2019		Possibly attend relevant meeting/conference on Biogas (AW/Research consultant)
Nov/ December 2019		Final fieldwork Dunga, with Adoyo (Research consultant) Final report draft and production (Jan 2020)

Appendix B: Research Methodology

Broadly the research approach to this pilot survey follows fairly conventional lines for development research. This combines: background literature review and situational analysis, discussion with project stakeholders and other key informants or experts, developing questionnaires and field testing and further field work with meetings and interviews in the pilot study location. This is followed with data inputting, triangulation, cleaning and analysis prior to report completion. See below for more detail. Our underlying methodological research approach is realist, using qualitative and quantitative data sources– that people will share a version of reality that is based on individual perception. Triangulation of data is important where possible, and self-reflection by the researchers to check assumptions and our own perspectives when interpreting situations.

Area	Research Methods
1. Background and context • Kisumu and Lake Victoria region economy • fishing community • political situation especially Luo culture • environmental issues • social and health issues in the area • Kenya economy and outlook	• Literature review (reports, news articles) • Discussion with community leads (DMBU, women's group leaders) • Discussion with community members and householders • Observation and questioning in Dunga Beach
2. Innovation Implementation and Impact • Biogas innovation research key findings and research gaps • Dunga Beach community past history with innovations in Biogas • Contact with key stakeholders potentially interested	• Literature review on Household and Community level Biogas digesters highlighting key areas and how to ask questions about these (RE-AIM, questionnaire surveys) on health, economic impact, gender implications, labour etc. • Focus groups and community group discussions on biogas and other issues in the community • Initial Baseline questionnaire with qualitative and quantitative results to be designed and executed in 50 pilot households that will form the basis for a before-and-after analysis of the impact of the biodigester on recipient households • Stakeholder analysis of key biogas implementers and researchers in Kenya • Contact with biogas implementers in Kenya (visit by NG to Nairobi 10-11 to see 2-3 main biogas institutions if possible)
3. Feasibility/sustainability • Business supply chain for biogas digesters in Kenya • Feasibility analysis	• Discussion of business approach with BIL, previous experience and research undertaken • Literature review on adoption and disadoption rates and reasons, business analysis and feasibility, financing options • Stakeholder analysis and interview of key biogas implementers and researchers in Kenya

Ethics: We gained ethical clearance prior to the project from the University of Cambridge. A copy of this is available on request. Household interview data is anonymised where written into publications. Names of expert informants are not anonymised. Information is shared between the researchers in CISL and Adoyo confidentially; interview data is kept in a shared system that is accessible by the CISL researchers but not available outside of CISL and Adoyo as the research partners.

Consent to interview: In initial discussions with the DBMU BIL sought permission to install the pilot biodigesters, which was discussed and agreed with the Luo elders (we were not present). CISL sought permission from DBMU also to undertake research around these two sets of innovations in the community. We sought verbal or written consent in all household interviews, providing a full explanation of the reason for the request for interview and the uses of the data, and providing Adoyo's contact details if any questions came up later. We ensured that either a written or verbal consent was given and recorded this. We did not record any interviews.

Interview process: DBMU decided that they needed to attend the interviews as gatekeepers to ensure trust and openness from the householders. Whilst initially a little cautious about the possibility of officials joining these interviews and this interfering with responses, in several cases householders explicitly stated that they trusted us because Maurice was with us. Sometimes the DBMU official took some time out to attend to some business during the interview; and in no cases did this appear to change the quality of responses, or did we feel that there was information given more confidentially when the DBMU member was not present. Interviews were conducted in Luo/English language with a researcher/interpreter.

Impartiality as researchers: On several occasions the householders asked us substantive questions about the biodigester, and in particular about payments schedules expected. Mostly we requested that they check with BIL about details agreed with them, and gave them a telephone number to follow up, or passed this information to BIL, but if the information was very basic, then we provided this. Given that we are perceived as being part of the project, there is some tension and blurring of lines, at the least in terms of households' perceptions of our roles. We expect this slight tension to continue throughout the project, and will need to navigate it carefully to retain impartiality as far as possible without being obstructive to the implementation of the project.

Field research detail

A. Households: we use a sampling approach that is 'before-after' design, with 100 per cent coverage of households within the sample size of 50. A baseline survey of household's characteristics, livelihoods, wealth and attitudes towards biogas will be followed with two post-installation surveys: one approximately 3-4 months after installation, and the other six months later. Survey questionnaires were developed for the baseline with several iterations pre-tested on the four 'pilot' households that had installations early on to check pitch level of language, and flow of interview. Adoyo translated the final version and consent forms into Luo for the interviews. A combination of CISL and Adoyo researchers, or just Adoyo in the final 25 interviews, visited each household over a four-week period in August/September, with notification before our arrival to ensure their availability. We were accompanied by a member of the DBMU acting as a trusted gatekeeper for the community, and assisting with finding the houses in the unplanned settlement. Structured interviews had some open questions in order to triangulate opinions, and took between 30-60 minutes to administer. On five occasions due to ill health of the interviewee (ethical consideration relating to

physical stress) or their need to return to work, we ensured several times that we were still welcome to interview the householder, and then shortened the questionnaire to essentials.

B. Community biodigester: we used a less formal a qualitative semi-structured approach to the community biodigester, involving discussion with several groups of women, triangulating evidence with DBMU members and others. We also triangulated some evidence when we came across the fish-frying women in household interviews, or used this opportunity to probe more into further questions about their fish frying activities.
C. Expert interviews: we interviewed a number of experts or key stakeholders during the course of the baseline survey, with semi-structured and open questions tailored to the topic and expertise area. We wrote up detailed notes from each of these and read over interview data for each related section of the baseline report to flesh out and triangulate information against other data sources. We did not formally code and analyse this data.

Data processing and analysis involved reflection, note writing and discussion between the three researchers Alexandra Winkels, Natasha Grist and Shirley Ombuyah. We inputted quantitative and coded qualitative data into excel, highlighting potentially unreliable or untrustworthy data, bringing up additional points for reflection.

Reporting - an initial inception report on research approach and methodology was produced for internal compliance and checks (Grist 2018). Following this, the field research was undertaken and the baseline report was produced as a CISL paper for general circulation and to be made available as a public product on the website. It will be used also for developing interest over the course of the project from interested stakeholders and as the basis for outreach communications and presentations.

Appendix C: List of key informants and stakeholder interviews

Int No.	Date/time/place	Name(s)	Org/ Affil'n.	Subject(s) and contact details (if appropriate)
01	20/8/2018 Skype	Saras Rosin, Beth Gikonyo	AZ HH	Healthy Heart Africa, AZ part in project – health clinics
02	23/8/2018 Sovereign Hotel, Kisumu	Adoyo Akoth, Shirley, Rose	Adoyo	Project outline and planning
03	23/8/2018 Sovereign Hotel	Biogas Int Dom, Julius, Josephat	BIL	• Status catch up • Household criteria discussion • Context information
04	23/8/2018 Sovereign Hotel	Beth Gikonyo	AZ HH	• Introductions • Screening intervention details • Kisumu Health Ministry sign off
05	24/8/2018 Dunga Beach	**DBMU meeting Dunga Beach** Maurice Misophi, Vice Chair Godfrey Ogong, Treasurer Nicholas Didi, Sec. Richard Ojijo, Asst. Sec Charles Apiyo, Sub County Public Health Officer Dom & Julius BIL Alex & Natasha CISL Beth AZ Akoth, Shirley, Rose Akoyo	DBMU Kisumu Govt BIL CU AZ HH Adoyo	• Inception and introductions • Biogas International Limited and related research component • Health AstraZeneca component discussions PHONE CONTACT DETAILS OMITTED HERE NB all committee leaders are male (5) and 4/8 committee members are male / 4 female
06	24/8/2018 Dunga Beach	Household Biogas Pilots visit		• Dom demonstrating biogas • Some householder comments • Side discussions • Video and photos
07	27/08/18 Dunga Beach	Chiela Women's Group (see notes for names) Nyamenda MENA		• Women's group functions • Biogas previous • Biogas Dom BIL
08	27/08/18 Dunga Beach	Dunga Beach Walkabout and Richard Ojiyo DBMU		• Fish frying area/ fisherman observations • Conservation Wetland Area • Cage Fishing • Fisherman's declining catch • Ecology of lake declining

Int No.	Date/time/place	Name(s)	Org/ Affil'n.	Subject(s) and contact details (if appropriate)
09	1/9/2018	Dominic Wanjehia	BIL	• BIL biogas systems
10	5/9/2018 Dunga Beach	Fish trader women	Dunga Beach	Fish trading Dismal state of business Biodigester Please can we help them!
11	6/9/2018 Skype	Andreas Wilkes	Unique Forestry	Expert informant - Gender research on Kenya Biogas Background on ABPP and other biogas companies
12	7/9/2018 Dunga	Maurice Misodhi and NG reflections on Dunga	DMBU	DMBU elections Dunga social issues Fishing trip to see wetlands and fish cages
13	20/9/2018 Skype	David Güereña, CIMMYT/ICRAF	ICRAF/CIMMYT	Water Hyacinth + getting government to see it as a resource, not pest
14	10/9/2018 Nairobi, AstraZeneca office	Beth Gikonyo Allan McKenzie Dominic Wanjehia	AstraZeneca	Debrief on Dunga Pilot – interest in gender impacts, avoided emissions Update on Healthy Hearts Africa plans for Dunga
15	10/9/2018 Nairobi SNV Office	Bert van Nieuwenhuizen Kevin Kinusu,	SNV, ABPP	Africa Biogas Partnership Programme, Kenya
16	10/9/2018	Dominic Wanjehia	BIL	Visit to BIL Nairobi experimental station

Appendix D: Household interview baseline study questionnaire v7

Dunga Beach Biogas Pilot Questionnaire
Pre-installation baseline questionnaire *CONFIDENTIAL*
Introduction of project ☐ Consent form ☐

Interview Number _____
Date _____
Interviewer(s) _____
GPS _____
Phone no. _____

1. Respondent background

1.1 Name_____ 1.2 Age _____ 1.3 Gender F / M

1.4 Married ☐ Widowed ☐ Separated ☐ Single ☐ 1.5 Name of spouse _____

1.6 Female headed / Male headed 1.7 How many people stay at this household? _____

1.8 Adults # _____ 1.9 under 18s # _____ 1.10 Dependents # ____

1.11 How long have you lived in this community? All your life ☐ *OR* Year you arrived _____

2. Attitude and decisions about Biogas

2.1 Have you heard about Biogas before? Y / N

2.2 What did you think about Biogas? _____

2.3 How did you hear about the BIL Biogas system?

Directly from Mr Dom/Julius ☐ From DMBU members ☐ From others in Dunga Community ☐

2.4 What have Julius and others from BIL told you about the Biodigester? _____

_____

2.5 Have you seen one of the new pilot Biodigesters? Y / N

2.6 What did you think of them? _____

2.7 Did you hesitate to accept a Biodigester? Y / N ?

2.8 Why Y/ N ? _____

2.9 Did you discuss with spouse? Y / N / N-A

2.10 Who decided? Me ☐ Spouse ☐ Both ☐ Other ☐ _____

2.11 What do you see as the benefits for your family having the Biodigester? _____

_____

2.12 What are your concerns or worries about Biogas? _____

_____

2.13 Do you have any concerns over where to put the Biodigester? Y / N

2.14 Why? not enough land ☐ rent land ☐ other _____

2.15 How much are you expected to pay towards the Biodigester? _____ KSh

2.16 How will you pay? MPesa ☐ Cash ☐ By other means _____

2.17 Frequency of payments? lump sum ☐ monthly ☐ other _____

2.18 Will you have to borrow money? Y / N

2.19 Do you think you will save time or money when using biogas? Y / N

2.20 Why? _____

2.21 When will the Biodigester be installed? *Month/ Year* _____

2.22 Who will be responsible for daily management of Biodigester: Male / Female_____

1

2.23 Who will be responsible for repairs? _____

2.24 Who is considered the owner of the biogas digester? _____

3. Household assets

3.1 *Type of house: Wattle & Mud* ☐ *Rendered W&M* ☐ *Brick and durable flooring* ☐ *Iron walls* ☐

3.2 Do you own or rent your house? Own ☐ Rent ☐ Other _____

3.3 How much livestock do you own? Cows # ___ Goats # ___ Poultry # ___ Other _____ # ___

3.4 Do you have electricity? Y/ N

3.5 What cooking facilities do you have at the moment? 3 stone ☐ Firewood Jiko ☐ Charcoal Jiko ☐

LPG ☐ Other _____

3.6 Cooking is done mostly … inside ☐ outside ☐(notes)_____

3.7 Does your household own …. Boat ☐ / Bike ☐ / Motorbike ☐ / Car ☐/ Other _____/ None ☐

3.8 How many people in the household have a phone? None ☐ # _____

3.9 Have you currently got a loan? No ☐ Yes ☐ Cannot access ☐ Not necessary ☐ Other _____

(notes) _____

3.10 Where is/ are the loan(s) from? _____

4. Income earning activities (who, what, how much, average total income)

4.1 What is your total household income per month? *(circle)*

< 5,000 KSh 5,000 - 15,000 KSh 15,000 - 50,000 KSh Over 50,000 KSh

4.2 Are gifts from relatives (money, food, goods) important for your household to get by Y/ N

4.3 Who pays school fees for the children in the household (if they go to school)?_____

4.x Who does what in the household and how much do they earn per activity (approx.)?

(Income per activity)	Adult female	Adult male	Children	Others	Notes (e.g. frequency e.g. per day/per month etc)
4.4 Fishing					
4.5 Fish brokering/ selling					
4.5 Trading					
4.6 Selling cooked food/drink					
4.7 Renting out land/ accommodation					
4.8 Looking after livestock					
4.9 Other					
4.10 Other					
4.11 Other					

(Other e.g mat weaving, renting out boats, making nets, tour guide)

PILOT BASELINE HOUSEHOLD QUESTIONNAIRE PAGE 3

5. Fuel and water uses

	Quantity e.g. 1 bale	Frequency e.g per day/ week/ month/	Costs per unit (KSh)	Total (KSh)	Source	Time spent/ collecting/ preparing	Who is responsible?
5.1 Wood							
5.2 Charcoal							
5.3 Papyrus							
5.4 Paraffin/Kerosene							
5.5 Other fuel source ….							
5.10 Water for household use *(Source: tap, distance to Lake)*							

6. Cooking activity

Meals cooked	3 stone	Jiko	LPG	Other	Biogas
(record which food)	*Cooking time*				
6.1 Breakfast:					
6.2 Lunch:					
6.3 Dinner:					
6.4 Supper:					
6.5 For selling:					
6.6 Special meals (e.g. igeri):					
6.7 Other …					

6.8 Do you think food will taste different if cooked on biogas? Y/N/DK

6.9 Why? _____

7. Biogas Feasibility

7.1 What will you use as feedstock for biodigester?

7.2 Do you think you will have enough feedstock available? Y / N

7.3 Will your source be reliable? Y / N

7.4 *If not*, what will you do to get enough feedstock? _____

7.5 Where will you get the water from for your biodigester? Lake ☐ Tap ☐ Household waste water ☐

7.6 Do you expect to have any problems with slurry disposal ? Y/ N

7.7 *(If yes)* What problems? _____

8. Health information

8.1 Have you experienced any issues in relation to cooking with firewood, charcoal or papyrus? Y / N

8.2 What are these issues? _____

_____

8.3 Has anyone in the household suffered from health problems in the last **3 months? *Who?***

Problems with breathing (asthma) ☐ _____
Respiratory (lung) infection or bronchitis ☐ _____
Heart disease ☐ _____
High blood pressure ☐ _____
Dizziness or headache ☐ _____
Eye irritation/soreness ☐ _____
Burns ☐ _____
Diarrhoea ☐ _____
Fatigue ☐ _____
Back pain ☐ _____
Other issues ☐ _____
Other issues ☐ _____
Other issues ☐ _____

8.4 Has anyone in your household been to a clinic with any of these problems in **last 3 months**? Y/N
8.5 (details) _____

8.6 Do you think that cooking with biogas will change any of these problems? Y/N
8.7 In what way? _____

8.8 How much do you think you have spent on health related issues in last 3 months? KSh _____

8.9 Do you have health insurance (NHIF)? _____

9. Social connections

9.1 Which groups do people in your household belong to? *(Church/ Savings, Coop, Women's, Men's groups ...)*

Group name	Type of Group	Activities	Time participating

Appendix E: Consent Form

Note: none of the interviews were voice recorded during this baseline

I understand that I am free to withdraw from this study at any time [ ]

I understand that all information and data collected will be securely stored and that all efforts will be made to ensure that I cannot be identified as a participant [ ]

I have received the information sheet about the study [ ]

I have had an opportunity to ask questions and discuss this study and I have received satisfactory answers to all my questions [ ]

I agree to be voice- recorded [ ]

I agree to continue to take part in this study [ ]

Verbal consent given [ ]

Signed (Participant) ..... Date.....

Name in block letters.....

Signed (Researcher) ..... Date.....

Name in block letters.....

Contact details:

Dr Alexandra Winkels

Email: xxxxxxxxxx

Phone: +44 xxxxxxxxx

Skype: xxxxxxxxx (UK)

Appendix F: Participant information form

Note: no interviews were voice recorded during the baseline survey

Participant Information Sheet

The purpose of the study

This study is led by the Cambridge Institute for Sustainability Leadership and is part of a pilot project introducing biogas as cooking fuel to households and small enterprises. We are interested in the impact of this technology on livelihoods, health and the environment.

We are asking households and small businesses here in Dunga Beach to participate in a number of interviews.

The results of this study will be used to assess the impacts of this technology on households and the community. It will also help us to know whether things need to be improved for future use and distribution. Results may be published in reports and scientific publications. *All data collected will be completely anonymous and you will not be identified in any report/ publication.*

Participation in the study

If you decide to take part in the study, you be asked to participate in at least three interviews over a period of 18 months. Each interview will take between 45 - 60 minutes. Interviews will take place individually, or in small groups. Interviews will be arranged at a time and place convenient to you.

Risks and confidentiality

The interviews will be recorded (unless you tell us otherwise) and we will take field notes. However, all interviews are strictly confidential and we will delete any detail that could lead to your identification.

No personal or confidential data will be disclosed during or after the end of the study. All data will be stored or analysed in line with legal regulations in the United Kingdom and the European Union.

You are free to withdraw from this study at any time, without giving any reason. If you choose to drop out of the study, the information collected up to that point will not be used.

You may choose to skip particular questions if you do not feel comfortable answering.

For problems and concerns

If you have a concern about any aspect of this study, you can ask to speak to any of the researchers involved.

If you need further information about this research please contact:

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