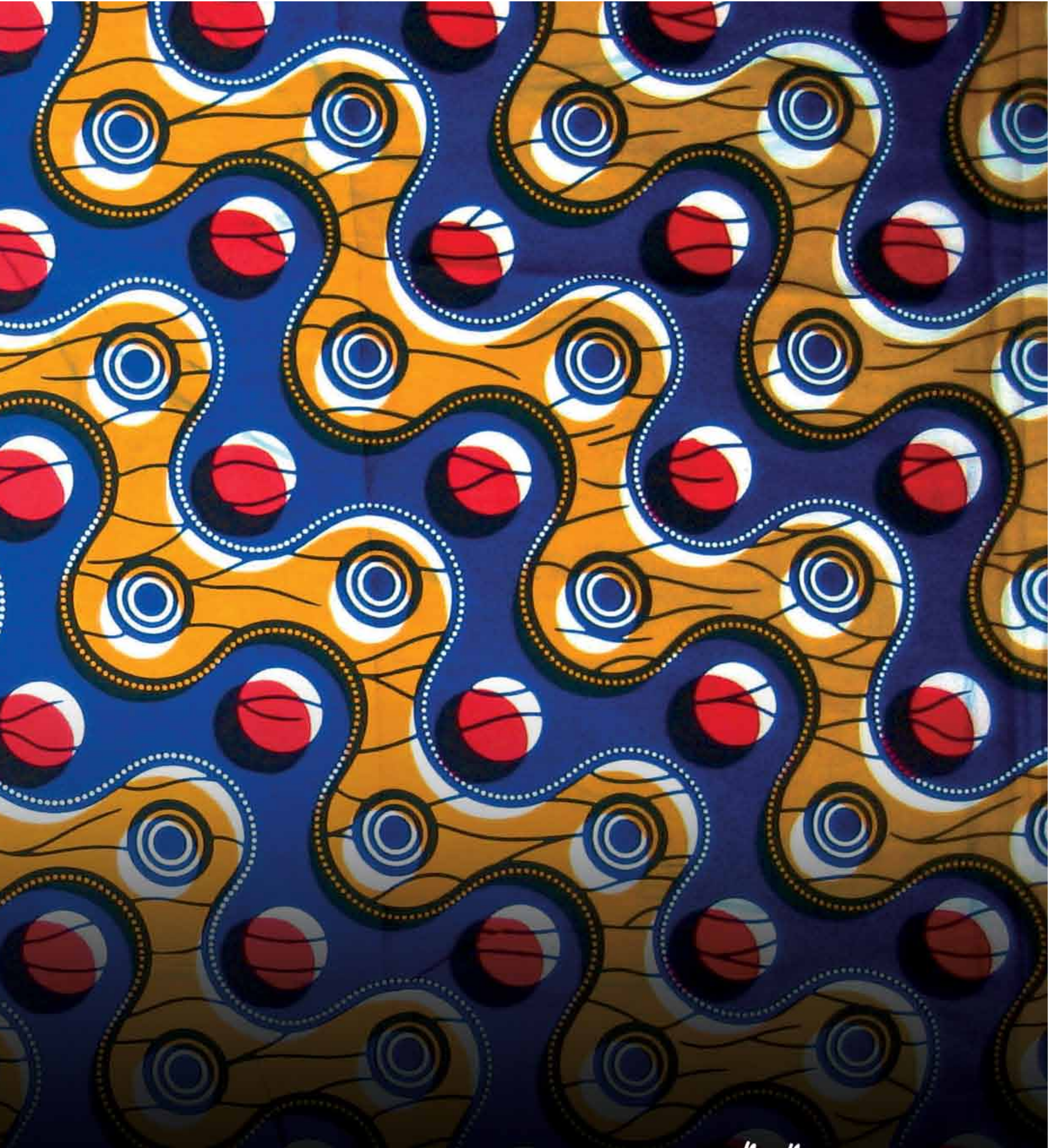

matter

Empowering Entrepreneurs for Rural Electrification

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matter

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And all the safe boda boda drivers

Executive Summary

The starting point for this project was to develop the technical layout and business plan for a biogas-based battery charging station in Uganda for FACT Foundation. This report presents the research and analysis, the evolution of the project as well as the proposed solution and its evaluation.

Access to energy in Uganda is problematic, like in many other African countries. Poor infrastructure, improper management of resources as well as a lack of steady income for most of the population results in less than 10% of the population being able to make use of the electricity grid. The Ssese Islands, where this project has been initiated, are not connected to this mainland grid at all.

A research trip to analyse the physical and social situation was carried out, resulting in re-framing the initial project brief and creating some alternative solutions. After evaluating all of the possibilities afforded by biogas, and carrying out some simple calculations and tests, the final concept and direction was determined.

Models have been constructed to calculate and better comprehend the relationship between the waste input and energy output, as well as the financial structure of such an enterprise. This allowed us to optimize the charging station system, before developing a system to enable other entrepreneurs to start their own charging station.

This system is called Factory. It consists of a physical kit, a website with a complementary SMS service, and requires the use of multifunctional lamps to distribute electricity. It also requires FACT Foundation to address some structural changes within its organization. Setting up such a system to recruit and enable entrepreneurs in developing countries requires some closer control and more local knowledge. This is why the position of a Regional Representative is proposed, who is in charge of screening, supervising and supporting the entrepreneurs in his assigned region. The Regional Representative also forms the link between FACT Foundation and the entrepreneurs.

The cash flow of such an enterprise has been modelled to be flexible and accomodate regional differences, but according to the project already initiated on the Ssese Islands, after making the investment in the first year and starting operations at the start of the second year, the entrepreneur can expect to break even at the end of the third year. This model also includes monthly wages of €200 for the entrepreneur, and foresees an annual profit of approximately €18,500 after breaking even.

Possible risks of the proposed system from social and technical perspectives are evaluated with suggestions for minimizing them. The main benefits in the short term include the contribution of this project to waste management, improving the well-being of the rural population, empowering and employing local entrepreneurs and creating a sustainable fertiliser. In the long-term, the project contributes to FACT Foundation's strategic goals, helping them become a stronger organization, and establishing them as a leader in their field, while exploring the more human impact of their technologies.

3

Context Analysis

4

Synthesis

7

Conclusion

1. Introduction

This report is the result of four Industrial Design Master students at TU Delft, wishing to use their skills to create social impact in developing countries.

The initial design brief, presented in the next section, was developed with FACT Foundation, in order to address their needs as a client as well as our different Master's specializations. In brief, we were to research and develop a system for off-grid biogas-based energy distribution in Uganda. The project was officially started in September 2011, and also included a research trip to Uganda lasting approximately one month.

Design Brief	Context Analysis	Research Methodology	Reframing the Problem	Concept Generation	Final Concept	Evaluation	Conclusion

Section 3 provides an overview of the context of the project, on macro and micro levels. This introduces FACT Foundation as an organization, some general principles of biogas, and Base of the Pyramid markets. Additionally, some key facts and figures about Uganda are presented, followed by our more in-depth and location-specific insights from our research trip.

Based on our findings, some decisions were made in order to adjust and optimise the initial project brief, as well as regarding alternative concepts. Section 4 outlines these decisions and their justifications.

Section 5 presents our final concept, with a thorough explanation of the concept, an as well as a detailed financial and technical analysis.

Section 6 is an evaluation of the proposed concept in terms of feasibility, addressing possible risks and how they may be mitigated. Finally, the report is concluded in Section 7, with recommendations for further development.

All examples, numbers and calculations presented in this report are valid for the case of Kalangala, Uganda. Additionally, they are subject to change and based on the Euro - Ugandan Shilling exchange rate as on 22.01.2012.

2. Original Project Brief

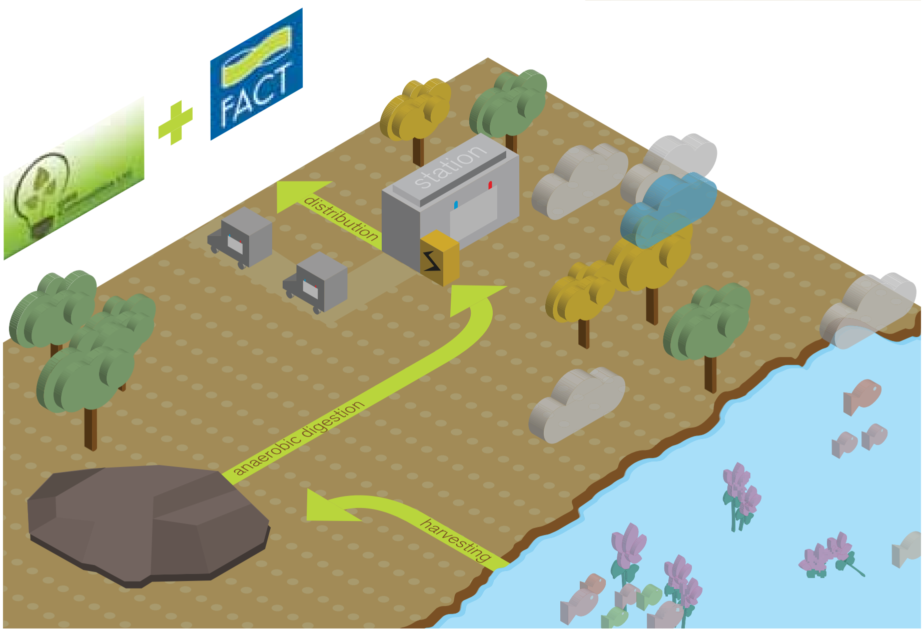


Fig. 1 Initial Project Map

Brief
Researching, developing and testing of an off-grid biogas-based energy distribution system for Lutoboka Village in Uganda.

Goal
To develop the technical layout, business and implementation plan for supplying energy to Lutoboka Village. Based on the local waste products: water hyacinth and fish waste.

Background Information
The project will be based in Lutoboka village, Bugala, the biggest of the Ssese IslandsThe Ssese Islands are located at Lake Victoria and are referring to 84 islands. The total population of the islands is approximately 42,000, whose primary income is mainly based on fishing and tourism.
Currently the Ssese Islands are not connected to the mainland electricity grid of Uganda. Energy is supplied by diesel generators, which provide an expensive and unclean source of energy.
The project is the result of a collaboration between FACT Foundation and GRS Commodities Ltd. FACT Foundation has a strong presence in developing countries, helping local partners with the production of bio-fuel solutions. GRS Commodities is also involved in developing and disseminating bio-energy for commercial applications in rural communities. GRS will act as the local partner and FACT Foundation will provide technical assistance in the project.
Both organizations have expertise in biofuels and related technologies and we would like to work together to create a successful application.
Our project will focus on ensuring the commercial distribution of bio-energy for off-grid applications. This will be based on water hyacinth and fish waste as feedstock for the production of biogas. The project will also reduce the problematic water hyacinth and pollution from fish waste in fishing villages.

2.1 Input

- Technology and know-how regarding energy production (FACT Foundation & GRS)
- Skills and labor towards energy distribution (Matter)
- Finances (FACT Foundation & additional sponsors)
- Insights (local people and context)

2.2.Research Objectives

To understand:
- the physical and social conditions on the island and in the village

- the culture, mindset and lifestyle of the local people

- the current methods for distribution and use of electricity

- the current energy use of locals, in terms of amount and purpose

- the costs involved in setting up a new system

2.3 Research Methods

- Ethnography
- Context mapping
- Creative sessions with locals

2.4. Development

The project will involve developing the full technical layout to ensure performance, as well as the business model and economic feasibility. Technical work will involve looking at battery and charger efficiencies, charging systems, and user requirements based on local research. The business model should also explore different options such as renting or leasing batteries, and should be worked out based on the conditions of the country, again with insights obtained during our field work.

2.5 Outcomes

- A full technical layout and economic business feasibility with risk analysis of such a system. This should be able to serve 100 to 200 customers charging batteries every week. The local communities, by gaining access to energy, will be able to improve their quality of life and generate new sources of employment and income.

- Reduction of water hyacinth problem on the Lake Victoria shoreline

- Reducing the fish waste pollution problem in fishing villages

- Reduction of fossil fuel usage

- New small business opportunity (energy distribution)

CONTEXT ANALYSIS

3.

3.1 FACT Foundation

FACT Foundation is a civil organization, which promotes the use of sustainable biofuels in developing countries. They do this by working together with local counterparts, supporting them with knowledge and expertise as well as by field testing innovative biofuels projects and giving specialist advice.

3.1.1 Vision

FACT has seen the need of 1.4 billion people without access to affordable energy for further development. These people will be marginalized and remain in poverty. FACT believes that the production and use of biofuels from local feedstock can create opportunities for local business development. They would like to support rural populations in developing countries by enabling sustainable production and use of biomass for energy purposes, with a focus on biofuels.

3.1.2 Mission

FACT works to achieve their vision through the following:

-Demonstrating sustainable projects which provide energy to a substantial number of beneficiaries and with a high replication potential,

- Developing models of best practice for technology and social implementation,

- Accelerating innovation in the development of biofuels for development,

- Supporting local organizations in large scale dissemination, using their knowledge and expertise from projects.

3.1.3 Project Criteria

FACT Foundation subjects their projects to a number of criteria. These include:

- *Socio-organizational criteria,* e.g. the level of participation of the community and the strength of the implementing organization

- *Technological criteria*, e.g. the appropriateness of the proposed technology and its replication potential

- *Financial economic criteria,* e.g. the long-run commercial prospects and the risks for the actors involved,

- *Environmental criteria*, e.g. the environmental impacts and the carbon payback of land conversion,
- *Innovativeness*, i.e. the extent to which the project includes distinctive new in the field of biofuels for local development.

Fig. 2 SWOT Analysis for FACT Foundation

3.1.4 SWOT Analysis

From our personal communications with FACT Foundation, we were also able to identify that one of their goals for the future is to become a more interactive and social organization and improve their relationships with the users of their technologies. This is also apparent in their recent initiative, the FACT Innovation Award, a public competition for biofuel and bioenergy solutions. With the award being financial support to execute the concept, this is clearly a move to illustrate their drive for innovation as well as their social sensibilities.

3.2 Biogas

3.2.1 Biogas Production

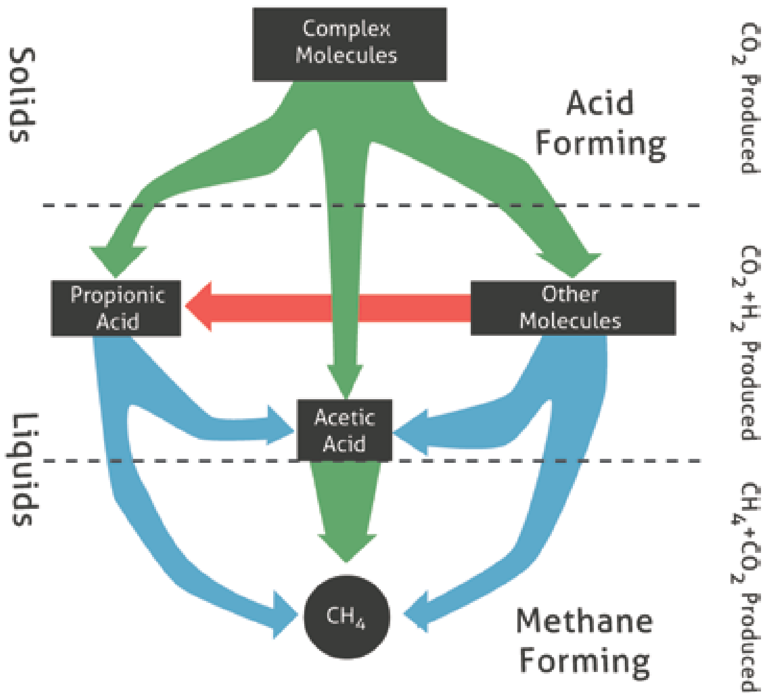
Biogas can be produced with any biodegradable organic material. Nevertheless, some materials are more suitable than others.
Depending on their economic value, availability, and/or gas production per kilo, some materials are more suitable for biogas production. Figure 3 shows the gas production per kilo of some of the most common materials used for biogas production.

Biogas is produced in three different stages; Hydrolysis and acidogenesis, Acetogenesis and dehydrogenation, and Methanogenesis (see figure 4).

Fig. 3 Biogas production per type of dung

Biogas Production	
Type of Dung	Gas Production per kg [m^3]
Cattle	0.023 - 0.040
Pig	0.040 - 0.059
Poultry	0.065 - 0.116
Human	0.020 - 0.028

Fig. 4 The three stages of the methane process



Stage 1 – Hydrolysis and acidogenesis

This first stage consists on “breaking down” (hydrolyzing) with anaerobic bacteria all the carbohydrates, lipids, and proteins into sugars, amino acids, and fatty acids.
Known as the polymer breakdown stage, during this stage polymerized glucose is broken into monomeric sugar molecules by cellulolytic bacteria.

Stage 2 – Acetogenesis and dehydrogenation

During the second stage, acetate and H_2 are produced by fermenting glucose which has been produced during stage 1. Acid-forming bacteria will “break down” the fatty acids, and generates others like acetic acid, butyric acid, and ethanol for later use in the third stage.

Stage 3 – Methanogenesis

Acids produced during stage 2 are processed by methanogens in anaerobic conditions; this process is called methanization. The bacterias are highly influenced from the environment, which can disrupt the methane production.

Fig. 5 Methanization process

Methanization Process						
Acetic Acid		Methane		Carbon Dioxide		
CH_3COOH	-->	CH_4	+	CO_2		
Ethanol		Carbon Dioxide		Methane		Acetic Acid
$2CH_3CH_2OH$	+	CO_2	-->	CH_4	+	$2CH_3COOH$
Carbon Dioxide		Hydrogen		Methane		Water
CO_2	+	$4H_2$	-->	CH_4	+	$2H_2O$

Acidity

For a proper anaerobic digestion pH levels must range from 6.8 to 8. Having a more basic or acid mix will derivate in low speed fermentation. With a low pH mix digestion will be slower until bacteria absorbs the acid, and with a high pH mix acidic carbon dioxide will be produced to neutralize the mixture (House, 1981).

Fig. 6 C:N Ratios

C:N Ratio of Common Organic Materials	
Raw Materials	C:N Ratio
Duck Dung	8
Human Excreta	8
Chicken Dung	10
Goat Dung	12
Pig Dung	18
Sheep Dung	19
Cow Dung/Buffalo Dung	24
Water Hyacinth	25
Elephant Dung	43
Straw (Maize)	60
Straw (Rice)	70
Straw (Wheat)	90
Sawdust	Above 200

C:N ratio

Bacteria in anaerobic conditions require carbon and nitrogen. Carbon is consumed faster (30x) than nitrogen, hence the need of 30:1 ratio from the raw material fed into the digester. A high carbon ratio will slow the digestive process, and a high nitrogen ratio will reduce the quality of the by-product; slurry. An adequate ratio will derive in a better quality of slurry and methane (Fulford, 1988)

Temperature

Anaerobic digestion occurs at temperatures ranging from 0°C to 69°C, but below 16°C bacteria activity decreases.
The production of methane is more efficient and stable between 29°C and 41°C. Outside of this range a higher percentage of CO_2 and other gases are produced. (Fulford, 1988)

3.2.2 Biogas Composition

Biogas is the result of the digestion of organic materials in anaerobic conditions (oxygen-free conditions). It is composed essentially by methane (CH_4), carbon dioxide (CO_2), and other gases such as nitrogen (N_2), hydrogen (H_2), hydrogen sulphide (H_2S), and water vapor (H_2O). (See Figure 7)

Fig. 7 Biogas Composition

Biogas Composition		
Substances	Symbol	Percentage
Methane	CH_4	50-70
Carbon Dioxide	CO_2	30-40
Hydrogen	H_2	5-10
Nitrogen	N_2	1-2
Water Vapor	H_2O	0.3
Hydrogen Sulphide	H_2S	Traces

3.2.2 Biogas Digesters

Digester bag

This plant consists of a PVC bag, where the inlet and outlet are connected directly to the bag. Pressure is obtained by adding weight on top of the bag. It has the disadvantage of a short life cycle; it is susceptible to damage and reduced generation of local employment, but it has a big price advantage.

Fixed-dome

This type of plant consists of a digester with a fixed gas holder on top of the digester. It has low construction costs, a long life cycle, and due to its underground construction it is protected from changes of temperature.

Gas pressure varies depending on the amount of stored gas. The construction of such a plan provides opportunities for local employment. It is recommended the supervision of experienced biogas technicians for its construction.

Floating-drum

Similar to the fixed-dome, this plant is composed by an underground digester and a moving gasholder. The gas is stored in a drum, which moves up or down depending on the amount of stored gas. It is a simple plant operation and the construction does not require experienced biogas technicians. Gas pressure is constant, but it is determined by the weight of the gasholder. Construction materials are might be expensive; considering the use of steel for the drum. Also and due to the steel components corrosion is an issue, which translates into a shorter life cycle than fixed-dome plants.

3.2.3 Biogas Common Uses

Direct combustion systems

Direct combustion is the simplest method. For applications such as heating, cooking and lighting, direct combustion represents an ideal solution. Biogas can also be used to operate fuel cells in order to generate electricity.
In cooking, biogas can be used to fuel ovens and stoves. For lighting, biogas can replace LPG or kerosene used in lamps.

Additionally, it can be used as fuel in boilers for heating purposes, but gas purification is required to eliminate corroding gases such as CO_2 and H_2S. The main concern with biogas combustion is the quality and stability of the energetic content, which affects the efficiency of the appliance used for direct combustion.

Internal combustion systems

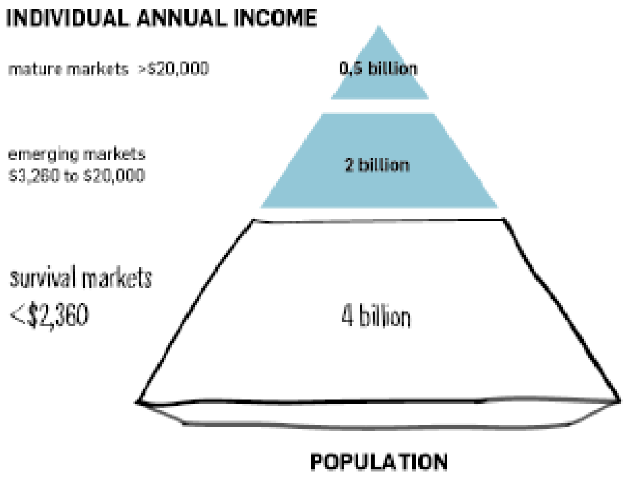
Biogas can be used on Internal Combustion Engines (ICE) due to its high octane rating (100 to 110) (Persson et al.,1979). However, biogas needs to be stored in large fuel tanks, which makes it difficult to adapt it to vehicles and having stationary tanks make it more reliable. Whether it is used in a spark or sparkless IC engine, biogas needs to be scrubbed. This means that it has to be cleared from some impurities, such as carbon dioxide, water vapor, and hydrogen sulfide.

When used in diesel engines (sparkles) a mix of 20% of fuel and 80% of biogas is needed (Persson et al.,1979), this with the purpose to obtain explosion inside the cylinder. Biogas can also be used in spark engines, and does not need to be mixed with other fuel due to its high octane rating. Biogas can also be used on cogenerations plants. Combined heat and power (CHP) plants can reach an efficiency of 80-90% (Sims, 2004) .
Carbon dioxide can be inhibited by compressing and cooling biogas, but does not represent a major improvement of the combustion due to the high costs and complications of the scrubbing. Only if the biogas is to be commercialized removal of CO_2 is justified. Water vapor increases corrosion on metallic components and may interfere with the pressure components of some devices. Water vapor can be removed at early stages by driving the biogas through condensation traps. Hydrogen sulphide must be removed when biogas is used in engines or if it will be piped. The most common technique to remove H_2S is to pass it through steel wool, iron filings or ferrous oxide.

Slurry

Slurry is a by-product of the anaerobic digestion system.
It can be used to maintain soil fertility and enhance production. Slurry is pathogen-free manure that can be present in different forms such as solid, watery and viscous states. The final outcome can be a homogeneous mix if the appropriate ratio of water / excrement is used, and mixed properly before feeding the digester.

3.3 The Base of the Pyramid Market



The Base of the Pyramid refers to the division of the economic pyramid that lives on less than 2 dollars per day.
Despite their insignificant purchasing power, these people make up a significant portion of the world's population. Almost 3.7 billion people make up the BoP market, which is more than half the world's population (Hammond et al., 2007).
Together, this group of people spends approximately 2.3 trillion USD a year. This amount is also rapidly increasing and expected to reach 4 trillion USD in 2015. Therefore, this slice of the economic pyramid and global market represents a rapidly growing economic power, with many needs and aspirations.

Although many lack basic resources such as food, water and energy, they should not be mistaken for needy victims. The base of the pyramid has just as much potential to be loyal and demanding consumers and to show entrepreneurial spirit (Prahalad, 2005).

Prahalad & Hart indicates four important strategies for creating products or services for the Base of the Pyramid. (Prahalad & Hart, 2002)

It is important to consider buying power, and to create a means for income generation or access to credit for consumers (add image). Access to the product or service is also vital as many developing countries lack the infrastructure necessary for conventional methods. The product or service must also be specifically tailored to local needs, and must be born from a bottom-up approach in order to ensure success. And finally, consumers must be educated in adopting these more sustainable or appropriate answers to their needs.

3.3.1 Energy at the BoP

The measured BoP household market for energy is 228 billion USD, with Africa making up 12 billion USD (253.3 million people). This is the smallest BOP energy market measured, however the actual estimate is closer to 27 billion USD (486 million people).
Africa's BoP energy markets are unique in that rural households spend only a third as much on energy as their urban counterparts. Access to energy is a pressing need, with 589 million people living without it in Africa. Grid connections are used by 35% of the population, and even these experience frequent blackouts (Lighting Africa, 2012)

3.4 Uganda

3.4.1 Population and economy

Population 26,1 million
Total national household market $28,475,4 million
Households 4,7 million

Although Uganda is a relatively small country, it has a population that is very rich in diversity, culture and languages. Uganda's population is predominately rural, and its population density 160,61 is highest in the southern regions.
In spite of its high GDP growth rates recorded in recent years, most of the population still lives in poverty.
Agriculture is the most important sector of the economy, employing over 80% of the work force, with coffee being the main source of foreign trade. However in most of the cases agriculture is only for subsistence. Uganda is still slightly below the GDP levels of the Sub-Saharan region (see diagram below).
The country possesses substantial natural resources like fertile soils, regular rainfalls, small deposits of copper, gold, and recently discovered oil. For instance, when comparing Uganda with its neighboring countries, Kenya and Tanzania, Uganda has scores the highest income per capita ($1,800.00) but the lowest in life expectancy (45,7). A more thoughtful analysis of this can be found in the next sections.

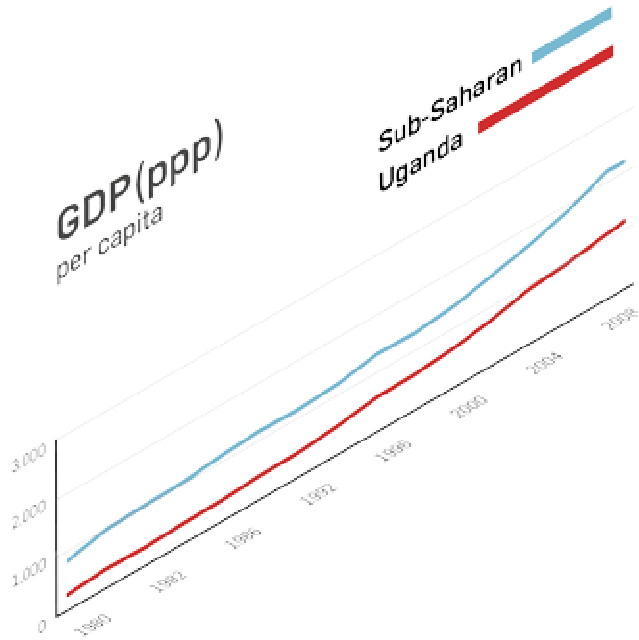


Fig. 8 Comparison GDP Uganda / Sub-Saharan region

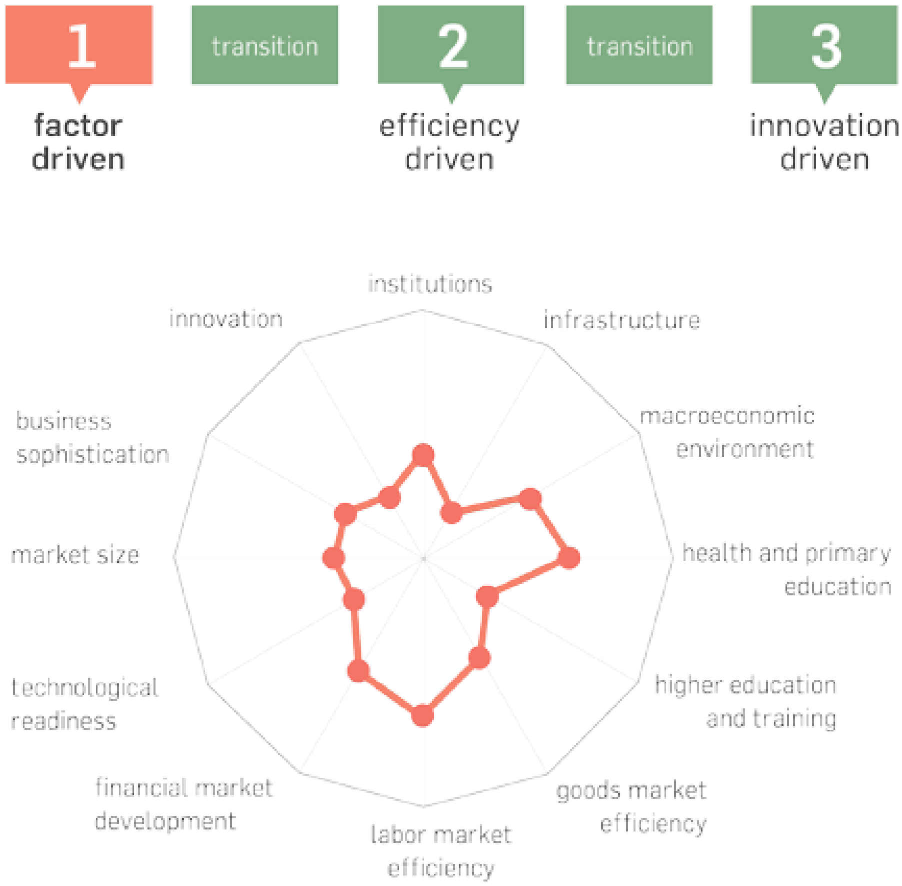


Fig.9 Pillars of Global Development

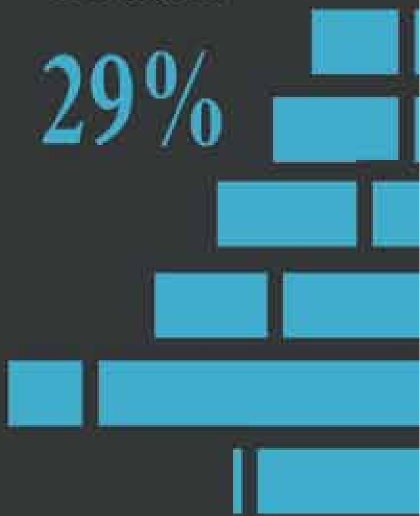
Economic development

The process of calculating country competitiveness is far more complex than the measurement of the GDP.
The World Economic Forum captures the complexity of how several factors affect the development of the country. "The GCI aims to gauge the ability of the world's economies to achieve sustained economic growth over the medium - to long term." (Blanke, Paua et al. 2005)
Uganda is still at the first stage of development; it's a factor driven economy with a GDP (per capita) below 2000. Details about how Uganda fits a factor driven economy can be found in the scatterplot presented above. An assessment of the 12 pillars of global development follows as well on top.
Some values will be more significant than others for our project. For instance, the score of 2nd pillar: Macroeconomic environment (41 / 139 rank). On a not so positive note, even though education is one of the most important things for Ugandans, it scored rather low in comparison to other countries.

Uganda

Urban

29%



lit

26,1 million

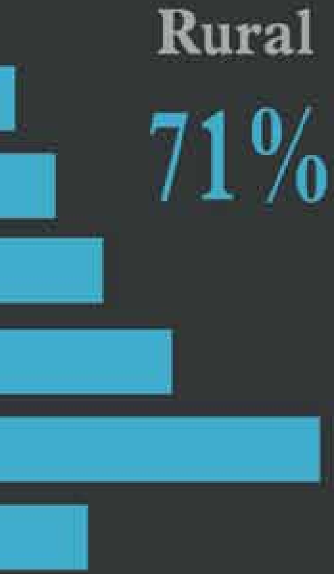
Population

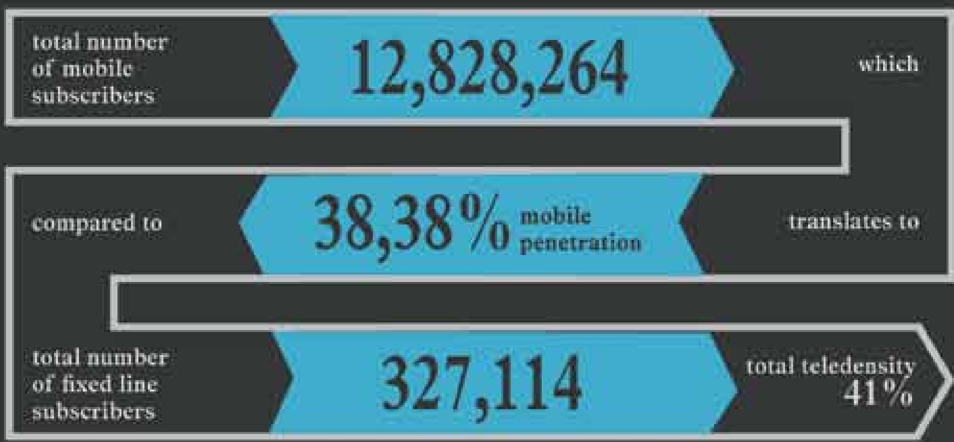
4,7 million

Households

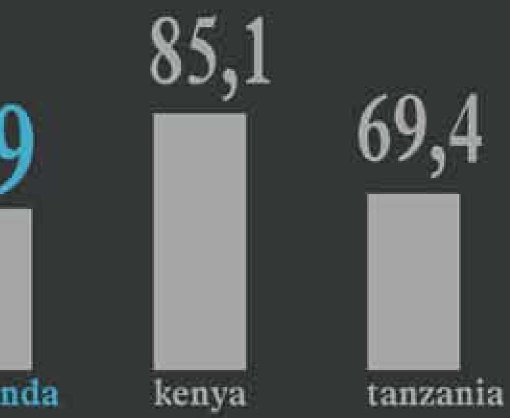
69

uga

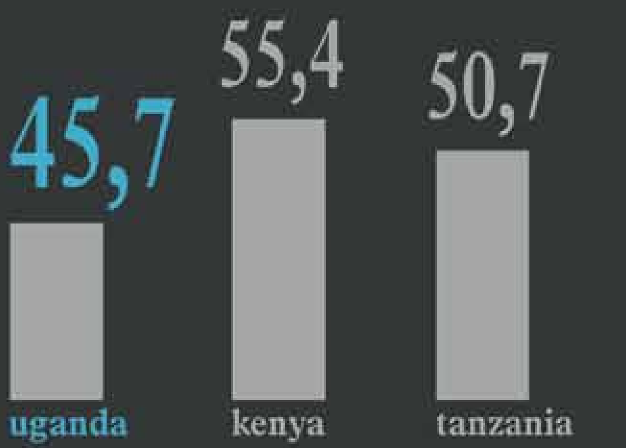


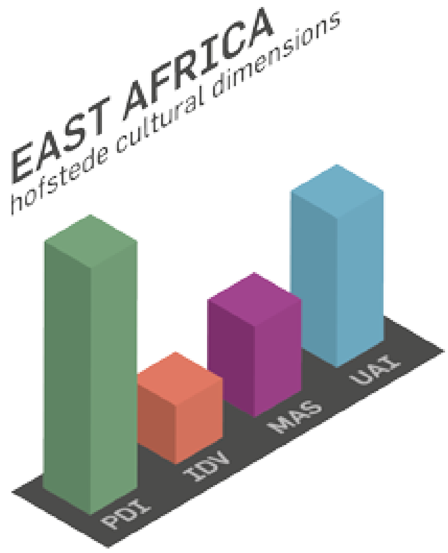


eracy rate (%)



life expectancy(years)





3.4.2 Culture and society

There are several aspects where a culture is reflected. As defined by Hofstede's cultural dimensions, power distance, individuals, masculinity/femininity and uncertainty avoidance are some of these, as well as time perception as defined by Hall. (Hofstede, G. & Hall, E.T.) These Hofstede Dimensions are only available referring to East Africa in general, but are supported by our personal observations.

Power Distance

East Africa his given a composite value of *64*. For Uganda, Power Distance is rather prominent in society. It is the measure of hierarchy in a society, college degrees are king, and one of their main priorities is to invest in education. Aspirational images of university graduates, books and news on how to become rich and powerful are everywhere.
In sum, hierarchy plays a fundamental role on East African societies. This is something to consider when creating a business plan for this project. The business model should have a hierarchical structure where roles are clear.

Individualism - Collectivism

East Aftica scores a rather low score of *27* on Individualism. This means that in general East African countries have a collectivist society. As it was described by Hofstede, one should expect that there will be "large classes split socially into smaller cohesive subgroups based on particular criteria".
The individual comes after the group, which for instance in Uganda is quite clear in their social structures such as tribes and clans, which are central to their way of life.
In the case of this project, this will mean that the business is not solely concerned with the well-being and success of the manager or entrepreneur, but must always consider the social dynamics and possible conflicts of a larger population.

Masculinity - Femininity

East Africa has a score of *41*, which means it is considered to be a feminine society. Feminine societies have bigger emphasis on the "working to survive" philosophy. People are not ambition-driven nor long-term oriented, they just live by the day. This is

also the motivation to have a job: something to do that will be enough to make a living.
Similarly, feminine societies are keener to avoid confrontations, leading sometimes to misunderstandings or miscommunications. Therefore communication surrounding this project should be clear and constant.

Uncertainty Avoidance

This dimension looks at a society's tolerance for uncertainty and ambiguity and how comfortable one is with unstructured situations. East Africa scores a 52, indicating that the population is generally uncomfortable with uncertainty, relying on rigid codes and behaviors.
This might also explain why some people in Uganda are not keen on change, and usually prefer to remain with what is already known.

Time

Uganda, with regard to time, is known by being rather diverse than other East African countries. In general Ugandans are extremely relaxed with their attitude towards time and appointments. This "serenity" is clear in both a psychological and physical dimension: studies have showed that Ugandans have the slowest walking pace of the world.
Patience should be one of the preconditions when thinking about setting up a business in Uganda. One needs to be prepared to deal with uncertainty, flexibility and waiting times.

3.4.3 Uganda's mainland electricity grid

Uganda's primary energy source is the Nile River. From the installed capacity of 492 MW (Uganda Bureau of Statistics, 2010), 91% is generated by hydroelectric stations Nalubale and Kiira, which generate about 300 MW (see figure 10). Nalubale has an installed capacity of 180 MW divided into 10 units of 18 MW each; this plant was created in the 1950s. Meanwhile, Kiira is designed to generate 200 MW with 5 units of 40 MW each. Additionally, there are independent installations connected to the primary grid.

These independent hydropower plants generate about 15 MW. By 2012 Bujagali Energy Limited will have installed a 250 MW power-generating facility near the town of Jinja.

Installed Capacity [MW]		
Plant Name	2008	2009
Installed Capacity	**527**	**492**
Hydro Electricity	**315**	**328**
Kiira	120	120
Nalubale	180	180
Kasese Cobalt	10	10
Kilembe Mines	5	5
Bugoye	-	13
Thermal Electricity	**200**	**150**
Lugogo	50	-
Kiira	50	50
Namanve	50	50
Mutundwe	50	50
Bagasse Electricity	**12**	**14**
Kakira	12	12
Kinyara	-	2

Fig.10 Uganda Installed Capacity

Currently, less than 10% of the population is connected to the grid, with 70% of the population that receives electricity residing in major cities of the country, such as Kampala and Entebbe. The other 30% of the electricity is distributed in smaller cities and rural areas.

According UMEME Limited, the energy distribution company in Uganda, there are about 300,000 customers whose annual electricity consumption is about 40 kWh. However, even for the small number connected to the grid, the grid is extremely unreliable. UMEME cannot meet the actual demand for electricity, and this, combined with poor infrastructure leads to frequent blackouts.

The Ugandan National Development Plan 2010/11-2014/15 addresses these issues. Accelerating rural electrification and promoting renewable energy have been identified as two of the main objectives for the energy sector. (2010)

3.4.4 Commonly used energy sources

Wood

In rural areas, firewood is collected from the surroundings, while in urban centers it is sold through small shops. Annually, 13.5 (Uganda Bureau of Statistics, 2010) million tons of wood is being consumed, which causes the resource to become scarce and require more time and effort for collection. In urban areas, the price per ton ranges from 16 to 38 Euros (Uganda Bureau of Statistics, 2010). Most households with low or no income will use firewood as it is available for free.

Charcoal

Annually, 3.12 million (Uganda Bureau of Statistics, 2010) tons of charcoal is consumed in Uganda. This fuel is commonly used in stoves, called sigiri, usually constructed from scrap metal. During the rainy season, prices tend to rise due to scarcity; charcoal might reach the price of 200 euros per ton.

Kerosene

Kerosene is an expensive resource (800 Euros per ton) and is the most widely used fuel for household lighting. This fuel can be bought through small shops and gas stations.

3.5 Research Findings

Following the context analysis, we spent four weeks in Uganda, getting a better understanding of the cultural, socio-economic and physical environment.
Our data was largely obtained through observations, visits to relevant organizations and user research on Buggala Island.
We encountered many unexpected situations, some regarding our research methods (see Appendix 1) and others regarding the specific context, which will be presented in this section.

Kalangala District

Uganda is broken down into 4 main administrative regions, and sub-divided into 111 districts. Kalangala District is the governmental body encompassing all of the Ssese Islands. There are a total of 84 islands, around half of which are inhabited. The largest island in the archipelago, Buggala Island, is where this project is being developed and is also home to the district headquarters, Kalangala.

Very particular physical, economic and social characteristics of Kalangala District pose challenges for the development of the district in general and for adult education in particular. With the smallest land area among the rural districts of Uganda, Kalangala is perhaps the most difficult to reach in all its corners.

Kalangala Paradoxes

Kalangala has the highest population growth rate but the smallest population of any district, although numbers are difficult to establish with any certainty because of the high population mobility. Kalangala is considered to be among the least developed districts of Uganda but has the highest literacy rate after Kampala. Kalangala district has an income and consumption index second only to that of Kampala and yet the general welfare of the district is low.

Lutoboka Village

The initial project brief was based on a charging station, which would be located in Lutoboka Village.
Upon our arrival, this information turned out to be inaccurate. The site for the charging station had been changed and already purchased, located further uphill on the main road. This decision had been made to make the station accessible to all of the villages on the island.
However, this meant the station was not located in one village but in an unpopulated area in-between several villages. Therefore, the users of the charging station and the focus of our research shifted from the residents of a single village to all of the villages on the island.

The island with locations of the charging station and relevant villages is shown on the map on the right.

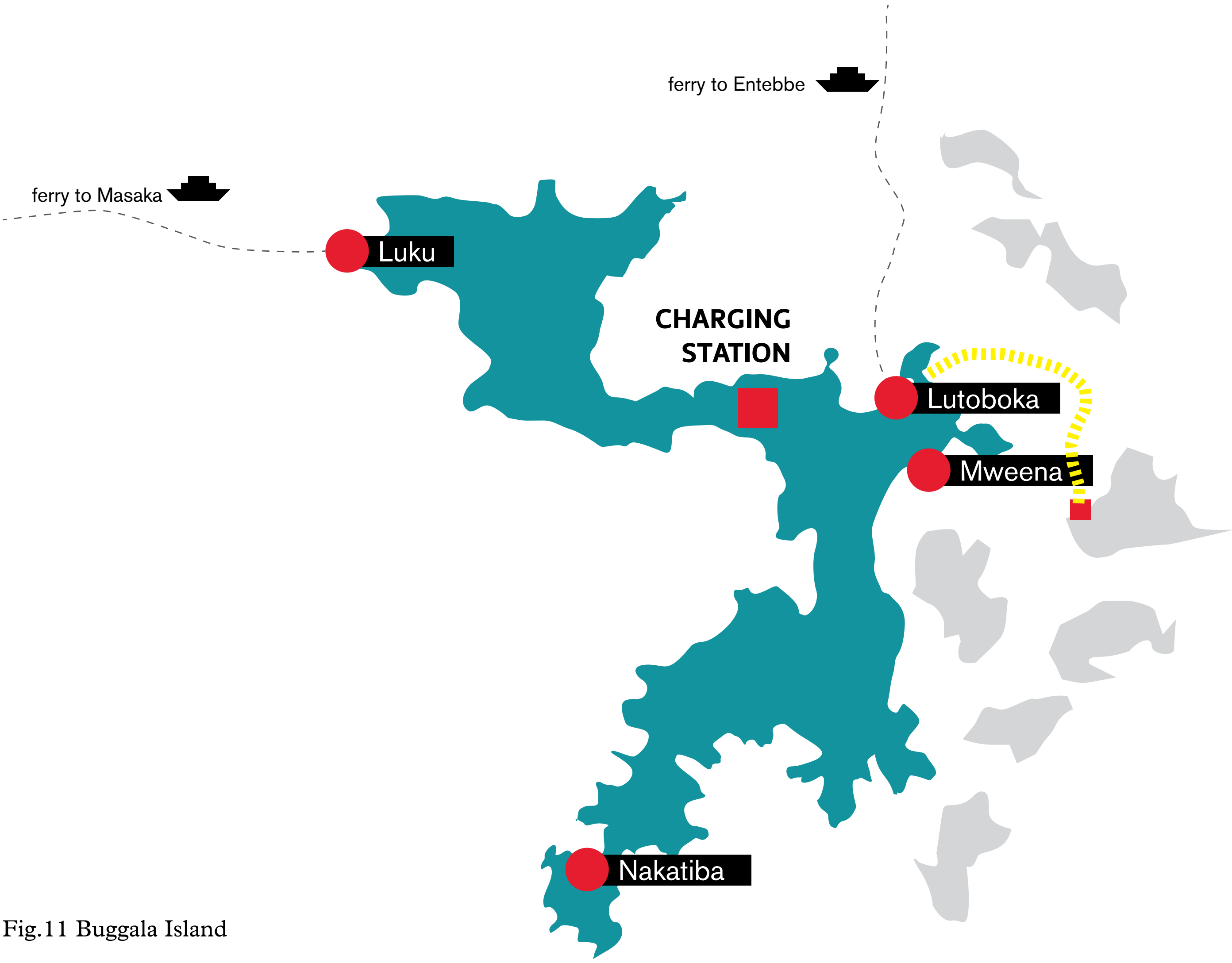


Fig.11 Buggala Island

3.5.1 Fishing industry

Since Uganda is richly endowed with water bodies, the fishing industry plays an important role in the economy. Fishing also plays a really important role for subsistence households.

Lake Victoria is the largest and economically most significant of Uganda and Africa. It is also the main source of employment and income for the Ssese Islands.

"By some estimates, annual exports, primarily of Lake Victoria products, amount to as much as US$ 41 million. (...) It is estimated that some 700,000 Ugandans are involved in fisheries-related employment (around 150,000 for the harvest sector as fishers, crew, and boat and gear owners; 550,000 engaged in secondary or tertiary sectoral activities relating to processing, trading and the provision of miscellaneous support services)." (Nordenfjeldske Development Services, 2009)

Lake Victoria is also widely known for its illegal fishing activities. Fishermen who don't want to be under the control of a fishing company (and lose some of their profit) can make use of dynamite and nets with smaller holes. In the long run, this has led to problems with overfishing, and a ban of fishing for Nile perch.

The initial project brief identified fish waste as feedstock for the system. One would expect to find a good amount of fish waste on the island, however we found that this was not at all the case. Fish leaves the island whole, either unprocessed or just smoked.

There is a large fish processing facility on the island in Mwena, built in 2006. However, as a result of bad planning, the facilities have never been used and are now totally abandoned. There is simply not enough fish to warrant running such a large facility.

Fishing is not as stable as it could be, and comes with many problems. Since fishing can be seasonal and fishermen must travel to find a good catch, they often have multiple sexual partners. Sex can even be sense has a trade for fish:

"Women have no capital to invest in fishing. In the bar there is no need for capital, they use their bodies" (MGLSD-ICEIDA 2009, pp. 39)

This, combined with the lack of sexual education leads to fisherman contributing greatly to a high HIV infection rate on the islands.

Moreover, even though Uganda is endowed with water bodies, it is quite rare for a Ugandan to know how to swim - they are afraid of the water, and fishermen are curiously not an exception. This is a serious danger for fishermen on the island and a major cause of death.

3.5.2 Water hyacinth

One of the biggest problems faced by Lake Victoria is the existence of water hyacinth on the shoreline. In fact, in 1999 the amount of water hyacinth reached a peak, covering 80% of the shoreline. This was also a severe impediment to boats and affected mobility and transportation across the lake.
"Stationary water hyacinth became a common feature along much of the lake shoreline and riverbanks. On the Uganda portion of Lake Victoria, water hyacinth attained its peak biomass cover" (Balirwa et al., 2009).

Furthermore, water hyacinth is known in literature (Lindsey & Hirt, 1999), for having a negative impact on populations.

Direct effects

Increase parasites in the water.

Decrease water quality.

Unsustainable use of major wetlands.

Alteration of the species composition of the lake.

Indirect effects

Damage for the health of the inhabitants (e.g. malaria).

Decreased amount of fish.

Impact on economic activities (e.g. fishing, agriculture).

These are part of the reasons why water hyacinth was initially targeted as the main feedstock for the production of biogas in Kalangala.
However during our field research, we found that the situation was a little different. Water hyacinth was indeed a big problem in the past, but nowadays has been controlled biologically, particularly along the coast in inhabited areas. Which raised some questions, regarding the suitability of water hyacinth as a feedstock for this system.

During our stay on Buggala Island, we were able to take a trip across the lake to a water hyacinth 'hot-spot', simulating how the water hyacinth would be accessed if harvested for feedstock. This trip, marked on the map (Fig. 11) in yellow, took us approximately 1.5 hours. From this basic assessment, we were able to calculate the approximate costs of collecting water hyacinth (see Synthesis section).

3.5.3 Social & Demographic

The physical and economical conditions of the islands also contribute to a unique social context. Since fishing is a valuable source of income, and the island is also a touristic location, many people move to the islands to have a better life. However, living a comfortable life is still a very competitive sport. As with the rest of Uganda, unemployment is a serious problem and many people aspire to have a good life, become wealthy and admired. On the island however, a regular income is practically non-existant as the main opportunities for employment rely on unstable resources (i.e. tour-

3.5.4 Energy Use and Resources

Market size

Kalangala Town is third largest sub county within the Kalangala District; it is composed of 7 villages (Kalangala, Mwena, Kanyogoga, Kizzi, Buggala, Kibanga and Lutoboka), and the population is estimated at 3221 inhabitants (MGLSD-ICEIDA, 2002). As previously mentioned, the islands are not connected to the (already insufficient) mainland grid of Uganda. There is a small mini-grid shown on the map below, but this is limited in reach and capacity.

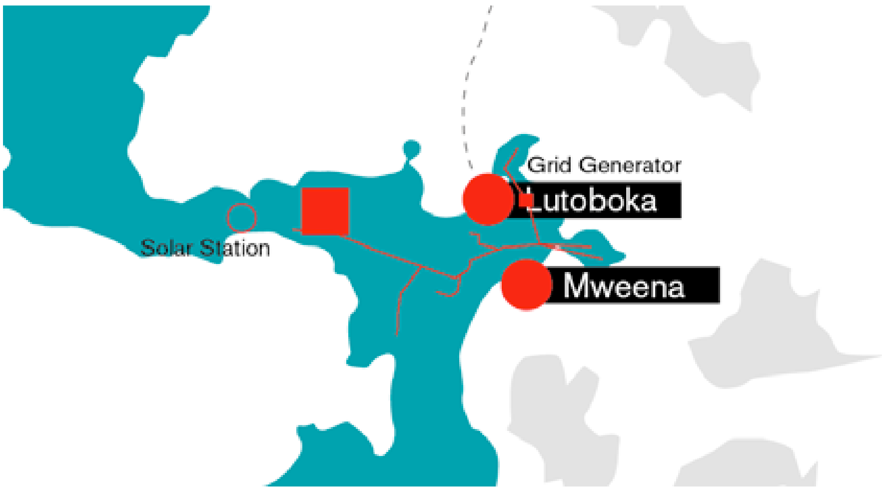


Fig.12 Buggala Island Mini Grid

Current situation

The existing island grid only covers the Kalangala sub county and does not reach other villages on the same island. This grid is fed by a diesel generator, and can theoretically supply 6 hours of electricity per day. However, lack of proper maintenance and a badly managed system means the generator is often down.

The grid has an Indamex diesel generator which is powered with diesel transported from Kampala. This generator is in fact a second hand generator. It was firstly installed by KIS (Kalangala Infrastructure Services) but later acquainted the Uganda Electricity Distribution Company. Maintenance is generally difficult due to the distances from the island to the mainland, for lack of expertise's and components at the island.

The Ugandan Ministry of Energy does intend to connect the island to the mainland grid via a submarine cable. However, these are all plans as reported by the government, and are seldom executed in time. Another plan is to bring a new generator so the grid can supply 12 to 15 hours of electricity per day.

Usage habits

The majority of the population makes use of kerosene or paraffin 'candles' (primitive homemade lanterns) for lighting. For cooking, villagers use charcoal and firewood. The latest is preferred as it is widely available and 'free of charge', as people can collect it themselves. Charcoal is produced on the island and is used especially during the rainy season when firewood is not dry.

The use of dry cell batteries is also important for locals. They use them as energy source for lighting and mainly for transistor radios. Radios provide people with a connection to the outside world, as well as allowing them to pass the time.

Often mobile phones are also used as light source. They can be easily charged at commercial phone charging stations, usually twice a week.

A small amount of households are actually connected to the grid, nonetheless they still have the need to support themselves with other energy sources than the grid.

Similarly, a select few can afford to invest in a small generator for their personal use. However, fuel is generally expensive in Uganda, and even more on the islands.

Car batteries are somewhat familiar to villagers as an energy source, but batteries are an expensive investment (200,000.00 USh/65 per battery) and there is only one poorly functioning solar-powered charging station on Buggala Island. The station can only charge 3 batteries at a time, and most of the time it takes more than 2 days to charge a single battery. Battery charging stations are more commonly found on the mainland, but due to the high prices and lack of reliable charging services, villagers prefer not to make use of batteries.

Fuel generators are also widely used for specific purposes such as cinema halls, resorts and discos. There is one of these in every village, run by a local entrepreneur. Younger villagers gather here to pass the time, to watch movies in the evenings or football matches. Some resorts also depend on fuel generators to run their business; some others make use of solar panels.

Energy Resource - Prices & Expenditures				
Energy Resource	Price per Unit [USh]	Average Unit Consumption per Week	Average Spending per Week [USh]	Average Spending per Month [USh]
Charging fee big battery	1,500 per charge	2	3000	12000
Charging fee cellphone battery	750 per charge	2	1500	6000
Dry Cell Battery	650 per battery	1	650	2600
Paraffin	6,000 per liter	1	6000	24000
Kerosene	3,500 per liter	1	3500	14000
Firewood	1,000 per kilo	5	5000	20000
Charcoal	1000 per kilo	5	5000	20000
Diesel	3,350 per liter	10	33500	134000
Regular unleaded	3,650 per liter	9	32850	131400
Electricity	426.1 per unit (1 kWh)	7	2983	11931

Fig.13 Energy Resource - Price and Expenditures Overview

Prices and Payment methods

People connected to the island grid are required to pay an initial connection fee and their monthly unit consumption.
A major issue reported to us by the electricity company was the collection of payments. Sometimes they are required to actually cut off the power from a household in order to collect a payment for their monthly use.
Some villagers believe that the government should provide electricity for free.
If people have a car battery (we saw only a few) a completely different situation happens when people need to recharge their batteries. They need to pay in advance, but this comes with more problems. They often need to ship their battery to Masaka (on the mainland). It takes more than 3 days to return, and due to their lack of control over the process, the batteries often comes back undercharged or even damaged.
Because people cannot afford to bring their battery to the mainland themselves they often give it to a boda rider who puts it on the ferry. On the mainland another person needs to pick up the battery to bring it to a charging station. Due to the number of different people handling the battery, it is likely that the battery will get lost, stolen or damaged during this process.

Personas

(see next spread)

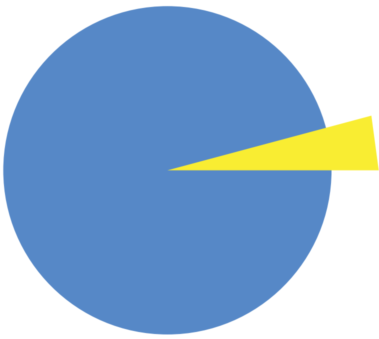
Based on the interviews conducted and the data we collected, we were able to identify different types of users for the charging station, which we summarized in the following personas.

As it can be seen from the image above, the total expenditures on energy vary according to income and lifestyle. However, what is important to point out is that being connected to the grid actually means spending more on energy. Since the grid is unreliable, one still needs to make use of other energy sources such as kerosene and dry cells for lighting and powering their devices.

Sylvia

On-grid

Sylvia lives in Lutoboka, with her husband and child.
She has two other children at boarding school in Kampala.
She works at a local tourist resort as a housekeeper.
Her husband is unemployed.
Sylvia's home is connected to the grid, but the grid is often down.This means they still have to spend money on candles for lightingand dry cells to power their radio.



Monthly income:
300,000 USHS
97 euros

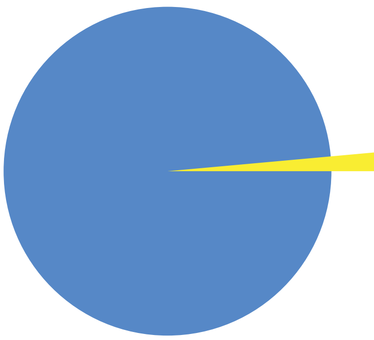
Energy expenditures:
45,000 USHS
14,5 euros

"We have to go three days without power"

Henry

Off-grid

Henry lives in Nakatiba, with his wife and 3 children.
He is a fisherman.
His wife is takes care of the kids and their home.
Henry's home is not connected to the grid because his village is too remote and not connected to the grid. This means they spend money on kerosene candles for lighting and dry cells to power their radio, which they use sparingly.



Monthly income:
200,000 USHS
64 euros

Energy expenditures:
10,000 USHS
3,2 euros

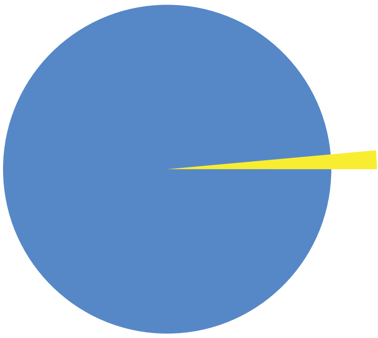
"We only listen to radio in the weekends"

Mike

Off-grid

Mike lives in Kizi, with his wife and 2 children.
He is a bicycle repairman and a mechanic.
His wife is a trader and sells matoke.

Mike's home is not connected to the grid because he doesn't think it works very well.
Instead, he and his wife use their phones as a light source.
They also own a generator, which they use to power their TV. However, fuel is expensive, so they only watch TV around twice a month.



Monthly income:
400,000 USHS
129 euros

Energy expenditures:
18,000 USHS
5,8 euros

"The electricity grid is almost useless"

Betty

Subsistence farmer

Betty lives in Kanyongoga, with her mother, brother and 6 children.
They are subsistence farmers, and do not use much cash.
Betty wants to be a teacher but has to spend her time taking care of the farm & home.

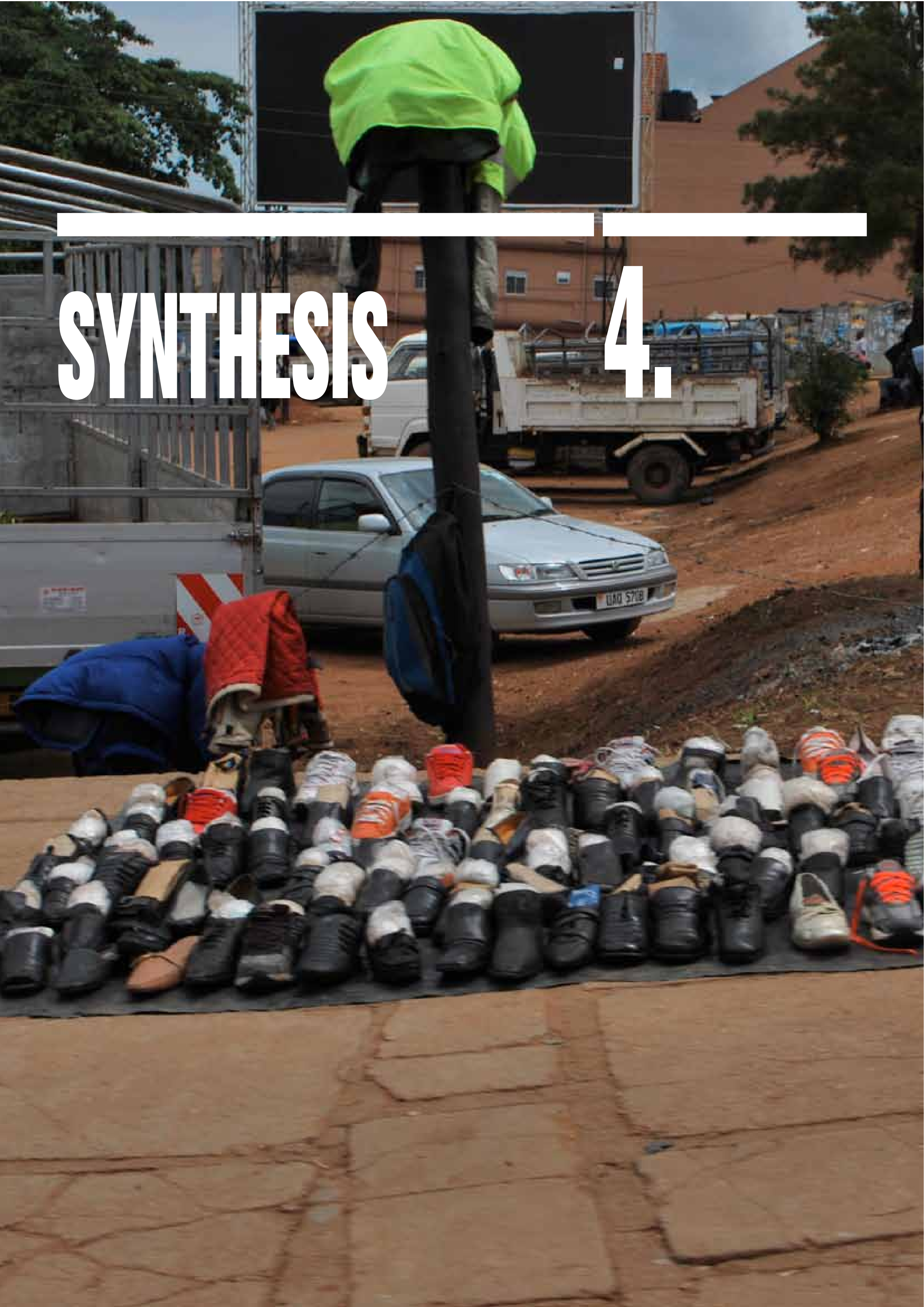
Betty's home is not connected to the grid.
They only use paraffin candles for lighting when absolutely necessary.

Monthly income:
± 0 USHS
± 0 euros

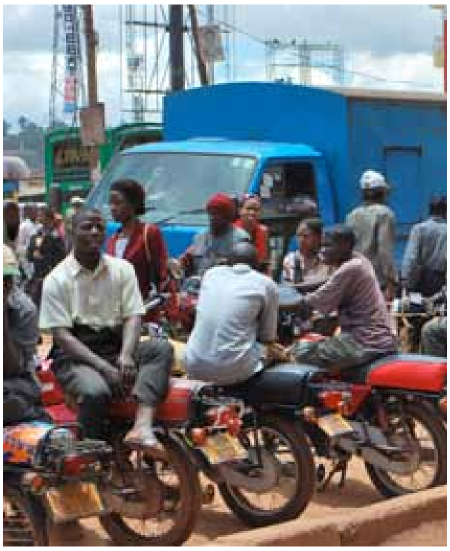
Energy expenditures:
± 0 USHS
± 0 euros

"We don't have money but we're not starving"

4. SYNTHESIS



4.1 Re-framing the Problem



Met by some unexpected situations on the island, we had to reframe our initial project brief and problem in order to continue with the project and deliver a valuable outcome for FACT Foundation. Some of these are already indicated in the previous section, but there are some that are particularly significant:

- Lack of batteries

Batteries were not a common source of energy on the island. Thus, if a battery charging station were to be initiated, locals would have to first understand batteries and invest a significant sum of money in them.

Lack of fish waste

Fish waste is not present on the island as fish is either consumed by locals or leaves the island in one piece.

Lack of water hyacinth

Water hyacinth is less of a plague than it initially appeared. Along coastlines, it has been removed or controlled biologically. To find it, it is necessary to travel by boat to hot spots, which increases costs significantly due to fuel prices. To illustrate, travelling from the charging station to the furthest point on the island had a cost of €8 per return trip, whereas a boat trip to the nearest hot spot had a cost of €30 per return trip.

In Jandl's (2010) study of floating invasive weeds for biogas production in West Africa, water hyacinth was found to be technically and financially viable. The main barriers to success were identified to be the labour costs and effort required for this process. However, the study was based in Ghana, where harvesting is carried out with rowboats - the existing vehicles used by fishermen. In our case, motorised boats and the physical situation will add fuel costs, labor costs and effort, therefore making success unlikely.

The direct need for a battery charging station disappeared with the absence of batteries on the island. And since water hyacinth is not generously available we excluded it as a form of feedstock for the digester.

4.2 Concept Generation

With this new information in mind, we started the concept generation. The full process can be found in Appendix 2).

We concluded the idea generation phase with the following 3 directions, presented during our interim presentation:

Charging station

This concept is still focusing on the charging station, in any form and therefore also with the potential to be adapted to locations outside Uganda. There are several ideas for improving the feedstock, making it easier for consumers to use a battery at home, making transportation more safe and hereby also prolong the lifetime of the batteries and come up with some extra services for users.

The other two concepts are more novel to the African market and need a good evaluation:

Bio-vehicles

This concept entails the development of a vehicle that will run on biogas. This was done with a focus on boda-bodas, the motorbike taxis which are all over Uganda and Africa. Since they are so common, they result in a lot of pollution, as well as high and unstable fuel prices making boda riders unhappy.

Bio-radio/TV

During our time on the island, we observed that TVs and especially radios are extremely popular. They serve to entertain people who otherwise have little to do and allow them to stay in touch with the world by listening to the news. Therefore, one idea was to see if they could be powered directly with biogas.

The above three concepts are presented more thoroughly in Appendix 3.

4.3 Biogas vs. Electricity Generation

The concepts we considered vary in their source of energy, some making use of the biogas directly, and others using it to generate electricity. Both have different consequences, from a financial and technical perspective. The diagram below shows all the possible outputs of the anaerobic digestion process.

Converting the gas to electricity causes a loss in energy, however using the gas directly would require a more complicated process to compress and store it. The full analysis and comparison is presented in Appendix 4.

Storing or transporting gas came with more risks, so eventually we decided to convert the gas to electricity using an IC engine. Although there is some energy loss in this process, there are simply more possibilities for distribution and reaching more people.

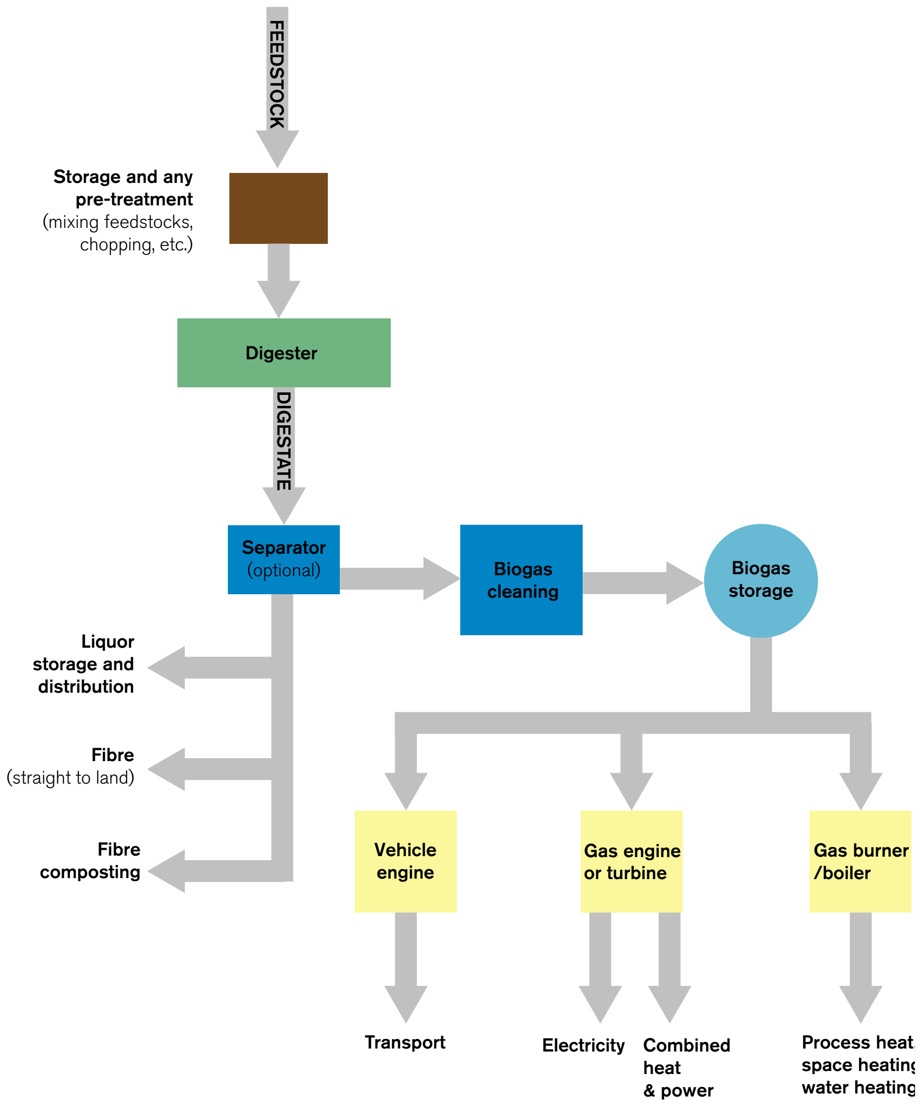


Fig.14 Overview of the Anaerobic Digestion Process (adapted from El Bassam and Maegaard, 2004)

4.4 Batteries

At this point, we still struggled with the fact that batteries are not as present on the island as previously thought. Since a mini-grid is not currently a feasible option on the island, it is necessary for users to invest in a way to store and carry energy. However, batteries are unfamiliar to them, require a large investment and are fairly complicated to use in the home with an inverter.

In order to better evaluate the suitability of batteries to this purpose, we also carried out some tests on a deep-cycle battery and a regular car battery, both lead-acid. The results of these tests can be found in Appendix 5.

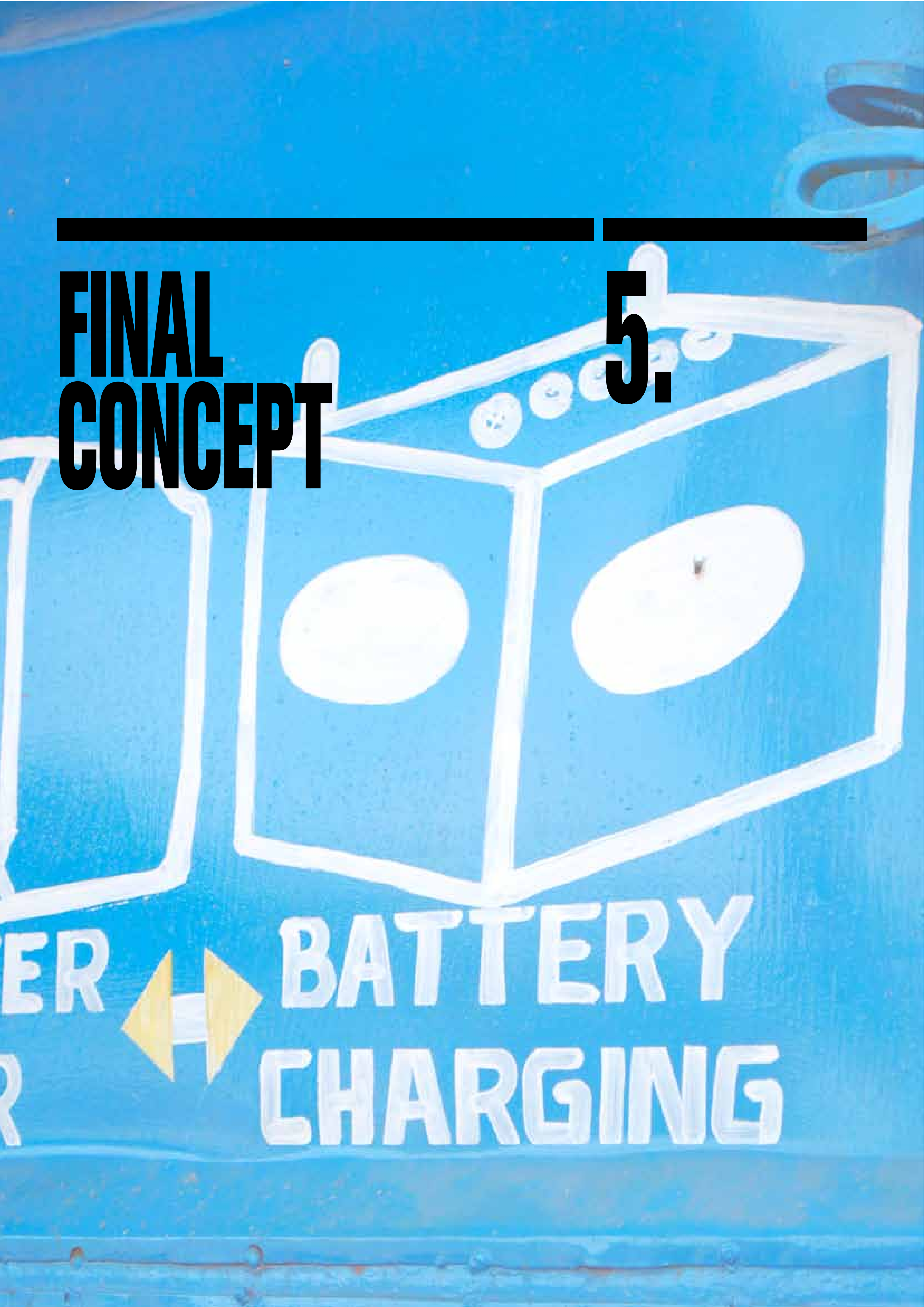
With this, we were able to get a better understanding of how these batteries behave, and if there is a difference between these two types of lead acid batteries. Although car batteries are fairly large and not part of our final concept, the chemical composition of the batteries and therefore their performance is similar. More tests should be carried out for a definitive result, but the tests showed us concrete data which helped us to define and decide which type of battery to use in our final solution.

Taking the local energy needs and buying power into consideration, we came up with the following solution: a portable lamp, containing a small deep-cycle battery, where a light, phone charger and a radio are integrated. This rechargeable device combines the main energy needs present on the island in one product. This product communicates its benefits directly, is easier to understand and significantly less expensive than a car battery.

Following this stage, we selected the charging station to develop into our final concept. It has been developed into a business model and system which will serve local entrepreneurs who want to set up their own charging station. This appears to be the solution that is most viable and also the most useful for FACT Foundation.

FINAL CONCEPT

5.



5.1 Factory

Factory is a system to support entrepreneurs in developing countries in setting up biogas-based charging stations.

Factory will be an initiative of FACT Foundation: creating a place where all the technical and financial aspects of setting up a charging station will be made accessible to entrepreneurs in developing countries. This will also propel FACT Foundation towards their wider strategic goals of building more interactive relationships with their 'customers' and promoting bioenergy.

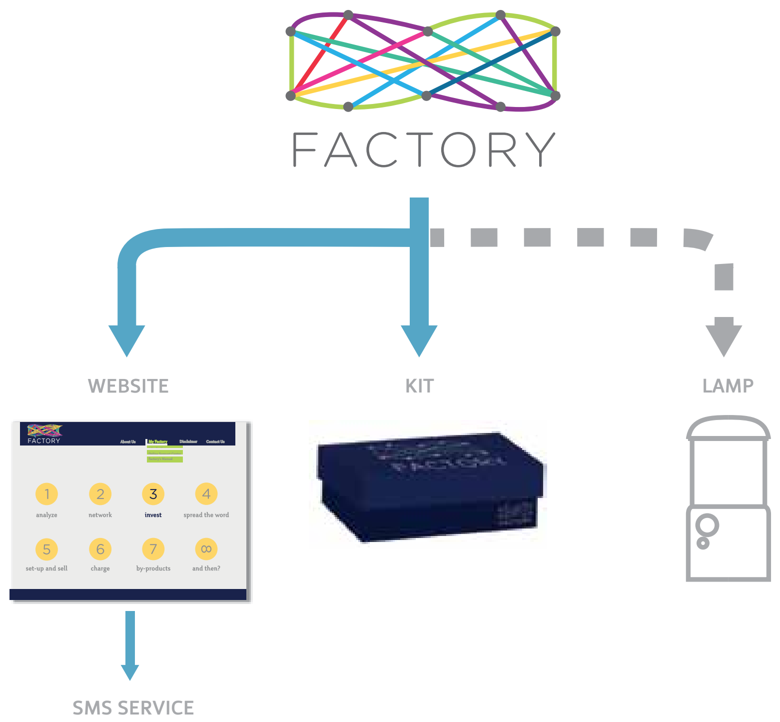
The project will exist in different dimensions:

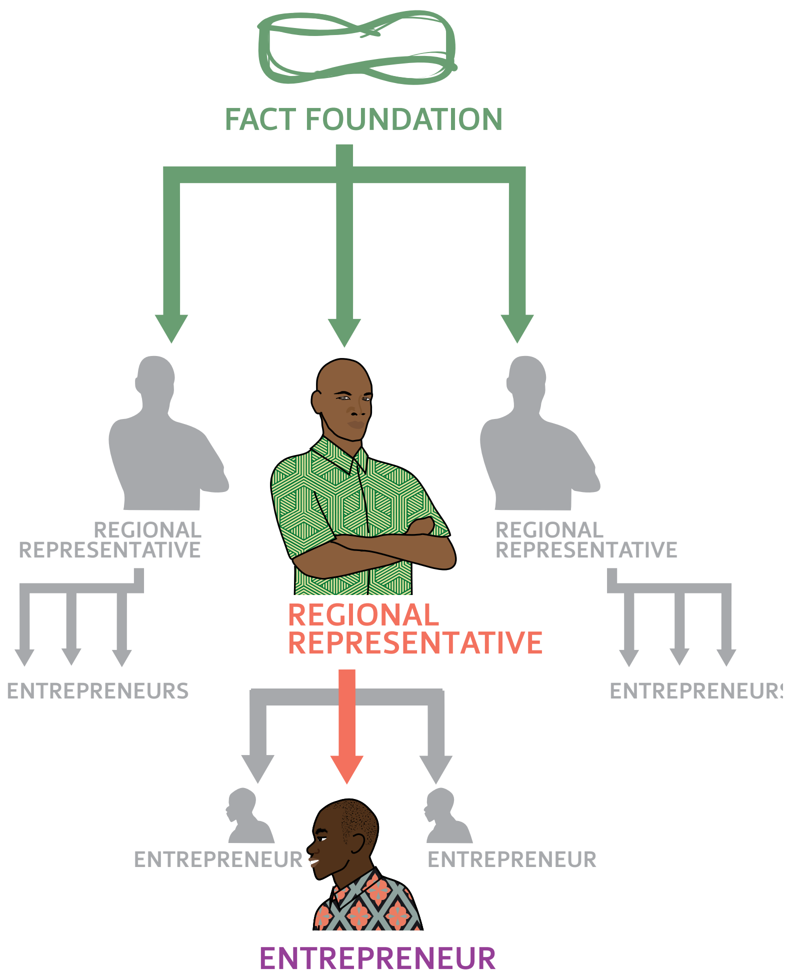
- *virtually*, through a website where one can register if interested in setting up such a business

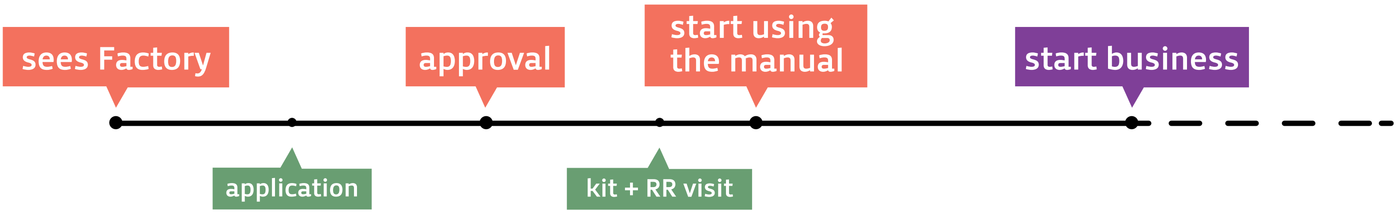
- a *physical* "kit" with a step-by-step guidance handbook and support materials to promote the project

The product-service system which will be set up by these local entrepreneurs relies on the use of lamps with deep-cycle batteries as a means for their clients to use the energy they will supply. (see section 5.2.4)

To implement Factory, some small structural changes within FACT will be required. To have more control and better relationships with the users of their expertise, FACT Foundation should employ Regional Representatives, who have a good understanding and network within a given region. This will be described in more detail in the following section.







5.1.2. Walkthrough

Local entrepreneurs must apply to become a part of Factory through the website. Their application is screened by the Regional Representative, and in the case of an approval, he/she will visit the local entrepreneur, as a final stage in the screening process as well as to physically hand over the Factory kit.

After this point, the entrepreneur must follow the start-up guide in the kit to carry out the necessary steps to get his charging station up and running. The Regional Representative will always be available to contact for advice, along with the website which will provide him tools for support.

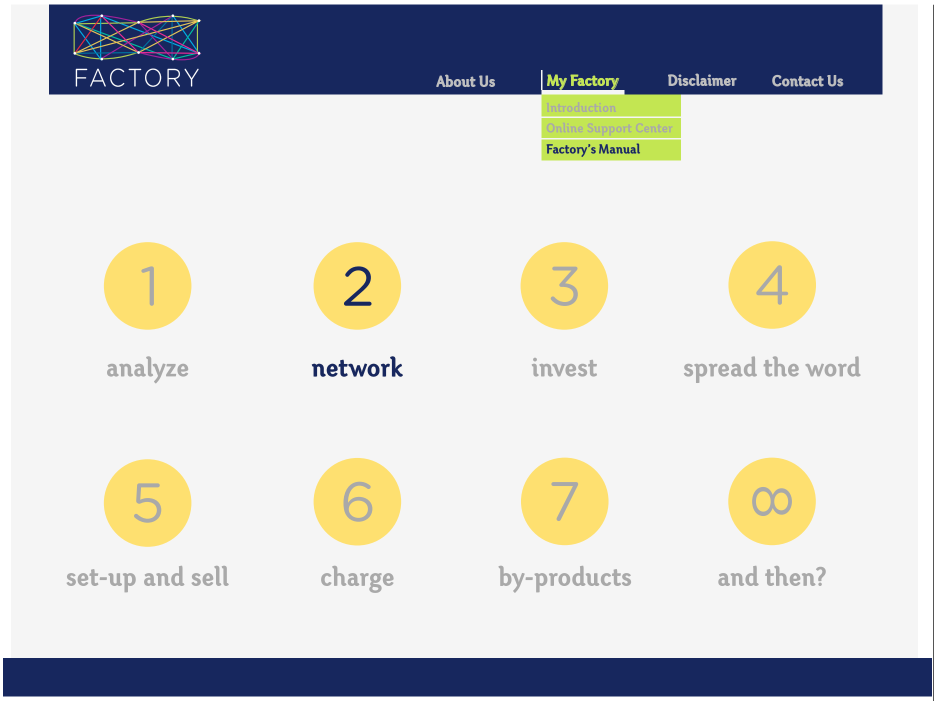
5.2 System Elements

5.2.1 Website

The website will be the first point of contact for the potential entrepreneur, where information regarding the entire system can be found. Factory's website will be tool which will introduce and guide the entrepreneurs through the development of a charging station, and will enable FACT Foundation to recruit and select entrepreneurs who will benefit from their know-how.

Any potential entrepreneur will need to apply to be selected to start a battery charging station. This will require them to provide some basics, such as personal details and information on their location. These applications will be reviewed and verified by the Regional Representative. Based on the location, potential customer base and wealth of feedstock he will assess the application and make a decision.

Once a potential entrepreneur's application is approved, the Regional Representative will visit the entrepreneur to present him with



his kit and discuss with him what is needed and how to proceed.

The entrepreneur will have a personal account on the website, which will guide him through the process of setting up the station, as well as the tools to maintain the station once it is established. The items in the kit, such as the start-up guide, will also be available online, together with additional tools to aid the financial and technical aspects of managing their charging station.

The website will support the entrepreneurs, but will be optional, so that those with little internet access can still continue to run their business. The kit will serve as the basic support mechanism, with the additional tools and documents to maintain their business available to print and use offline.

For example, for those with regular internet access, it will be possible to keep an online log of your customers' names and charging frequency. However, for entrepreneurs with limited internet access, this could also be printed out as a table and filled in manually.

These tools will assist them with tasks such as tracking their customers, making a log of the waste fed into the digester and keeping a record of their finances. Entrepreneurs can make use of the simplified interface on the website to see their cashflow without having to deal with complicated tables and calculations.

The website will also include an online support center, where they can chat with FACT experts and a forum to exchange knowledge with peers.

An outline of the website can be found in Appendix 6.

In short, the website will continue to assist the entrepreneur over the lifetime of the project by providing guidance and support.

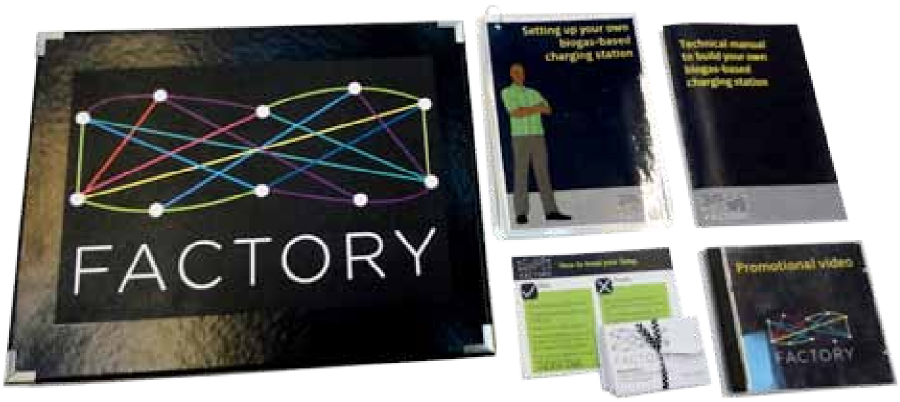
5.2.2 SMS Service

As the entrepreneurs make use of the online tools to keep track of their project, this data will be used by Factory to provide an SMS service, reminding the entrepreneur to perform certain maintenance tasks. The reminders can alert the entrepreneur of several issues: cleaning, removing slurry, checking the engine, etc.

Mobile phones are an important part of daily life for this region, so this service will help to establish a closer connection between Factory and the entrepreneur.

5.2.3 "The Kit"

As previously mentioned, once the entrepreneur has been approved, he/she will receive a kit which consists of:



A start-up guide

The start up guide is a step-by-step guide to the process of starting a charging station. It is an illustrated and clear guide, outlining the different steps and considerations which have to be made to make a successful business venture.

Rather than focusing on the technical aspects, the start-up guide is written in simple and friendly language, made to accompany the entrepreneur through his journey.

Technical manual

This makes use of the existing open source FACT Foundation biodigester manual, but has been rewritten in appropriate language and structured to suit this particular purpose. It is made to be more accessible to the entrepreneur, given his possibly limited understanding and experience of biogas systems. It is a step-by-step guide to installing and the charging station itself.

It will also address Frequently Asked Questions and the general dos and don'ts of how to install and maintain a battery charging station, so that the entrepreneur may refer to it for technical issues.

Business cards

As observed in this region, business cards are a common way for people to establish contact with others. The entrepreneur will have provided Factory with his personal information, so these will be custom-printed for him to help him establish himself as a credible businessman in his community.

Promotional video

This should be a simple video, produced to suit the country or region and made for the general public to understand the principles and main benefits of using the lamps. This can be shown publicly, for example at cinema halls, so that the entrepreneur can expand his/her client base.

Lamp stickers

These stickers will be provided to the entrepreneur to give away with the lamps that he sells. They have a short list of dos and don'ts to remind users of the correct way to handle their lamps.

5.2.4 Lamp

As previously mentioned, the lamp will consist of an LED light, a radio and phone charger. With one full battery, users will be able to charge a phone for 3 hours twice a week, use the light for 4 hours daily, and listen to the radio for 3 hours a day. (see Figure 15)

If doing all of the above, the battery should last for one week, when it will be charged again. (See Section 5.5 to see these calculations in more detail)

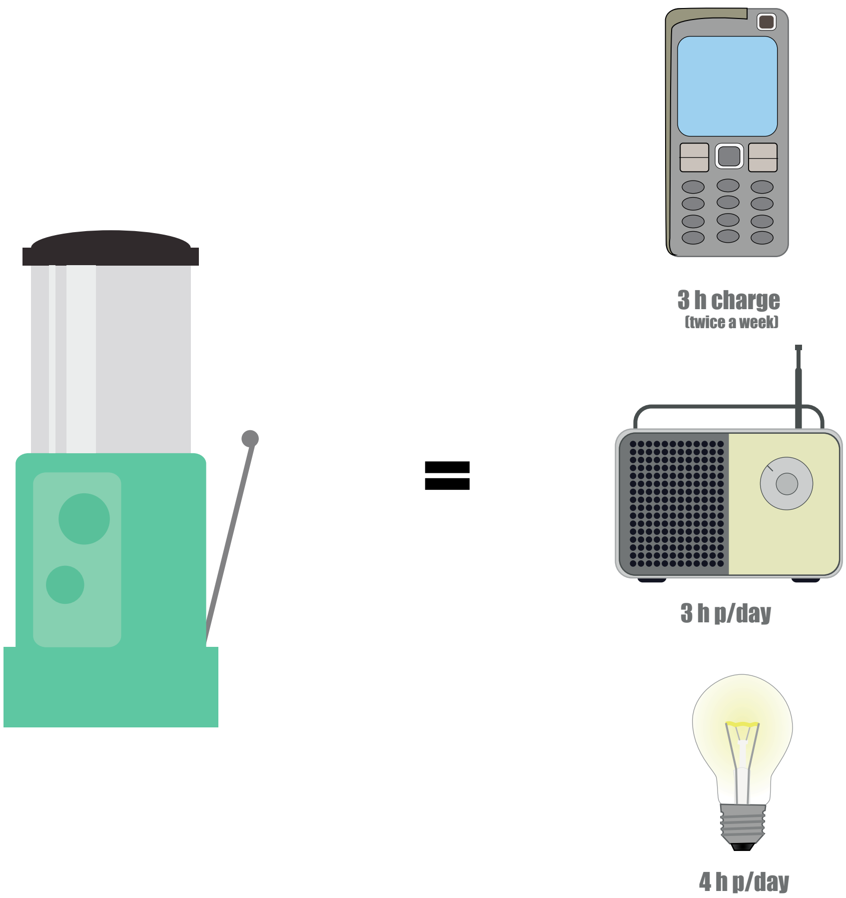


Fig.15 Battery Lifetime

Among others, one benefit of this product is providing better quality light. Currently, kerosene candles are used for lighting, and according to Mills (2003) “typical kerosene lamps deliver between 1 and 6 lumens per square meter (lux) of useful light, compared to typical western standards of 300 lux for tasks such as reading”. Research by Lighting Africa has shown that 1 in 3 off-grid households would improve their homes by investing in better lighting. By storing, transporting and using the energy in one product, these benefits become more apparent to the user.

Given the geographic situation in rural Uganda, we suggest that the charging station will provide a delivery and pick-up service included in the charging fee.
A employee of the charging station can visit surrounding villages on a weekly basis: going to each village on a given day of the week to replace their depleted batteries with new full ones.

According to the design brief, presented in Appendix 7,
the battery within the lamp is a sealed lead-acid battery, which will be removable from the lamp. In order to minimize tampering, the battery compartment should only be accessible with a ‘key’ owned by the charging station. So once a week, the charging station will remove and collect depleted batteries and immediately replace them with full ones.

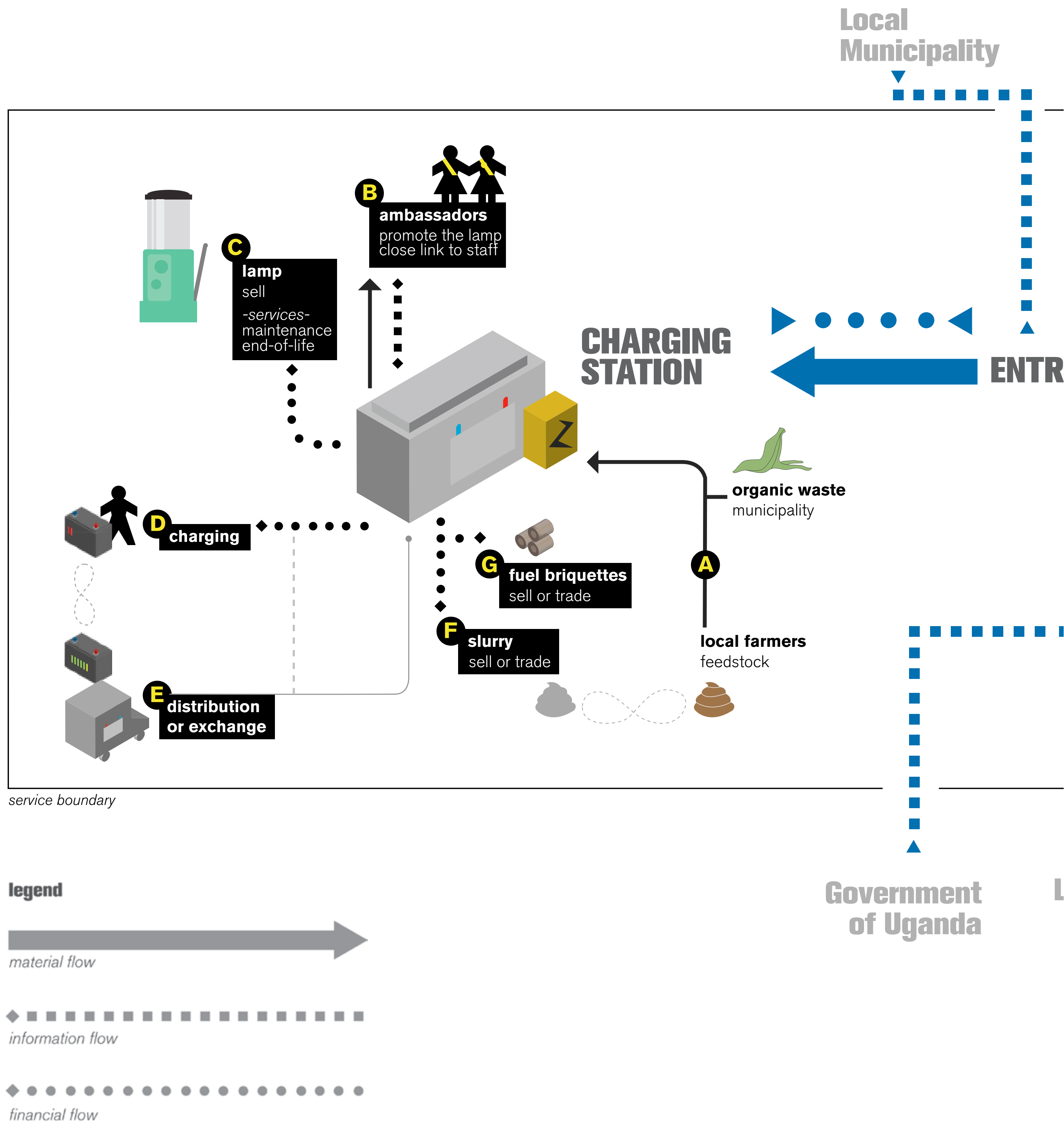
Of course the user can also decide to keep the battery for longer if it has not depleted fully. Conversely, if the battery is empty before a week has passed, the user can go to the charging station. Since lamps as a product lie outside of FACT Foundation’s scope, we recommend building partnerships with relevant companies and organizations.

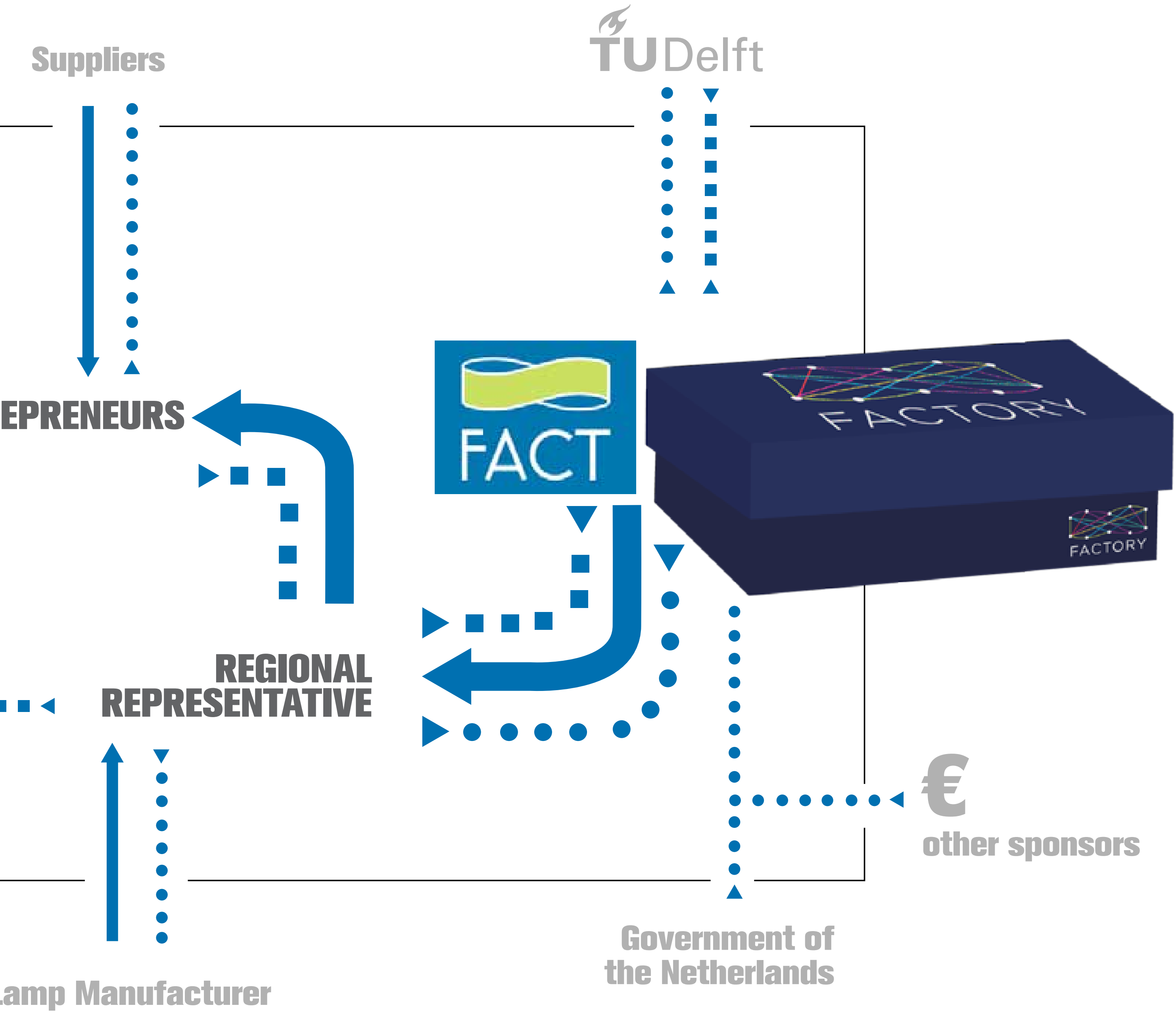
Initiatives such as Lighting Africa are currently pushing to develop off-grid lighting and improve access to energy, which would be the perfect platform for FACT to garner the support of relevant companies and actors.

There are many existing lamps which have been designed and manufactured for Africa, however extensive research has led us to believe that all of them are made in China and shipped to Africa. It would be ideal if the lamp could at least be assembled locally, so as to support the local economy and create more opportunities for employment.

In the meantime, there are plenty of lamps made in China that meet the requirements as defined in our design brief. In any case, a pilot should be carried out with these lamps so as to test the system.

5.3 System Actors



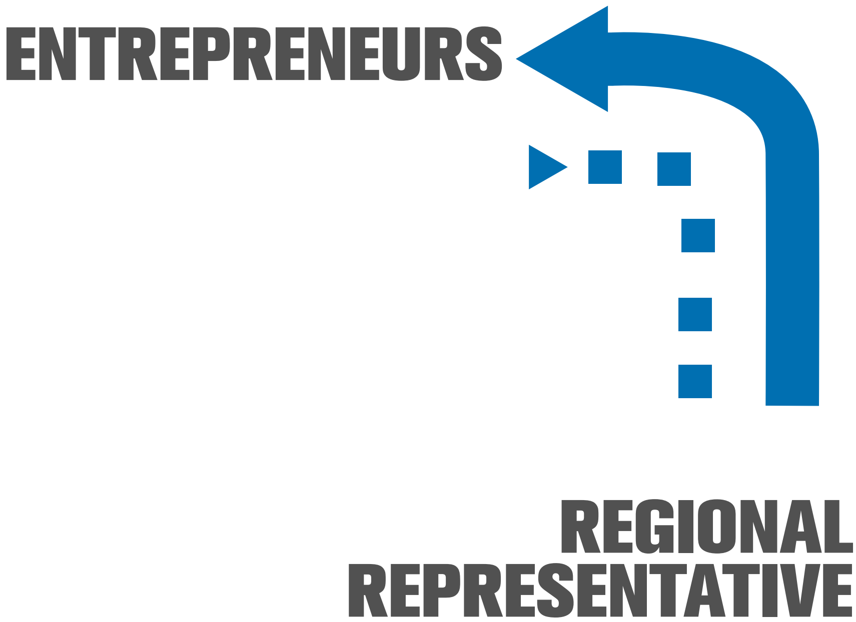


Suppliers
TU Delft
EPRENEURS
FACT
FACTORY
REGIONAL
REPRESENTATIVE
€
other sponsors
Government of
the Netherlands
.amp Manufacturer

5.3.1 Main Actors

FACT Foundation

FACT Foundation is the initiator and enabler of Factory. In sum, FACT Foundation will be responsible for creating all the necessary tools to make Factory work and for communicating them within their network.
FACT is not responsible for providing financial support. However, they can inform the Regional Representative of the possibilities for loans and credits, facilitating the spread of charging stations.
Even though FACT is the main actor of this entire system, their function is merely advisory, consulting with and supporting the Regional Representative.



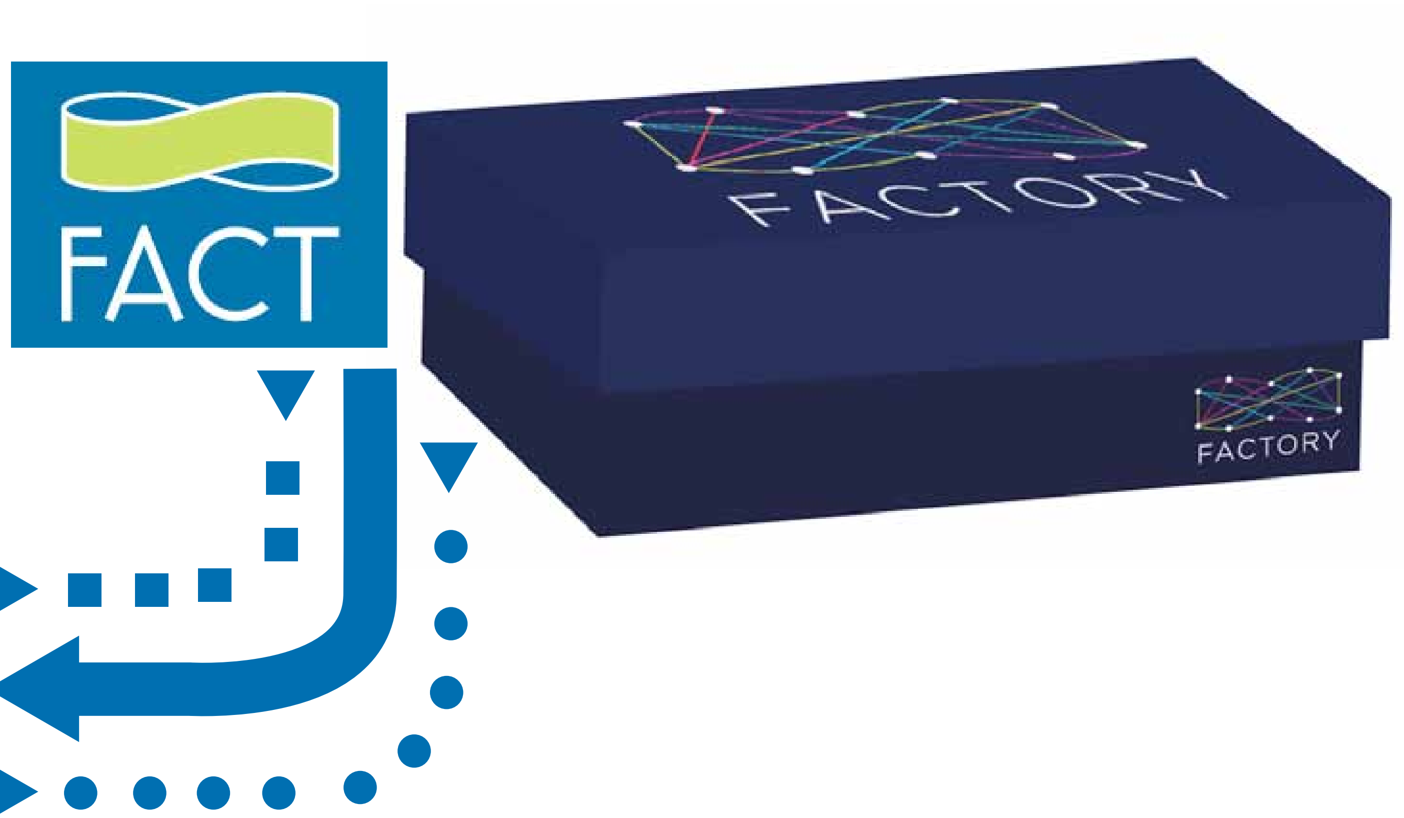
Regional Representative

The Regional Representatives will assist FACT Foundation in having a more personal, tailored presence in countries where they wish to be active. They will have a vital role, mainly in verifying the information provided by entrepreneurs, delivering the kit, and adapting the Factory concept to the specific local context.
The Regional Representative will take on some of FACT's roles by being responsible for all of the direct communication with the local entrepreneurs and relevant authorities. This will also allow the communication and overall system to be adapted to the local context, wherever that might be.

The representative will also be the eyes and ears of FACT Foundation, by checking the validity of information provided by applicants, screening and selecting them and visiting the entrepreneurs personally.

Currently, the position of Regional Representatives does not exist within FACT Foundation. However, as we consider this project to be contributing to their wider strategic goals, we also consider this small change in structure important for the success of the project.

This Regional Representative does not have to be a direct employee of FACT. It would be more beneficial to make use of existing networks and expertise and simply partner up with another company or organization that already has access to the relevant channels and networks. This could be a company who is the distributor of the equipment required for the charging station in the corresponding country.



Entrepreneurs

The local entrepreneur must have a proactive attitude, some relevant education or experience as well as interest and a vision for running a business.
The entrepreneur must also be able to seek finances, and bring the project to life. They should have good relationships within the community where they wish to initiate the project, in order to understand users and keep in close contact with the district, municipality, etc.

A case study on AREED and their support of a successful Cook Stove business in Africa (AREED, 2010) outlines a similar system, where the organization provides support for local entrepreneurs to start an energy business. Two of the factors they identify as being key to the success of the system are:

- A highly motivated entrepreneur with a vision and determination to succeed.

- Ability of the entrepreneur to communicate with rural people, cultivate and retain the trust of individual households, and develop innovative marketing and sales skills.

These factors are therefore also important for our system to succeed, and although difficult to assess, should be an important criteria in selecting the entrepreneurs. This selection process will occur either at the point where the Regional Representative will assess the potential entrepreneurs, or naturally as they face the challenges of setting up their charging station, such as acquiring funding.

5.3.2 Secondary Actors

TU Delft

This is a "consultancy" based collaboration with us, Matter, where we research and assess the local context to provide a business model for both FACT and the local entrepreneur.

Government of the Netherlands

Provides financial and legal support to FACT Foundation.

Government of (project country)

Energy is heavily regulated and subsidized around the world. Governments can have a vital interest in securing energy and support these types of initiatives. One of the main factors contributing to the success of previous biogas initiatives in Africa is the support (legislative or otherwise) of the government. (Parawira, 2009)

"Particularly in developing countries, where access to energy is not universal, governments often set up policies that provide incentives for the private sector to invest in electrification of rural areas and slums." (Gradl and Knobloch, 2011, pp.14)

Therefore it is important that the Regional Representative invests in a good relationship with governmental institutions. This relationship can help him promote Factory and for issues concerning laws and regulations.

Lamp manufacturer

As previously stated, the project will need to be initiated or tested with existing lamps. Eventually, FACT Foundation could consider investing in a partnership or collaboration, which would allow them to design a purpose-specific lamp which can be manufactured or assembled in Africa.

Local Municipality

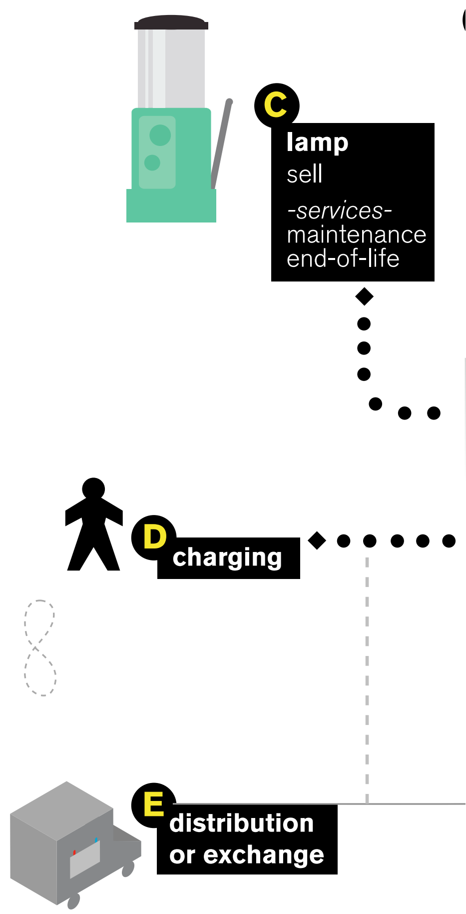
The local municipality will have access to information or statistics concerning the communities where the project will take place. This will assist the entrepreneur or Regional Representative in assessing the potential customers for a charging station.

Municipalities can also be an important source for feedstock. In the case of an existing waste collection system (as in Kalangala) the entrepreneur could build a partnership with the municipality to make use of this household waste as feedstock.

Suppliers

These are the manufactures or companies supplying the materials and equipment needed to set up a battery charging station. The Regional Representative will be responsible for advising entrepreneurs on the correct equipment, as well as ordering and ensuring delivery. However, FACT Foundation will of course advise on the choice of equipment so as to ensure the quality of the system.

5.4 Charging Station



A- Feedstock

Animal, agricultural and food wastes can all be viable feedstock for the biogas system. Specific calculations regarding the feedstock and energy output can be found in (Section 5.5)

We advise the creation of a "feedstock network" by the entrepreneur, identifying and connecting with local farmers, the municipality or other potential providers of feedstock. This way fixed collection days can be agreed with different local farmers, and the feedstock supply can be kept relatively stable, increasing the efficiency and reliability of the system.

B - Ambassadors

Given the context, the best way to reach potential users is by word of mouth. With limited access to printed media or television, conversing, either face-to-face or by mobile phone is the most common means of communication.
Direct marketing models are becoming increasingly popular in emerging markets.
They increase the consumer's confidence while at the same time evading high distribution costs incurred while trying to establish complex networks to channel products to often remote locations. (Gradl and Knobloch, 2011, pp.14)

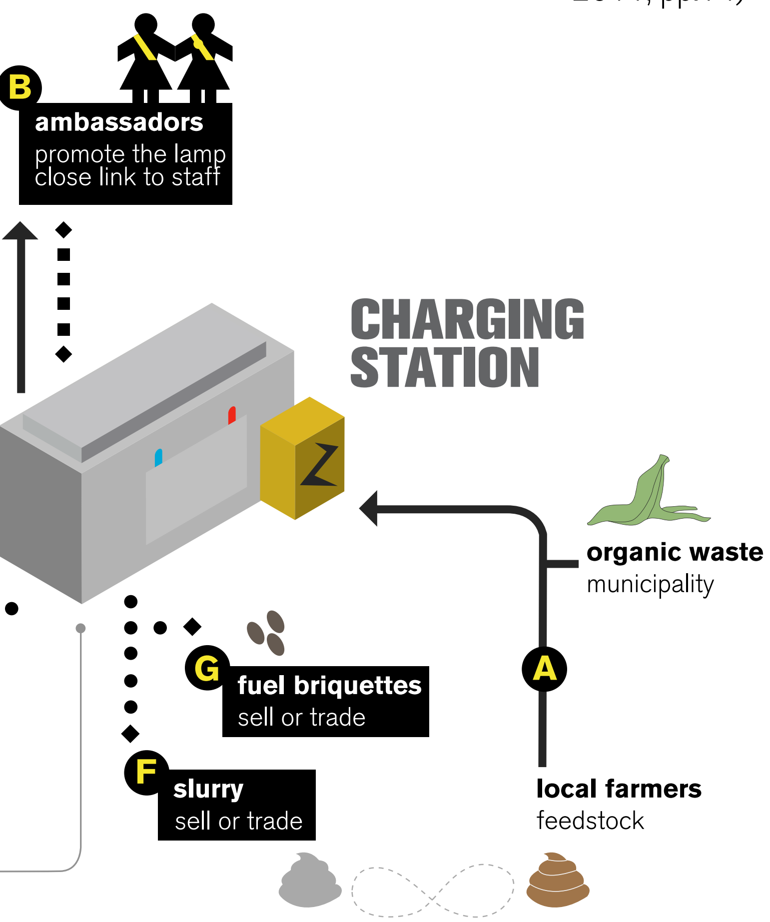
We suggest the use of carefully selected battery 'ambassadors' who can promote the use of lamps in their own village. By reaching out to respected villagers and recruiting them as informal sales and promotion agents, it will be possible to clearly communicate the benefits of using the station and build trust.

These ambassadors should be able to find a clear benefit of performing this task, and have a distinctly positive impression of the product. Therefore, they could be given a lamp for free or at a reduced price, to 'get the ball rolling'.

C - Lamp

From the consumer point of view, the charging station provides them with energy. The lamp is the most tangible part of the system.
From the perspective of the entrepreneur, a user who buys a lamp is ultimately signing up to become a regular customer of the charging station. The lamp allows the energy to be translated into direct tangible functions for the user, and minimizes the complications of using only a battery.

The charging station is also responsible for the product guarantee and maintenance. Assuming there is a manufacturer's guarantee, it should be valid for the first year of the lamp's lifetime and would not cover misuse from the customer (as outlined in the instructional video and stickers provided with the lamp)



Therefore, the charging station staff will need to keep track of all users as well as their lamp and battery status. During this first year, the charging station will also perform any maintenance tasks for free, for both the lamp and the battery.
The entrepreneur will therefore need to ensure that his staff will have sufficient technical skills and knowledge to perform these actions.

D - Charging

The user will be paying a fixed fee per charge, which from our research and calculations we defined as being approximately 3500 USh. This almost half of the weekly energy spendings (excluding biomass for cooking) of the average villager. It includes both the battery charging fee, delivery and maintenance if needed.

The capacity of the battery charging station will be presented in more detail in Section 5.5.

E - Distribution

By implementing a distribution system, where the charging station personnel can go to each village to exchange old batteries for the new, the risks associated with misuse and transport will be minimized. The responsibility for keeping the batteries safe will lie with the charging station. When picking up the batteries, the personnel can also use a volt-meter to check the charge on the batteries if necessary. The delivery system will also enable the charging station to address customers with a lower income, who could not afford to travel to the charging station by their own means.

F - Slurry

Slurry is rich in nutrients. It is a by-product of the bio-digestion process and can be sold to the farmers to improve their soil and their crops.
The value of nutrients available in the bioslurry is actually five to six times that of the biogas (Austin & Morris, 2012) so the slurry is much more than a simple by-product.
This requires no additional investment, since the slurry must already be removed from the system daily. For the example of Buggala Island, the slurry would be especially useful as the soil is sandy and not fertile. As subsistence farming is also common, perhaps a trading system could be set up with farmers to exchange this excellent fertiliser for their agricultural waste. This would allow the charging station to reach customers that cannot afford to invest in a lamp.
Furthermore our calculations have showed that slurry, sold at a recommended price of 1000 USh per kilo (approximately €0.30) will be a good, steady source of income for the charging station.
There will actually be an abundance of slurry from the system, which if sold can be more lucrative than the battery charging itself. However, selling fertilizer on this scale would require the entrepreneur to acquire customers who need much more of it, such as larger commercial farms and plantations.

G - Fuel briquettes

Briquettes are an alternative use for the slurry. As previously mentioned, there is an abundance of slurry coming from the system on a daily basis, which would make fuel briquettes a good way to use this excess byproduct. They are simple to produce from slurry, and would also make a good alternative to charcoal.

In order to make briquettes, the slurry needs to be shaped (with molds) and left to dry for 2-3 days. The manufacturing process is simple and presents a better alternative to the usual coal and firewood. At the same price of 1000 USh per kilo, they would be even be slightly cheaper than charcoal. Again, this would allow the battery charging station to target more users in alternative ways.

They do require the entrepreneur to invest in some basic equipment as well as additional manpower. This is why it is not a primary activity of the station, but only a recommendation for the future.

5.5 Technical Feasibility

For the proposed Biogas-Based Battery Charging Station some energy calculations were made (CD enclosed in appendices). The energy calculations determine the amount of waste that needs to be consumed by the digester in order to achieve the energy demand. For this specific Biogas-Based Battery Charging Station (BBBCS) it is proposed to charge a minimum of 370 batteries per week, based on a 50% market share in Kalangala District. This is approximately 60 batteries per day, for the specific case of the BBBCS located at Kalangala, Uganda.

In order to charge 60 batteries per day, it is necessary to produce 32m^3 of biogas daily. This is calculated based on the power consumption of the battery bank, as explained below.

On the specific scenario of Kalangala BBBCS, a minimum of 20 adult cows, 30 adult pigs and a weekly supply of 100kg of organic waste is needed to fulfill the monthly demand of 988m^3 of biogas.
Cows produce 28 kilos of dung per day, while adult pigs produce 4kg. Nearly 0.05m^3 of biogas is produced from 1kg of cow dung, and 0.06m^3 from 1kg of pig manure. Organic waste has higher production per kilo, 0.2m3 of biogas.
The amount of methane generated per kilo of waste allows us to calculate the total monthly energy output of the BBBCS: 4.7 GJoules.

It is necessary to mention that in most cases 1 kilo of dung should be mixed with 1 liter of water, and given the retention time[1] of 30 days it is necessary to consider building a digester plant with a capacity of 80m^3.
With organic waste, it is necessary to use about twice the amount of water, depending on the exact composition.

Nearly 34 tons per month of slurry are being produced, which can be used as fertilizer, and for fuel briquettes. Slurry first needs to be dried, because slurry is 80% water and 20% of dry matter.

The daily charge of the 60 battery bank has a calculated nominal capacity of 300Ah. The nominal energy required can be determined with the mathematical equation of :

$$Wh = Ah*V$$

where V stands for battery voltage, Ah is nominal capacity, and Wh nominal energy.
From the equation we obtain 3660Wh, and considering an efficiency loss of 20% due to the battery chargers, we can determine that the BBBCS will have a daily power consumption of 4.4 kWh.

This daily demand can be translated into approximately 15 MJoules, which is a unit of energy determined by the power consumption (kWh) of the battery bank; where 0.75m^3 of biogas is one kWh, and one kWh is equal to 3.6MJ.

The proposed battery (5Ah, 12V and 60Wh, see Design Brief in Appendix 7 is determined by the energy consumption of the lamp's DC components; SMD-LED, radio, and cellphone charger. The SMD-LED is a component of 12V and 1.2 watts, and is designed to give light for about 4 hours per day. The radio, as well as the LED, is a low consumption component of 3V and 0.75 watts, and it is estimated to run for 3 hours per day. Finally, the cellphone charger component is able to charge a 3.7V, 900mA cellphone battery twice a week. Adjustments are made according to the efficiency loss of 25% during the necessary DC-DC conversion.

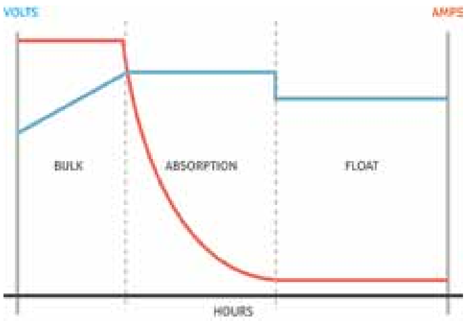


Fig.16 Battery Charging Process

For the battery charging, a 3 stage charger is used, the graph above illustrates the battery charging process.

Bulk charge: As shown in the graph, on this stage the voltage increases but the current remains constant. During this stage the charger will bring the battery voltage to level required by the second stage, absorption stage.

Absorption charge: At this stage the battery is charged to 80% of its capacity. During this stage current is no longer constant and is constantly decreasing, while the voltage remains constant at 14.1 to 14.8 VDC. At the end of this stage the battery should be charged to almost 95% of its capacity.

Float charge: During the last stage voltage is reduced (13 to 13.8 VDC) and held constant, and the current is reduced to less than 1% of battery capacity.

5.6 Business Model

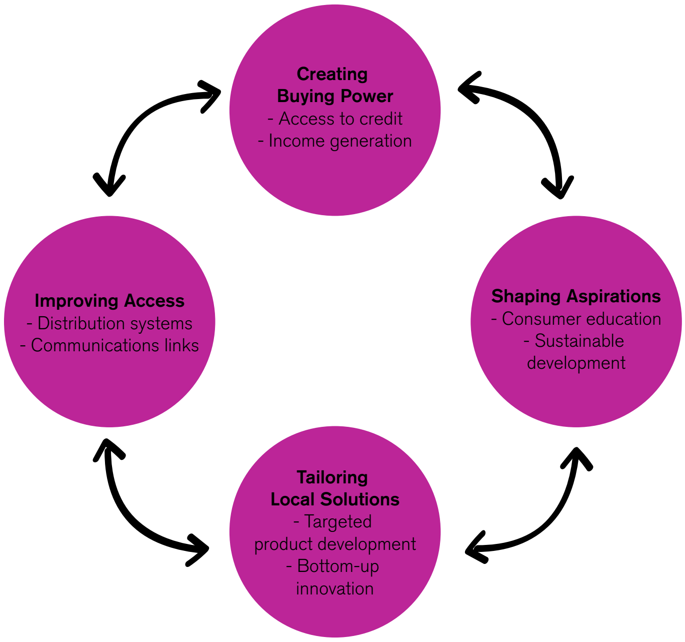


Fig.17 Commercial Infrastructure at the Bottom of the Pyramid (Prahalad, 2002)

"New business models must not disrupt local cultures and lifestyles. An effective combination of local and global knowledge is needed, not a Western system." (Prahalad and Hart, 2002, pp.12)

Bearing in mind the local context and "the commercial infrastructure at the Bottom of the Pyramid" as described by C.K. Prahalad (see Figure 17), and using the "Business Model Canvas" by Alexander Osterwalder (2010) as a basis, a business model for Factory has been developed.

As it has been described in the system map in Section 5.4, Factory's business model needs to be addressed on two different levels:

- A strategy for FACT Foundation, as initiator and system enabler

- A thoughtful financial analysis, having in mind the initial investment and further financial interactions between the local entrepreneur and his/her customers.

5.6.1 Strategy Outline

Factory will allow FACT Foundation to develop closer and more controlled relationships with the initiators of biogas projects. This will help FACT Foundation establish itself as the expert on bioenergy innovation in emerging markets.
Additionally, making use of their technical know-how to create business opportunities for local entrepreneurs will elevate FACT Foundation from technical experts of their domain, to becoming instigators of social change. FACT Foundation advises projects in a variety of countries.

This, combined with their open-source approach leads to relatively weak links with the end-users of these technologies, That is where the Regional Representative will play an important role, in representing FACT in the smaller local context, creating closer and direct connections with other NGOs, the government, etc. These investments and their benefits are summarized on the right.

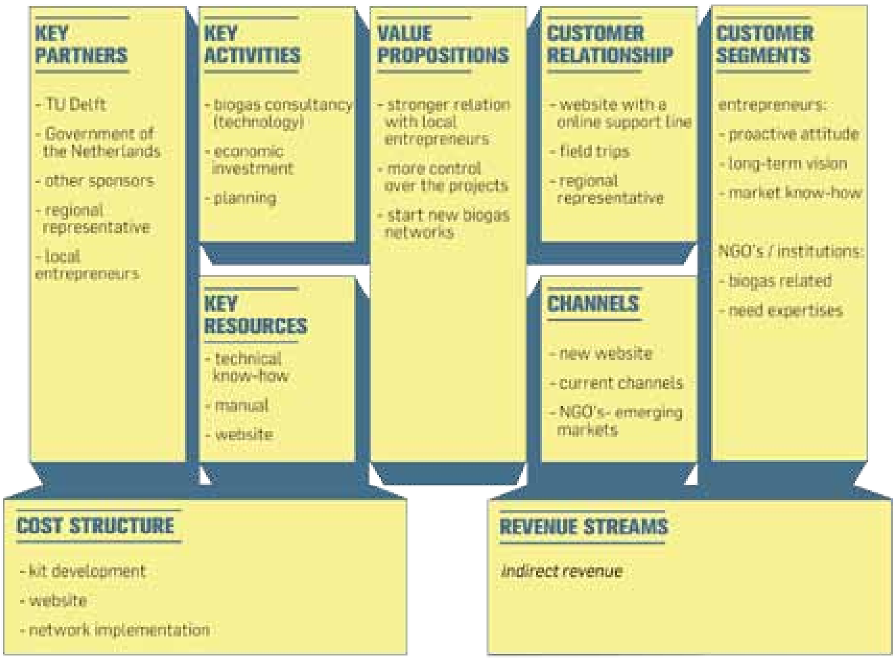


Fig.18 Business Model for FACT Foundation

Factory, as a packaged business model has been explained in the previous section and can be summarized with the chart below:

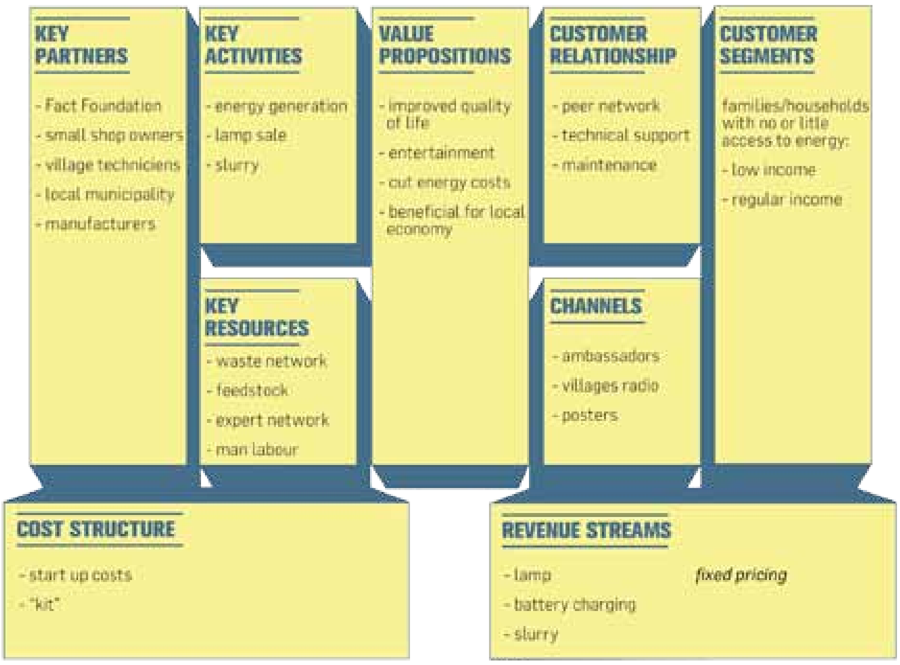


Fig.19 Business Model Entrepreneurs

5.7 Charging Station
– Financial Analysis

The business model for the charging station will take into account the following financial inputs:

- Initial investment, covering the costs of the equipment & a vehicle
- Wholesale purchase of lamps
- Monthly wages for employees & entrepreneur
- Office, maintenance and fuel costs

Income will be generated from the following:

- *Sale of lamps*
- *Charging fee for lamps*
- *Sale of slurry (or briquettes)*

The outcome of this analysis depends greatly on the specific location of the charging station. The equipment must come from outside the country, making taxes and transport costs for the equipment a significant expense. Because of this, the financial analysis as presented here is based on the existing example of Buggala Island.
The assumption is also the basic setup of the charging station, however should the entrepreneur wish to make changes such as additional employees or a different charging fee, the cash flow has been constructed to simulate the consequences. (CD enclosed in appendices)

Start-up costs

130,500,000 USh / € 42,260

Similarly to Fact's current business plan, the local entrepreneur is the only responsible for the initial investment. The role of FACT is merely advisory. The local entrepreneur should search for ways to finance his/her own project with Fact's guidance and support.

This figure includes all taxes, based on the real costs already incurred on Buggala island.

Wages

In order to maintain the charging station, we suggest that the entrepreneur should hire at least two other people, one skilled and another unskilled.
The skilled employee will have the technical expertise, taking care of the electricity generation, battery charging and maintenance tasks. The unskilled employee will be responsible for the battery delivery service and the waste collection. The cash flow also accounts for wages for the entrepreneur. This means that *despite making a large investment initially, he will have a guaranteed steady income.*
The wages are planned as follows:

Entrepreneur/Manager:

€200 (approx. 617,000 USh)

Skilled employee:

€100 (approx. 308,800 USh)

Unskilled employee:

€45 (approx. 138960 USh)

Product costs

After looking into lamps produced in China, we have found several with the features needed (phone charger, lamp and radio) and established that such a lamp can be purchased (wholesale) for around 2 euros.

Due to the lack of accurate information available regarding shipping costs, we have simply put a 1000% margin on the lamp to account for any shipping costs as well as profit.

Charging fee

The charging fee has been established at

3500 USh (approx. €1.10)

Based on our personas, this charging fee should be affordable for most people, excluding subsistence farmers. It is almost half of the weekly costs of using kerosene, charging a phone and using dry cells for a radio.

Market share

As this is based on the example of Buggala Island, we have taken the official population statistics from the island, and assumed an initial ***50%*** penetration rate in the villages easily accessible from the charging station site.

This results in around ***370 households*** initially buying the lamp and making use of the charging station.

Retail price

The retail price of the lamp will be around ***€20 (62,000 USh)***

Based on the costs of the smaller investments that locals will make for their homes (e.g. radios, small lamps) this appears to be affordable for the majority of the population. Also, given the multiple functions of the device, it appears to be quite reasonable.

Based on the experiences shared by Lighting Africa, this also appears to be in the correct price range:

> “Most low-income consumers are able to pay approximately US$10-30 per unit (even though there are significant market niches for higher priced products) and consumers appear to increase their willingness to pay once they become more familiar with modern products”.
> (Lighting Africa, 2010)

5.7.1 Break-even period

If the initial investments are made at the start of the first year, and battery charging can start at the start of Year 2, the initial investment will be recovered at the end of Year 3. The entrepreneur will always be paid a manager’s wage to ensure his financial security.

Fig.20 Break-even Overview

5.7.2 Best and worst case scenarios

As previously stated, the calculations above are based on the example of Kalangala, but best-case and worst-case scenarios have also been developed (CD enclosed in appendices) to see the effects of changing different variables.

In the *best case scenario* the variables have been set at the following:

Number of customers: ***500***

Amount of slurry sold per month: ***30 tonnes***

Kilometers travelled per month: ***300 km***

This results in a *break-even point after 1 quarter of operations,* in Year 2. This is based on a scenario where all of the slurry produced (minus 80% of the volume, which is water) can be sold, either in bulk to large farms, or as briquettes. It is clear that this has a huge impact on the financial outcome, generating more (money) than the battery charging itself, and recovering the large initial investment cost almost immediately. It should also be noted that 500 customers is the maximum which can be served according to the number of batteries which can be charged with the given equipment.

Fig.21 Break-Even Scenarios Comparison

The *worst case* has been based on the following scenario:

Number of customers: ***250***

Amount of slurry sold per month:

300 kilograms

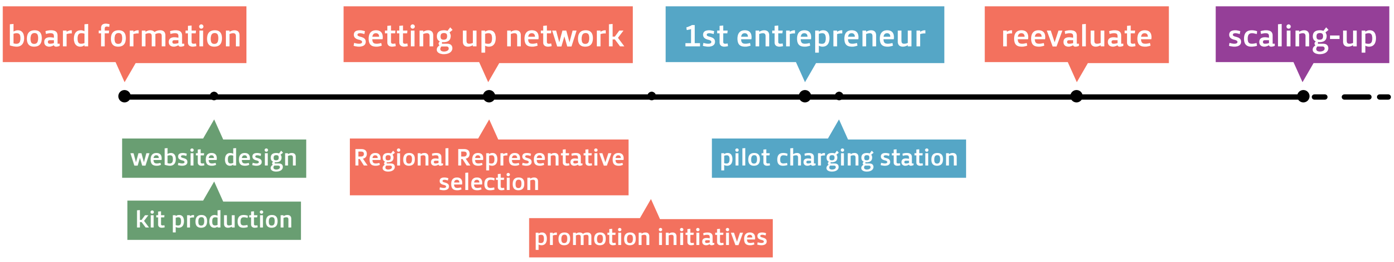
Kilometers travelled per month: ***700 km***

In this case, the *break-even point occurs during Year 6*, after 5 years of running the charging station. The customer base is smaller, and the slurry sales are minimal. This also represents the minimum number of customers required to justify starting up a charging station, based on the investment costs.

As previously mentioned, this analysis has been based on Kalangala charging station. In the case of a different location, or perhaps the choice of different equipment, the investment costs and therefore break-even point would be altered.

5.8 Implementation

As previously mentioned, FACT Foundation is the initiator of Factory. Therefore it is FACT's responsibility to implement the project, both in the short and long term.
The following diagram represents the implementation process, from the perspective of FACT Foundation.



The starting point of this implementation plan is the creation of Factory's board of directors. We suggest that it consists of at least 4 people, with expertise on biogas, financial and social matters.

Biogas

Will be responsible for managing the technical aspects of the service and support the acquisition of the right equipment from the right manufacturers. He/she should have some engineering background, experience of previous projects with FACT and also stay up-to-date regarding new technologies.

Financial

Will not only be in charge of Factory's finances and money "allocation" but also for supervising the entrepreneurs' investment.
For example, once entrepreneurs start using the website to keep track of their finances, the financial expert should have an overview of how they are doing. This financial expert should preferably have experience doing business in BoP markets.

Social

A team of two, one focusing more on communicating and developing the Factory concept at large, and the other on more specific personal relationships such as managing Regional Representatives.
The latter, being in charge of direct communication with the Regional Representatives, should also be in charge of organizing training sessions.
These two members should have complementary skills, with a balance between good communication skills, social skills and a keen interest in development work.

Certain tasks will also need to be outsourced, such as a web developer to build the website and a team to design and develop the other support materials together with FACT Foundation. For a better fit with FACT's current philosophy, we would advise them to recruit young professionals with a social entrepreneurial spirit.

5.8.1 Guidelines

As the system depends on recruiting entrepreneurs, it is vital that the components of the system comply to certain guidelines to ensure clear communications and maximum accessibility.

Although implementation of this project may require a more in-depth analysis of these matters, it is important to indicate certain points which we have deemed important and also considered in our prototype.

The language used by Factory, referring to both the visual and written content, should be easy to understand and follow, as well as culturally appropriate. It should also be accessible, in terms of how information is presented and how it must be navigated by the user (in this case, the entrepreneur)

As well as these general guidelines, below are some more detailed ideas and directions for the implementation of different elements in the Factory concept.

Website

The website should be extremely efficient, easy to understand and use for the local entrepreneurs. In sum it is the virtual representation of the start-up guide, with simple language and an intuitive interface.

From a more technical perspective, it should also be built 'lightly' so that it can be accesssed easily with even the slowest of internet connections, avoiding heavy graphics, animations and such.

Although this project was intended for Uganda, it is of course a possibility that it may be tested or initiated in other countries or regions. (see Section 5.7.2) Needless to say, this also needs to be a consideration during the design and development of the website.

In our example, we have tried to create a neutral website, reflecting the visual identity of FACT Foundation, and not specific to Uganda.

The kit

Although delivering this physical object may present some difficulties, we believe it is important for the Regional Representative to make this trip, meet each new entrepreneur and hand over the kit.
More importantly, it is the physical manifestation of Factory, the sign that the entrepreneur has been selected to be a part of this enterprise or 'club'.

- Start-up guide

A physical and verbal representation of the steps which one has to follow to set-up the BBBCS. Since it is a companion to the entrepreneur and will probably encounter a lot of different situations, it should be resistant to external conditions. This was why the prototype was developed to be in separate, simplified steps, laminated and connected by a ring. This way, the entrepreneur can even remove the cards if necessary, selecting one to keep with him or hang somewhere else.

- Promotional video

Differently from the other components of the kit, this promotional video is focused on promoting the lamp to the end users.
Firstly, it should introduce the lamp to the community, how can it improve their daily lives. This should be done by showing concrete examples of all its functions in action, using actors which they can relate to easily.
Secondly it should clearly communicate how to maintain and take proper care of the lamp,
as well explaining the delivery procedure.
Ultimately, the video must explain why it is a good investment in a simple way. From our experience money is the best incentive, so the eventual savings they can make on kerosene, dry cells, etc. by purchasing this lamp should be clearly illustrated at this point.

Communication / promotion strategies

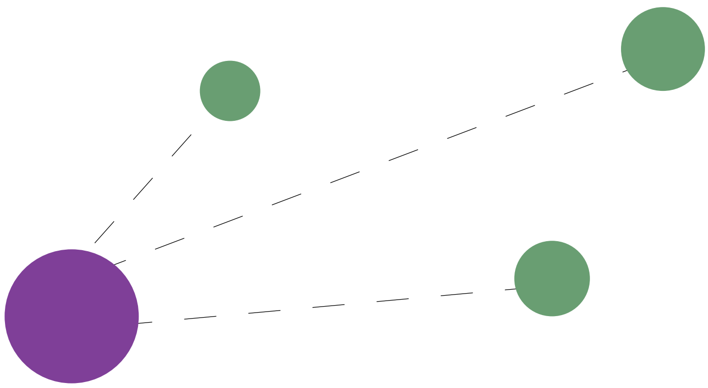
Factory needs to reach the right people, in order to recruit the right entrepreneurs for the success of the project.

One common practice we have observed in Uganda, is painting buildings to become giant advertisements. Below is a real-life example from Uganda, together with a mock-up image for Factory. We suggest this, or a similar culturally specific practice to communicate the concept.

Additionally, we were also able to understand the importance of personal connections and networking. Therefore, the Regional Representative serves a very important role in simply talking to people and spreading the word among his network.

By connecting with the right people, he or she can increase the likelihood of encountering a possible entrepreneur.

5.8.2 Scaling-up



A big part of Factory as a system, relies on its potential to scale up: its potential to be implemented and used in other developing countries.

Although our research was focused on a specific country and region, the fact that we have developed a self-contained package to start a charging station already creates possibilities for taking this concept and system elsewhere.

Clearly, Factory should start with a pilot in Uganda, which can make use of the existing site and equipment purchased for the ongoing project on Buggala Island. If successful, we suggest that FACT Foundation can focus on Uganda, by creating a strong network and solid strategy enhanced over time by their experiences. This can serve as a second pilot, which can determine whether there is enough interest from entrepreneurs, and if it is feasible to use this 'kit' format and approach.

At this point, the board should reevaluate the project. If all feedback is positive, they can perhaps look into other geographical regions, perhaps where FACT Foundation is already active with other projects and can use their existing networks.

Of course, in the case of the project being executed in other countries, changes in communications, and perhaps in kit itself may need to be made in order to address cultural and physical differences.

In any case, we suggest FACT Foundation to focus initially on Sub-Saharan Africa, where they can create a cohesive network of Regional Representatives and suppliers. This also creates possibilities for cooperation and support from Lighting Africa, who are already tackling similar issues.

EVALUATION 6.

6.1 Risks

With such a broad Product Service System there are a couple of issues that should be kept in mind during an implementation phase. Even if most of these risks are outside the scope of this academic project, we must acknowledge them and present valid solutions to all. For a clear overview of those we clustered them and presented an explanation and how to mitigate each.

Financial

- Large initial investment for entrepreneur

Even though getting credit to set-up a charging station is not the responsibility of FACT Foundation, it is extremely important that the entrepreneur is approved for credit solutions so that he can receive financial support for the initial investment.
Therefore the Regional Representative should be well informed of credit solutions for his region, as well as good connections with energy related government divisions to benefit from grants or other incentives.

- Unstable costs, such as exchange rate, fuel prices, etc.

The business model has been constructed based on the costs as we know them, and as they are valid today. In the case of fuel prices or the exchange rate, this creates a lot of instability. However, it has been modelled to be flexible, so that all variables can be changed to see their consequences. The Regional Representative should keep an eye on these fluctuations and keep the entrepreneurs' virtual cashflows up-to-date accordingly.

Technical

- Equipment supply

Currently most of the equipment suggested by FACT Foundation comes from different countries. There are also no suppliers in Africa. In order to create a more feasible project, this supply should be optimised and local partnerships should be created (e.g. SNV) so that they can become regional distributors.

- Entrepreneurs (lack of) technical skills

The process of applying and becoming a Factory entrepreneur has some selection naturally built into it. For example, having the proactive attitude to initiate this process, as well as the ability to access and appropriately use a website are already tested before the application. Beyond this point, a good screening and selection process for entrepreneurs will minimize this risk.

- Biodigester lifetime

It is known that a biodigester bag is rather fragile in contrast to other digester forms. The lifetime of the specific digester should be considered in the overall business plan. Additionally, the lifetime can be prolonged by protecting the digester, or alternative digester types can be used.

Scaling-up

- New territory for FACT Foundation

Factory as a tool to enable entrepreneurship is something totally new to FACT. Starting up a new initiative and trying to form new networks can be quite demanding for a single organization, so we recommend that FACT partners up with local experts or organizations to exchange knowledge and cooperate on different levels.

- Bigger network requires more control and supervision

Particularly in the case of Factory being implemented in more than one location, it will be a challenge for FACT Foundation to create and operate such a big network without partnering up. By having good partnerships with other organizations, FACT can delegate some of the responsibilities and create a more decentralized structure.

- How can FACT Foundation stay innovative?

As mentioned FACT Foundation operates within the domain of bioenergy and biofuel innovation, working on novel projects and sharing their learnings with the world. Therefore, maintaining and managing the Factory enterprise is a fairly stable, constant task, unlike their usual activities. However, using an iterative approach of testing, learning and evolving will keep the Factory concept dynamic. This way, they can fine-tune the system, and fully explore the potential for using bioenergy to enable entrepreneurship.

Social

- Acceptance of the project and product

The penetration of a new product in developing markets can demand a lot of time. As suggested to the entrepreneur in the start-up guide, a grassroots promotion strategy should be initiated before the charging station is even running.

- Understanding of the system

A system as complex as Factory can be difficult to be understood by all.

There are a lot of variables, agents and stages to keep track of.

Constant training for both Regional Representatives and for entrepreneurs should be provided, the former provided by Factory and the latter provided by the Regional Representative.

6.2 Benefits

The benefits of initiating this project exist on two levels: the more short-term direct benefits, and the long-term benefits for FACT.

Direct benefits:

- Improve the well-being of the rural population

The case for rural electrification in Africa is quite clear, and Factory would be contributing to improve access to energy in these areas, with many consequences for the lives of the rural population.

- Empower local entrepreneurs to support their communities

Rather than imposing a Western product and system in a developing country, Factory relies on enabling locals in this more decetnralised approach. This way, the entrepreneurs can be granted more independence and the business can always be adapted to the specific location, increasing the chances of success.

- Contribute to waste management

Waste management is a non-existent concept in Uganda. Waste, if collected at all, simply ends up in landfill. Factory will create an opportunity for waste matter to be used productively.

- Create a sustainable fertiliser

As well as making use of waste, the charging station system actually adds value to it, creating a valuable and sustainable fertiliser at the end of the process.

Indirect benefits:

- Develop closer and more controlled relationships with the initiators of biogas projects. Creating this structure with Regional Representatives acting as mediator and coordinators of local entrepreneurs will allow FACT Foundation to spread the reach of their technical know-how, while still keeping a personal connection.

- Establish FACT Foundation as the expert on bioenergy innovation in emerging markets.

Setting up biogas systems requires a certain level of expertise, and therefore other renewable solutions such as solar power are currently more popular in developing countries. By creating such a 'kit', FACT Foundation will be breaking down some of the barriers preventing the widespread use of biogas. If the pilot can run successfully, and Factory can be launched as a total package, it will be a unique example in this category and make FACT Foundation a true innovator in promoting bioenergy.

- Elevate FACT Foundation from technical experts to instigators of social change.

Currently, FACT Foundation works to test and develop technologies and concepts in the field of bioenergy and biofuels. A project such as Factory will make use of their extensive know-how but translate it into a more approachable, accessible format,

7. Conclusion

7.1 Recommendations

There are always unexpected situations when trying to design for the BoP. However, in our case we also discovered many weaknesses of the original project brief.

One of our main recommendations, to the local entrepreneur reading the start-up guide, but also to FACT would be to avoid defining a project before you have seen the context yourself and made a quick assessment of the feasibility of the project. In this instance for example, water hyacinth was initially seen as a viable feedstock. Upon visiting the physical location and making some quick calculations, we could quickly conclude that the costs of retrieving it were unnecessarily high. From our limited experience, we can already say that physically being somewhere and simply experiencing certain things will already give you a completely different and improved perspective.

Another recommendation is to cooperate and partner up with other organizations to better target the Base of the Pyramid market.
It is impossible for FACT Foundation to act alone and achieve success. They will need to partner up with those which have relevant expertise regarding the design and manufacture of the lamp, or access to relevant distribution channels so that they may become the 'Regional Representatives' of FACT Foundation.
There are of course risks involved in such collaborations, a lot of time and money must be invested, but the chances for success will also increase tenfold.

Conclusions

This report documents the process of designing a Product Service System including a business model for a battery charging station for the BoP. The initial starting point was to research, develop and test an off-grid biogas-based energy distribution system for Lutoboka Village in Uganda.

Our trip to Uganda to carry out field research allowed us to make observations and these findings eventually led to a change in the focus of the project. Based on certain problems which were identified in the existing brief, and new opportunities which were initially overlooked, we were able to optimise this charging station and reshape the project to become a more feasible, future-oriented enterprise.

The resulting final concept enables FACT Foundation to distribute their extensive technical know-how about bioenergy to off-grid locations. It also assists potential entrepreneurs in setting up their own business, which in turn improves the well-being of their communities.

Additionally, the original concept of charging batteries has changed to include a new product which will contain a similar battery. This was based on our assessment of the local energy needs, and includes a phone charger and a radio, two things we found to be very important for our target user.

This solution represents a strategic move for FACT into new territory, as well as a socially significant impact on the lives of many.

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