SECTION II – ENERGY RECOVERY FROM ORGANIC WASTE

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Recovering energy from waste: An overview of presented business cases and models

Access to affordable and sustainable energy is key to economic prosperity and sustainable development in developing countries. Energy plays a critical role not only in ensuring quality of life at individual or household level but also as one of the factors of production whose cost affects other goods and services (Amigun et al., 2008). Access to energy or the lack of it affects all facets of development: social, economic and environmental aspects. It is the key to sustaining the livelihood of the poor as well as ensuring industrial development of a country. Energy is crucial for achieving almost all of the Sustainable Development Goals (SDGs), from eradication of poverty through advancements in health, education, water supply and industrialization, to combating climate change (UN, 2016). SDG 7 is dedicated to the access to affordable, reliable, sustainable and modern energy for all, with target 7.2 calling for a substantial increase of the share of renewable energy including power derived from solid and liquid biofuels, biogas and waste.

With the aim of achieving a more sustainable natural environment while providing reliable and affordable energy to different sectors of the economy, interest in alternative sources of energy as a means of reducing dependence on fossil fuels has grown. Studies have shown that energy demand will increase during this century by a factor of two or three while about 88% of this demand is met by fossil fuels (IEA, 2006). The negative effects of the conventional energy sources coupled with the limited capacity of current energy infrastructure and the increase in energy demand have spurred interest in alternative sources of energy which are environment friendly and renewable.

Around 3 billion people cook and heat their homes using solid fuels (i.e. wood, charcoal, coal, dung, crop wastes) on open fires or traditional stoves. Such inefficient cooking and heating practices produce high levels of household (indoor) air pollution which includes a range of health-damaging pollutants such as fine particles and carbon monoxide. About 4.3 million people a year die from the exposure to household air pollution (WHO, 2016).

Under increasing deforestation, the global waste to energy market was valued at USD 24 billion in 2014 and it is expected to reach USD 36 billion by 2020 – a growth rate of 7.5% (Figure 5). Waste-to-energy is a waste treatment process to generate energy in the form of electricity, heat or fuel from both organic and inorganic waste sources. In this book, the focus is only on cases and models targeting energy generation from biomass (organic waste). While recovering energy from organic waste streams is essential to ensure energy security and sustainable development, waste-to-energy solutions still face numerous barriers including high investment cost, inadequate policy support and insufficient revenue generation due to limited experience with business or cost recovery models. This section addresses this last void, while opportunities and barriers in the enabling environment are discussed in Chapter 19.

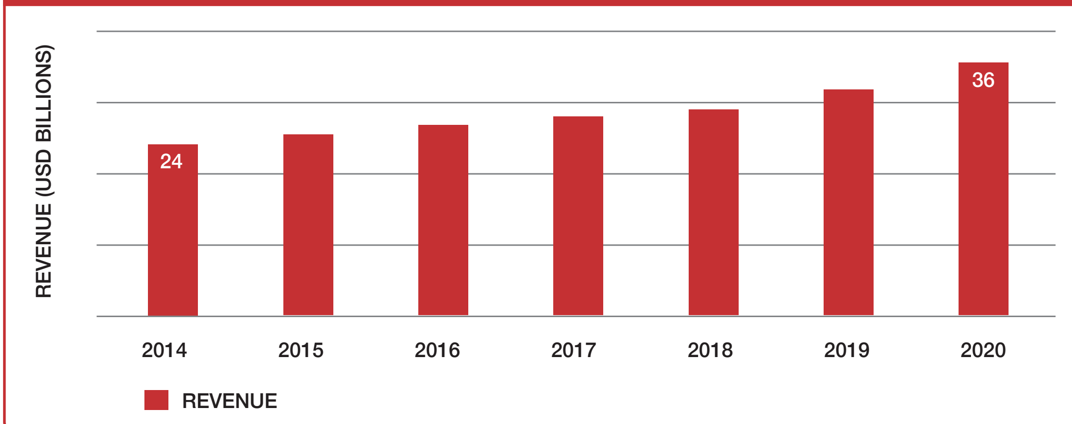
In this section of the catalogue, waste-to-energy conversion process in all the business cases and models can be broadly presented as in Figure 6. The energy recovery models and cases use one of the waste streams (agro-waste, agro-industrial waste and effluent, livestock waste, fecal sludge and organic fraction of municipal solid waste) to produce energy products in solid (briquette), liquid (bio-fuel/ethanol) and gaseous (producer gas and biogas) forms. These energy products are used to generate heat, electricity or fuel for transport.

The energy recovery chapter describes in total 9 business models derived from 19 business cases, and these 9 business models can be broadly classified into 4 categories:

- Production of Solid Fuels from Waste.
- Sustainable and Renewable Power Generation.
- Institutional (In-house) Biogas for Energy Savings.
- Emerging Technologies for Bio-fuel Production from Agro-waste.

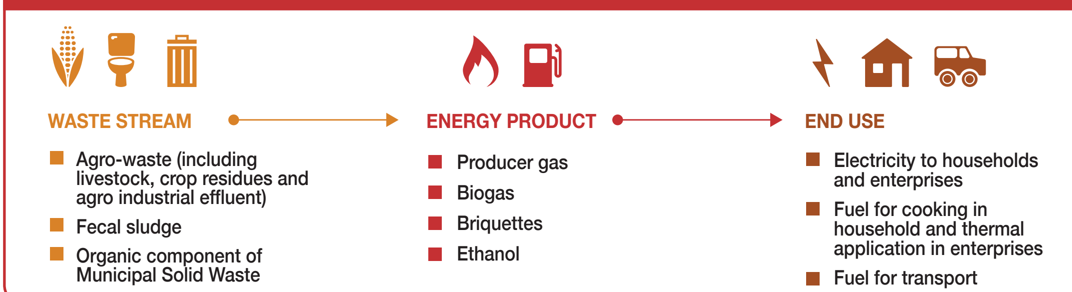
Energy products made from waste can be in one of the three physical forms and a relatively straightforward process is to convert waste into solid fuel by transforming organic fraction of municipal solid waste, market waste and agricultural residues into briquette fuel. This is an emerging scalable model in Sub-Saharan Africa particularly in East Africa and there are similar observations in Asia (**Business models 1 and 2: Briquettes from agro-waste** and **Briquettes from municipal solid waste**). Briquettes are a form of solid fuel produced by compacting loose biomass residues into solid blocks that can be burned for heat energy and can substitute traditional biomass based energy sources such as charcoal and firewood for domestic or institutional cooking as well as for industrial heating processes. The business cases highlight different strategies and processes such as simple technology for ease of maintenance, research and development (R&D) for right combination of different agro-waste to produce high calorific value briquettes as is the case in Kampala Jellitone Suppliers; franchise models to scale operations as is the case in Eco-Fuel Africa in Uganda; and implementation of a public-private partnership (PPP) to get contracts of waste collection as is the case in COOCEN, which is a women cooperative in Rwanda.

FIGURE 5. GLOBAL WASTE-TO-ENERGY MARKET, 2014–2020 (USD BILLION)



Source: ZION Research Analysis, 2016.

FIGURE 6. WASTE-TO-ENERGY PROCESS FRAMEWORK USED IN THIS SECTION



One of the most common waste-to-energy solutions that is widely implemented in developing countries is production of biogas from organic waste. Biogas can be produced from nearly all kind of biological feedstock – various organic waste streams including human waste (Holm-Nielsen et al., 2009). **Business models 3 and 4: Biogas from fecal sludge at community level** and **Biogas from kitchen waste** present institutional biogas models for energy savings. The business case examples are from India, Nepal, the Philippines, Rwanda and Kenya which highlight successful partnership with local authorities, non-governmental organizations and communities for successful implementation.

In this section of the catalogue, biogas production is demonstrated at different scales with the lowest scale of biogas production at the institutional level and large-scale production at industrial level. As the target stakeholder is industries in the later, the scale of waste generated is higher resulting in higher gas production and thus enabling to generate electricity from biogas. This is the case for livestock industry which generates biogas from manure for onsite use (**Business Model 5: Power from manure**). The case examples presented demonstrate rural electrification models from livestock waste along with innovative financing mechanisms of using carbon credits to invest in the technology. For example, Sadia, a company from Brazil, processes meat, and in order to mitigate the social and environmental impacts associated with livestock production systems, it has installed bio-digesters on the farms within its supply chain on a Build, Operate and Transfer (BOT) basis. Sadia uses carbon credit method to finance biogas systems on the farms that supply meat to the processing factory while taking the responsibility of registration of the project as a CDM and the management of the carbon credit revenues.

In addition to business models that highlight power generated from manure, there are also other business models that use agro-waste or municipal solid waste (MSW) to generate electricity (**Business Models 6–8: Power from agro-waste; Power from municipal solid waste (MSW);** and **Combined heat and power from agro-industrial waste for on- and off-site use).** Agro-processing industries, such as sugar and palm oil factories, and slaughterhouses in low-income countries, are diversifying into creating by-product value addition through co-generation and bioethanol production. The energy production technologies are either owned and operated by the factory or are installed by an external private entity on a Build, Own, Operate, Transfer (BOOT) model. These business models allow agro-industries to be self-sufficient in energy while securing additional revenue streams by exporting excess electricity to the national grid and trading carbon credits. The cases here also highlight social enterprise models for rural electrification.

In this section of the Resource Recovery and Reuse (RRR) catalogue, while the focus is on innovative energy recovery business models with relatively simple technology, there are also few business models and cases which use more sophisticated and high investment cost energy solutions. There is limited focus on advanced technologies to produce biogas, syngas and liquid fuels except in the case of **Business model 9: Bio-ethanol and chemical products from agro and agro-industrial waste** which highlights production of biofuel from cellulosic sources such as agro-waste produced from mills processing cassava, rice, wheat, coffee and so on. The model also covers processing of vinasse waste generated during ethanol production. Vinasse can be used to produce an organic binder (lignosulfonates) which has numerous applications across many industries.

Further business cases and models where energy generation plays a role are presented in the section **on wastewater treatment for reuse**.

Waste-to-energy business cases and models described in this section demonstrate improved economic viability from RRR to provide not only environmentally beneficial solutions along with increased energy

access to governments, donors, entrepreneurs and non-government organizations in developing countries but also offer larger socio-economic benefits from safe waste management. By adopting these solutions, they not only help meet the ever-increasing demand for energy but also pull out millions of underserved communities from extreme poverty in an environmentally responsible manner. For increased energy security and to meet SDG 7 indicators, there is a need to triple investments in sustainable energy infrastructure per year from USD 400 billion to USD 1.25 trillion by 2030 (UN, 2016) and waste-to-energy RRR business models and cases provide a means to achieve not only SDG 7 indicators, but also, for example, SDG 12.5 to substantially reduce waste generation through prevention, reduction, recycling and reuse.

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3. BUSINESS MODELS FOR SOLID FUEL PRODUCTION FROM WASTE

Introduction

Urban and rural populations in developing countries predominantly depend on traditional biomass fuels such as charcoal and firewood for cooking due to lack of affordability and access to modern fuels. Despite more than a decade of work to reduce domestic air pollution sources, progress toward universal access to clean cooking fuels remains far too slow. According to the World Health Organization (WHO, 2016), almost 3.1 billion people still rely on polluting, inefficient energy systems, such as biomass, coal or kerosene, to meet their daily cooking needs – a number virtually unchanged over the past decade. The same applies to heating and lighting. For instance, almost half of all African households across the 25 countries surveyed by WHO rely primarily upon highly-polluting kerosene lamps, compared to about 30% of households surveyed in South-East Asia. Women and girls bear the largest health burden not only from domestic pollution sources, but often also from related fuel-gathering tasks. For instance, available survey data from 13 countries showed that girls in sub-Saharan African homes with polluting cook stoves spend about 18 hours weekly collecting fuel or water, while boys spend 15 hours. In homes mainly using cleaner stoves and fuels, girls spend only 5 hours weekly collecting fuel or water, and boys just 2 hours (WHO, 2016). There are also environmental impacts, such as deforestation and climate change, associated with the consumption of charcoal and firewood due to the unsustainable nature of their production and use.

Overdependence on firewood has resulted in reduced availability and consequently necessitates the efficient utilization of agricultural residues and municipal solid waste as a source of heating and cooking fuel by transforming them into alternative fuel products called briquettes. The briquette business model aims to tap into this potentially vast market by providing urban and rural populations with affordable and environmentally friendly alternative efficient fuel products. In developing countries, the briquette industry is gaining momentum in certain regions such as in East Africa and Asia. The empirical business cases, which led to this business model, are primarily from East Africa as there is more experience in briquette business in this region.

The business models (**Business Models 1 and 2: Briquettes from agro-waste** and **Briquettes from MSW**) highlight production of briquettes from different waste streams, carbonized or non-carbonized, and distinguish between end users such as households, and commercial and institutional users which have different needs and requirements. Competition from alternative fuels, firewood and charcoal, is a major threat to the success of this business model. Thus, to compete with alternative fuels, different strategies are used such as targeting of segmented market, designing an efficient and effective value chain using local technology to reduce production cost and providing products with consistent quality.

References and further readings

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CASE

Briquettes from agro-waste (Kampala Jellitone Suppliers, Uganda)

Solomie Gebrezgabher and Abasi Musisi

Supporting case for Business Model 1	
Location:	Kampala, Uganda
Waste input type:	Agricultural farm waste/residues (saw dust, millet husks, ground nut shells, wheat bran, maize combs, coffee husks)
Value offer:	Briquettes (Clean cooking fuel), briquette burning stoves
Organization type:	Private
Status of organization:	Operational since 2001 (briquette business)
Scale of businesses:	Medium
Major partners:	Fuel from Waste Research Centre, Danish International Development Agency (DANIDA), United States Africa Development Foundation (USADF), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)

Executive summary

Kampala Jellitone Suppliers (KJS) is a limited company located in Kampala, Uganda that produces non-carbonized briquette from agricultural residues. KJS has been operational since 1981 and at the time of the assessment employed over 100 people, 70% being women. The company started with roasting coffee using diesel burners, followed by a bakery that used firewood ovens. The baking and roasting propelled the need to look for an alternative fuel source and gave rise to the production of briquettes made from agricultural waste. This has led to KJS becoming the first large scale non-carbonized briquette producer in Uganda and wining the ASHDEN Global Green Awards in June 2009. Its clients now include institutional and commercial users who previously used wood fuel and charcoal for cooking and heating. KJS provides them with briquettes which have high heating value and consistent properties and burn longer than alternative cooking fuel, as well as selling efficient briquette-burning stoves. The company has also set up the Fuel from Wastes Research Centre (FWRC), an NGO which conducts innovative research and development in suitability of agricultural wastes for briquetting, briquette making, and designing and manufacturing of briquette burning stoves.

KEY PERFORMANCE INDICATORS (AS OF 2012)						
Land use:	2.4 ha					
Capital investment:	USD 698,964					
Labor:	100 full-time workers and 400 external laborers along the value chain					
Operation and Maintenance (O &M) cost:	0.240–0.260 USD/kg of briquette					
Output:	1,680 tons of briquettes per year based on one shift operation					
Potential social and /or environmental impact:	Savings to users of 0.08–0.32 USD/kg compared to charcoal, CO_2 emission savings of approx. 6.1 ton CO_2/ton of briquettes, additional income to farmers – USD 3 to USD 14 per ton of input					
Financial viability indicators:	Payback period:	14.5 years	Post-tax IRR:	7%	Gross margin:	10%

Context and background

Kampala Jellitone Suppliers, Kampala, Uganda was founded in 1976 to produce cosmetic products from petroleum jelly. KJS diversified into coffee processing and baking, using liquefied petroleum gas (LPG) as the fuel. In 1992, KJS started to look for cheaper alternative fuels. The production of briquettes was initially started to meet internal energy needs for coffee roasting and bakery, but KJS soon recognized the potential and became a large-scale producer of non-carbonized briquettes. As well as manufacturing briquettes which provides a cleaner, cheap and easy to handle cooking fuel, it also supplies efficient briquette-burning stoves. The initial business set up was supported by the Danish Embassy through Danish International Development Agency (DANIDA), which funded a feasibility study on biomass briquetting and assisted KJS to buy the first briquetting machine, and carry out research in briquetting technology. The company is now selling briquettes to 35 institutions including schools, hospitals and factories. It is financed by its founder and own income, as well as grants from DANIDA (USD 100,000) and the United States African Development Foundation (USADF) (USD 85,000) for developing business plans and staff training.

Market environment

Biomass is still the most important source of energy for the majority of the Ugandan population. About 90% of the total primary energy consumption is generated through biomass, which can be separated in firewood (78.6%), charcoal (5.6%) and crop residues (4.7%). Firewood was most commonly used by rural households (86%) while charcoal is commonly used in urban areas (70%). In Kampala, 76% of the population use 205,852 tonnes per year of charcoal as their main source of fuel for cooking. The urban household use accounted for about 70% of that demand while commercial establishments, such as hotels, accounted for 25%. The charcoal use is estimated to increase at 6% per year, which matches the rate of urbanization. High demand for wood fuels used inefficiently results in overuse and depletion of forests. About 90,000 hectares (equals 900 km^2) of forest cover are lost annually, which leads to fuel wood scarcity in rural areas and increasing price levels of charcoal and fuel wood. The production of charcoal is carried out under primitive conditions with an extremely low efficiency at 10–12% on weight-out to weigh-in basis and an efficiency rate on calorific value basis at 22%. At the same time, households use biomass in a very inefficient way as the three-stone fire is still widely used.

Non-carbonized briquettes serve as a replacement to natural firewood and raw biomass fuel. They offer greater energy per unit weight than wood or raw biomass but release as much smoke. Consequently, these are more appropriate for industrial/commercial processes or institutions where emissions can be controlled. Customers like the convenience of buying, handling and storing briquettes. The cooks like

the reduced smoke, heat and charcoal dust, and faster cooking. Table 5 shows the prices of briquettes and other competing fuels in Kampala. The financial savings are significant where charcoal has been used in the past. One primary school now spends USD 24 (51,000 USh) per day on briquettes, instead of about USD 32 (69,000 USh) per day on charcoal.

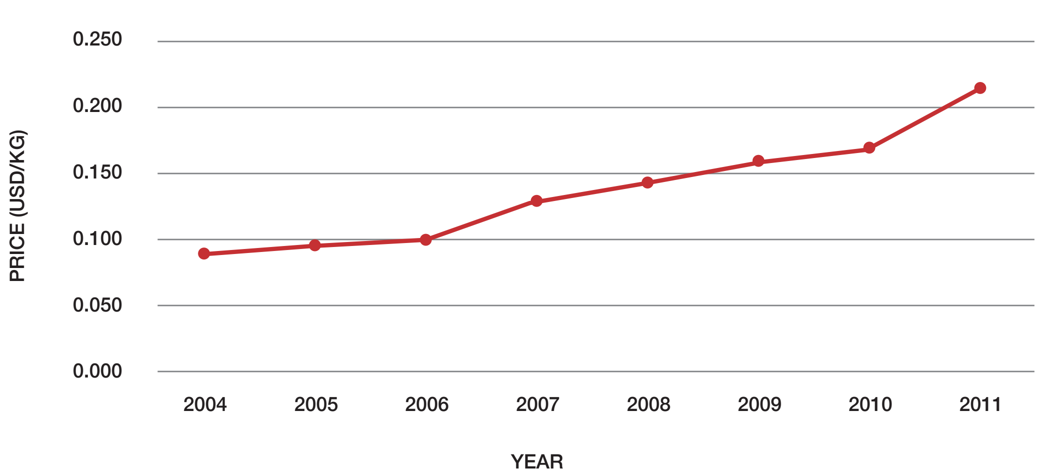
TABLE 5. PRICES OF BRIQUETTES AND ALTERNATIVE FUELS (DEC 2011)

FUEL TYPE	PRICE (USD/KG)
Eco-Fuel Africa briquettes	0.17
Firewood	0.24
Kampala Jellitone Suppliers Ltd. briquettes	0.28
Informal producers briquettes	0.40
Charcoal	0.60

Source: Ferguson, 2012; Personal communication with Eco-Fuel Africa; Personal communication with KJS

In Uganda, there are 180,000 schools and a wide range of agricultural and food processing businesses that could use briquettes. Institutional stoves cost around USD 740 (1.6 million USh). About 65% of customers pay KJS for the stove in installments, others pay the full cost at the time of installation. KJS recently dropped the domestic users due to lack of briquette stoves on the market to match the briquettes whereas for the other segments, the briquettes can be used without modifications in the existing stove. Hence, there is a considerable opportunity and scope to expand production and supply the existing client base. Recent increases in charcoal prices, as shown in Figure 7, have created an opportunity for briquette businesses to serve these users.

FIGURE 7. CHARCOAL PRICE IN KAMPALA, UGANDA, 2004–2011



Source: Uganda Bureau of Statistics, 2010 and 2012.

Macro-economic environment

The biomass has historically been a cheap and accessible source of fuel for Uganda's population but this is unlikely to continue. The FAO reported that between 1990 and 2005 Uganda lost 26% of its forests (78% in areas around Kampala), and the National Environment Management Authority (NEMA)

State of the Environment Uganda 2008 report predicts that this deficit will lead to complete depletion of the nation's forests by 2050. The unsustainable levels of the charcoal production operations are increasingly a source of environmental concern, especially considering that slow-growing, hard-wood tree species are targeted without plans for replacement planting.

The contribution of firewood and charcoal to Uganda's GDP is estimated at USD 48 million and USD 26.8 million respectively (UNIDO, 2015). The fact that the biomass wood industry represents a significant economic activity implies that wood fuel will continue to be the dominant source of energy in Uganda for the foreseeable future. This has implications for briquette business as the success of briquette business depends on its price competitiveness to the wood fuel/charcoal. In terms of employment, biomass production creates nearly 20,000 jobs for Ugandans.

Business model

KJS implements a value-driven business model. The establishment and partnership with the Fuel from Wastes Research Centre has enabled KJS to be innovative in its use of varieties of agricultural waste, in making consistent quality briquettes and in designing efficient stoves (Figure 8). Briquettes are sold via distributors while briquette stoves are customized and installed at the user's site. The company provides its briquette and stove customers pre-sales and post-sales support by giving a training/demonstration on how to use the products. It also conducts sensitization and training workshops for farmers on the best ways possible to preserve the agricultural wastes by milling it before delivery to allow the transport of larger quantities as well as for end users on how to use the briquettes and stoves effectively and efficiently to get value for their money. Thanks to these practices, KJS has been making profits for the last five years and has plans to scale up its operations by targeting industries which rely on biomass for industrial energy supply, such as cement factories, bricks, tile production, etc.

FIGURE 8. KAMPALA JELLITONE SUPPLIERS LTD BUSINESS MODEL CANVAS

KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITIONS	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
• Fuel from Waste Research Centre • Farmers • Transport companies • DANIDA, USADF, GiZ	• Train agricultural residue producers • Research different agricultural residues for briquette production • Buy farm agricultural residue • Produce and sell briquettes • Manufacture stoves • Train clients (post-sales support) • Install stoves	• Low cost and reduced smoke cooking fuel with consistent properties • High efficient briquette-burning stoves	• Direct or via distributors	• Institutional and commercial briquette users • Institutional and commercial stove users

KEY RESOURCES

- Financial resources
- Laboratory
- Research expertise
- Land, building, equipment, labor
- Agricultural residue
- Training
- Name, brand, ASHDEN, reputation

CHANNELS

- Direct or via Distributors
- Pre-sales awareness and after-sales support to users

COST STRUCTURE

- Investment cost (Land, building, briquetting machines)
- Environmental impact assessment cost
- Operational cost, marketing and packaging cost
- Tax = 18% VAT and 6% withholding for all governmental institutions KJS supplies
- R&D
- Stove installation services

REVENUE STREAMS

- Sales of briquettes
- Sales of stoves

SOCIAL & ENVIRONMENTAL COSTS

- Laborers' health risk due to handling of waste and/or inorganic/foreign particles such as glass and plastic
- Loss of jobs (livelihood) for charcoal and wood fuel traders

SOCIAL & ENVIRONMENTAL BENEFITS

- Contribute to reduction of deforestation
- Reduction of environmental pollution
- Reduction of open burning of agricultural residues
- Energy saving
- Creation of jobs/additional income for farmers
- Improved household/users' health

Value chain and position

KJS is overlooking all the activities across the value chain from research, supply of inputs to final sales of briquettes and stoves (Figure 9). KJS conducts its own research in briquette making and stove manufacturing through the Fuel from Wastes Research Centre, a research NGO set up by the company.

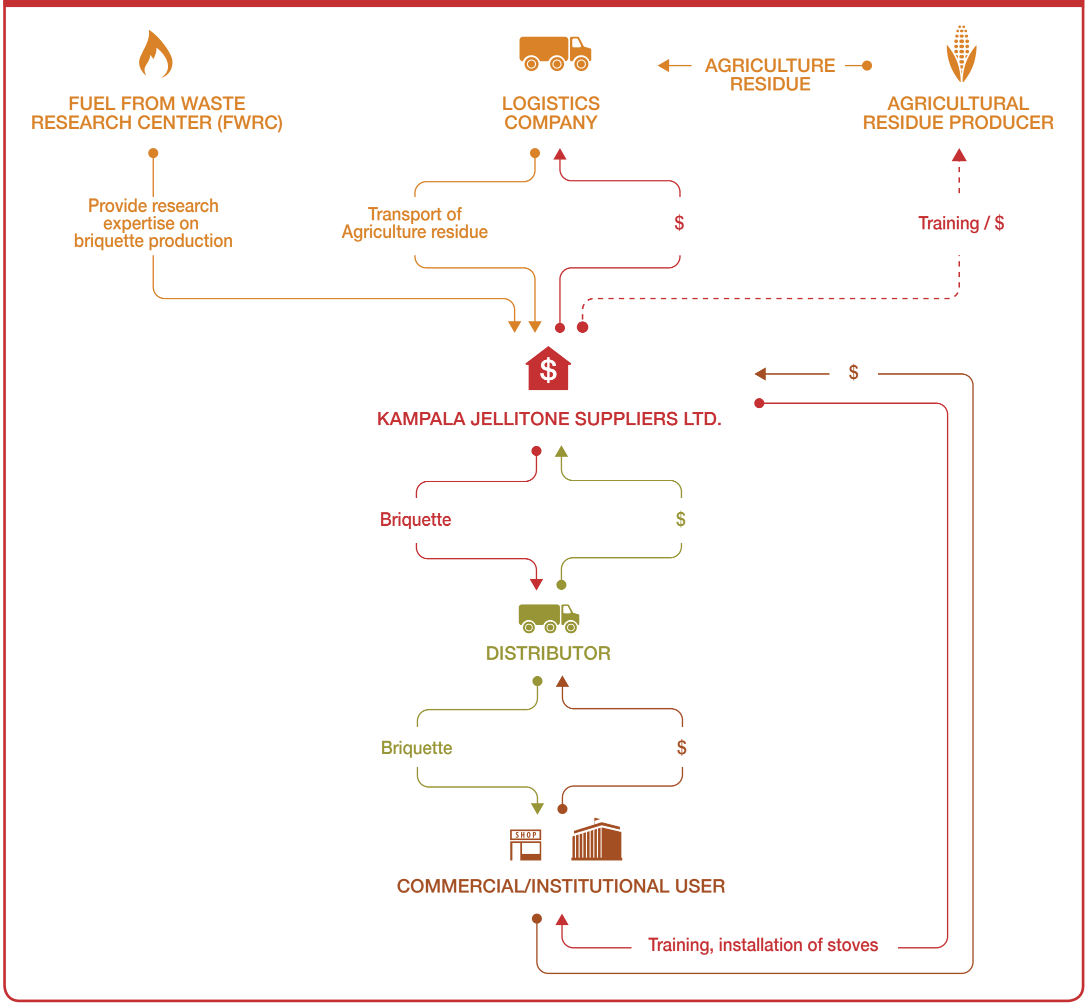
KJS's customer segments include institutional and commercial users which previously used firewood for cooking and heating. Although prices of firewood are high which gives briquettes a competitive advantage, buyers can easily shift back to firewood as briquettes are used without modifications in the

existing stoves. Threat from existing briquette businesses or new entrants is low. KJS is the first large-scale non-carbonized briquette producer in Uganda. The majorities of briquette producers in Uganda are small-scale and are targeting household customer segment. Furthermore, a high investment cost is required to start up a large-scale briquetting business.

Input suppliers (farmers) are key partners as KJS depends on their reliable supply of agricultural waste. The processing of commercial crops generates large volumes of biomass residues including rice husks, coffee pulp and maize stalks. These, along with sawdust from sawmills and furniture factories, often go to waste. Residues are usually simply dumped in large heaps which are then burned to dispose of them. Data provided by the government in the Uganda Renewable Energy Policy 2007 suggests that 1.2 million tons of agricultural residues are available each year.

KJS briquetting business has created employment opportunities and has generated additional incomes to its agricultural residue input suppliers. KJS employs about 100 staff at the factory, and also uses contractor to collect the residues from the agricultural processors and sawmills and other

FIGURE 9. KAMPALA JELLITONE SUPPLIERS LTD VALUE CHAIN



haulage companies to deliver briquettes to customers. The residue producers are paid between USD 3 and USD 14 (6,000 and 30,000 USh) per ton of residue and earn extra income from something that was once regarded as waste. KJS pays a higher price for processed feedstock (already milled) and are seeking to supply farmers with milling machines in an attempt to improve transport efficiency.

Institutional environment

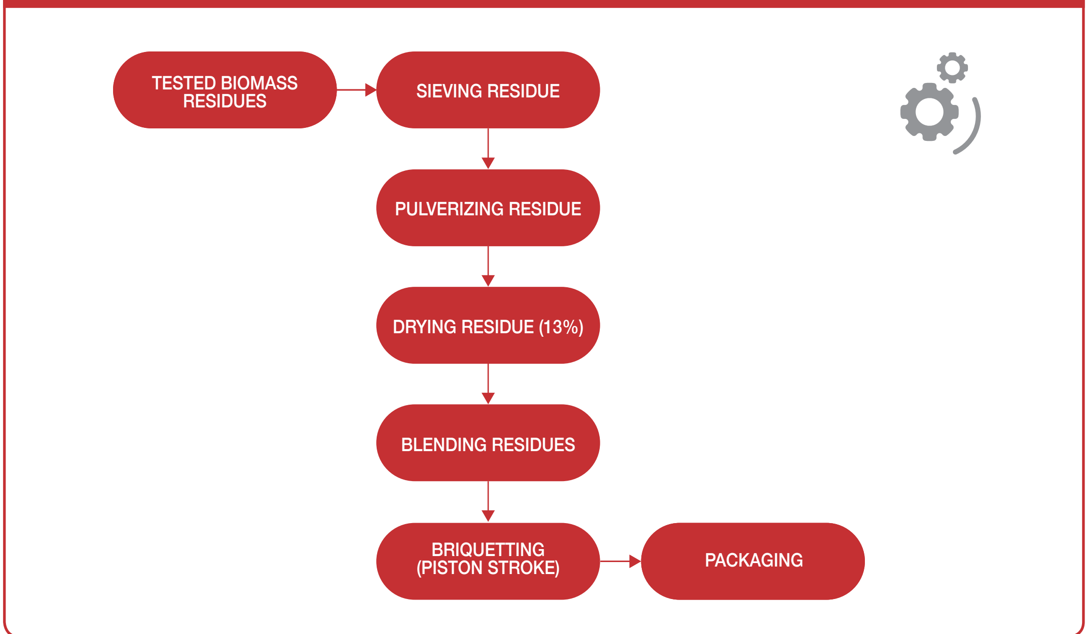
In order to support alternative clean energy initiatives, government strategy on the demand side is dissemination of more energy efficient technologies (Renewable Energy Policy, 2007). Furthermore, with support from the UNDP, the government is implementing key interventions in charcoal production which includes increasing the charge that the National Forestry Authority levies on charcoal burners. This provides an opportunity for alternative fuels to compete further with the cost of charcoal.

Several initiatives to conserve biomass resources have been undertaken by government and the private sector, including NGOs. These include the promotion of improved stoves and afforestation. However, the impact of these efforts is still limited.

Technology and processes

A study conducted by KJS funded by DANIDA in 2002 identified 16 possible agricultural farm waste/residues, such as coffee husk, rice husk, sawdust, wheat, groundnut husks, etc., that could be used for making briquettes. Before production takes place, the agricultural waste undergoes intensive tests to ascertain different characteristics including burning characteristics, ash content and the calorific value (Figure 10). At the factory, the residues are sieved (to remove large pieces, glasses and stones), pulverized using a hammer mill and dried to a moisture content of 13% using a flash drier in addition to sun-drying. Each agricultural residue is then blended by pouring it into a separate hopper which feeds it into a mixing machine to get a homogeneous mixture of different materials with the required

FIGURE 10. PROCESS DIAGRAM OF KAMPALA JELLITONE SUPPLIERS LTD BRIQUETTING



proportions. The mixed biomass is fed into the briquetting machine which compresses it using a piston stroke. KJS operates two imported electrically-powered piston machines with a combined capacity of 1.25 tonnes per hour (3,500 tonnes per year) as well as an industrial drier for drying feedstock. However, these machines do not operate at full capacity, limited by the throughput of the feedstock drying process. Under pressure, the natural lignin in the agricultural residues binds the particles together to form a solid block and thus the use of binders is not necessary in this process. Finally, the agricultural wastes are compressed into a solid particle with a heat value of about 14.5 MJ/kg and packed in sacks (40 kg) ready for delivery. The sacks are held in a dry store until delivery to the customers. KJS has also designed an efficient briquette-burning stove, for institutions such as schools and colleges and for food processing industries. The stove is made from fired bricks with a grate and combustion chamber and a chimney to remove the smoke and is constructed on site by KJS staff.

Funding and financial outlook

The total investment cost is estimated to be USD 698,964 (Table 6). The owner invested own cash towards 85% of the total investment and the remaining was obtained from donors. Operational cost including cost of input, labor, utilities, operating and maintenance is estimated to be approx. 238 USD/ton. Marketing and packaging costs are estimated to be approx. 16.3 USD/ton. To meet growing demand, the enterprise plans to expand production. For this it needs to procure 5 briquetting machines with production capacity of 750 kg/hr, trucks to deliver farm residues, agricultural milling machines and other equipment. The whole project requires about USD 2 million. The United States African Development Foundation (USADF) promised to finance about 12.5% (USD 250,000) of the total capital needs.

KJS produced and sold about 1,530 tons of briquettes at a price of 282.8 USD/ton and installed 1,309 institutional stoves for USD 740 in 2009. KJS's sales are estimated to be 1,680 ton of briquettes at a price of 282.8 USD/ton (Table 7).

KJS have registered their venture as a CDM project in Uganda and with support from the Belgian Embassy are aiming to develop an appropriate methodology for carbon financing.

TABLE 6. KJS INVESTMENT AND OPERATIONAL COST OF THE BRIQUETTE UNIT

ITEM	AMOUNT (USD)
Investment cost:	
Land	232,200
Buildings	227,272
Machinery / equipment	234,492
Environmental impact assessment	5,000
Total investment cost	**698,964**
Operational costs:	USD/ton
Input cost	129.2
Labor	23.52
Operating and maintenance	41.92
Utilities	42.16
Marketing	12.16
Packaging	4.16
Vehicle maintenance	1.00
Depreciation	8.00
Total operational costs	**262.12**

TABLE 7. FINANCIAL SUMMARY OF KJS BRIQUETTE BUSINESS (YEAR)[1]

ITEM	AMOUNT (USD/YEAR)
Total revenue from briquette sales *(1680 ton @ 282.8 USD/ton)*	475,104
Total production cost	440,362
Net income	34,742
Net cash flow	48,182
Payback period (Year)	14.5
Internal rate of return (IRR) (%)	7%

Socio-economic, health and environmental impact

In agriculture-based countries like Uganda, there is a vast natural supply of biomass found in the form of agro and forest residues. Often these residues are simply burned in the fields. This is not only an unfortunate waste of an energy source, but it is also a cause for increased pollution in local regions. In combination with an energy-efficient stove, briquette use contributes to reduction of deforestation, helps fight climate change and enables the end user to save money. This business reduces the amount of biomass waste that is discarded, decreasing the incidence of fires and its associated risk and avoids the release of methane due to its decomposition. The briquettes manufactured from the agricultural waste are much cleaner to burn than coal. This business further provides communities with economical and safer sources of energy for cooking. The sale of agricultural wastes by farmers to the factories creates additional source of income thereby improving the incomes of the farmers.

A study by the University of Makerere estimated that 1 ton of briquettes replace 1.2 tons of firewood and 0.3 tons of charcoal. KJS's annual production of 1,680 tons would replace about 2,016 tons of firewood and 504 tons of charcoal. Assuming CO_2 emissions of 1.55 tons and 14.02 tons per ton of firewood and charcoal respectively, this is equivalent to saving emissions of 3,125 tons of CO_2 from wood equivalents and 7,066 tons of CO_2 from charcoal equivalents.

Scalability and replicability considerations

The key drivers for the success of this business are:

- Regulations against cutting down trees.
- Increased charge that the National Forestry Authority levies on charcoal burners.
- Rising prices of charcoal and fuelwood.

KJS is a promising business case with significant potential for scaling-up and replication in Uganda and in other low-income countries where there are regulatory frameworks on use of firewood/charcoal. This business could potentially be up-scaled and replicated in urban centres where access to both raw material and high potential markets for the briquettes exist and charcoal prices are high. KJS's existing clients have a consumption estimated at 1,200 tons per month. KJS's production is just 140 tons per month. There is considerable scope to expand production to 1,060 tons per month from a new briquetting factory and supply the existing client base. KJS has more demand than it can address, mainly because of limited drying capacity. The company is in the process of moving to a new and larger factory to increase production. The project is labor intensive involving the collection of agricultural residues that were formerly burnt as more and more farmers are taking benefit of added income.

Summary assessment – SWOT analysis

The key strength of KJS is application of strategic practices such as conducting its own research in briquette making and stove manufacturing, which enables it to make briquettes with high energy value and consistent properties (Figure 11). KJS maintains good partnership with its input suppliers and good customer relationship. In addition to that, the fact that it won the ASHDEN award will boost its image. The weaknesses of KJS are its challenge to meet market demand due to its inability to maintain consistent supply of briquettes. Opportunities arise from the fact that there is increasing government support for renewable energy and increasing prices of substitute products which result in significant potential demand for briquettes in the future. KJS aims to reduce deforestation and GHG emissions and this presents opportunities for KJS to earn carbon credit sales by registering the business as a CDM project. Competition from alternative fuel providers and availability of and competition for needed raw materials are the largest external threat.

FIGURE 11. SWOT ANALYSIS FOR KJS

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Research expertise and innovation through blending of different residues ▪ Product diversification by selling complementary stoves ▪ Strong partnership with suppliers of input ▪ Good customer relationship through training and installing briquette stoves onsite ▪ Simple substitute for wood without stove modifications ▪ Good image due to winning of the ASHDEN award ▪ Briquettes less expensive than wood and charcoal	**WEAKNESSES** ▪ Loss of household customer segment due to lack of briquette stoves ▪ Failure to maintain consistent production, performance quality and supply of briquettes ▪ High transportation cost of agricultural residues from rural areas ▪ Initial start-up cost ▪ Dusting and high noise levels in production areas ▪ Lack of finance required for expansion
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Significant potential demand for briquettes and briquette stoves ▪ Increasing price, diminishing supply and high demand of substitute products – charcoal and fuelwood ▪ Unused agricultural waste ▪ Carbon credit – registering the business as a CDM project ▪ Government support for renewable energy ▪ Cooperation with rural groups and support from local councils	**THREATS** ▪ Competition from suppliers of raw materials and other dry fuel suppliers, especially from price-driven enterprises ▪ Lack of financing ▪ Customers' behavior – Habitual excess fuel loading ▪ Unstable grid power ▪ A lack of appropriate regulatory, framework and policy ▪ A lack of standards and quality assurance ▪ Domestic markets remain difficult to penetrate due to the lack of awareness (and acceptance) among household consumers and difficult distribution in rural areas

Contributors

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Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflect our best knowledge at the time of the assessments 2015–2016. As business operations are dynamic, data can be subject to change.

Note

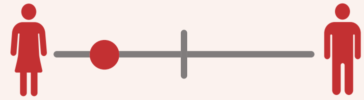
1 KJS has recently introduced additional briquetting line which produces carbonized briquettes to support clients who prefer carbonized briquettes as a replacement to charcoal. However, data was not available to incorporate cash flows into the business case.

BUSINESS MODEL 1

Briquettes from agro-waste

Krishna C. Rao and Solomie Gebrezgabher

A. Key characteristics

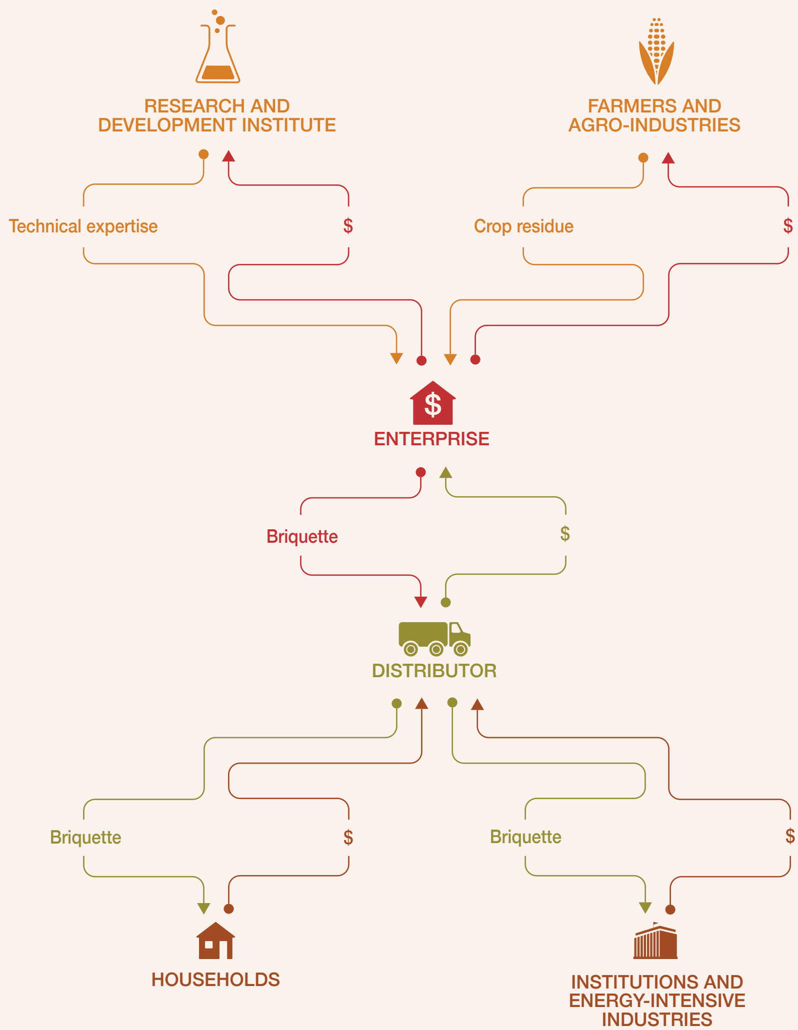
Model name	Briquettes from agro-waste
Waste stream	Agricultural farm waste/residues (saw dust, millet husks, ground nut shells, wheat bran, maize combs, coffee husks, etc.)
Value-added waste product	Briquettes (clean cooking fuel)
Geography	Region with ease of availability of crop residue and lack of ease in availability of fuel wood
Scale of production	Medium scale; 1,000–2,000 tons per year of briquettes
Supporting cases in this book	Kampala, Uganda
Objective of entity	Cost-recovery [ ]; for profit [X]; social enterprise [ ]
Investment cost range	Approx. USD 200,000 to 450,000
Organization type	Private
Socio-economic impact	Reduction in deforestation and environmental pollution, reduced indoor air pollution resulting in improved health for household and employment generation
Gender equity	Beneficial to women and children using fuel with less indoor air pollution than firewood; time savings in fuel collection for women 

B. Business value chain

The business model is initiated by either a standalone private enterprise or agro-industries such as coffee processing units or rice mills that generate large quantities of crop residues as waste. The business processes crop residues such as wheat stalk, rice husk, maize stalk, groundnut shells, coffee husks, saw dust etc. and converts them into non-carbonized briquettes as fuel. Non-carbonized briquettes serve as a replacement to natural firewood and raw biomass fuel. They can also be offered as a replacement fuel among rural populations where firewood is still dominant. Further commercial processes such as drying of crop, drying of tea, curing of tobacco and firing of ceramics/brick can also make use of briquettes. The key actors in the business value chain are the suppliers of crop residue such as farmers and agro-industries, product distributors and end users of the product: households and energy intensive industries (Figure 12).

The characteristics of the agricultural waste including burning characteristics, ash content and the caloric value are first ascertained before making briquettes. The process of briquetting involves sieving of agricultural waste to remove large content such as glasses and stones, pulverizing, drying, mixing of different materials with the required proportions, briquetting using high pressure compression such

FIGURE 12. VALUE CHAIN OF BRIQUETTES FROM AGRO-WASTE



as by piston stroke and using binding agent. The high pressure and resulting high temperature causes the lignin (the natural woody material in plants) to flow and bind the material together. The action of the piston pushes the material through a dye, to make a continuous rod about 50 mm in diameter. The rod cools in the air and breaks into 'sticks' or briquettes about 400 mm long. As multiple crop residues with differing calorific value are the raw material input, it is ideal for the enterprise to collaborate with a research institution to find a suitable combination of crop residue to produce briquettes with higher calorific value and consistent quality.

There are two technologies for making briquettes, reciprocating ram/piston press and screw press technology. The screw pressed briquettes are generally found to be superior to the ram pressed solid briquettes in terms of their storability and combustibility. While the briquettes produced by a piston press are completely solid, screw press briquettes on the other hand have a concentric hole which

gives better combustion characteristics due to a larger specific area. The screw press briquettes are also homogeneous and do not disintegrate easily.

Another option is to produce carbonized briquettes or charcoal from crop residues by burning them in low-oxygen atmosphere. The resulting charred material is compressed into carbonized briquettes. Carbonized briquettes can act as a replacement for charcoal for domestic and institutional cooking and heating, where they are favoured for their near-smokeless use. Moreover, briquettes can be used as fuel for gasifiers and generators to generate electricity or powering boilers to generate steam. The business model described in this section is focused on using briquettes as fuel for thermal applications only.

C. Business model

The primary value proposition of the business model depends on the entity initiating the business model. For an agro-industry generating large quantities of crop residue, the value proposition is to dispose the crop residue to mitigate risks from negative externalities of social and environmental impact and, in the process, incur savings from reduced energy costs. However, for a standalone private enterprise the value proposition is to use crop residue to provide briquettes to households, institutions, such as schools and prisons, and small and medium enterprises that need fuel for heating (Figure 13). The business model described in this chapter presumes the operation for a standalone private enterprise.

The briquettes are delivered to the customers either through direct sales, network of distributors or micro-franchising[1]. The direct sales requires large human resource of sales and marketing team and thus has related challenges associated with managing large staff base. The business requires developing strategic partnerships with farmers and agro industries to ensure reliable supply of crop residues at an agreed price. The key activities of the business model are procurement and processing of crop residue, briquette production and sales. To improve the production efficiency and product quality, training of farmers can be a useful activity so that farmers provide crop residue with lower moisture content and store crop residue in an appropriate manner to reduce moisture content. Research and development (R&D) would be a useful activity to streamline a process that delivers higher calorific value product. However, the cost-benefit of R&D should be assessed and ideally partnership with a research institution would mitigate the risk of need for high-skilled labor.

FIGURE 13. BUSINESS MODEL CANVAS – BRIQUETTES FROM AGRO-WASTE

KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITIONS	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
• Farmers • Agro industries generating crop-residues as waste • R&D institute • Transport companies	• Train input suppliers and (postsale) clients • Research and buy different agricultural residues • Produce, test and sell briquettes • Train clients (post-sales support)	• Customers obtain low cost cooking fuel with consistent properties and less smoke	• Technical support in use of briquettes and stoves directly or through distributors	• Households • Institutional users • Small and medium enterprises • Voluntary Emission Reduction (VER) market

KEY RESOURCES

- Financial resources
- Laboratory
- Research, engineering, training and extension expertise
- Crop residue
- Network of distributors
- Marketing and sales force
- Contracts with institutional users and small-medium enterprises

CHANNELS

- Direct interaction with users as well as agricultural waste suppliers/farmers
- Pre-sales awareness and after-sales support to users
- Distributors
- Micro-franchisees

COST STRUCTURE

- Investment cost – Land, building, and machinery
- Operational cost - Transportation, labor, utilities, maintenance, marketing and packaging, training of farmers and distributors/micro-franchisees and voluntary emissions reductions costs

REVENUE STREAMS

- Briquette sales
- VER sales

SOCIAL & ENVIRONMENTAL COSTS

- Laborers' health risk due to handling of waste and/or inorganic/foreign particles such as glass and plastic
- Loss of jobs (livelihood) for charcoal and wood fuel traders

SOCIAL & ENVIRONMENTAL BENEFITS

- Contribute to reduction of deforestation
- Reduction of environmental pollution
- Reduction of open burning of agricultural residues
- Energy saving
- Creation of jobs/additional income for farmers
- Improved household/users' health
- Saves time in the case of time spent in collecting firewood
- Contribute to improving the educational opportunities among girls who previously missed school to fetch firewood

The business enterprise's key capital costs are building and machinery and primary operational costs are transportation, labor, utilities and marketing. Briquette sales is the only revenue source unless the enterprise is able to tap into the carbon market. A briquette enterprise is potentially eligible for carbon offset depending on the type of fuel replaced and the baseline used to calculate benefits from reduced greenhouse gas emission. In comparison to fossil fuels, briquettes produce net lower greenhouse gas

as the raw material inputs are already part of the carbon cycle. Even for regions with high deforestation where wood is used as fuel, briquettes from crop residue will make a strong case for carbon benefits. However, briquette enterprises are unlikely to be individually able to apply for Clean Development Mechanism (CDM) projects due to associated transaction costs, and therefore the preferred route would be to apply via producer associations or for carbon offset on Voluntary Emission Reductions (VERs).

D. Alternative Scenarios

The business model can incorporate two additional value propositions in addition to briquette production from crop residues: a) produce low cost compost, a by-product from briquette production and b) vertical integration of business by manufacturing and selling improved cook stoves and ovens (Figure 14).

Scenario I: Compost production

Production of briquettes results in generation of crop residual waste, which can be used to produce compost. The compost can be either sold or given away to the farmers on good will basis and strengthen their relationship with farmers for reliable supply of crop residue. The additional key activity required for this value proposition is production of compost and related costs incurred. The sales and distribution process will be similar to sales of briquettes.

Scenario II: Manufacturing of improved cook stoves

The business model offers scope for vertical integration as the briquette enterprise could potentially manufacture improved cook stoves and ovens that use the briquettes produced by the enterprise. The improved cook stoves have high social benefits for households especially for women and children through reduced indoor air pollution. In addition, with improved cooking efficiency and reduced fuel consumption, household would earn savings. The business model does not require significant alteration to its distribution process. The additional key activity required is for the manufacturing of improved cook stoves, which has related capital and operational costs. Similar to briquette production, R&D is a required activity to design the cook stoves and oven that meet the customer's requirements. The product also requires specific marketing and awareness campaign.

E. Potential risks and mitigation

Market risks: Briquettes are targeted for households that do not have access to fossil fuels and that are dependent on firewood for cooking. This customer segment has low market risks in the urban areas due to scarcity of firewood. However, in the rural areas in developing countries the market risks for households as customers is high due to free availability of firewood if picked up from forest/plantation on community land. The business should target diverse customer base to mitigate these risks. It is preferred for the business to have both household and institutional customers. The business could also get into bulk contractual arrangement with institutional customers and have assured sales.

Competition risks: Briquettes have strong competition risks from competing alternative products such as charcoal, wood, kerosene and liquefied petroleum gas (LPG). Fuel choice typically depends on availability, consumer preference, price, convenience and at times social status associated in using certain types of fuels like LPG. Ideally briquette should be targeted to customer segment that uses firewood and charcoal because briquettes can be more competitive, convenient and efficient.

Risks associated with stoves are similar to briquette and there are multiple suppliers of different types of stoves in the market. In the case of compost as mentioned above the enterprise could give it away for free as goodwill measure to the farmers in exchange for assured reliable supply of crop residues which can be procured either directly from the farm gate or have the farmers deliver the agro-waste for a fee. A key risk in procuring crop residue from farmers is that with time they are likely to demand

higher price. To mitigate this risk in addition to giving low cost compost for free, the enterprise should target different types of farmers cultivating different crops so as to negate the rising input cost or have a longer-term agreement with the farmers.

Technology performance risks: The technology used is mechanical compressing with a binding agent or pyrolysis. The technology has been widely used commercially and is proven. It doesn't require high skills for operating it and doesn't have complications towards repair and maintenance.

FIGURE 14. BUSINESS MODEL CANVAS – BRIQUETTES FROM AGRO-WASTE ALTERNATIVE SCENARIO

KEY PARTNERS

- Farmers
- Agro industries generating crop-residues as waste
- Transport companies
- R&D institute

KEY ACTIVITIES

- Train input suppliers and clients (post-sale support)
- Research and buy different agricultural residue
- Produce, test and sell briquettes made from different agricultural residues
- R&D to optimize different stoves and briquette combinations

KEY RESOURCES

- Financial resources
- Laboratory
- Research, engineering, training and extension expertise
- Crop residue
- Network of distributors
- Marketing and sales force
- Contracts with institutional users and small and medium enterprise

VALUE PROPOSITIONS

- Customers obtain low cost cooking fuel with consistent properties and less smoke
- Provision of efficient and improved cook stove
- Low cost compost

CUSTOMER RELATIONSHIPS

- Technical support in use of briquettes and stoves directly or through distributors

CHANNELS

- Direct interaction with users as well as agricultural waste suppliers/farmers
- Pre-sales awareness and after-sales support to users
- Distributors
- Micro-franchisees

CUSTOMER SEGMENTS

- Households
- Institutional users
- Small and medium enterprises
- Farmers
- Voluntary Emission Reduction (VER) market

COST STRUCTURE

- Investment cost – Land, building, and machinery
- Operational cost – Transportation, labor, utilities, maintenance, marketing and packaging, training of farmers and distributors/ micro-franchisees and VER costs
- Stove production costs

REVENUE STREAMS

- Briquette sales
- Sales of improved cook stoves
- Compost sales
- VER sales

SOCIAL & ENVIRONMENTAL COSTS

- Laborers' health risk due to handling of waste and/or inorganic/foreign particles such as glass and plastic
- Loss of jobs (livelihood) for charcoal and wood fuel traders

SOCIAL & ENVIRONMENTAL BENEFITS

- Contribute to reduction of deforestation
- Reduction of environmental pollution
- Reduction of open burning of agricultural residues
- Energy saving
- Creation of jobs/additional income for farmers
- Improved household/users' health
- Reduce indoor air pollution by substituting wood with cleaner burning fuel and improved cook stoves that give out less smoke
- Saves time in the case of time spent in collecting firewood
- Contribute to improving the educational opportunities among girls who previously missed school to fetch firewood

Political and regulatory risks: In most developing countries, cooking is a social issue and governments in developing countries provide subsidy for fuels such as kerosene and LPG. These competing products are priced lower than briquettes and hence can pose significant risks to the business. Diversifying customer base and including energy intensive small and medium enterprise as primary customers can considerably negate this risk. Increasing government support through financial incentives and policies that promote renewable energy reduce this risk considerably in the long term.

Social-equity-related risks: The model is considered to have more advantages to women as culturally in developing countries women collect fuel wood and do the cooking at household. The model provides employment opportunities and additional revenue for farmers to sell their crop residues. The users of briquettes are low-income households who are using other unhealthy and inefficient fuels, or more costly ones.

Safety, environmental and health risks: Organic waste when left in open begins to decay and releases methane, which is more damaging to the environment than carbon dioxide. The waste-processing technologies are not without problems and pose a number of environmental and health risks if appropriate measures are not taken. The safety and health risks to workers are present and thus standard protection measures should be put in place (Table 8). There is a potential risk for those households where less harmful cooking fuels such as LPG, kerosene or electricity are replaced by biomass briquettes especially without introduction of safer cooking stoves.[2]

TABLE 8. POTENTIAL HEALTH AND ENVIRONMENTAL RISK AND SUGGESTED MITIGATION MEASURES FOR BUSINESS MODEL 1

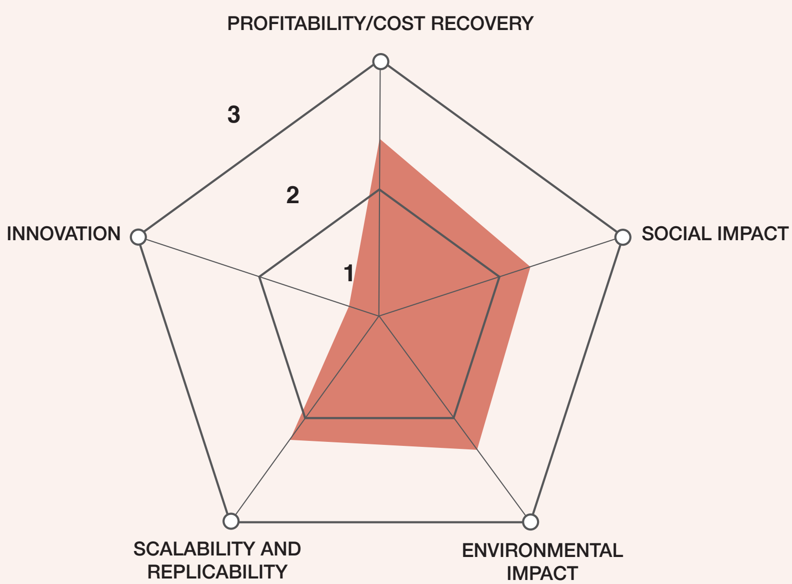
RISK GROUP	EXPOSURE ROUTE					REMARKS
	DIRECT CONTACT	AIR	INSECTS	WATER/ SOIL	FOOD	
Worker						Health risk for households might increase or decrease depending on the quality of the used fuel. Possible exposure to air and noise pollution
Farmer/User						
Community						
Consumer						
Mitigation measures		  				

Key: NOT APPLICABLE; LOW RISK; MEDIUM RISK; HIGH RISK

F. Business Performance

This business model is rated high on profitability followed by environmental impact (Figure 15). The business model has a strong revenue source and diverse customer base. It has potential for additional revenue source from sale of stoves and VERs. The environmental impact is specifically high for regions with deforestation.

FIGURE 15. RANKING RESULTS FOR BRIQUETTES FROM AGRO-WASTE BUSINESS MODEL



The business model has high potential for replication in developing countries as there are no limiting factors such as new technology, special policies and regulations, institutional capacity, waste availability that can limit replication of the business model. It can be scaled horizontally and has potential for vertical scaling by expanding into the business of selling pressing machines for briquettes through a franchising model and getting into manufacturing of improved stoves. It also has a potential to be implemented in agriculture intensive regions and which have high usage of firewood and charcoal for cooking. The model is straightforward with no sophisticated or innovative financing and technology requirements and hence scores low on innovation.

Notes

1 Micro-franchising borrows the traditional franchising concept with scaled-down business concepts found in successful franchise organizations. It operates as a micro-enterprise following proven marketing and operational concepts with systematic replication. The concept is predominant in delivering services to the poor along the lines of microfinance and microcredit. Micro-franchise entrepreneur has similarities to an agriculture extension worker and typically such an entrepreneur sells multiple product like seeds, fertilizers, water filters, Fast Moving Consumer Goods (FMCG) etc.

2 Winkler, M.S., Fuhrimann, S., Pham-Duc, P., Cissé, G., Utzinger, J., Nguyen-Viet H., 2017. Assessing potential health impacts of waste recovery and reuse business models in Hanoi, Vietnam. Int J Public Health 62 (Suppl 1): 7–16.

CASE

Briquettes from municipal solid waste (COOCEN, Kigali, Rwanda)

Andrew Adam-Bradford and Solomie Gebrezgabher

Supporting business case for Business Model 2	
Location:	Kigali, Rwanda
Waste input type:	Municipal solid waste (MSW)
Value offer:	Briquettes (Clean cooking fuel) and compost
Organization type:	Cooperative/Public-private partnership (PPP)
Status of organization:	Operational since 2002
Scale of businesses:	Medium
Major partners:	Kigali City Council, UNDP, city residents

Executive summary

Coopérative Pour La Conservation De L'Environement (COOCEN), established in 2002, is a women's cooperative that delivers waste collection and briquette production service in the low-income Nyamirambo District of Kigali, Rwanda through the implementation of a public-private partnership (PPP) with the Kigali City Council. The PPP is based on the delivery of waste collection services by COOCEN, and as a component of the partnership, the Kigali City Council provided 7 ha of land in Nyamirambo District for COOCEN from where the primary waste sorting and briquette production takes place. At the time of the assessment, the cooperative collected waste from more than 4,000 households for a fee, while till now demand for briquettes constantly exceeds production. The reason is that COOCEN is the sole supplier of fuel briquettes to 16 prisons in Rwanda, which has become a sustained market segment. The cooperative provides solutions to various issues related to the environment and to living conditions of communities. COOCEN contributes to cleaning of the city and provides sanitation services to local communities, which benefit from improved health and sanitary conditions. It contributes to reduction of CO_2 emissions and to reduction of deforestation by avoiding the burning of firewood. In addition to these, the cooperative generates employment, mostly to women.

KEY PERFORMANCE INDICATORS (DATA AS OF 2012)						
Land use	7 ha					
Capital investment:	USD 162,075					
Labor:	110 workers (90% women)					
O&M cost:	USD 94,875					
Output:	1,500 ton/year (retailed at 0.122 USD/kg)					
Potential social and/ or environmental impact:	Job creation and income generation (women members earn 50 USD/month), households benefit from improved sanitary and health conditions, avoided burning of firewood of 1,200 tons/year, CO_2 emission saving of 297 tons/year					
Financial viability indicators	Payback period:	3	Post-tax IRR:	N.A.	Gross margin:	42%

Context and background

COOCEN initially focused on waste collection in a congested urban area that previously had no waste collection facilities or services. The cooperative expanded its operations and constructed a briquette production plant in the low-income Kimisagara Sector of Nyamirambo District. It collects waste from 4,000 households for a fee, sorts waste, extracts organic fragment and produces briquettes from organic components through the implementation of a strategic PPP with the Kigali City Council. As the component of the partnership, the Kigali City Council provided 7 ha of land to COOCEN. The project obtained further financial assistance from the Global Environmental Facility's Small Grants Programme (GEF-SGP), implemented by the United Nations Development Programme (UNDP). Environmental conservation is a key component of the COOCEN strategy and was an instrumental aspect to securing project grants from the European Union (EU) and UNDP. At the assessment time, the cooperative produced and sold around 1,500 tonnes of briquettes per year to schools, prisons and factories.

Market environment

In the capital of Rwanda, Kigali, wood and charcoal are the primary sources of fuel used for cooking and heating, causing major environmental problems such as deforestation and pollution. Charcoal is the preferred fuel for urban households, serving 51% of households, and demand is pushing up the price. As Rwanda also faces a serious wood fuel deficit, there is a need for alternative sources of fuel. Between 2007 and 2012, the amount of municipal solid waste (MSW) grew almost fourfold. COOCEN's environmentally friendly briquette made from MSW is retailed at 0.122 USD/kg while the price of charcoal in 2014 was 0.20–0.22 USD/kg. However, about 1.6 kg of MSW briquettes will be required to replace 1 kg of charcoal. So far, demand from its customer segments constantly exceeds production particularly as COOCEN is the sole supplier of fuel briquettes to the Rwandan prison service, which has become a long-term customer. COOCEN anticipates an increase in briquette demand as a result of the rising price of charcoal coupled with the government policy to protect the environment and promote alternative sources of energy. COOCEN is aiming to increase production however, there are constraints due to limited production capacity and availability of capital. COOCEN also acknowledges that overtime competition in briquette production will increase and thus it aims to improve the manufacturing process and the quality of the final product.

Macro-economic environment

The primary energy supply in Rwanda is dominated by wood, which accounts for about 80% of the supply, of which 57% is direct supply and 23% for charcoal (Ndegwa et al., 2011). There is a combined per capita demand of wood (both for fuelwood and charcoal) of 1.93 kg/person/day, which creates an unsustainable situation because it largely surpasses the production capacity of 0.46 kg/capita/day. Rwanda lost 37% of its forest cover (around 117,000 ha) between 1990 and 2010. Firewood is

associated with environmental, social and health problems, stemming from deforestation and the emissions from wood and charcoal burning respectively. Furthermore, population growth is intensifying deforestation and causing more environmental degradation.

Most of the charcoal is consumed in Kigali, and the main supply areas are the rural areas of Southern and Western Provinces, where charcoal is produced using the traditional earth mound kilns with an efficiency of merely 12%. The chief actors in the supply chain are also poor and unable to invest in the expensive and more efficient biomass conversion technologies – a factor resulting in massive wastage of the wood fuel resource. There are significant health and social benefits of transitioning to charcoal, but it is likely to increase the pressure on the limited wood supplies. The country is taking a 'green economy' approach to economic transformation as a priority. Although fuel wood consumption is expected to increase in the short-term, the long-term strategy of the Government of Rwanda is to reduce fuel wood consumption to 50%.

Unlike in many African countries, the demand for wood fuel is met through forest plantations, mostly of eucalyptus, which are owned by the state or districts and by private entities. About 450,000 hectares or 17% of the country is covered by forests, with 46% being natural forests and the rest public and private plantations. Sixty-five percent of the plantations are state and district owned, while institutions and private citizens own 9% and 25% respectively. Thirty percent of the state forests is left for soil protection, which reduces the amount of plantations that can be harvested to 194,000 hectares.

Vision 2010, the Rwanda development strategy has identified a target of increasing the production of wood for fuel and other uses through the expansion of forest and tree cover to 30% of the national land area by 2020. The wood fuel sector is a major economic activity in Rwanda employing about 20,000 people, which in turn support about 300,000 people (Ndegwa et al., 2011). However, Rwanda still faces a serious wood fuel deficit, which directly impacts the availability and affordability of biomass energy including charcoal production. This gives an opportunity for briquette businesses to fill the charcoal supply and demand gap.

Business model

Figure 16 shows the business model for COOCEN. The cooperative collects waste, extracts organic fragment and produces briquettes from organic components and efficient briquettes cook stoves through the implementation of a PPP with the Kigali City Council. As a component of the partnership, the Kigali City Council provides a site (7 ha of land) for COOCEN from where the primary waste sorting and briquette production takes place. Thus, COOCEN's principle business idea is providing a waste collection service to the local community and then converting the organic waste into fuel briquettes, which are sold to prisons, schools, brick factories and in some cases to households. Initially, the cooperative had difficulties motivating the residents to pay for waste collection services. However, through its awareness campaigns about waste, sanitation and the environment, the cooperative was able to change peoples' attitude. Therefore, waste collection fee and sales of briquettes are the two major revenue streams while selling compost and improved cooking stoves are minor revenue streams. The compost is supplied to the Kigali City Council and is used for city greening and urban amenities including flowerbeds, parks and green walls on the steep urban roadsides.

FIGURE 16. COOCEN BUSINESS MODEL CANVAS

KEY PARTNERS

- Community
- Kigali City Council
- Rwanda Environment Management Authority (REMA)
- Other organic waste producers (such as peat)
- UNDP

KEY ACTIVITIES

- Collection of MSW and other organic waste (such as peat)
- Organic fraction separation
- Production and sales of briquettes and compost
- Promotional campaigns

KEY RESOURCES

- Consumables (MSW and peat)
- Human resource
- Capital
- Land as provided through partnership
- Equipment
- REMA certification

VALUE PROPOSITIONS

- Waste collection service
- Environment friendly briquettes that are cheaper than charcoal and wood (price leadership)
- Organic fertilizer (compost)
- Purposely built briquette stoves

CUSTOMER RELATIONSHIPS

- Direct with households for collection of waste
- Short and long-term contract for sale of briquettes with Institutional customers

CHANNELS

- Direct personal help at point of source of MSW with households
- Selling of briquettes to households directly
- Supply of briquettes to institutional customers directly

CUSTOMER SEGMENTS

- Community
- Households
- Kigali City Council
- Prisons, schools, brick factories, households

COST STRUCTURE

- Investment cost
- Building = 67% of total investment cost
- Machinery = 33% of total investment cost
- Operational cost = (input transportation – MSW and peat, labor, disposal of inorganic waste in landfill, Vehicle rental cost, utilities, maintenance, marketing and awareness campaigns)

REVENUE STREAMS

- Waste collection fee (major revenue stream)
- Briquette sales (major revenue stream)
- Compost sales (minor revenue stream)
- Stoves sales (minor revenue stream)

SOCIAL & ENVIRONMENTAL COSTS

- Possible human health risk when treating MSW

SOCIAL & ENVIRONMENTAL BENEFITS

- Contributes to MSW management
- Generates income and employment
- Creates environmental sanitation awareness
- Saves time and energy for users
- Reduces deforestation
- Reduce GHG emissions

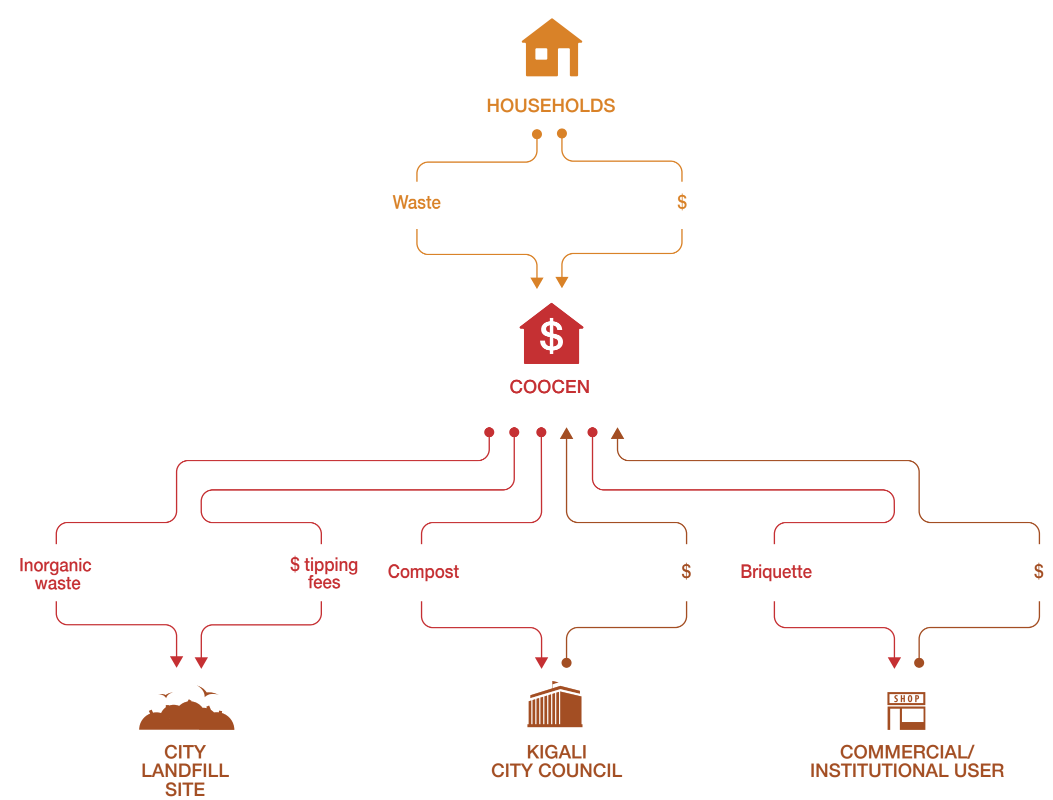
Value chain and position

COOCEN is vertically integrated i.e. it owns the waste collection and briquetting business (Figure 17). As per the recent estimates, about 1.8–2 kg of waste containing 59–65% food waste, is generated per person per day in Kigali (Bazimenyera et al., 2012). Kigali City produces about 100 tons of waste on a daily basis and volume of waste is expected to increase as the population of the city increases.

Currently, the demand for briquettes exceeds supply. COOCEN has a long-term offtake contract with 16 prisons in Rwanda since 2007. The substitute products for briquettes are wood and charcoal. The prices of these substitute products are higher than briquettes, and nowadays, wood is increasingly difficult to get in Rwanda due to government regulations against cutting down trees. With more stringent regulations on cutting down trees and with government policy that promote renewable energy sources, the demand for briquettes from institutions and factories will increase in the future and hence substitute power is low. However, the Rwanda Vision 2010 targets to increase production of wood for fuel through the expansion of forest and tree cover. This may result in more wood available, possibly at a lower price and consequently may dampen briquette market strength.

Moreover, new briquette businesses with more efficient technologies and better product qualities pose a threat to COOCEN due to the fact that its briquette operation is not efficient as it uses mechanical process and heavily relies on uncertain weather conditions to dry its inputs and briquettes. There is

FIGURE 17. COOCEN VALUE CHAIN



also a possibility of installation of bio-digesters at institutions (like prisons) to self-supply biogas for cooking and heating applications. However, it is anticipated that the market for briquettes will grow, which will drive the revenues of briquette business to rise. COOCEN is also looking at the possibility of recycling plastics as an additional income generating activity.

Institutional environment

The main policy objective of the government of Rwanda for the biomass sub-sector is to improve the sustainability of biomass by improving efficiency of use of wood, improving charcoal production methods, facilitate fuel switching from traditional biomass energy carriers toward modern biomass energy technologies, including modern carriers, and cleaner fuel alternatives. The proposal is to decentralize implementation of biomass programmes to the local government levels to improve the impact on the end users, streamline implementation and speed up dissemination. The government has put in place very strict tree harvesting regulations and only licensed persons with tree harvesting permits are allowed to cut trees, including those from private lands.

The Rwandan government initiated an Improved Cook Stove (ICS) programme in the late 1980s or 1990s to combat deforestation. Various programmes have been implemented since, which has led to a penetration rate of "improved'" stoves of over 60% in 2012. However, the World Health Organization (WHO) suggests that some "improved" cook stoves still have emissions 20 times above safe air quality levels and there is a need to provide standards for further improvements. Given that around 85% of all energy in the country is in the form of biomass used for cooking, such an intervention on improving cook stove standards could be one of the most significant interventions in the energy sector.

The Ministry of Infrastructure (MININFRA) is the lead Ministry responsible for developing energy policy and strategy, monitoring and evaluation of projects and programmes implementation. The Department of Energy within MININFRA governs energy policy in Rwanda. The government is targeting to ensure that 80% of households have access to improved cook stoves by 2017 and 100% of households by 2020. The government supports sensitization workshops and training seminars on the economic use of improved cook stoves. This will boost demand for modern and improved cooking technologies, increasing private sector motivation to invest in this business and reduce the use of inefficient and traditional three-stone wood stoves.

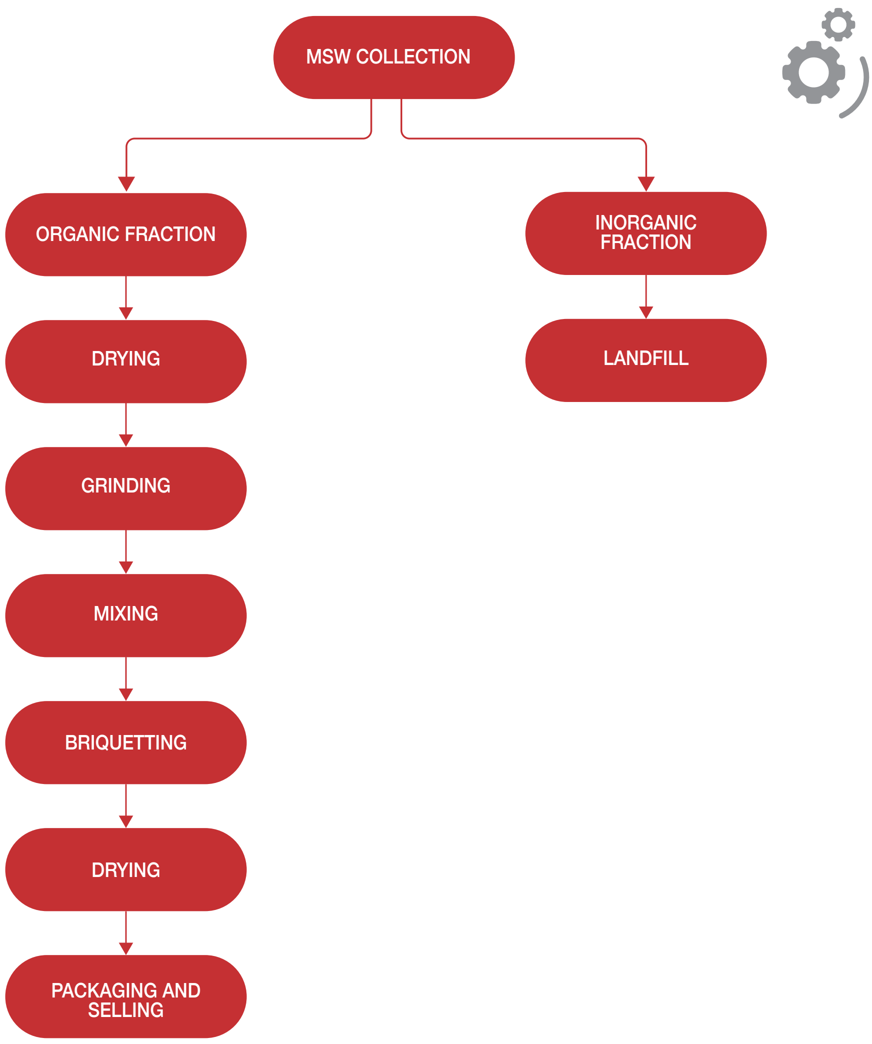
COOCEN has received institutional support in the form of two grants and the provision of land from the Kigali City Council. COOCEN has also been licensed to carry out waste collection services and the project has been certified by the Rwanda Environment Management Authority (REMA) although no specific laws, regulations or policies are in place for briquette production. Rwanda Environment Management Authority (REMA) has the mandate to coordinate, oversee and implement environmental policy. Kigali City has partnered with UNDP for support in areas of technical, financial and maintenance techniques on waste management.

In pursuant of Law no. 39/2001 of 13 September 2001, Rwanda Utilities Regulatory Agency (RURA) was established with a mandate to regulate sanitation services. RURA principal mandate is to ensure consumer protections from uncompetitive practices while ensuring that such utilities operate in an efficient, sustainable and reliable manner. RURA gives consent to any city or town, company, or sector cell, public/ private, to acquire and operate a dump site. It is responsible for improvement in the delivery of sanitation services including waste disposal and management. The Rwanda Development Board (RDB) also plays the lead role in investment mobilization and promotion for the energy sector, acting as a gateway and facilitator. RDB is developing briquette standards for minimum performance and energy requirements.

Technology and processes

COOCEN collects waste from households and brings it to the local COOCEN station where sorting teams separate the organic and inorganic fractions. The organic fraction is solar-dried and then mechanically ground into smaller particles which are then pressed into cylinder compact briquettes (Figure 18). The mechanical technologies that are used for shedding and briquette pressing are based on locally manufactured electricity-driven machines that are easy to operate, maintain and repair. COOCEN also investigated methods of improving the energy efficiency of the briquette through blending of different organic inputs. Consequently, peat is now added as it increases the conformity of the crude materials and also improves the briquette energy efficiency. Peat is a heterogeneous mixture of more or less decomposed plant (humus) material that has accumulated in a water-saturated

FIGURE 18. PROCESS DIAGRAM OF COOCEN



environment and in the absence of oxygen. Peat is sedentarily accumulated material consisting of at least 30% (dry mass) of dead organic material. Peat is also less compactable than organic waste and thus it provides density to the briquette. However, peat increases production costs due to the extraction and transportation costs.

COOCEN is regularly facing technical constraints due to seasonal changes in the weather pattern and due to the limited processing capacity of the briquette pressing machines. In the rainy season, it takes longer to dry the organic matter which can take up to one week to dry before the organic waste is ready for shredding and mixing with other organic fractions. With respect to the processing capacity, COOCEN is equipped with two manually-operated mechanical briquette-pressing machines which have the capacity to produce 10 tons of briquettes per day, but with automated machines this could be increased to 30 tons per day. However, funds to invest in this technology are hard to get.

Funding and financial outlook

The total capital investment of COOCEN is USD 162,075 comprising of building which accounts for 67% of the total investment and machinery accounting for 33% of the total investment (Table 9). The project secured funding of USD 162,075 from an EU grant during its establishment phase in 2002. In 2007, 7 ha of land was provided by the Kigali City Council for the briquette production plant in Nyamirambo District. In the same year, COOCEN received further financial assistance with a grant of USD 43,760 from the UNDP GEF Small Grant Programme and a bank loan to the value of USD 24,311 was also secured.

TABLE 9. COOCEN INVESTMENT, OPERATIONAL AND MARKETING COST

ITEM	AMOUNT (USD)
Investment cost (USD):	
Land	Free
Buildings	108,590
Machinery / equipment	53,485
Total investment cost (USD)	**162,075**
Operational costs (USD/year):	
Waste transportation and collection	42,788
Electricity	49
Water	175
Wages and salaries	38,898
Repairs and maintenance	9,724
Marketing	3,241
Depreciation	10,805
Total operational costs	**105,680**
Revenue (USD/year)	
Sales of briquettes (1,500 ton at 122 USD/ton)	183,000
Sales of compost (50 ton at 5.67 USD/ton)	284
Total revenue from briquette and compost sales	183,284
Revenue from waste collection service	144,000
Profit before tax (PBT) – briquette business	**77,604**
Profit before tax (PBT) – waste collection and briquette business	**221,604**

Socio-economic, health and environmental impact

COOCEN provides waste collection service to communities, contributes to cleaning of the city and provides sanitation services to local communities (more than 4,000 households) which benefit from improved health and sanitary conditions. Emissions from wood fuel stoves without proper ventilation contain poisonous fumes that can cause respiratory and other human health impacts on women and children, who are traditionally charged with the duty of cooking in Africa. Many more suffer respiratory illnesses resulting in reduced productivity, quality of life and exert an additional burden to the community. The improper waste management can result into bad odor, methane gas explosions, risks of garbage landslides and groundwater pollution. However, from an air quality perspective, also dry fuel can result in net negative health impacts if households do not use safer cooking stoves, or switch from gas to briquettes (Winkler et al., 2017).

COOCEN improves both the efficiency of cook stoves in order to close the gap between supply and demand of fuelwood and charcoal. Harvesting of trees for fuel wood and making charcoal contribute to pressures on forests. Briquettes are more efficient and burn more cleanly, preventing release of excess greenhouse gases that are contributing to climate change. COOCEN's briquetting project contributes to reduction of deforestation by avoiding the burning of 1,800 tons of firewood per year or the cutting of at least 9,000 trees per year, which represents around 9 ha of forest plantation (GEF, 2012). The project has also contributed to reduction of 297 tons of CO_2 emissions per year.

The project not only prevents pollution by implementing better waste management, it also recycles materials that would otherwise go to waste. In addition to these, the cooperative employs 110 persons, mostly women, who earn at least 50 USD per month. In Rwanda, nearly 60% of the population lives below the poverty line, with almost 40% living in extreme poverty on less than USD 0.90 per day (http://www.feedthefuture.gov/country/rwanda). In terms of employees' safety and health, employees are equipped with gloves, protective masks and boots to protect them from injuries and respiratory diseases while manipulating garbage.

Scalability and replicability considerations

The key drivers for the success of this business are:

- Strong partnership with city municipality.
- Regulations against cutting down trees.
- Government policy that promote renewable energy sources.
- Rising prices of fuel wood and charcoal.

The briquette making project by COOCEN has shown the importance of empowering community based organizations as key actors in environmental protection. It also demonstrated that socio-economic benefits are key for project sustainability. Kigali City of Rwanda is making progress towards solid waste management partly because of the house-to-house collection system and a franchise system which involved collection, treatment, recycling and disposal of residues. This system in Kigali City is worthy of emulation by cities in other developing countries. High charcoal price is a pre-requisite for the business to be up-scaled and replicated in other regions. There are already on-going projects which demonstrate the replicability of COOCEN in Kigali. For example, a larger-scale project supported by UNIDO, where the biggest garbage collection company in Kigali started to make and promote use of briquettes at the start of 2011 is evidence that this business can be scaled-out and replicated in other cities. Since the enterprise requires procuring municipal solid waste, developing strong partnership ties with city municipalities is important for reliable supply of input.

Summary assessment – SWOT analysis

The strength of the cooperative business emanates from the fact that it is vertically integrated coupled with a strong marketing strategy and securing of offtake contracts with its customers (Figure 19). Government support for alternative sources of energy and rising prices of wood and charcoal are seen as key opportunities for the business. However, the cooperative is facing technical constraints due to limited drying capacity particularly during rainy season and processing capacity of the briquette pressing machines, limited human and institutional capacity, and limited availability of capital which hinder expansion of the business. It is also anticipated that overtime competition in briquette production will increase. COOCEN has a strategy to improve its manufacturing process and the quality of the final product. The major threats to the business are power shortages, lack of a well-coordinated institutional framework to manage existing and prospective investments, lack of clear technology standards and regulations, as well as unclear processes for approving investments.

FIGURE 19. SWOT ANALYSIS FOR COOCEN

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Vertically integrated cooperative with abundant availability of organic waste and long term contract with customers ▪ Diversified revenue streams from waste collection and briquette sales ▪ Strong marketing strategy effectively created market	**WEAKNESSES** ▪ Limited drying capacity particularly during rainy season ▪ Limited processing capacity of the mechanical briquette machines ▪ Part of the collected MSW is still dumped to landfill sites ▪ Lack of finance to invest in more automated machines and to expand business ▪ Limited human and institutional capacity
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Government support for alternative source of energy ▪ Rising prices of wood and charcoal ▪ Briquette market growth ▪ Possibility of recycling plastics as an additional income generating activity	**THREATS** ▪ Competition from other briquette manufacturing businesses ▪ Seasonal changes in the weather pattern affects production ▪ 2010 Rwanda development strategy includes developing the wood fuel production, is a counter-force to briquette market growth ▪ Power shortages ▪ Lack of a well-coordinated institutional framework to manage existing and prospective investments ▪ Lack of clear technology standards and regulations

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Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflect our best knowledge at the time of the assessments 2012/13. As business operations are dynamic data can be subject to change.

CASE

Briquettes from agro-waste and municipal solid waste (Eco-Fuel Africa, Uganda)

Solomie Gebrezgabher and Charles B. Niwagaba

Supporting case for Business Model 2	
Location:	Lugazi Town, Buikwe District, Uganda
Waste input type:	Agro-waste, municipal solid waste
Value offer:	Briquettes (Clean cooking fuel), biochar
Organization type:	Private
Status of organization:	Operational (since 2010)
Scale of businesses:	Small
Major partners:	National Bureau of Standards, Calvert Foundation (equity), Global Catalyst Initiative (grant)

Executive summary

Eco-Fuel Africa (EFA), located in Lugazi Town, Buikwe District, Uganda, converts farm and municipal waste into briquettes and biochar fertilizer. With good understanding of local fuel usage conditions, EFA ingeniously developed simple, low-cost, easy-to-use technologies – *kilns* for carbonization of waste and *eco-fuel press machine* – to convert it into briquettes, which are cheaper than charcoal and other

KEY PERFORMANCE INDICATORS (AS OF 2012)						
Land use	0.4 ha and 0.8 ha in 2 sites					
Capital investment:	USD 10,500 owner's investment and USD 60,000 from donors; in 2013, USD 372,892 capital required to expand the business					
Labor:	19 full-time and 3 part-time workers					
Total cost of operation in 2012:	USD 98,259 per year					
Output:	200 tons of briquette per year sold for 170 USD/ton					
Potential social and/or environmental impact:	Household savings 200 USD/year, women retailers earn 1,825 USD/year, 1,500 farmers earn 360 USD/year, 43 micro-franchisees earn 1,728 USD/year, job creation, avoidance of GHG emissions and improvement of educational opportunities for women					
Financial viability indicators:	Payback period:	N.A.	Post-tax IRR:	N.A.	Net profit	USD 3,000

briquettes. EFA implements a micro-franchising system whereby it trains its important chain actors (i.e. rural farmers, micro-franchisees and women retailers) to produce and distribute its briquettes to its final customers (i.e. poor households). The project, in addition to combating deforestation and climate change, generates jobs, creates entrepreneurs through its micro-franchising scheme and boosts rural incomes. In addition to the positive effect from the business, a portion of the business' income is donated to tree-planting initiatives to restore destroyed forests.

Context and background

In Uganda, over 90% of the household energy is derived from biomass, mainly firewood and charcoal. The continuous dependence on firewood and charcoal contributes to deforestation. As forests disappear, gathering of firewood, which is mainly done by women and children, becomes difficult. Inspired by the problem of collection of firewood, and by the problems girl children were going through in missing school to fetch firewood, as well as the rate at which Africa was losing forest cover, EFA set out to find a solution. The enterprise invented a simple technology, which can be used by poor communities to convert farm and municipal waste into briquettes and biochar fertilizers. The briquette made, known as 'green charcoal' is a carbon neutral cooking fuel that is made from renewable biomass waste such as sugarcane waste, coffee husks and rice husks. In Uganda, the institutional setting in waste management and recycling supports innovations in renewable energy. However, at the assessment time, no statutory guidelines were available for carbonization and charring.

Market environment

The enterprise's target customer segment is households living in villages, who rely on firewood and charcoal for fuel. Uganda has faced rising charcoal prices due to, among other factors, increased levies on charcoal burners by the government of Uganda in recent years. Between 2009 and 2011, the price of charcoal increased from 0.25 USD/kg to 0.60 USD kg (an increase of 140%) (Ferguson, 2012). With soaring charcoal prices and increased awareness about the problems related to charcoal use, there is increased demand for *cheap* and *clean fuel* for cooking. Briquettes can serve as a direct replacement for firewood and charcoal. This gives EFA the opportunity to tap into the growing market where charcoal prices are rising. It is also planning to tap into other market segments such as small enterprises (restaurants) and institutions (schools) in the near future. Market competition is relatively moderate. Although there are a number of other producers producing briquettes such as Kampala Jellitone Suppliers Ltd. (KJS) and other small informal producers of briquettes, EFA's briquettes are cheaper as it uses mechanical methods with very little electricity input which keeps costs lower than those of competitors (Table 10). EFA business has a great potential as it has a low investment cost while at the same time, the product has a high market demand.

TABLE 10. PRICES OF BRIQUETTES AND ALTERNATIVE FUELS (DEC 2011)

FUEL TYPE	PRICE (USD/KG)
Eco-Fuel Africa briquettes	0.17
Firewood	0.24
Kampala Jellitone Suppliers Ltd. briquettes	0.28
Informal producers briquettes	0.40
Charcoal	0.60

Source: Ferguson 2012; Personal communication with Eco-Fuel Africa; Personal communication with KJS.

Macro-economic environment

In Uganda, wood is by far the most important source of energy, even though the importance of petroleum and hydroelectric power is growing. The contribution of firewood and charcoal to Uganda's GDP is estimated at USD 48 million and USD 26.8 million respectively (UNDP, 2011). In terms of employment, biomass production creates nearly 20,000 jobs for Ugandans. The fact that the biomass wood industry represents significant economic activity implies that wood fuel will continue to be the dominant source of energy in Uganda for the foreseeable future. This has implications for briquette business as the success of briquette business depends on its competitiveness to the wood fuel/ charcoal.

In September 2002, the Government of Uganda adopted a new energy policy. The main policy goal is to meet energy needs of the Ugandan population for social and economic development in an environmentally sustainable manner by substantially using modern renewable energy. The overall policy goal is "to increase the use of modern renewable energy, from 4% to 61% of the total energy consumption by the year 2017." There is still limited use of efficient wood fuel, charcoal stoves and biogas in households, institutions and industries. To support alternative clean energy initiatives, government strategy on the demand side is dissemination of more energy efficient technologies (Renewable Energy Policy, 2007).

Furthermore, with support from the UNDP, the government is implementing key interventions in charcoal production which includes increasing the charge that the National Forestry Authority levies on charcoal burners. This provides an opportunity for alternative fuels to compete further with charcoal.

Business model

Briquettes are sold to households via women retailers (Figure 20). The business invented two low-cost and energy-efficient technologies, namely low-cost kiln, which carbonize agricultural waste, and briquetting machine, also called eco-fuel press machine. EFA has invented simple tailor-made briquetting technology which does not need electricity to operate and which can be easily used and maintained by people with limited skills. EFA leases the kilns to farmers and provides the farmers training on how to convert their agricultural waste into charcoal powder using the kilns. The eco-fuel press machine is used by the micro-franchisee to convert charcoal powder brought from farmers to clean burning briquettes. The micro-franchisees sell all the briquettes to EFA, which packages and sells them to its network of women retailers.

Through micro-franchising, EFA have created a decentralized network of village based micro-factories using their already tested technology and business model to convert locally sourced biomass waste into briquettes (green charcoal) and making it easily accessible through women retailers to local people. This eliminates the need to transport biomass waste and green charcoal over very long distances, keeps the cost of green charcoal down which makes it affordable and creates local sustainable jobs.

Value chain and position

The briquette value chain involves three important actors, namely farmers, micro-franchisee and women retailers (Figure 21). EFA is the focal point in the value chain. It is involved in technology transfer and in training each of the chain actors. It provides training to the farmers to convert their agricultural waste into charcoal powder using kilns invented by EFA. The kilns are made out of old oil drums and provided to farmers on a lease-to-own basis. The farmers sell the powder directly to EFA or to the local micro-franchisee. The charcoal powder is then converted into briquettes using the eco-fuel press machine. The press machine is designed to ensure that it can be operated and maintained by local people with no or little formal education. EFA recently invented a low-cost briquetting machine

FIGURE 20. EFA BUSINESS MODEL CANVAS

KEY PARTNERS

- National Bureau of Standards (UBOS)
- Calvert Foundation
- Global Catalyst Initiative

KEY ACTIVITIES

- Producing and selling briquettes
- Training of farmers on how to carbonize
- Production and sale/lease of production hardware (kilns, pressing machines)
- Research and development
- Maintenance of franchised machines
- Network (franchisees, farmers) management

KEY RESOURCES

- Technical competency
- Kilns
- Eco-fuel press machine
- Agricultural residues
- Capital
- EFA brand
- Networks

VALUE PROPOSITIONS

- Less expensive and clean cooking fuel
- Simple, steady franchise income generation by producing briquettes
- Income generation from selling charcoal powder
- Low cost organic fertilizer

CUSTOMER RELATIONSHIPS

- Network of distributors
- Staff trainers from EFA
- Staff trainers from EFA

CHANNELS

- Women retailers
- Direct sales at EFA
- Direct lease

CUSTOMER SEGMENTS

- Households
- Micro-franchisee (briquette pressing)
- Farmers (carbonize agro waste)

COST STRUCTURE

- Investment cost (land, kilns, eco-fuel press machine)
- Research on technology
- Buy-back of briquettes made by franchisees
- O&M cost (training to farmers and micro-franchisee, maintenance of machines, labor cost)

REVENUE STREAMS

- Sales of briquettes
- Franchising fees
- Lease of kilns

SOCIAL & ENVIRONMENTAL COSTS

- Potential loss of income for firewood and charcoal traders
- Possible workers' health risk while manually handling waste
- Air quality decline where households used gas before

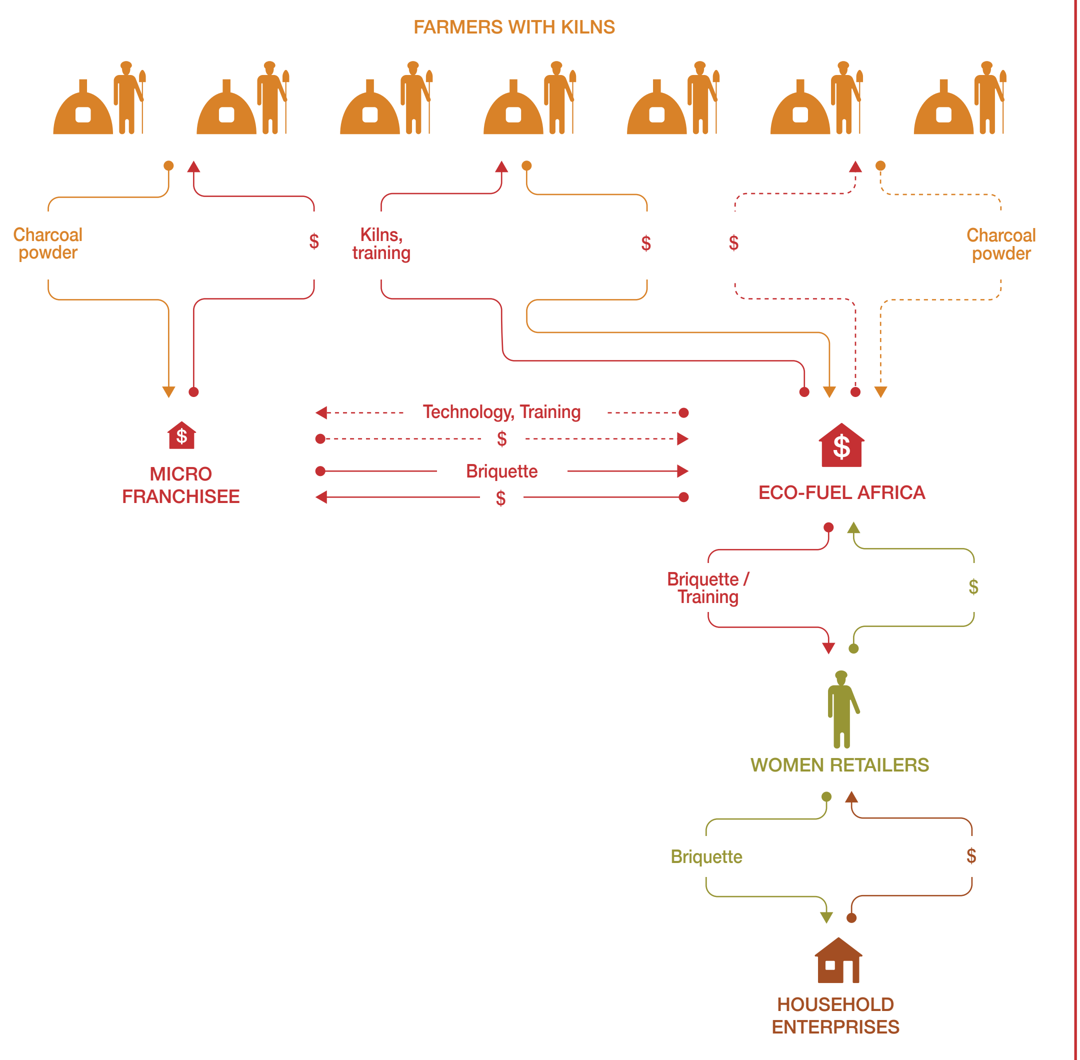
SOCIAL & ENVIRONMENTAL BENEFITS

- Contribute to slowing the rate of deforestation
- Reduce indoor air pollution
- Reduce GHG emissions
- Contribute to better MSW management
- Creation of entrepreneurs and jobs
- Contribute to improving the educational opportunities among girls and women

called eco-fuel press which compresses charcoal powder bought from farmers into clean burning fuel briquettes without using electricity.

Each micro-franchisee can make enough fuel briquettes to meet energy needs of at least 250 local households. EFA mainly makes money from micro-franchising through leasing the technology. Micro-franchisees also pay EFA for training and business support. The micro-franchisees sell all the briquettes to EFA which are packaged and sold to its network of women retailers. Most of these women are illiterate. EFA trains these women thoroughly in areas such as basic book keeping, marketing and customer service. EFA builds a kiosk for each of the selected women after 3 days training, which they use as a retail shop to sell EFA's briquettes to final users. EFA's women retailers sell other items like fruits and vegetables in addition to EFA's briquettes at the kiosks.

FIGURE 21. ECO-FUEL AFRICA BRIQUETTE VALUE CHAIN



Each community-based briquetting micro-factory needs 10 farmers with kilns who supply the char needed by the factory to make fuel briquettes, five local retailers to sell briquettes to the final consumers in the local community and five employees to run the machines, handle the packaging and distribution of the fuel briquettes. Each of these farmers can earn up to 30 USD/month in extra income. These farmers are also able to use these kilns to make organic fertilizers called biochar which helps them to increase their farm yields by over 50%. Each of these micro-franchises will earn at least 1,728 USD/year. Each of these micro-retailers can earn up to 152 USD/month in extra income. These people are from local community with limited skills.

EFA is making profits and has plans to scale up its business and to serve other customer segment such as small enterprises. EFA has a challenge of attracting funding, which has slowed down their expansion plans. They are growing the business slowly, utilizing internally generated funds. As a long-term strategy, EFA intends to construct a training centre in Lugazi, Buikwe District, Uganda. Investment is already made on two acres of land in this area valued at USD 13,000 where the training centre will be constructed. This centre will enable the enterprise to adequately train its micro-franchisees, farmers with kilns, women retailers and other stakeholders.

Looking at the supply side of the value chain, EFA sources its input from various farmers. It relies on their farm productivity and the resulting farm residue to produce the briquettes. Supplier power is weak as the reuse of farm residue and MSW is very limited in Uganda and thus the farm residues have low market value. But in the future, with the emergence of more briquettes, compost and other reuse businesses, supplier power is expected to be higher. Furthermore, new businesses with more automated and efficient technology and a resultant low-priced briquette pose a threat to EFA whose operations are mechanical and less efficient. On the demand side, EFA targets households who previously relied on firewood for cooking. Experience has shown that, even where cleaner fuels are available, households often continue to use simple biomass fuel as they are more familiar with it. EFA must maintain a price that is lower than firewood/charcoal as households will easily shift to firewood. Buyer power thus plays an important role. There is also the threat of substitutes which exists when the demand for the product is affected by a change in price of a substitute product. Market competition from existing briquette businesses is low. There are few briquette businesses (less than 10) which are operating at the same scale of operation as EFA and only one business operating at a larger scale (about 2,000 tons/year). Most of the briquette businesses are small scale and informal. So far, EFA has a competitive advantage over other producers since it is retailing the briquettes at a lower price and demand is constantly outstripping supply. Briquetting industry is in its infancy in Uganda and even with the emergence of more businesses, the increase in market growth (expanding market) would result in increased revenues. The market for briquettes can grow based on households, institutions and industrial sectors shifting to briquettes for their fuel demand.

Institutional environment

The body charged with the duty to oversee and regulate activities in waste management is the National Environment Management Authority (NEMA). It is responsible for ensuring that waste management activities, e.g. recycling, is carried out in a sustainable manner and do not pollute the environment. Others institutional agencies include the Ministry of Energy and Mineral Development (MEMD). The MEMD produced an energy policy for Uganda in 2002 and a renewable energy policy for Uganda in 2007. This was reinforced in the first National Development Plan (NDP) 2010, and in the current NDP II, 2015–2020.

The Renewable Energy Policy 2007 called for innovations and research in waste management and recycling. To promote the conversion of municipal and industrial waste to energy, the government will

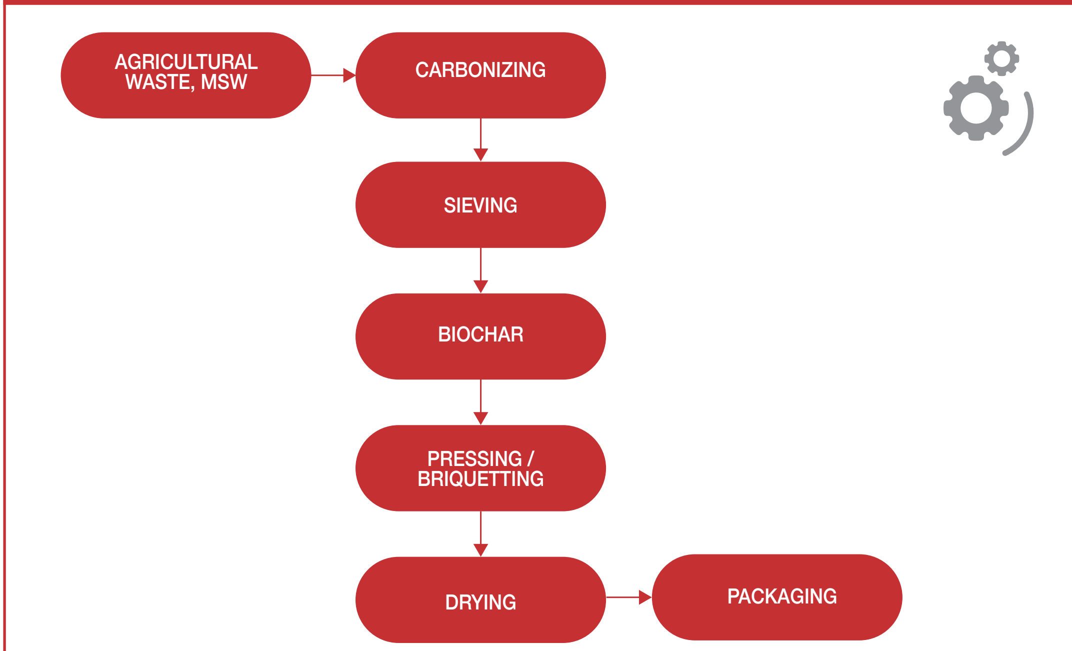
provide incentives for the conversion of wastes to energy and put in place fiscal measures that will discourage open burning or disposal of wastes without extracting their energy content. This will cover the conversion of waste to energy through direct combustion, gasification or biological conversion to biogas and therefore wastes will become part of the energy resource base. To foster this development, MEMD will work with municipal authorities and industries that generate lots of waste in developing this potential. Appropriate incentives shall be put in place to promote the conversion of waste to energy. This could be through the Credit Support Facility (CSF), tax waivers and other incentives.

However, no statutory guidelines are available for carbonization and charring. The government is implementing key interventions in charcoal production and is increasing levies on charcoal burners. The Uganda National Bureau of Standards (UNBS) is a key institution, charged with ensuring that products on the market including packaged charcoal meet certain quality standards. However, all charcoal in the market in Uganda is produced and sold by the informal sector and is therefore not certified.

Technology and processes

One of the most common variables of the biomass briquette production process is the way the biomass is dried out. Manufacturers can use torrefaction or carbonization, based on increasing degrees (temperatures, oxygen) of pyrolysis. Researchers concluded that torrefaction and carbonization are the most efficient forms of drying out biomass, but the use of the briquette determines which method should be used but all of them involve heating biomass with little or no oxygen to drive off volatile gasses, leaving carbon behind. The EFA invented a low-cost kiln made out of old oil drums. The kiln carbonizes agricultural waste to produce charcoal powder through pyrolysis. The charcoal powder is sieved and converted into briquettes and the remaining coarse material is mixed with compost and used as organic fertilizer or as biochar (Figure 22).

FIGURE 22. ECO-FUEL AFRICA BRIQUETTING PROCESS FLOW



Compaction is another factor affecting production. Some materials burn more efficiently if compacted at low pressures, such as corn stover grind. Other materials such as wheat and barley straw require high amounts of pressure to produce heat. There are also different press technologies that can be used. A piston press is used to create solid briquettes for a wide array of purposes. EFA has also invented a low-cost briquetting machine called eco-fuel press, which compresses charcoal powder bought from farmers into clean burning fuel briquettes. The eco-fuel press requires no electricity and is easy to use. Previously, the machines used by the enterprise were powered by electric motors which required constant monitoring and expensive repairs. With the prevailing unreliable electricity grid, production stoppage was a major problem. The new machine makes much denser briquettes which are more resistant to transport than briquettes produced using the old machine. There are no binders involved in this process. The natural lignin in the wood binds the particles of wood together to form a solid briquette.

The finished briquettes are dried through sun drying which can take up to three to four days. The briquettes are finally packaged in clear plastic bags printed with the enterprise's logo. The technologies invented and used by EFA are simple and low-cost, require no specialized skills and are suitable for the local conditions. EFA provides the workers with hand gloves.

Funding and financial outlook

EFA started with a capital of USD 500 from personal equity. It received a grant of USD 10,000 from the Ugandan government. In 2011, EFA received a grant of USD 20,000 from Calvert Foundation and USD 40,000 from Global Catalyst Foundation. Part of the revenues generated by the business and the grants received are invested to expand the business. With support from the Unreasonable Institute (https://unreasonablegroup.com), EFA was able to raise more than USD 3 million in funding and to be profitable, earning USD 1.2 million in revenue (https://vimeo.com/146802104).

Socio-economic, health and environmental impact

Use of EFA's cooking briquettes reduces the rate of deforestation, avoids GHG emissions, reduces indoor air pollution and improves educational opportunities among girls and women by eliminating the need for collecting wood.

In 2015 and after receiving attention by different investors, EFA was able to claim the following impact:

- Brought clean cooking fuel to over 105,000 households served daily. These households are now able to save up to half of the money they previously spent on charcoal from wood, and with these cost savings, they are able to improve their household living conditions like cooking more consistent meals. Over 57,500 marginalized girls enabled to enrol, stay and study in school. Some of these girls could not previously attend school because they had to walk arduous distances to gather wood for their households.
- Increased incomes and food harvests of 3,500 farmers, about 40% of which are women, who use EFA technology to convert farm waste into organic fertilizers (biochar). Farmers earn on average 360 USD/year in extra income as a result of EFA's project.
- Turned 2,300 local women into micro-retailers of clean cooking fuel. All these women had no jobs before they started retailing for EFA. These women now earn about 1,825 USD/year from clean energy retail businesses.
- 500,000 acres of forests saved in averted deforestation.
- About 127,650 tons of CO_2 mitigated every year.

Scalability and replicability considerations

The key drivers for the success of this business are:

- Regulations against cutting down trees.
- Increased charge that the National Forestry Authority levies on charcoal burners.
- Rising prices of charcoal.
- Government policy that promote renewable energy sources.
- Access to both sufficiently dense community networks and rural markets without electricity.
- Charismatic leader with a business plan gaining international attention.

EFA's business model is based on low-cost and simple technologies that can easily be used by local communities. Within Uganda, EFA was planning to expand to all regions of Uganda by 2015 and to up-scale its operations by building a bigger factory near industrial sources of sugarcane waste to meet growing demand. This business model is highly replicable in other low-income countries where firewood is predominantly used, where wood is scarce and where agricultural waste or municipal solid waste is abundant. With raising more capital to improve its technology and with the franchise model, the business could be out-scaled to other regions in sub-Saharan Africa, latest by 2010. For this business to be out-scaled to or replicated in other regions, high charcoal prices and presence of regulatory frameworks on use of firewood are required.

FIGURE 23. SWOT ANALYSIS FOR EFA

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Low-cost technology ▪ Dynamic and skilled entrepreneur ▪ Well distributed production and micro-franchising system ▪ Access to rural markets with no electricity ▪ Good relationship with chain actors and investors	**WEAKNESSES** ▪ Poor logistics in transporting briquettes to retailers ▪ Lack of local technical and institutional capacity and finance to improve technology ▪ Lack of standardization of the briquettes ▪ The low-margin, high-volume nature of the business with insufficient profit margins for green charcoal producers
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Possible patenting of technology (IP) ▪ Good opportunity for up-scaling through franchising ▪ Good image through its tree-planting initiatives ▪ Increasing prices of substitute products (charcoal) ▪ Increasing demand and market growth of briquettes ▪ Supportive local community	**THREATS** ▪ Competition for input may raise prices of inputs ▪ Low farm productivity (harvest fail) may lead to shortage of supply of farm waste ▪ Lack of finance may slow down expansion and limit research efforts ▪ Competition from other similar products and technologies ▪ Inadequate policy, regulatory and institutional framework and lack of product quality and standards

Summary assessment – SWOT analysis

The key strengths of the business are its application of low-cost technology coupled with a well distributed production and franchising system which contributed to the competitive advantage that EFA has over its competitors (Figure 23). The franchise scheme presents EFA a good opportunity to expand its business. However, lack of finance may slow down expansion and limit research efforts to improve technology.

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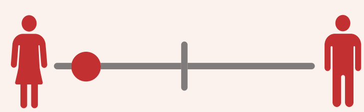
Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflect our best knowledge at the time of the assessments 2012–2015. As business operations are dynamic, data can be subject to change.

BUSINESS MODEL 2

Briquettes from municipal solid waste

Krishna C. Rao and Solomie Gebrezgabher

A. Key characteristics

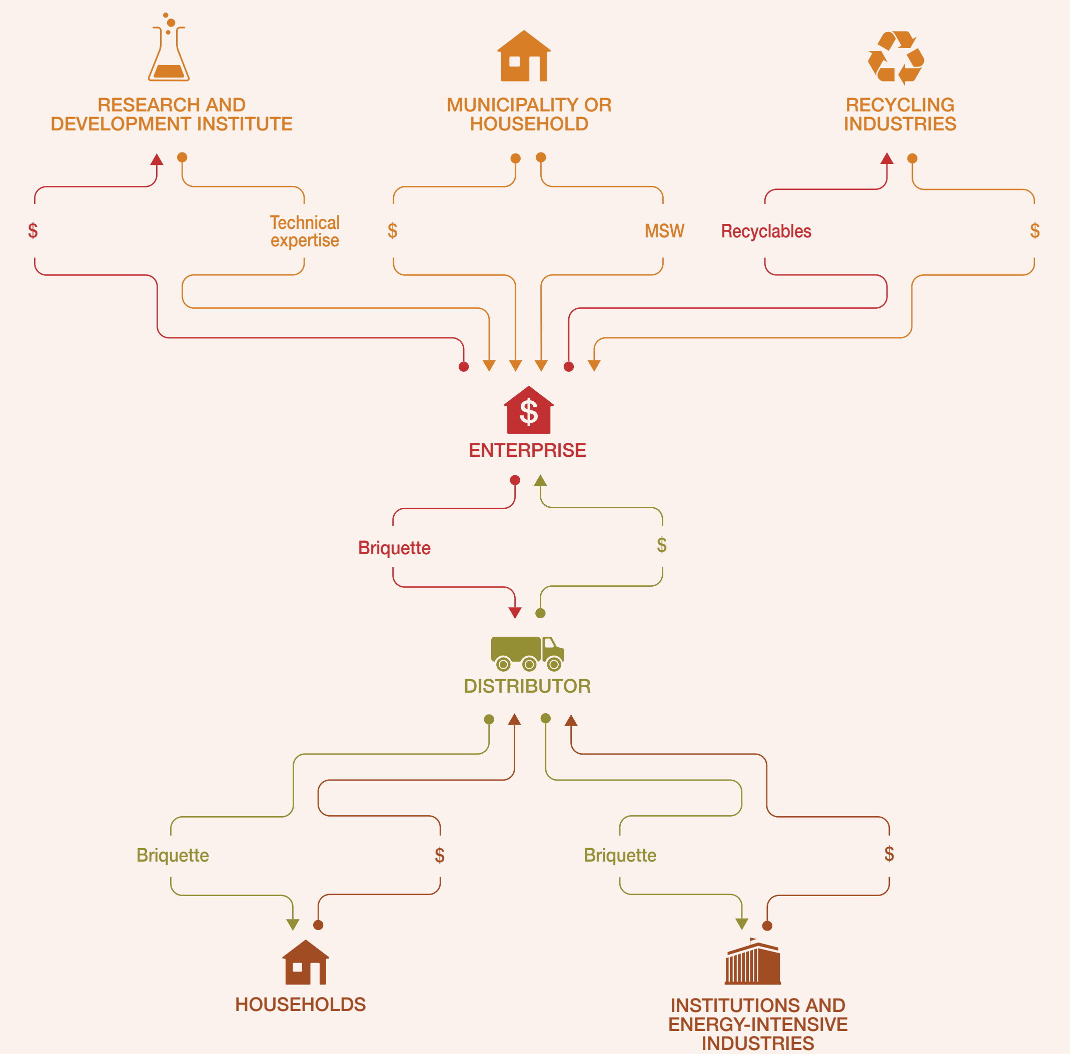
Model name	Briquettes from municipal solid waste (MSW)
Waste stream	Organic waste – Organic component of MSW and agro-waste (crop residues)
Value-added waste product	Briquettes used as clean cooking/heating fuel
Geography	Region with lack of ease in availability of fuel wood
Scale of production	Small scale (<300 tons per year) and medium scale (300–1,500 tons)
Supporting cases in the book	Kigali, Rwanda; Kampala, Uganda
Objective of entity	Cost-recovery [ ]; for profit [X]; social enterprise [ ]
Investment cost range	USD 30,000 to USD 450,000 for medium scale
Organization type	Private or cooperative public-private partnership
Socio-economic impact	Reduction in deforestation and environmental pollution, reduced indoor air pollution resulting in improved health for household and employment generation, improved educational opportunities for girls
Gender equity	Beneficial to women and children using fuel with less indoor air pollution than firewood; time savings for girls in fuel collection which can be used for education. 

B. Business value chain

The business model is initiated by either a standalone private enterprise or a cooperative under public-private partnership (PPP) where a private entity partners with the municipality to manage the solid waste generated by the city. The business processes organic component of municipal solid waste (MSW) and convert it into briquettes that can be used as clean fuel. The key stakeholders in the business value chain are the waste suppliers – either household or the municipality, product distributors and end-users of the briquettes (household and businesses) (Figure 24).

The process of briquetting involves reducing moisture content in the organic waste, which is shredded and the biomass is compressed at high temperature and using a binding agent. The organic component in MSW consists of multiple substances with different calorific values. Collaboration with a research institution or in-house research laboratory will help in developing suitable process to produce briquettes with higher calorific value. Another option is to produce charcoal from organic waste by carbonizing/ burning it in low-oxygen atmosphere. The resulting charred material is compressed into briquettes.

FIGURE 24. VALUE CHAIN OF BRIQUETTES FROM MSW



The briquette is used as fuel for cooking and/or thermal energy in small and medium industries and households. Briquettes can also be used as fuel for gasifiers to generate electricity or powering boilers to generate steam. The business model described is focused on using briquette as fuel for cooking and thermal applications only. The process of making briquettes from MSW requires segregation of organic component, which results in recyclables such as plastics, paper and glass that have good resale value.

C. Business model

The primary value proposition of the business model depends on the entity initiating the business model, which is either a standalone private entity or cooperative. For both the entities, producing high-quality briquettes for households and institutions such as schools and prison and small and medium enterprises who need fuel for cooking and heating is a common value proposition. However, for a PPP, providing waste collection and waste management service is the primary value proposition (Figure 25).

FIGURE 25. BUSINESS MODEL CANVAS – BRIQUETTES FROM MSW

KEY PARTNERS

- Municipality
- Community
- R&D institute
- Other organic waste producers

KEY ACTIVITIES

- Collection of MSW and other organic waste
- Organic fraction separation
- Production and sales of briquettes
- Awareness raising and promotional campaigns
- R&D for briquette combinations
- VER management and administration processes

KEY RESOURCES

- Consumables (MSW and organic waste)
- Human resource
- Capital, land (via partnership) and equipment
- Certification
- Network of distributors
- Contracts with institutional users
- Research expertise
- Marketing and sales force

VALUE PROPOSITIONS

- Environment-friendly briquettes from MSW that are cheaper than charcoal and fuelwood (price leadership)
- Waste collection and management service
- Sale of recyclables recovered from segregation of MSW

CUSTOMER RELATIONSHIPS

- Direct with households for collection of waste
- Short and long-term contract for sale of briquettes with institutional customers direct or with distributors network

CHANNELS

- Direct personal help at point of source of MSW with households
- Supply of briquettes to institutional customers directly
- Distributors
- Micro-franchisees

CUSTOMER SEGMENTS

- Household and institutional users
- Small and medium enterprises
- Municipality
- Recycling industry
- Voluntary Emissions Reduction (VER) market

COST STRUCTURE

- Investment cost – Land, building, and machinery
- Operational cost – Transportation – MSW and organic waste, labor, disposal of inorganic waste to landfill, utilities, maintenance, marketing and packaging, training of distributors/micro-franchisees and VER costs

REVENUE STREAMS

- Briquette sales
- Waste collection and management fees
- Sale of recyclables
- VER sales

SOCIAL & ENVIRONMENTAL COSTS

- Potential loss of income for firewood and charcoal traders
- Potential health risks for workers at production facility
- Potential environmental risk if the waste is not treated and disposed properly
- Increased health risks if households switch from gas to briquettes

SOCIAL & ENVIRONMENTAL BENEFITS

- Reduces deforestation and GHG emissions
- Saves time in the case of time spent in collecting firewood
- Contribute to improving the educational opportunities among girls who previously missed school to fetch firewood
- Contributes of improved MSW management
- Generates income and employment
- Creates environmental sanitation awareness

The briquettes are delivered to the customers either through direct sales, network of distributors or micro-franchising[1]. The direct sales involves managing a large human resource base for sales and marketing staff. The business requires developing strategic partnerships with municipality to procure MSW and it would likely require contractual arrangements with the municipality. The business will have to collect MSW from the municipal landfill site or have the municipality garbage trucks deliver MSW to the plant. The business can also organize collection of MSW directly from households at a collection fees.

The key activities of the business model are MSW collection and processing, briquette production and sales. Since MSW consists of both organic and inorganic material, the business enterprise must undertake segregation of waste to separate out organic material, which is the key raw material for briquette production. Research and development (R&D) would be a useful activity to ensure high quality and calorific value of the product. However, the cost-benefit of R&D should be assessed and ideally partnership with a research institution would mitigate the risk of need for high-skilled labor.

Key capital costs are building and machinery and primary operational costs are transportation, labor, utilities, marketing and packaging. Briquette sales and waste collection and management fees are the key revenue source. A briquette enterprise is potentially eligible for carbon offset depending on the type of fuel replaced and the baseline used to calculate benefits from reduced greenhouse gas emission and hence there is potential for increasing revenue from sale of carbon. Depending on the scale of MSW processed and managed, the briquette enterprise could apply for Clean Development Mechanism (CDM). However, due to associated transaction costs, a preferred route would be to apply for carbon offset on Voluntary Emission Reductions (VERs). MSW consists of inorganic waste such as plastics, paper and glass that has high resale value and sale of recyclables is another revenue source for the business model.

D. Alternative scenarios

The business model can incorporate two additional value propositions in addition to briquette production from MSW: a) produce low cost compost, a by-product from briquette production and b) vertical integration of business by manufacturing and selling improved cook stoves and ovens (Figure 26).

FIGURE 26. BUSINESS MODEL CANVAS – BRIQUETTES FROM MSW ALTERNATIVE SCENARIO

KEY PARTNERS

- Municipality
- Community
- R&D Institute
- Other organic waste producers

KEY ACTIVITIES

- Collection of MSW and other organic waste
- Organic fraction separation
- Production and sales of briquettes, compost and stoves
- Awareness raising and promotional campaigns
- R&D for briquette combinations
- VER management and administration processes

KEY RESOURCES

- Consumables (MSW and organic waste)
- Human resource
- Capital, land (via partnership) and equipment
- Certification
- Network of distributors
- Contracts with institutional users
- Research expertise
- Marketing and sales force

VALUE PROPOSITIONS

- Environment friendly briquettes from MSW that are cheaper than charcoal and fuelwood (price leadership)
- Waste collection and management service and sale of recyclables recovered from segregation of MSW
- Provision of efficient and improved cook stove
- Provide low-cost compost

CUSTOMER RELATIONSHIPS

- Direct with households for collection of waste
- Short and long-term contract for sale of briquettes and stoves with institutional customers direct or with distributors network
- Direct

CHANNELS

- Direct personal help at point of source of MSW with households
- Supply of briquettes and stoves to institutional customers directly
- Distributors
- Micro-franchisees

CUSTOMER SEGMENTS

- Households Institutional users
- Small and Medium enterprises
- Municipality
- Farmers and real estate landscaping
- VER market

COST STRUCTURE	REVENUE STREAMS
Investment cost – Land, building and machinery Operational cost – Transportation – MSW and organic waste, labor, disposal of inorganic waste to landfill, utilities, maintenance, marketing and packaging, training of distributors/micro-franchisees and VER costs	Briquette sales Sales of improved cook stoves Compost sales Waste collection and management fees and sale of recyclables VER sales
SOCIAL & ENVIRONMENTAL COSTS	**SOCIAL & ENVIRONMENTAL BENEFITS**
Potential loss of income for firewood and charcoal traders Potential health risks for workers at production facility Potential environmental risk if the waste is not treated and disposed properly Increased health risks if households switch from gas to briquettes	Reduces deforestation and GHG emissions Reduce indoor air pollution by substituting wood with cleaner burning fuel & improved cook stoves that gives out less smoke Saves time in the case of time spent in collecting firewood Contribute to improving the educational opportunities among girls who previously missed school to fetch firewood Generates income and employment Creates environmental sanitation awareness

Scenario I: Compost production

Production of briquettes results in generation of organic residual waste which can be used to produce compost. The compost can be either sold to the farmers or landscapers. The additional key activity required for this value proposition is production of compost and related costs incurred. The sales and distribution process will be similar to sales of briquettes.

Scenario II: Manufacturing of improved cook stoves

The business model offers scope for vertical integration since the enterprise into briquette production could potentially manufacture improved cook stoves and ovens that use the briquettes made by the enterprise as fuel for cooking or heating. The sales of stoves could potentially stabilize sale of briquettes as it entices users to not switch to a competing/substituting product. The improved cook stoves have high social benefits for households especially to women and children through reduced indoor air pollution. In addition, with improved cooking efficiency and reduced fuel consumption household incurs savings. The business model does not require significant alteration to its distribution process. The additional key activity required is for the manufacturing of improved cook stoves which has related capital and operational costs incurred by the enterprise. Similar to briquette production, R&D is a required activity to design the cook stoves and oven that meet the customer's requirements. The product also requires specific marketing, certification from independent organization and awareness campaign.

E. Potential risks and mitigation

Market risks: The key customer segment for briquettes are households that do not have access to fossil fuels and are dependent upon firewood and charcoal for cooking. Market risks are high as the

willingness to pay is significantly lower among households using firewood for cooking. The business should target diverse customer base to mitigate these risks. It is preferred for the business to target household, institutions and small and medium enterprise as customers. The business could get into long-term bulk contractual arrangement with institutional customers and have assured sales.

Competition risks: The briquette product has strong competition risks from competing products like charcoal, wood, kerosene and LPG. Fuels choice typically depends on consumer preference, price, convenience and at times social status associated in using certain types of fuels like Liquefied Petroleum Gas (LPG). Ideally, briquette should be targeted to customer segment that uses firewood and charcoal because briquettes can be more competitive and efficient. This customer segment has lower competition risks in the urban areas due to scarcity of firewood. However, in the rural areas in developing countries the competition risks for households as customers is high due to free availability of firewood from nearby plantations and forest.

Improved cook stoves and compost have competition risks as there are multiple suppliers of different types of stoves and compost in the market. Stove sales can potentially stabilize briquette market as it lowers chance of customers switching to competing products.

Technology performance risks: The technology used is either mechanical compressing with or without the binding agent or pyrolysis and mechanical compressing. The technology has been widely used commercially and is proven. It doesn't require high skills for operating it and doesn't have complications towards repair and maintenance of equipment.

Political and regulatory risks: In most developing countries, fuel for cooking for household is a social issue and the governments provide subsidy for fuels such as kerosene and LPG. Such fuels are also more reliable and convenient to use. If these competing products are priced lower or even slightly higher than briquettes, it can pose significant risks to the business. Diversifying customer base and including energy intensive small and medium enterprise as primary customers can considerably negate this risk. Increasing government support through financial incentives and policies that promote renewable energy reduces this risk considerably in the long term.

Social-equity-related risks: The model is considered to have more advantages to women as culturally in developing countries women collect fuel wood and do the cooking at household. The model provides employment opportunities in the enterprise producing briquettes. The users of briquettes are low-income households who are using other unhealthy and inefficient or more costly fuels.

Safety, environmental and health risks: The safety and health risks to human arises when processing any type of waste. The risks are even higher when processing MSW. Labor in such enterprises should be provided with appropriate gloves, masks and other appropriate tools to handle the waste to ensure their safety. The risk of environment pollution is high if leachate from MSW is untreated and seeps into groundwater or other natural water bodies. Organic waste when left in open begins to decay and releases methane, which is more damaging to the environment than carbon dioxide. The waste processing technologies are not without problems and pose a number of environmental and health risks if appropriate measures are not taken (Table 11). There is a potential risk for those households where less harmful cooking fuels such as LPG, kerosene or electricity are replaced by biomass briquettes. The risk is lower where also safer cooking stoves will be introduced (Winkler et al., 2017).

TABLE 11. POTENTIAL HEALTH AND ENVIRONMENTAL RISK AND SUGGESTED MITIGATION MEASURES FOR BUSINESS MODEL 2

Risk group	Exposure route					Remarks
	Direct contact	Air	Insects	Water/Soil	Food	
Worker						Health risk for households might increase or decrease depending on the quality of the used fuel. Exposure to sharp objects in MSW, air and noise pollution possible. Fly control measures for MSW and leakage control for composting are required.
Farmer/User						
Community						
Consumer						
Mitigation measures		  				

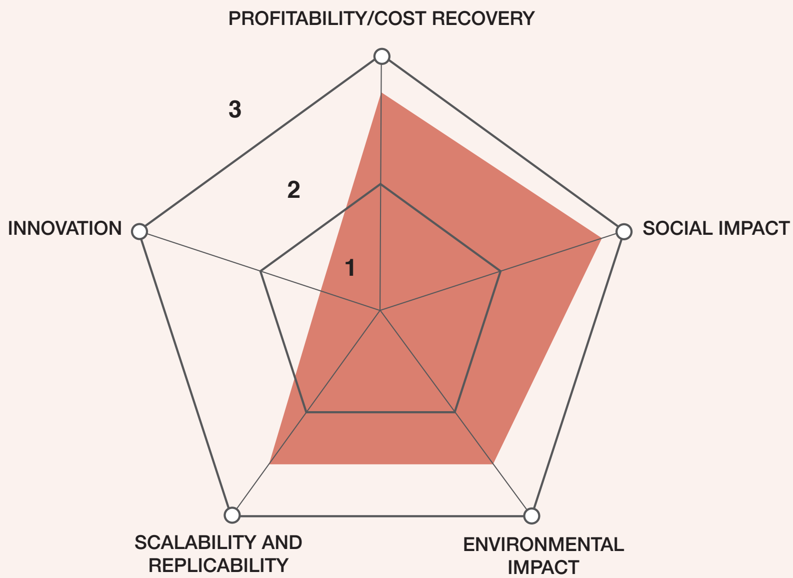
Key: NOT APPLICABLE | LOW RISK | MEDIUM RISK | HIGH RISK

F. Business performance

This business model is rated high on social impact followed by profitability (Figure 27). The business model provides high number of jobs especially when it is involved in the collection of waste from households. The business model has strong revenue sources from sale of briquette and waste collection and management fees, building on a diverse customer base. It has potential for additional revenue sources from sale of stoves, compost and VERs. The environmental impact is specifically high for regions with deforestation and proper treatment of MSW improves the local health of the environment.

The business model has high potential for replication in developing countries as there are not any strong factors such as new technology, special policies and regulations, institutional capacity, waste availability and so on that can limit replication potential of the business model. The business model has can be scaled horizontally and has potential for vertical scaling by expanding into the business of manufacturing of improved stoves. The business model is straightforward with no sophisticated or innovative financing and technology requirements; however, it requires special partnership arrangement with the municipality for waste collection and management.

FIGURE 27. RANKING RESULTS FOR BRIQUETTES FROM MSW BUSINESS MODEL



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Note

1 Micro-franchising borrows the traditional franchising concept with scaled-down business concepts found in successful franchise organizations. It operates as a micro-enterprise following proven marketing and operational concepts with systematic replication. The concept is predominant in delivering services to the poor along the lines of microfinance and microcredit. Micro-franchise entrepreneur has similarities to an agriculture extension worker and typically such an entrepreneur sells multiple product like seeds, fertilizers, water filters, Fast Moving Consumer Goods (FMCG) etc.

4. BUSINESS MODELS FOR IN-HOUSE BIOGAS PRODUCTION FOR ENERGY SAVINGS

Introduction

Energy recovery from fecal sludge or kitchen waste through the installation of biogas systems provides opportunities for domestic, institutional and industrial sectors to save on energy costs by using biogas produced onsite for cooking, power generation and lighting. While household biogas installations are very common, experience in institutional biogas systems is limited and is gradually gaining traction in developing countries in Asia and Africa. The consensus is that the larger onsite biogas units that are run by institutions such as schools, hospitals and prisons to manage their waste have proved to have higher viability than the small-scale household bio-digesters.

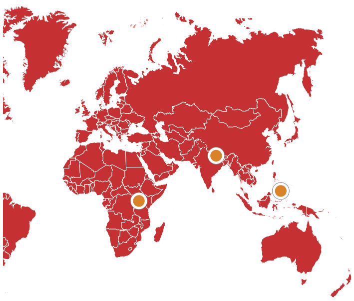
There are a number of examples where energy recovery from fecal sludge and kitchen waste through the installation of biogas systems has been a success in institutions such as schools, hospitals, prisons and other institutions consisting of large number of residents (**Business model 3: Biogas from fecal sludge at community level** and **Business model 4: Biogas from kitchen waste**).

The business cases presented under these business models are from India, Nepal, the Philippines, Rwanda and Kenya. These businesses were selected as they present a unique example of successful partnership of local authorities, non-governmental organizations and communities.

CASE

Biogas from fecal sludge and kitchen waste at prisons

Krishna C. Rao and Kamalesh Doshi



Supporting case for Business Model 3	
Location:	Nepal, the Philippines and Rwanda
Waste input type:	Fecal sludge, wastewater, kitchen waste
Value offer:	Biogas, bio-fertilizer
Organization type:	Public entity
Status of organization:	First biogas plant operational since 2000
Scale of businesses:	Small, medium and large
Major partners:	International Committee of Red Cross (ICRC); Local technology partners in Nepal, Philippines, Rwanda

Executive summary

The International Committee of Red Cross (ICRC) under its water and habitat unit has implemented numerous institutional biogas sanitation systems across prisons in Rwanda, Nepal and the Philippines in partnership with local organizations for the last 10 years. Biogas sanitation systems are seen as a promising technology for institutional settings in developing countries as they combine effective treatment of human excreta and kitchen waste in a safe and environmentally-friendly manner, while at the same time generating a renewable fuel source for cooking while reducing indoor air pollution and a nutrient-rich fertilizer. The projects reduce the prison costs and contribute to reduction of deforestation from reduced use of fuelwood.

ICRC's prison biogas plants use human waste and in some cases kitchen waste to generate biogas, which is used as fuel for cooking in the prison. The biogas systems consist of fixed dome digesters of varying sizes according to the number of detainees in each prison. The digesters used are of size 10 m^3, 20 m^3, 35 m^3 and 100 m^3 with one to two digesters in each prison. The prison biogas projects resulted in improved sanitation of prisons thereby reducing health risks of inmates. The Nepal prisons are much smaller and the number of detainees ranges from 106 to 270. The prisons in Rwanda are large and typically house around 5,000 detainees.

KEY PERFORMANCE INDICATORS (AS OF 2009)						
Capital investments:	USD 12,960 for all three prisons in Nepal; USD 27,700 for Cagayan de Oro City prison, Philippines; and USD 74,000 for 500 m^3 plant in Rwanda					
O&M cost:	2% of capital investment					
Output:	25–62 L/person/day of biogas (higher when kitchen waste is used)					
Potential social and/or environmental impact:	Improved health of detainees, improved sanitation of prisons, reduced air pollution in the kitchen/reduced GHG emissions, reduced deforestation, renewable source of energy for cooking and better landscaping (by use of bio-fertilizers)					
Financial viability indicators:	Payback period:	1.5–5.4 (Nepal prisons)	Post-tax IRR:	N.A.	Gross margin:	N.A.

Context and background

Prisoners are among the world's most discriminated groups often suffering from detrimental sanitary conditions. The main objectives of the systems that are implemented by the ICRC are to improve the sanitary conditions, reduce the health risks and provide a renewable and smoke-free source of cooking fuel. From 2002 to 2009, the ICRC helped build 13 biogas systems in 11 prisons of Nepal (Kaski, Chitwan, Kanchanpur), the Philippines (Cagayan de Oro, Davao, Sultan Kuradat, Manila, Cradle) and Rwanda (Muhanga, Gikongoro, Cyangugu), two of which (Manila and Cradle) were not functioning during surveys between 2009 and 2011.

In 2007, an agreement between ICRC and the local expert partner Biogas Sector Partnership Nepal (BSP-N) was signed to implement five biogas sanitation systems in three district jails in Nepal. The Philippines' prisons, managed by the Bureau of Jail Management and Penology (BJMP), are overcrowded and underfinanced due to a legal system that is unable to keep up with the influx of new suspects. The ICRC implemented biogas systems in several jails including the Cagayan de Oro City jail, which houses more than 1,000 prisoners. In 2009, the BJMP banned the use of firewood in its prisons, due to the deforestation issues it was creating. In Rwanda, the Kigali Institute of Science Technology and Management (KIST) in partnership with ICRC installed large-scale biogas systems including the construction of the system, providing on-the-job training to both civilian technicians and prisoners. Half of the construction cost was paid by ICRC and overseen by ICRC and National Prison Services. The first prison biogas plant (Cyangugu) started its operation in 2001 and has since run with no problems. Since then, KIST has installed biogas digesters in almost half of the 30 prisons in the country. With even the national newspaper reporting on it, it is hoped that more NGOs and government agencies will see the value in small-scale projects like this that not only address sanitation, but also financial, social, and other environmental issues too.

Market environment

According to a study done by the International Centre for Prison Studies (ICPS) in 2008, more than 10 million people are held in penal institutions throughout the world. For every 100,000 population, western Africa and southern African countries have 47 and 219 prisoners respectively. In Asia, South Asian countries has a median rate of 42, while in eastern Asian countries, it is 155. Prison population are growing across the world.

Prisons mostly use fossil fuels or firewood for cooking and incur significant costs. Biogas is a reliable alternative to reduce cost incurred from consumption of these fuels. The need for the biogas systems also arose mainly due to lack of proper sanitation systems in prisons and the associated health risks, risk of groundwater pollution from outdated sceptic tanks, the high costs of obtaining firewood for fuel,

as well as the increase in deforestation and GHG emissions. The biogas systems reuse fecal sludge and wastewater in a safe manner to produce cleaner energy thereby solving most of the problems faced by prisons.

Macro-economic environment

In developing countries including Nepal, the Philippines and Rwanda, consumption of firewood far exceeds annual production, causing deforestation. In order to curb this problem, governments are launching different programs and strategies. The Government of Nepal has a long tradition, dating back 1975, for promoting biogas in Nepal through the provision of low-interest-rate loans and subsidies for biogas systems to promote the technology.

In the Philippines, prisons managed by BJMP are posing environmental and fiscal problems due to high prison populations which are consuming much of the BJMP's budget in their need for food. In 2009, the BJMP banned the use of firewood in its prisons and started installing biogas digesters in prisons.

Under the Economic Development and Poverty Reduction Strategy (EDPRS), one of the long-term strategies of the Government of Rwanda is to reduce fuelwood consumption from 94% to 50% through the installations of biogas digesters in both residential homes as well as institutions with a large number of residents such as schools, hospitals and prisons.

Business model

The key value proposition of the biogas plant is to provide improved sanitation service to prison inmates using biogas digesters to process and treat the human waste generated at the prison facility (Figure 28). In the process, the system provides two additional value proposition: a) biogas as a cooking fuel and b) bio-slurry from biogas plant that can be converted into organic compost. Biogas replaces fossil fuels and firewood while the bio-slurry turned into organic compost is used onsite for growing crops and trees. Both these value propositions result in savings for the running of prison operations in terms of money spent on fuelwood or fossil fuel and fees for emptying sceptic tanks. In the Philippines, the prison has organized its inmates to undertake baking activities to create new livelihood opportunities for inmates. Potentially, this could be a source of revenue where baked goods cooked using biogas from human waste is sold in nearby towns.

Value chain and position

The prisons in Nepal, the Philippines and Rwanda rely on the ICRC and local partner organizations to provide the infrastructure, equipment, maintenance toolkit and training for the implementation and operation of a biogas system. The maintenance and operation of the system falls in the hand of prison staff or detainees (Figure 29). ICRC partners with local organizations to provide technical support for the implementation of biogas. By means of user trainings/workshops, the detainees are informed about the biogas system and its operations and maintenance (O&M) requirements of cleaning and flushing toilets, benefits of adding kitchen waste and countermeasures in case of blockages. The vast majority of detainees perceived the biogas systems positively, mainly because it provides a smoke-free source of cooking fuel that contributes to money saving and because it improved the hygienic conditions in and around the prison.

In 2007, with the help of ICRC, biogas sanitation systems were installed in three Nepalese District jails. All five fixed-dome digesters (sizes of 10 m^3, 20 m^3 and 35 m^3) revealed gastight domes and showed high process stability with no accumulation of inhibitory substances. Kitchen waste is added to three out of five digesters to enhance gas production. In the case of the other two digesters, the organic waste is sold to pig farmers.

FIGURE 28. ICRC PRISON BIOGAS BUSINESS MODEL CANVAS

KEY PARTNERS

- Local technology partners like BSP-N and KIST
- ICRC

KEY ACTIVITIES

- Biogas plant construction
- Operation and maintenance of biogas plants
- Training of prison staff and detainees to run biogas systems

KEY RESOURCES

- Biogas technology expertise
- Land
- Construction materials
- Labor
- Human excreta

VALUE PROPOSITIONS

- Improved sanitation service for prisons
- Biogas as cooking fuel
- Bio-slurry as fertilizer to grow crops (vegetables, fruits)

CUSTOMER RELATIONSHIPS

- Direct

CHANNELS

- Direct

CUSTOMER SEGMENTS

- Prisons

COST STRUCTURE

- Investment for Biogas plant construction
- Operation and maintenance costs primarily for technical repairs
- Heating and cooking costs (saved)

REVENUE STREAMS

- Baked goods (optional)
- No direct revenues but cost savings

SOCIAL & ENVIRONMENTAL COSTS

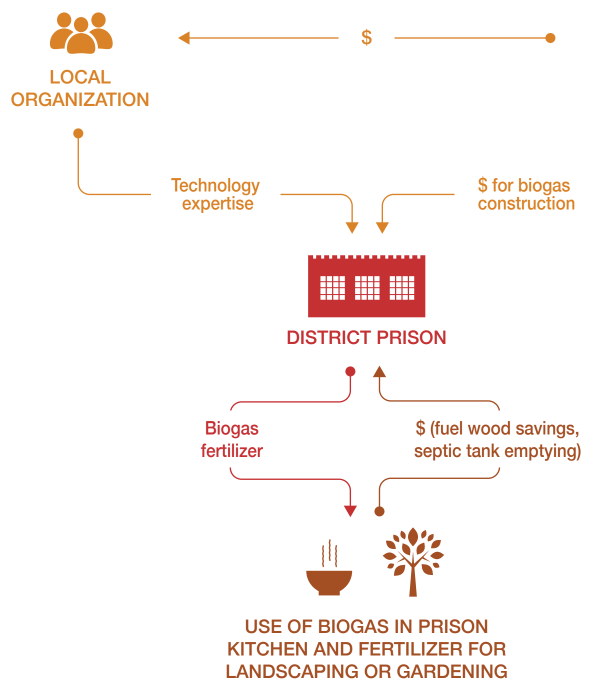
- Possible health risk for prisoners while managing biogas plant operations
- Environmental risk from possible gas leakages
- Using digested human excreta for crops may potentially pose health risks due to possible pathogen survival

SOCIAL & ENVIRONMENTAL BENEFITS

- Improved sanitation and hygiene
- Reduction of GHG emissions
- Reduction of deforestation
- Reduction in surface and groundwater pollution

Rwanda has 13 prisons with around a total of 54,000–58,000 prisoners in 2007–2015, who previously consumed around 10 tonnes of firewood a day, costing of around 1 billion Rwandan francs (USD 1.7 million). The Rwanda Correctional Services (RCS) started building large bio-digesters in all 13 prisons, financed by the Ministry of Internal Security, and Penal Reform International, with contribution from KIST. Biogas is used for more than 60% of all cooking fuel. KIST staff manage the construction of the system and provide on-the-job training to both civilian technicians and prisoners. They have

FIGURE 29. ICRC PRISON BIOGAS VALUE CHAIN



constructed a drainage line to take effluent from a prison biogas plant to a test site where experiments are conducted into growing water hyacinth in the effluent treatment ponds. The water hyacinth will be harvested and added to the biogas plants to increase gas production above the rate possible using sewage alone. Rainwater harvesting will be used to dilute effluent as it enters some of the treatment ponds, allowing fish to be farmed there as well. To date the project has trained a total of 150 artisans and technicians, out of which three private businesses have so far been established. It is planned that by 2013, no prison will be using firewood. After at least one year of operation, 11 systems out of the 13 implemented systems were in operation with satisfactory process parameters with daily biogas production ranging between 26 L/person and 62 L/person (obtained in prisons where kitchen waste was added to the digester). The first prison biogas plant started its operation in 2001, and has run with no problems since then.

Institutional environment

Biogas Sector Partnership Nepal (BSP-Nepal) is a professional organization involved in developing and promoting appropriate rural and renewable energy technologies, particularly biogas, effective in improving livelihood of the rural people. It was established in 2003 under District Administration Office, Kathmandu under the Social Organisation Act of the Government of Nepal. The Biogas Support Programme (BSP) was established by the SNV Netherlands Development Organisation (SNV) with the objective of promoting a wide-scale use of biogas as a substitute for fuelwood, agricultural residues, animal dung and kerosene that are generally used for cooking and lighting in most rural households in Nepal. BSP-Nepal is the implementing agency of BSP. BSP-Nepal was established as an NGO in 2003 to take over the implementation responsibility of BSP, which formerly was managed directly by the SNV.

BJMP is an attached agency of the Department of the Interior and Local Government mandated to direct, supervise and control the administration and operation of all district, city and municipal jails in the Philippines with pronged tasks of safekeeping and development of its inmates.

The College of Science and Technology of the **University of Rwanda**, the former KIST in Kigali, Rwanda is the first technology-focused institution of higher education to be created by the Rwanda government in November 1997. Within KIST, the Centre for Innovations and Technology Transfer (CITT) is mandated to transfer technical innovations, managerial and entrepreneurship skills into community applications. In 2005, KIST won an international environmental award in recognition of its innovative work at Cyangugu Prison, the ASHDEN Award for Sustainable Energy. Since winning the ASHDEN Award, KIST has worked in a variety of areas towards goals. They have begun work on a research project to investigate the use of porous volcanic rock inside the digesters. It is hoped that the rock will increase the surface area available for the anaerobic bacteria. After realizing the success of biogas in prisons, the Government of Rwanda introduced the National Domestic Biogas Program (NDBP) to develop a commercial and sustainable domestic biogas sector under the Ministry of Infrastructure with financial and technical support provided by SNV, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the Dutch Ministry of Foreign Affairs (DGIS).

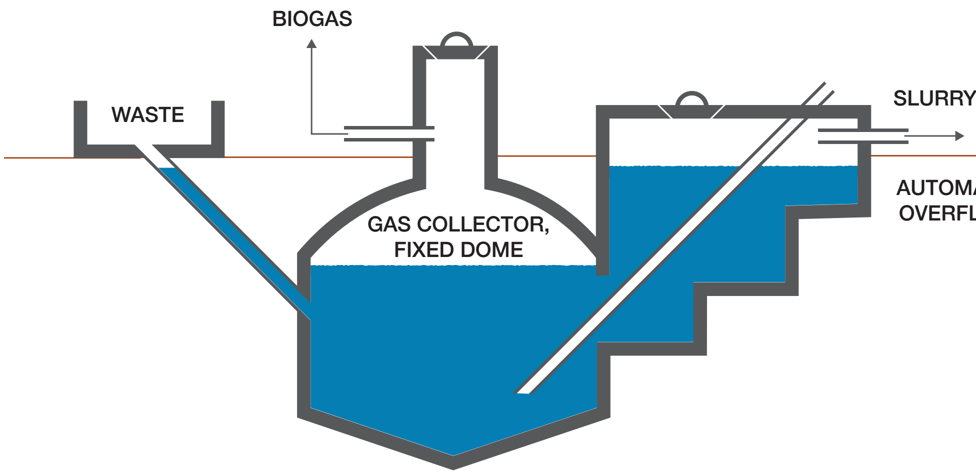
Technology and processes

The biogas system uses a number of individual fixed dome-type digesters, each ranging 10–100 m^3 in volume and built in an excavated underground pit. Toilet waste is flushed into the digesters through closed channels, which minimize smell and contamination. The digester is shaped like a beehive, and built up on a circular, concrete base using bricks made from clay or sand-cement. Biogas is stored on the upper part of the digester. The gas storage chamber is plastered inside with waterproof cement to make it gastight. On the outside, the entire surface is well plastered and backfilled with soil, then landscaped. From the manhole cover, the gas is piped underground towards the kitchen where it is used for cooking purposes. The continuous input of waste and the gas pressure push digested effluent out of the bio-digester to a stabilizing tank and from there, to a solid/liquid separation unit. The stabilizing tank allows additional gas production. The solids are composted for three months and then used as fertilizer in the prison gardens. The fertilizer is only used for crops that stand above ground, such as papaya, maize, bananas, tree tomato and similar crops (Figure 30).

The biogas reactor is an anaerobic, sealed chamber that serves as a primary settling tank, with relatively fast passage of the liquid effluent through the chamber and digestion of much of the settled sludge by anaerobic bacteria. In this way, it is much like a septic tank, except that its sealed nature allows all of the biogas (a mixture of methane and carbon dioxide that is released from anaerobic digestion) to be captured and used. Since most of the organic matter is converted to biogas, sludge production is relatively low. The settled sludge usually remains in the unit for several years and, when removed, is relatively pathogen-free, requiring only some post-composting to ensure sterility.

Satisfactory operation of a biogas system can be achieved if adequate attention is given to the site selection and dimensioning of the system. For this, it is crucial to understand the local climatic and geotechnical conditions, sanitary habits, waste flows and power relations in the prisons. Kitchen waste addition can boost (even double) the biogas production, but its use might be in conflict with potential competitors (e.g. local farmers who use it as animal feed). To deal with high fluctuation in detainee numbers, it is advised to install digesters in series instead of a single large one. It is absolutely essential to install condensation traps at the lowest points of the gas pipe. Vapour, a natural component of biogas, condenses in the pipe and eventually leads to blockage of the pipeline so that the gas does not reach the kitchen anymore. Regular emptying of these water traps is crucial.

FIGURE 30. SCHEMATIC DIAGRAM OF TYPICAL FIXED DORM DIGESTER



Regarding digester volume, 100 L of digester volume is required per person, (e.g. a prison with 200 detainees needs a 20 m^3 digester). This is based on the estimation that 3.3 L/pers. of diluted substrate (feces, urine and flush water) is added and a Hydraulic Retention Time (HRT) of 30 days is envisaged.

Funding and financial outlook

Funding for the implementation of the prison biogas systems was provided by the ICRC in partnership with local institutions. The average cost of a biogas system is 250 USD/m^3 in Nepal, 230 USD/m^3 in the Philippines and 300 USD/m^3 in Rwanda. The total cost of all five digesters in Nepal amounts to USD 12,960, for the Philippines USD 27,700 and for a 500 m^3 plant in Rwanda, it is about USD 74,000 which is paid for by the Ministry of Internal Security. The operational and maintenance costs are 2% of the total investment cost.

Implementation of biogas systems is an advantage for the prison management in terms of savings from substitution of fuel. The firewood savings are 22.5 tons/year in Nepal, approx. 40 tons/year in the Philippines and 6.35–7.35 tons/year in Rwanda. For the project in Rwanda, all 75,500 L of biogas are used for cooking. For an average 6,000-person prison population, where the prison once paid RWF 1,000,000 per month for firewood, the cost has been reduced to RWF 800,000 per month.[1] The savings in one year are RWF 200,000 x 12 = 2,400,000. Given the total investment of RWF 19,000,000 for the system, the payback period is roughly eight years. When evaluated on the basis of kerosene replacement, the payback period would be seven years. However, further savings are realized with the use of the improved manure in place of the imported mineral fertilizer. On the other hand, the post-treatment rids the wastes of the health hazards that may otherwise result in costly medical care and the loss of productive labor. The treatment of wastes in this way generates biogas, which can offset firewood consumption by 80%, thus mitigating the rate of deforestation and conserving the environment. On the bases of the demonstrated benefits, resources should be mobilized to utilize anaerobic treatment technology in a wider application for greater impact.

Socio-economic, health and environmental impact

The biogas systems are favourably perceived by the vast majority of detainees as energy systems rather than as sanitary treatment systems due to general improved living conditions of detention by:

1) Improving sanitary and hygiene conditions in toilets with cleaner surrounding areas resulting in less outbreaks of disease and fewer complaints from neighbours about odor and overflowing feces.
2) Reducing local deforestation by eliminating the need for firewood.
3) Reducing the emission of greenhouse gases by using the carbon-neutral biogas and surface and groundwater pollution.
4) Reducing the surface and groundwater pollution and removing sight and smell of the sewage, and their related health risks not only for prisoners but also for neighbouring areas, caused by the input of essentially untreated wastewater into the local environment.
5) Providing a renewable and smoke-free source of cooking fuel saving fuelwood as well as time for cooking and pot cleaning and removing unpleasantly hot and smoke-filled environment for the chefs. The biogas supply was assured unlike shortages of fuelwood.
6) Reducing costs to the prison by reducing the need for the purchase of cooking fuel.
7) Empowering the lives of the prisoners by engaging them in a new income-generation activities like inmate-run bakery that is fuelled in part by the biogas, keeping them busy and learning useful skills that they can apply when released.
8) Providing sludge as bio-fertilizer to benefit crop/vegetables production and fuel plantations by restricted irrigation, reducing costs further by eliminating the need for fertilizer purchases and also promotes sustainability by using the waste for local food production.
9) Development of private biogas companies by providing technical and business training to the civilian graduates, technicians, as well as prisoners. To date, over 30 civilians and 250 prisoners have received training, and three private biogas businesses have been started in Rwanda.

Scalability and replicability considerations

The key drivers for the success of this business are:

- Government support for renewable energy and improvements in living conditions in prisons.
- Existing funding resource to finance the investment for construction of biogas plant.
- Strong partnership with local partners, technology provider and prison authorities.
- High cost of fuel wood for cooking.
- Lack of proper sanitation systems in prisons and associated health and environmental problems.

With regard to operational aspects, the total organic waste management including issues of strong ownership and responsibilities for maintenance work needs to be examined carefully before dimensioning a biogas system and detainees should be convinced of the benefits of human waste feeding into the digester. The organization of anticipated kitchen waste feedstock has to be elaborated with the responsible persons. In terms of slurry use, there is a certain risk of public perception in the use of human excreta based product on food. Studies have shown that restricted irrigation is possible, and instead of promoting the use of slurry on vegetables, the irrigation of banana trees seems to be promising. If not properly operated and maintained, the adverse effects such as methane emissions or health risks of leaking gas pipes in the kitchen can clearly exceed the benefits.

Given above mentioned constraints that could be fairly resolved, this business case has high potential for widespread replication and scaling across institutions providing residency such as prisons, hostels, hospitals, hotels and so on. CITT has already undertaken smaller installations in three residential

schools in Rwanda. To ensure the replication of this success, the United Nations Development Programme (UNDP) is supporting a KIST-implemented biogas project for Kigoma Prison, with funding from the Netherlands Embassy. In addition, the Ministry of Internal Security, in partnership with the Red Cross, has plans to provide three prisons per year with biogas systems.

Summary assessment – SWOT analysis

The key strength of the business case is its strong local partnership with the prison authorities and local technology supplier to install the system and train prison inmates and officials to operate the plant (Figure 31). The weakness is in reliance on donor money to install the infrastructure. The business has threats of health risk of cultivating crops from bio-slurry. If the human waste is not treated appropriately killing pathogens, there is health risk for operators and inmates who come in direct contact with the bio-slurry. The business has high potential for replication and opportunities to expand its revenue source to include carbon offset.

FIGURE 31. ICRC PRISON BIOGAS SWOT ANALYSIS

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Continuous supply of input ▪ Strong partnership with prison authorities and local technology suppliers ▪ Reduced public expenditure to run prisons from reduced fuel cost ▪ An inclusive business model that improves sanitation for prisoners – a discriminated group ▪ Short payback period for an investment that improves sanitation	**WEAKNESSES** ▪ No financially viable plan set up for financing repair and maintenance of the plant ▪ Heavy dependence on donor money to finance construction of biogas plant ▪ Lack of strong management arrangement at the operational level to take the business to scale ▪ Irregular feeding, and lack of operation and maintenance ▪ Relatively high requirements of strong ownership and responsibilities for maintenance work
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Potential to increase revenue by bundling the biogas projects at different prisons and applying for carbon offset ▪ Potential to expand the business model to prepare cooked food and provide it to local market ▪ High potential for replication at other institutions providing food and residential services like hospitals, schools, hotels, etc.	**THREATS** ▪ Potential health risk from direct human contact with bio-slurry used for crop production and associated public perception risk ▪ Leakage of gas causing environment damage ▪ Resistance to change and perceptions of people on use of sludge from fecal waste

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Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflect our best knowledge at the time of the assessments (2015/2016). As business operations are dynamic, data that can be subject to change.

Note

1 RwF 800,000 was depending on the year about USD 1,100–1,400 in the assessment period.

CASE

Biogas from fecal sludge at community scale (Sulabh, India)

Solomie Gebrezgabher and Hari Natarajan

Supporting case for Business Model 3	
Location:	New Delhi, India
Waste input type:	Fecal sludge
Value offer:	Hygienic and affordable sanitation services; biogas and compost
Organization type:	NGO
Status of organization:	Operational (since 1970)
Scale of businesses:	Large
Major partners:	National government, local government bodies

Executive summary

The Sulabh International Social Service Organization (Sulabh), an Indian NGO, was founded in 1970 to develop a low-cost, easy-to-implement, environmentally-friendly and socio-culturally-acceptable toilet solution at the household level. Sulabh has also proved through its pay-and-use public toilet model that low-income people are willing to pay for use of toilet facilities that are clean and hygienic. The key technological solutions include the Sulabh Flush Compost toilet for households, the Public Toilet Complex and the Public Toilet Complex with a biogas system. Sulabh is noted for achieving success in the field of cost-effective sanitation, liberation of scavengers, social transformation of society, prevention of environmental pollution and development of non-conventional sources of energy.

The NGO implements a build, operate and transfer (BOT) model for public toilets. For the construction of the public toilets, Sulabh is approached by the municipality or other local government agencies and private sponsors to build a public toilet in a specific location. The agency is responsible for capital expenditures while Sulabh takes care of the operational and maintenance expenditure for 30 years. Sulabh charges a consultation fee of 20% of the project cost, which is the primary source of income that covers the overheads and administrative costs and sustains the operations of the overall organization. Sulabh has thus far installed over 7,500 public pay-and-use toilet complexes and 200 public toilets with biogas systems in 26 states of India. Owing to this technology, Sulabh has been able to liberate over 60,000 scavengers, offering programs to reintegrate them into society and has, through its public toilet complexes contributed in the field of community health and hygiene and environmental sanitation.

KEY PERFORMANCE INDICATORS (AS OF 2012)						
Land	1.75 m^2/toilet seat and 8.28 m^2/twin pits					
Water requirements:	1.5–2 L/flush at household toilet and 3–4 L/flush at public toilets					
Capital investment:	No data available (charges 20% of project cost to cover operational costs)					
Labor:	2–3 full-time per public toilet complex					
O&M cost:	Public toilet complex 10,320 USD/year					
Output:	1.2 million household toilets; more than 7,500 public toilet complexes; 200 public toilet complexes with biogas plant					
Potential social and/ or environmental impact:	1.2 million household obtained basic sanitation facility; 60,000 scavengers freed; over 50,000 jobs; 19,000 masons trained; Improved community health, hygiene and environmental sanitation, conserve water, use of biogas for cooking and to generate electricity for toilet complex lighting					
Financial viability indicators:	Payback period:	5–6	Post-tax IRR:	N.A.	Gross margin:	N.A.

Context and background

The local government bodies in cities and urban areas in India are entrusted with the responsibility of providing basic civic amenities including sanitation facilities. Lack of service coverage of a large proportion of the population, poor quality of service delivery and limited revenue generation are the universal problems faced by the local government bodies in view of the rapid urbanization and fast-growing slum and low-income population. The Sulabh is an Indian-based NGO noted for achieving success in the field of cost-effective sanitation, liberation of predominantly women scavengers, social transformation of society, prevention of environmental pollution and generation of biogas. Biogas is utilized for cooking, lighting through mantle lamps, electricity generation and being converted into energy to be used for lighting streetlights and other uses. The sludge at the bottom of the digester can be used as fertilizer. Recycling and use of human excreta for biogas generation is an important way to get rid of health hazards from human excreta without any manual handing of excreta at any stage. Under the system, only human excreta with flush water is allowed to flow into biogas plant for anaerobic digestion.

The key technological solutions included the Sulabh Flush Compost toilet (FCT) for households, the public toilet complex (PTC) and the public toilet complex with a biogas system (PTC-biogas). The social NGO has now become the international pioneer in pay-and-use toilets. Sulabh has thus far constructed over 1.2 million FCT, over 7,500 PTC, and 200 PTC-biogas of capacity 35–60 m^3 per day in different parts of India. This solution has been universally accepted by the state and central governments in India and the cost of the same is covered to a large extent by subsidies/grants. Sulabh takes 30 years maintenance guarantee for the toilet complexes constructed by it by collecting a fee of pay per use. There are 60,000 volunteers working with Sulabh that include technocrats, managers, scientists, engineers, social scientists, doctors, architects, planners and other non-revenue staff. This solution has also gained recognition from several multilateral development agencies such as the World Health Organization (WHO), United Nations Children's Fund (UNICEF) and United Nations Development Programme (UNDP) and has been taken up for adoption in other developing countries in southern Asia and Africa.

Market environment

The 2011 census indicates that nearly 50% of the households (18.6% urban households and 69.3% rural households) in India still do not have basic sanitation facilities. The problem lies not only in provision of appropriate toilets but also in inducing a behavioural change among the target

beneficiaries. This was further compounded by the fact that there were neither affordable solutions available in the market nor were there solution providers that could cater to the differing needs across different geographies. Sulabh plays the role of a catalyst and a partner between the official agencies and the users for the construction, operation and maintenance of public sanitation facilities. Sulabh has proven that poor slum communities are willing to pay for improved water and sanitation services and that such operations can be financially viable. Sulabh has constructed 1.2 million flush compost toilets, while 120 million households lack basic sanitation facilities. This indicates that there is still an opportunity for Sulabh to further scale up its operations and reach unserved population.

Cooking is the most convenient use of biogas. Biogas burners are available in a wide-ranging capacity from 0.2–2.8 m^3 biogas consumption per hour. It burns with a blue flame and without soot and odor. The biogas mantle lamp consumes 0.05–0.08 m^3/hour having illumination capacity equivalent to 40 W electric bulbs at 220 V. Motive power can be generated by using biogas in dual fuel internal combustion (IC) engine using 20% diesel and 80% biogas. Recently, Sulabh has modified the generator, which does not require diesel and runs on 100% biogas. About 30 m^3 of biogas is equivalent to 17 m^3 of natural gas, about 30 litres of butane (LPG), 24 litres of gasoline or 21 litres of diesel oil. For the safe reuse of human waste from public toilets, housing colonies, high-rise buildings, hostels and hospitals, a technology is developed for complete recycling and reuse of excreta through biogas generation and on-site treatment of effluent through a simple and convenient technology for its safe reuse without health or environmental risk. The treated effluent is colorless, odorless and pathogen-free and is safe for discharge into any water body without causing pollution. It can also be used for cleaning of floors of public toilets in water-scarce areas.

Sulabh in collaboration with UN-HABITAT, Nairobi has trained professionals from 14 African countries for their capacity development towards achieving the initial Millennium Development Goal (MDG) for sustainable development in water and sanitation, which predated the current Sustainable Development Goals (SDG), and trained more than 50,000 people to work in the construction and maintenance of community toilets in India.

Macro-economic environment

One of the challenges in the successful dissemination of basic sanitation facilities to communities is convincing the poor to use a toilet instead of the outdoors and convince them to pay for use of public toilet. This is because the hygiene practices of communities are deeply rooted in cultural and religious values. Therefore, the success of a business involved in sanitation service depends not only on installing the appropriate toilet models but also on the interaction between a complex and diverse range of institutions, processes and actors (both public and private).

An estimated 50% of all Indians, or close to 600 million people, still do not have access to any kind of toilet. Among those people who live in urban slums and rural environments are affected the most. Goal 7 of the MDG called on countries to halve by 2015 the proportion of people without improved sanitation facilities (from 1990 levels); while India had its even more ambitious goal of providing “Sanitation for All” by 2012, established under its Total Sanitation Campaign.

The restructured program moves away from the principle of state-wise allocation of funds, primarily based on poverty criteria, to a demand-driven approach. The successful state program moved from a high-subsidy to a low-subsidy regime, with investment of funds in building awareness and increasing sanitation coverage through public-private partnerships with non-profit organizations such as Sulabh.

Business model

Sulabh's target customer segment is the poorer section of the society, particularly urban slums with no access to basic sanitation facilities and users of public toilet complexes (Figure 32). Sulabh implements a build-and-transfer model for household toilets and a build, operate and transfer (BOT) model for public toilets. In the case of public toilet complexes, Sulabh was the first to introduce a pay-and-use system to cover the costs of maintenance of the toilet complex. For the construction of the public toilets, Sulabh is approached by the municipality or other local government agencies and private sponsors to build a public toilet in a specific location. The agency is responsible for capital expenditures while Sulabh takes care of the operational and maintenance expenditure for 30 years and trains toilet complex operators on how to run the public toilet. Sulabh charges the project sponsors a consultation and implementation fee of 20% of the project cost. In addition to its creating technologically and socially-efficient solutions, one of the strongholds of the organization is its partnership with the local governments, local authorities, international organizations and local communities. This partnership coupled with community participation has made a substantial impact in improving the sanitation services to the poor.

Value chain and position

The value chains for Sulabh's public toilet and household toilet are depicted in Figure 33. In the case of public toilet complexes, Sulabh is typically approached by a local government body or private entity for establishing a public toilet in a specific location. Based on a survey, Sulabh determines the appropriate capacity of the toilet complex and designs and constructs the same and operates and maintains it for 30 years based on fees collected on pay-per-use basis. For the construction, operation and maintenance of the toilet complexes, the organization plays the role of a catalytic agent between the government, local authorities and the users of toilet complexes.

Institutional environment

Recently, the Government of India has significantly increased the financial support for family-size biogas plant and also launched two schemes, mainly Biogas Fertilizer Plant (BGFP) and Biogas Power generation. In the case of household toilets, a large part of the costs is covered through central and state government subsidies and incentives. Under the scheme, community toilet complexes are to be established only when there are space constraints in the community that prevent the installation of household toilets. In the case of public toilet complexes, Sulabh is invited by a local government agency or private sponsor to construct and operate a toilet complex with or without biogas plant in a specified location. Land, as well as the funds for construction of the toilet, is provided by the sponsoring agency. In such cases, the cost (USD 4,000) is borne by central government, state government and the community in the ratio of 60:30:10. In the case of public toilets with biogas, 75% of the additional capital costs are subsidized by the government.

Technology and processes

In the case of public toilet complex with biogas digester and associated treatment plant for the effluent, a floating dome type was first tried. Abundant quantity of gas was produced for cooking and lighting but there was foul smell because human excreta, after decomposition, used to float. Moreover, using the floating dome type resulted in lower biogas production during winters. Finally, Sulabh switched over to the fixed dome biogas digester, with some change in the design. The digester is built underground into which excreta from public toilets flows under gravity. Inside the digester biogas is produced due to anaerobic fermentation by the help of methanogenic bacteria. The biogas, thus produced, is stored in inbuilt liquid displacement chamber.

FIGURE 32. SULABH BUSINESS MODEL CANVAS

KEY PARTNERS

- Municipality/ local authorities
- Local community
- Private sponsors

KEY ACTIVITIES

- R&D on toilet technologies
- Build and transfer household toilets
- Build, operate, maintain and transfer public toilets
- Consultation

KEY RESOURCES

- Technology/ expertise
- Construction materials
- Human resource
- Users (human excreta)

VALUE PROPOSITIONS

- Households get access to basic sanitation facilities
- Municipality get better management of human waste and communities get access to toilet facilities for a nominal user fee
- Private sponsors get an opportunity to contribute to fighting scavenging and promote good sanitation practices

CUSTOMER RELATIONSHIPS

- Subsidies and incentive programs to finance individual toilets
- Invitation

CHANNELS

- Direct
- Toilet operators (complexes)

CUSTOMER SEGMENTS

- Central and state governments, benefiting individual households
- Local governments or private sponsors benefiting communities

COST STRUCTURE

- Construction cost:
- Household toilet
- Public toilet complex; public toilet with biogas
- Utilities (water, power)
- Operation and maintenance (staff cost, chemicals)
- Toilet technology development costs

REVENUE STREAMS

- Implementation/installation fee (20% of project cost)
- Consultation, implementation and maintenance fee (20% of project cost)

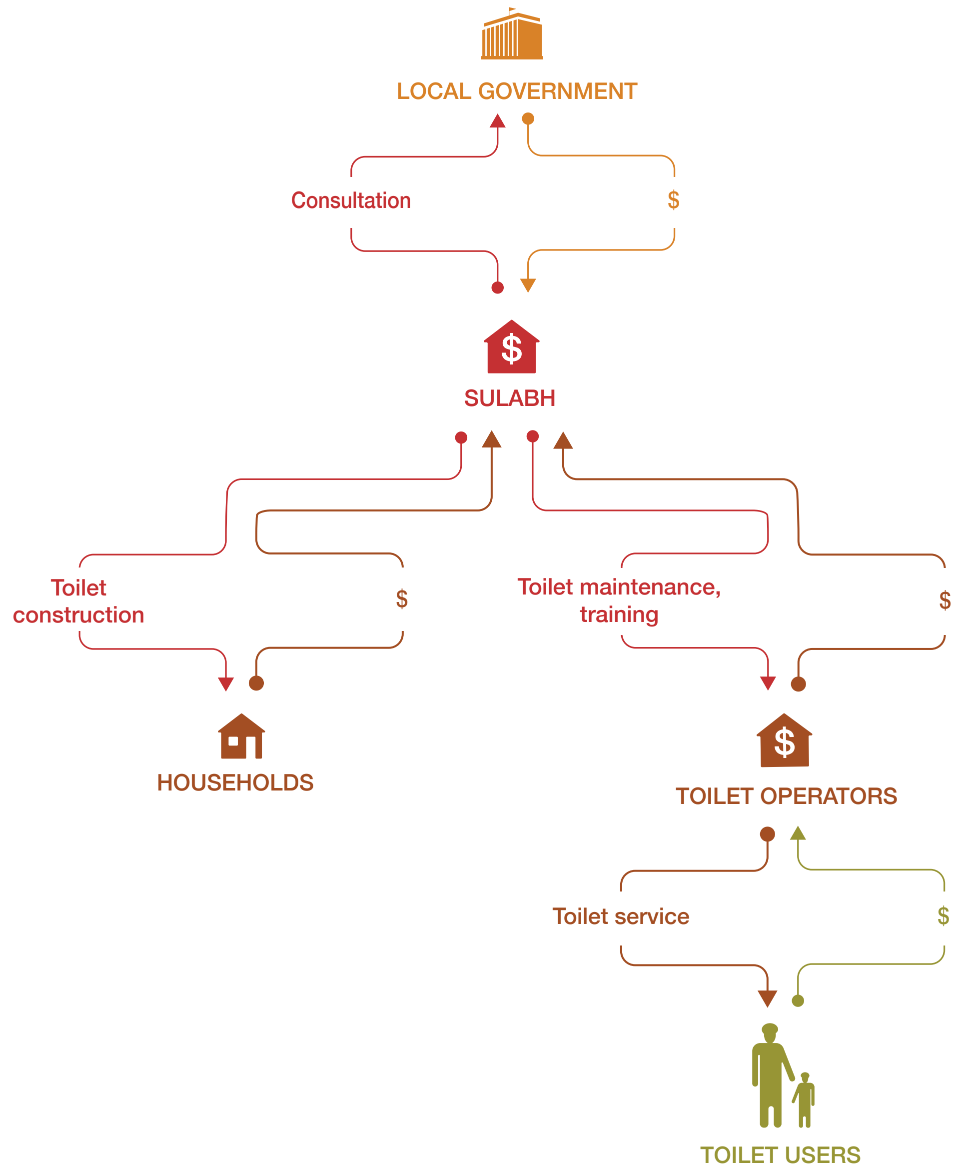
SOCIAL & ENVIRONMENTAL COSTS

- Using digested human excreta for crops may potentially pose health risks due to possible pathogen survival
- Potential leakage of methane gas from biogas systems

SOCIAL & ENVIRONMENTAL BENEFITS

- Improve community health, hygiene and environmental sanitation
- Elimination of practice of scavenging
- Saving for municipality from better management of human waste
- Safe processing and disposal of human excreta
- Conserve water from reduced usage for flushing toilets
- Change attitudes of people towards sanitation
- Create job opportunities
- Diffusion of innovation in toilet technologies

FIGURE 33. SULABH PUBLIC AND HOUSEHOLD TOILET VALUE CHAIN



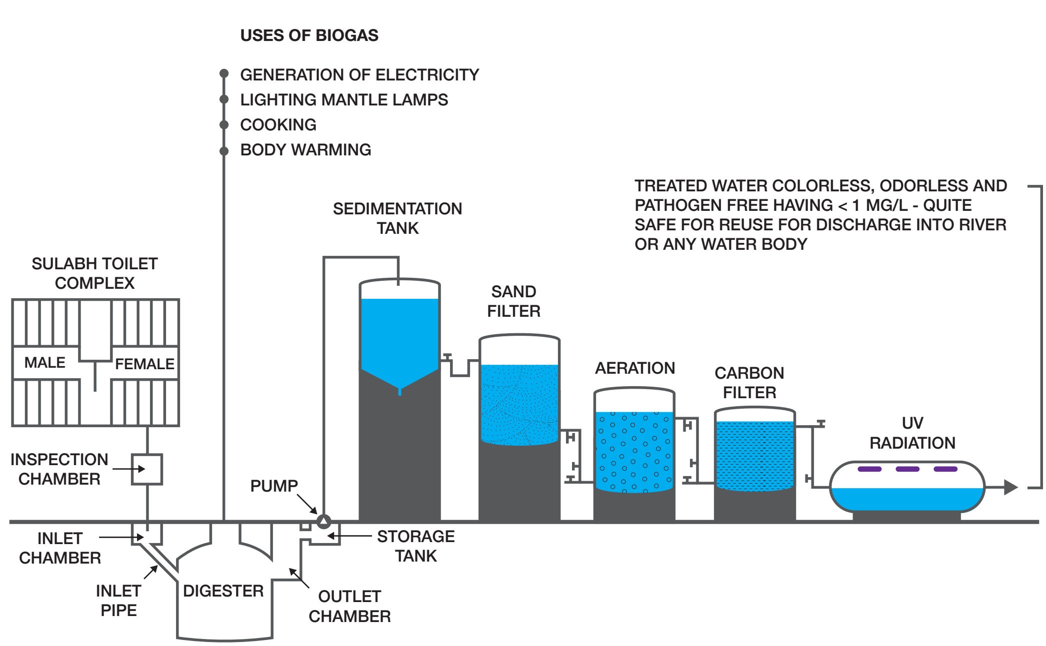
The design developed by Sulabh does not require manual handling of human excreta and there is complete recycling and resource recovery from the wastes. During biogas generation, due to anaerobic condition inside digester, most of the pathogens are eliminated from the digested effluent making it suitable for using it as manure. Sulabh has also carried out a series of experiments on biogas generation from water hyacinth (an aquatic weed) after harvesting, drying and pulverizing it; vegetables, fruit and household kitchen wastes with or without mixing with human wastes. Better results were obtained when human waste and vegetable waste were fed in combination.

One cubic foot of biogas is produced from human excreta per person per day. Human excreta based biogas contains 65–66% methane, 32–34% carbon dioxide and rest the hydrogen sulphide and other gases in traces. To convert biogas into energy, earlier the engine was run on diesel and biogas with a ratio of 20:80 and have now shifted to the battery system, where the engine is run 100% on biogas. A public toilet used by about 2,000 persons per day would produce approximately 60 m^3 of biogas which can run a 10 kilovolt-ampere (KVA) gen set for 8 hrs a day, producing 65 kilowatt hours (kWh) of power.

After a series of experiments a simple and convenient technology named Sulabh Effluent Treatment (SET) are invented to further treat effluent of biogas plant and turn it into a colorless, odorless and pathogen-free manure. The technology is based on sedimentation and filtration of effluent through sand, aeration tank and activated charcoal followed by exposure to ultraviolet rays. The effluent treatment plant consists of a series of filtration steps through sand and activated charcoal, followed by UV treatment, which eliminates not only the bad odor but also the bacterial content. The Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) of the wastewater is reduced significantly, with BOD being less than 10 mg/L post treatment, which is safe for agriculture, aquaculture, discharge into water bodies – practically safe for all purposes except drinking. The residue water from the plant can be used, too, as bio-fertilizer because it contains phosphorus, nitrogen and potassium. A detailed diagrammatic representation of Sulabh model is given in Figure 34.

The institute has successfully demonstrated its use as hydroponics, i.e. soil-less culture of plants. The effluent is first dried in earthen pots kept in sunlight where, owing to the evaporation of the liquid, the concentration of nutrients increases. It is filtered with a thin plastic mesh. Some trace elements are added in the filtered effluent. Such effluent is completely odorless. Various plants have been grown

FIGURE 34. SULABH MODEL OF THE TECHNICAL PROCESS



Source: Pathak, 2015.

exclusively on such an effluent when mixed (5–10% by volume) with tap water. Plants can be grown in glass bottles or any other jars and kept inside or outside the room. Such technology is useful for the culture of rare plants like cactus and other ornamental plants.

Funding and financial outlook

While Sulabh, as a not-for-profit, can access grants and donations. It does not depend on external agencies for finances and meets all the financial obligations through internal resources. Sulabh charges the project sponsors (local government or private sponsors) a consultation and implementation fee of 20% of the project cost and also takes on the maintenance responsibility for the toilet complex for a period of 30 years from user's charges. In the case of public toilet facilities, land and cost of construction is met by local body while maintenance is met from user's charges. Estimated project cost for public toilet facility is USD 4,000, financed by central government, state government and the community in the ratio of 60:30:10. In the case of public toilet with biogas plant, 75% of the additional cost of the biogas plant (USD 4,000) is financed by the government.

For a typical toilet complex that caters to approximately 2,000 users per day, annual revenues (assuming 50% of users are paying customers) are USD 10,800 whereas the operating costs are USD 10,320, thereby leaving very little surplus to cover capital costs. Within Sulabh's portfolio of 7,500 toilets, around 50% are generating enough revenues to be self-sustaining and profitable. The maintenance of the other toilet complexes is cross subsidized from the income generated from toilet complexes in busy and developed areas. In the case of public toilet with biogas, the gas is used for heating/electricity requirements of the toilet complex and thus results in cost recovery through reduced requirement for LPG/kerosene. Estimated payback period for the toilets with biogas plant is 5–6 years.

The complex with biogas plant recovers about USD 7,000 per year in terms of savings in diesel for power generation when an average of 1,000 people use the toilets, generating 30 m^3 biogas, equivalent to 21 L of diesel costing 0.9 USD/L. In addition, it reduces the GHG emissions by capturing methane and converting it to CO_2 during combustion in internal combustion engines.

Socio-economic, health and environmental impact

Sulabh is one of the pioneers in improving the sanitation levels in the country by shifting people from the practice of open defecation to use of toilets. Sulabh has developed toilet designs that cater to varying income levels and locations. It has installed more than 1.2 million household toilets and maintains more than 7,500 public pay-and-use facilities in different states of India. A Sulabh public toilet complex employs two to six persons. It has provided training to 19,000 masons to build low-cost twin-pit toilets using locally available material. Owing to this technology, Sulabh has been able to liberate over 60,000 scavengers, offering programs to reintegrate them into society.

Human excreta contains full spectrum of pathogens. Unsafe disposal of human excreta facilitates the transmission of oral-fecal diseases, including diarrhoea and a range of intestinal worm infections such as hookworm and roundworm. In this technology, most of these pathogens are eliminated in anaerobic condition inside the digester. Cost of collection of sewage and operation and maintenance of the system are very low. Provision of toilets connected to biogas digesters has helped communities gain access to sanitation and an inexpensive energy source. No manual handling of human excreta is required. It is aesthetically and socially accepted. The toilet requires only 1.5 to 2 L of water for flushing and thus conserves water. In addition to conserving and reusing water the system has additional inbuilt advantage of reducing greenhouse gas effect arising out of carbon dioxide and methane production due to degradation of human waste.

Due to design of leach pit (Sulabh Toilet) produced carbon dioxide is diffused in soil through honey combs. It does not escape in atmosphere as in other cases. During anaerobic digestion of human wastes during biogas production, methane is produced that is used for different purposes. Methane as such is not left to escape in the atmosphere. Thus, both these technologies are helping in reducing greenhouse effect and thus improve environment. Besides using biogas for different purposes, the plant effluent can also be used as manure or discharged safely into any river or water body without causing pollution. Treated effluent is safe to reuse for agriculture, gardening or discharge into any water body. In drought-prone areas, treated effluent can be used for cleaning floors of public toilets. If discharged into the sewer, pollution load on a sewage treatment plant (STP) will be much lower. Thus, biogas technology from human wastes has multiple benefits, i.e. sanitation, bioenergy and manure.

At the household level, manure obtained from a family of five members in a year is approximately 200 kg (40 kg/person/year). Assuming that manure obtained is utilized for agriculture purposes, the family saves 19 USD/year from using the manure (assuming a cost of 0.09 USD/kg of manure).

Scalability and replicability considerations

Key drivers for the success of this business are:

- Partnership with local governments, local authorities, international organizations/donors and local communities.
- Central and state government support and incentives.
- Low-cost and locally available technology.
- Movement toward low subsidy regime.
- User payment per use to fund O&M of the complex.

Sulabh's low-cost, environmentally-friendly and socio-culturally-acceptable toilet technologies are suited for up-scaling and replication in other developing countries. The Sulabh movement originated in one town of India but has now spread to 26 states in India. Such facilities should be provided on a pay-and use basis at all places of congregation where 'people throng in large numbers for worship and meditation' there is a need of a decentralized system based on biogas generation technology that is not only cost effective but also easy in operation and maintenance. The hygiene practices of communities are deeply embedded in cultural and religious values and therefore convincing the poor to use a toilet instead of the outdoors and to pay for the construction of a toilet, are great challenges. Moreover, the Sulabh toilet model, while being suitable for dry areas is unsuitable for those with a high water table such as coastal zones or those receiving high degree of rainfall, because of water logging of the pits.

Sulabh technology has been recognized not only by the Government in India but also by governments in other countries and by several international development agencies. In collaboration with UN-HABITAT Nairobi, Sulabh has imparted training to engineers, planners, administrators and entrepreneurs from 14 African countries which include Ethiopia, Mozambique, Uganda, Cameroon and Burkina Faso, Kenya, Tanzania, Cote d'Ivoire, Mali, Ghana, Rwanda, Senegal and Zambia. They have also been trained as part of achieving the Millennium Development Goals set for the sustainable development in water, sanitation, health and hygiene sectors. Sulabh technical team had gone to Ethiopia and Bangladesh for giving training on Sulabh Technologies. The Sulabh model has also been adopted by a number of countries, including China, Bhutan, Bangladesh, Afghanistan, Burkina Faso, Ghana, Kenya, Mali, Nigeria, Senegal, Tanzania and Zambia for expansion and promotion of sanitation facilities. Hence, it can be asserted that Sulabh's technologies have long since passed the test of replicability and scalability. However, for the Sulabh model to be successfully replicated in other countries, close coordination and partnership between the government, local authorities and NGOs backed by community participation is very important.

Summary assessment – SWOT analysis

In addition to its creating technologically and socially efficient solutions, one of the strongholds of the organization is its partnership with the local governments, international organizations and the local communities (Figure 35). Dependence on invitation from government and availability of public funds restricts ability to scale. However, the fact that this NGO is highly recognized by other governments and international NGOs presents opportunity for it to be expanded to other locations.

FIGURE 35. SWOT ANALYSIS FOR SULABH

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Strong partnership with governments and NGOs ▪ Low-cost and socio-culturally acceptable technology ▪ Strong capabilities of organizing communities and social mobilization campaigns ▪ Highly recognized by other governments and international NGO	**WEAKNESSES** ▪ Sulabh largely identified with one individual, the founder ▪ Dependence on internal funds limits ability to scale ▪ Centralized decision making ▪ Technology suitable only in dry regions limits ability to scale ▪ Limitations of NGO for raising capital funds from financial institutions ▪ Health risks from residual accumulation of toxic materials and pathogens
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Out-scaling & up-scaling combination opportunity in other locations through franchise model ▪ Raising more funds from other sources (grants from other NGOs) ▪ Multiple benefits of biogas plants (sanitation, energy reduction in GHG emissions and water supply in dry areas) ▪ Political will and recognition of benefits	**THREATS** ▪ Dependence on invitation from government and availability of public funds restricts ability to scale ▪ Too low revenue collection by pay per use for cost recovery and financial sustainability ▪ Uncertainty on willingness to pay by poor users ▪ Social constraints and psychological prejudice to use of human waste materials

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Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflect our best knowledge at the time of the assessments (2015/2016). As business operations are dynamic, data can be subject to change.

CASE

Biogas from fecal sludge at Kibera communities at Nairobi (Umande Trust, Kenya)

Solomie Gebrezgabher, Jack Odero and Nancy Karanja

Supporting case for Business Model 3	
Location:	Nairobi, Kenya
Waste input type:	Fecal sludge
Value offer:	Sanitation service, energy for cooking and compost
Organization type:	Civil Society Organization (CSO) registered as a trust
Status of organization:	Operational since 2004
Scale of businesses:	Small
Major partners:	Athi Water Service Board (AWSB), Nairobi Water and Sewerage Company, Umande Trust, Local community, Water service providers

Executive summary

Umande Trust–TOSHA 1 is one of the bio-centres that Umande Trust has successfully implemented by working with residents organized in formal groups within the informal settlements to improve access to safe, adequate and affordable bio-sanitation and to provide income generating opportunities for the community. Umande Trust is a civil society organization (CSO) which works closely with community groups, public sector agencies, local government and peer civil society organizations to design, plan and construct bio-centres. The bio-centre is a multi-purpose facility consisting of toilet facilities, a rental space, a meeting hall and a bio-digester. It provides a range of services to the community, i.e. toilet service to the community, biogas cooking facility to women street food vendors, bio-slurry to farmers and a rental space to private businesses. Umande Trust offers technical support and builds capacity of the members of TOSHA 1 to run the bio-centre successfully. Using a pay-for-use revenue model, the bio-centre makes an average net income of nearly USD 1,100 per month. In order for the business to be successfully undertaken, the local communities are important stakeholders in the whole project, thus making community-led strategy the key success factor for the bio-centre. TOSHA 1 is used by an average of 1,000 people per day, making it one of Nairobi's busiest toilets and a producer of biogas. It is a good example of an environmentally-friendly approach to providing sanitation services through safe processing and disposal of human excreta while creating livelihood and jobs to the members of the community-based organization (CBO). A community-led approach to sanitation contributes to capacity building of the community and also to changing people's attitude towards use of human waste as a source of energy and business.

KEY PERFORMANCE INDICATORS (AS OF 2012)						
Land:	0.01 ha					
Capital investment:	USD 22,500 for construction of each bio-centre; USD 10,000 for advertisement/ campaign					
Labor:	Skilled and unskilled labor for construction and running the bio-centre					
O&M cost:	3,720 USD/year					
Output:	Toilet facility 1,000 users/day; Biogas capacity 54 m^3					
Potential social and/or environmental impact:	Improved community health, hygiene and environmental sanitation, improved livelihood and capacity building of community, job creation, reduced environmental pollution					
Financial viability indicators:	Payback period:	3 years	IRR:	33%	Profit margin:	77%

Context and background

Kenya with urbanization rate of 5% per annum has more than 1,800 low-income informal settlements with a total estimated population of 12.5 million. The informal settlements of Nairobi cover about 5% of the total residential land area but they are inhabited by over 50% of the city's total population. The characteristics of an informal settlement (slum) are: lack of basic water at affordable prices, sanitation by public or private toilets and other infrastructural services; unplanned, underserved, high density, poor neighbourhood without legal recognition or rights. Kibera is the largest slum in Nairobi and the largest urban slum in Africa. The 2009 Kenya Population and Housing Census reports Kibera's population as 170,070. About 85% of households buy water from privately or communally-owned kiosks at prices four to five times higher per litre than tariffs charged by the Nairobi Water and Sewerage Services Company. TOSHA 1 is a bio-centre within the informal settlements of Kibera managed by TOSHA[1], a CBO that is supported by Umande Trust in Kenya. The bio-centres are bio-sanitation units that provide secure and adequate access to sanitation and income generation by converting human waste into biogas and liquid fertilizer. Once the bio-centre is constructed, Umande Trust provides technical support and trains the CBOs to run and operate the bio-centre.

Market environment

Despite a number of efforts by a range of actors to improve sanitation, the majority of households in urban areas lack access to healthy and affordable sanitation facilities. Over 60% of the Nairobi population lives in informal settlements with only 25% of the households having access to a private toilet facility while 68% of informal settlement dwellers rely on shared toilet facilities and 6% have no access to toilets and have to use open areas or flying toilets. In addition to household sanitation problems, there is also the challenge of household energy for the urban poor. The high and rising cost of fuel (e.g. kerosene, charcoal, firewood) has been a challenge for the urban poor. The little resources allocated to sanitation were basically used for awareness creation and hygiene education, leaving the development of sanitation infrastructure lagging behind. Residents therein are often unhealthier than their rural counterparts because they are deprived of basic public social services, such as health care, water supply, sanitation and garbage disposal. Slum dwellers, exhibit relatively high mortality rates because they are less likely to access preventative and curative medical care despite their proximity to the best hospitals and clinics located in cities.

One of the support projects of the Athi Water Service Board (AWSB) is the construction of bio-centres in selected areas of informal settlements. Bio-centres are not only initiated in informal settlements but also in community facilities, such as schools and churches, making it easy and quick to reach a large number of people in the communities.

Macro-economic environment

For the purposes of achieving the initial Millennium Development Goals (MDGs) on water and sanitation, the Kenya government, in its Vision 2030, proposed improving waste management accessible to all through the design and application of economic incentives and the commissioning of public-private partnerships (PPPs) for improved efficiency in water and sanitation delivery. The government had also initiated a program to replace the slum with a residential district consisting of high-rise apartments, and to relocate the residents to these new buildings upon completion. The apartments are being built in phases in line with the government's budgetary allocations, and a few apartments in phase 1 of the project have been occupied.

Business model

TOSHA runs TOSHA 1, one of the profitable bio-centres set up by Umande Trust. It is used by an average of 1,000 people per day, making it one of Nairobi's busiest toilets and a producer of biogas (Figure 36). Using a pay-for-use revenue model, the bio-centre makes profit of about USD 1,100 per month. Umande Trust offers technical support and builds capacity of the members of TOSHA 1 to run the bio-centre successfully. In order to gain acceptance for the innovative sanitation approach, public awareness campaigns and trainings were done by Umande Trust. The demand for biogas and bio-slurry as an alternative source of energy and fertilizer is slowly gaining popularity. However, due to cultural and social beliefs and preferences a lot of public awareness campaigns have had to be

FIGURE 36. TOSHA 1 BUSINESS MODEL CANVAS

KEY PARTNERS

- Umande Trust
- Local community
- Water service providers
- Athi Water Service Board (AWSB)
- Nairobi Water and Sewerage Company
- International development agencies and foundations

KEY ACTIVITIES

- Public campaigns and training
- Engineering and construction of bio-centre (build, maintain and transfer)
- Operation and regular maintenance of bio-digester

KEY RESOURCES

- Technical know-how
- Unskilled labor
- Land
- Construction materials
- Human excreta
- Community leaders as endorsers

VALUE PROPOSITIONS

- Affordable toilet and bathroom facilities
- Provide cooking facilities (biogas) at a nominal fee
- Rental space at an affordable rate
- Affordable and high nutrient fertilizer

CUSTOMER RELATIONSHIPS

- Self-service, pay per use
- Self-service, agreement for a nominal fee
- Personal, rent agreement
- Personal, raising awareness through campaigns

CHANNELS

- Direct sales
- Direct sales
- Direct sales
- Direct, focus on awareness phase

CUSTOMER SEGMENTS

- Community
- Street food vendors
- Institutions and private business
- Farmers

COST STRUCTURE

- 10% profit share to Umande Trust
- Toilet facility cleaning
- Construction cost of bio-centre
- Campaign and training
- Operation and maintenance costs (Salaries, toilet consumables, water and electricity, bio-digester repair, etc.)

REVENUE STREAMS

- Toilet and bathroom service fee
- Fees from cooking facility
- Rent for business facilities
- (Future potential: Fertilizer sales)

SOCIAL & ENVIRONMENTAL COSTS

- Using bio-slurry for crops may potentially pose health risks due to possible pathogen survival
- Possible employee health risk while handling digested human excreta

SOCIAL & ENVIRONMENTAL BENEFITS

- Provide livelihood to the members of the CBO
- Improve community health, hygiene and environmental sanitation
- Environmental-friendly approach to providing sanitation services
- Safe processing and disposal of human excreta
- Reduce environmental pollution
- Capacity building of community
- Changing people's attitude towards use of human waste as a source of energy

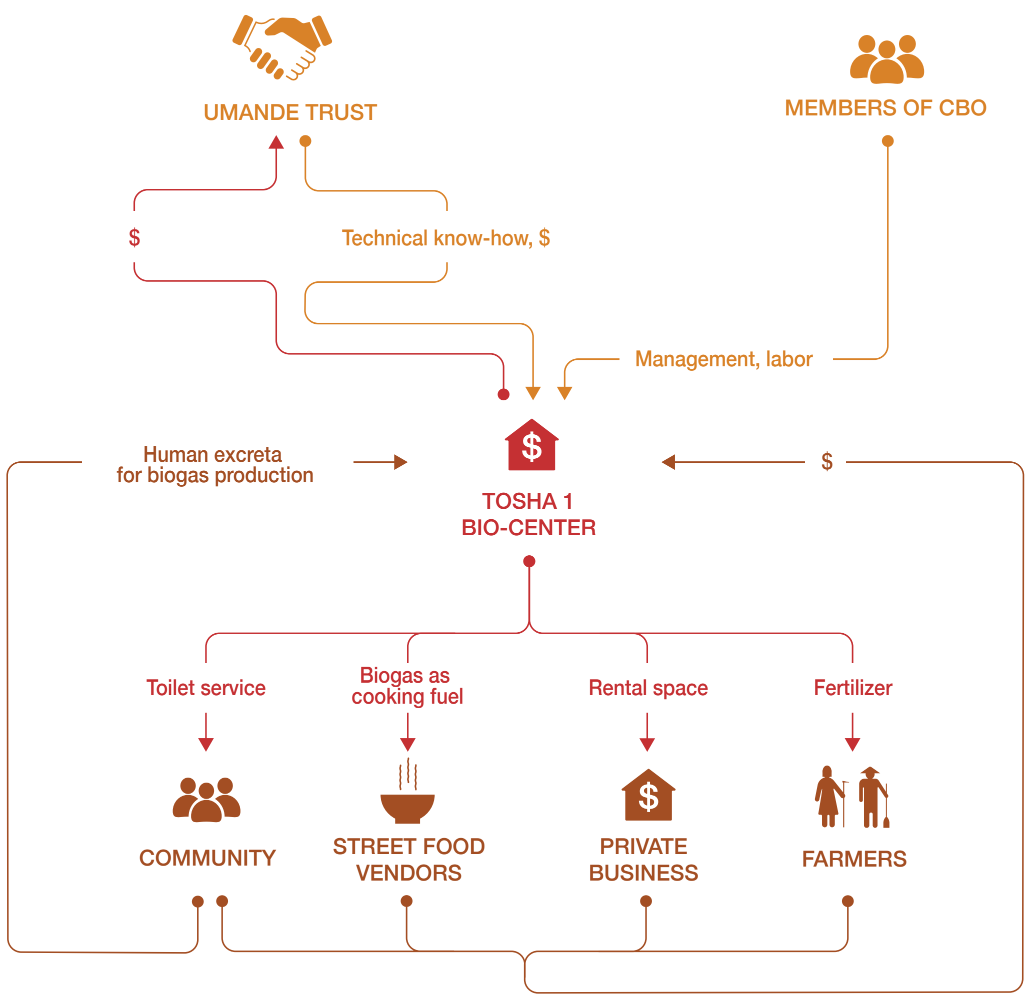
undertaken to break the stigma attached to using human waste by-products. The main customers using the facilities are the nearby residents, food vendors (mostly women), institutions and business people working at the market where the bio-centre is situated. Income generated from the bio-centre is shared amongst the members and 10% of its profit is given to Umande Trust.

Value chain and position

The value chain for TOHSHA 1 is depicted in Figure 37. Umande Trust is responsible for the plan, design and construction of the bio-centre and the success of the bio-centre by offering advisory support and also spearheading campaigns to promote the business activities. Before setting up a bio-centre, Umande Trust identifies, evaluates and selects existing organized groups or CBOs to run the bio-centre. Stakeholder workshops are undertaken to identify the site and the community is involved in selection of the best site. The user surveys, GIS mapping and participatory urban appraisal (PUA) processes ensure that individuals and community groups generate data on existing sanitation conditions and demands.

Once the project is completed, the CBO is trained on how to operate and manage the bio-centre. The TOSHA ensures that customers who come to use the facilities are served. The bio-sanitation centres charge 3 KSh per visit. The water kiosks within the bio-centres charge a flat rate of 5 KSh per 20 L jerry cans. Residents use facilities on a pay-for-use basis once a sponsoring agency provides investment funds for construction. It has also implemented two payment innovations: Beba pay (which exited the Kenyan market in 2015), a cashless system and Kopokopo, which reduce the use of cash handing and promote accountability.

FIGURE 37. TOSHA 1 BIO-CENTRE VALUE CHAIN



Institutional environment

The newly adopted Kenya Constitution has spelled out sanitation to be a human right, and the Ministry of Water and Irrigation (MWI) has drafted a new water policy and bill to align itself to the new constitution. Many sanitation stakeholders have embarked on efforts to improve sanitation situation in Kenya. These stakeholders include government ministries, national corporations and non-governmental Organizations (NGOs). The National Environment Management Authority (NEMA) is a government agency responsible for the management of the environment and the environmental policy of Kenya. The Ministry of Health (MOH) aims at an open defecation-free country by 2017 and has developed a roadmap to achieve this. The installation of bio-centres is part of the intervention targets under Nairobi Informal Settlements Water and Sanitation Improvement Programme (NISWASIP). Athi Water Service Board (AWSB) is one of the eight water boards under the Ministry of Environment, Water and Natural Resources created to bring about efficiency, economy and sustainability in the provision

of water and sewerage services in Kenya. The AWSB focuses on water and sanitation services to informal settlements by constructing bio-centres within its area of jurisdiction. Nairobi City Water and Sewerage Company is tasked to connect water to the bio-centres after completion. The plan was also aligned with the specific Millennium Development Goals (MDGs) on water and sanitation i.e. halving the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015.

Before the start of operation, to set-up a bio-centre, an environmental impact assessment (EIA) is required. There are two types of quality standards applicable to the bio-slurry: the agricultural standard and the NEMA standard. These quality standards require that the bio-slurry has to meet acceptable standards in order for it to be re-used in the farm and also to be safely disposed to the environment. The bio-slurry should be within recommended environmental guidelines.

The Water Services Trust Fund (WSTF) has developed a national sanitation concept for up-scaling public sanitation. Up-Scaling Basic Sanitation for the Urban Poor in Kenya-UBSUP-Kenya is a five-year program which is implemented by WSTF with support from the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). The program is financially supported by KfW, a German financial cooperation, and the Bill and Melinda Gates Foundation (BMGF) and in kind by GIZ. The on-site sanitation systems will have a strong focus on sustainable fecal sludge management.

Technology and processes

TOSHA bio-centre consists of toilets, showers, operator's office, meeting hall, restaurant and a bio-digester. The technology used at TOSHA bio-centre is an adapted replication of the sanitation systems by Sulabh International Social Service Organisation in India. The bio-digester unit is an anaerobic treatment technology that produces biogas and a digested slurry that can be used as liquid fertilizer. The bio-digester is fed with the fecal sludge from the sanitation facilities equipped with flush toilets constructed within the bio-centre serving nearly 600–800 people per day. Each of the three states of matter are rendered useful: gas for the production of energy, liquid i.e. the treated water recycled and the treated solid waste used as fertilizer. The success of this technology depends on the proper construction of the bio-digesters. This means skilled labor is required during the setting-up phase. Umande Trust prefers this type of bio-digester due to the simplicity of construction, operation and maintenance.

The bio-digester is a fixed dome 54 m^3 reactor comprising of brick-constructed dome chamber that has been built below ground. In principle the hydraulic retention time (HRT) should be a minimum of 15 days in hot climates and 25 days in temperate climates as per the design criteria. Average HRT of the bio-digester is 20 days at an ambient average temperature of 25 °C. During operations, water is necessary for proper decomposition of the waste. Hence the operators ensure that despite water shortage, water is made available for flushing the toilets. However, due to insufficient water supply from the water service providers, water is flushed manually using tins from water drums that have been placed within the toilets. In order to avoid foreign objects (non-biodegradable) entering the bio-digester, a sieve is placed at the entrance to trap them. Once waste products enter the digestion chamber, gases are formed through fermentation. The gas forms in the sludge but collects at the top of the reactor, mixing the slurry as it rises. As gas is generated, it also exerts a pressure and displaces the slurry into an expansion chamber. When the gas is removed, the slurry will flow back down into the digestion chamber. The pressure generated can be used to transport the biogas through pipes. The slurry that is produced is rich in organics and nutrients and is almost odorless. No further treatment is done on the slurry, as tests done by Umande Trust, confirm that it is safe to be applied directly by farmers on their farms.

Funding and financial outlook

The general approach used by Umande Trust to construct the bio-centres for CBOs is that they obtain funds to construct the facility while the community would provide all unskilled labor required for construction. The bio-centre requires nearly 100 m^2 of land to construct it. The bio-centre was constructed on private land and hence there was no cost of land acquisition. The cost incurred to construct the bio-centre was nearly USD 22,500 (in 2006) and an additional USD 10,000 for campaigns and training to sensitize the community on the new technology to ensure successful implementation of the project (Table 12).

The main expenses incurred during the operation of the bio-centre include: cleaning the sanitation facilities, operation and maintenance of the facilities and employees to manage the facilities. As part of handing over the facilities to the CBO, Umande Trust ensures that the operators are well-trained to effectively operate and maintain the bio-centre. Campaigns to eradicate the stigma of using biogas and the bio-slurry are also undertaken by Umande Trust. This is done by involving leaders and respected men in the society to endorse the innovation during commissioning of the project.

TABLE 12. TOSHA 1 INVESTMENT, OPERATIONAL AND MARKETING COST

ITEM	AMOUNT (USD)
Investment cost:	
Construction cost	22,500
Campaign	10,000
Total	32,500
Annual operating and maintenance:	
Salary	1,800
Toilet paper	1,200
Water and electricity	240
Maintenance costs	100
Exhaustion services	380
Total cost	3,720

TABLE 13. FINANCIAL SUMMARY OF TOSHA 1 BIO-CENTRE

ITEM	AMOUNT (USD/YEAR)
Toilet services	13,920
Biogas	720
Rent (cyber)	1,200
Total revenue	15,840
Total cost	3,720
Operating profit	12,120
Payback period (years)	3 years
Net present value (NPV) (USD)	50,000
Internal rate of return (IRR) (%)	33%

The major income stream is from toilet services accounting for 88% of the total revenue (Table 13). TOSHA 1 is hardly getting any revenue from the bio-slurry due to personal distaste over using it as fertilizer. Assuming that profits and cash flows will continue to be the same in the future and assuming that useful life of the project is 20 years, the payback period is 3 years, the NPV is USD 50,000 and the internal rate of return is 33%. A future plan of the bio-centre is to containerize the biogas and sell it to individuals, institutions and hotels as an alternative source of energy.

Socio-economic, health and environmental impact

TOSHA 1 is a good example of an environmental-friendly and sustainable approach to providing sanitation services through safe processing and disposal of human excreta. About 1,000 men, women, youth and children from poor slum households have benefited from the bio-centre. The availability of business premises to individual business owners at an affordable rate has contributed to creating entrepreneurs in the community. The provision of clean toilets and bathrooms as well as a cooking area at a very affordable rate have improved the lives of the community residing near the bio-centres. In addition to these, a community-led approach to sanitation contributes to capacity building of the community and also to changing people's attitude towards use of human waste as a source of energy and business.

Amongst the key benefits would be improved health status of the general population with resultant significant savings from medical bills and improved social relations among neighbours who would now be sharing the same facilities. The project promotes renewable energy, helping the shift from the usual wood, charcoal, kerosene and gas to biogas for cooking. This helps in improving energy efficiency, reducing carbon dioxide emissions and alleviating pressure on forests. It is also cheaper and relatively affordable. The consistent participation of communities as shareholders (not stakeholders) is designed to promote ownership, the sharing of responsibilities and profits accruing from community-managed water and sanitation initiatives.

Scalability and replicability considerations

The key drivers for the success of this business are:

- Lack of access to healthy and affordable sanitation facilities for households in urban areas.
- Government strategy, vision 2030 to improve waste management through application of economic incentives and appropriate PPPs.
- Community-led strategy to promote use of biogas and bio-slurry as alternative energy sources and fertilizer respectively.
- Sponsorship from various multilateral, bilateral and national entities.

Umande Trust is replicating this initiative on varying scales in Kenya using funds from sponsors who were encouraged by the success of the existing bio-centre projects. Umande Trust is planning to scale up the sizes of the bio-centres by increasing the size of the bio-digester and the number of latrines as well as commercial facilities. It plans to construct one large bio-centre where the other bio-centres can be emptied into so that they can generate more gas with a possibility of generating electricity. They also plan to construct a bio-centre that use solar and wind energy. With availability of financial resources the goal is also to containerize biogas or pipe it to nearby hotels to increase their sales. In order for this business to be successfully up-scaled and replicated in other locations, community-led strategy with sponsorship from various multilateral, bilateral and national entities is a key to the successful implementation of the project. Moreover, continued campaigns to promote use of biogas and bio-slurry as alternative energy sources and fertilizer respectively are needed.

Umande Trust and the communities have also formed a Sanitation Development Fund (SANDEF), a self-sustaining fund which loans out the funds needed to undertake a sanitation project. Government and NGOs can make a donation to SANDEF. It is after a project is completed that the loan will be repaid to SANDEF and those funds can be loaned out again for another project, hence multiplies the impact of donations.

Summary assessment – SWOT analysis

Key strengths of this business are implementing of community-led strategy and multiple revenue streams, which reduce the risk of failure (Figure 38). However, the business is highly subsidized and high dependence on donor grants pose sustainability issues.

FIGURE 38. SWOT ANALYSIS FOR TOSHA 1

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Community-led strategy ▪ Different revenue streams reduces risk of failure ▪ Strong partnership with local government and NGOs ▪ Low cost and environment-friendly proven technology	**WEAKNESSES** ▪ No immediate market for bio-slurry ▪ Highly subsidized (may pose difficulty in scaling-up) ▪ Limited technical and business skills of the community ▪ Inadequate space for sanitation development in low income urban areas
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Up-scaling potential ▪ Raising more funds from other sources (NGO or bilateral and multilateral entities) ▪ Development of a point-sales biogas market ▪ Unmet opportunities of ensuring access to basic sanitation for low income urban areas	**THREATS** ▪ Stigma against using human by-products and cultural barriers may lead to costly campaigns ▪ High dependence on donor grants pose sustainability issues ▪ Initial reluctance and lack of interest by community ▪ Too many fragmented actors in sanitation sector ▪ Most resources allocated on awareness creation rather than development of infrastructure

Contributors

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Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflect our best knowledge at the time of the assessments (2015–2016). As business operations are dynamic, data can be subject to change.

Note

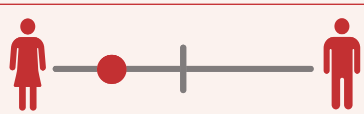
1 TOSHA stands for Total Sanitation and Hygiene Access and was founded in 2004 as a civil society network by the Umande Trust (in Swahili Tosha means ‘adequate’). Over time many CBOs left TOSHA to establish their own bio-centres, resulting in a decentralized approach with wide outreach.

BUSINESS MODEL 3

Biogas from fecal sludge at community level

Krishna C. Rao and Solomie Gebrezgabher

A. Key characteristics

Model name	Biogas from fecal sludge at community level (while providing sanitation services)
Waste stream	Fecal sludge/night soil and/or kitchen waste from public toilets and residential institutions (like prisons)
Value-added waste product	Biogas for cooking and lighting; bio-fertilizer
Geography	Applicable to residential institutions and public toilets that provide toilet facilities to underserved communities
Scale of production	Small to medium scale; as small as 10 m^3 up to 200 m^3 of biogas per day
Supporting cases in this book	Nepal, the Philippines and Rwanda, India, Kenya
Objective of entity	Cost-recovery [X]; For profit [X]; Social enterprise [X]
Investment cost range	About USD 10,000 to USD 85,000
Organization type	Private and public-private partnership
Socio-economic impact	Environment-friendly cooking fuel, reduced deforestation, air pollution and greenhouse gas emissions, improved fecal sludge management results in improved sanitation and health and reduced pollution of local water bodies, employment generation and better landscaping (by use of bio-fertilizers)
Gender equity	Clean indoor air and working environment; creating new and sustaining existing public toilets reducing personal risks especially for women and girls 

B. Business value chain

The business model is initiated by either enterprises/NGOs, providing sanitation services such as public toilets or by residential institutions such as hostels, hospitals and prisons that produce large quantity of human waste. The business concept is to construct new toilets with collection and transfer of waste to bio-digester, process and treat human waste and/or kitchen waste in a bio-digester to generate biogas. Biogas can be used for internal use for lighting and cooking or sold to nearby households and businesses. The bio-fertilizers can be used for landscaping or vegetables gardens within the complex or nearby. Value chain of the enterprise varies depending on the entity initiating the business model.

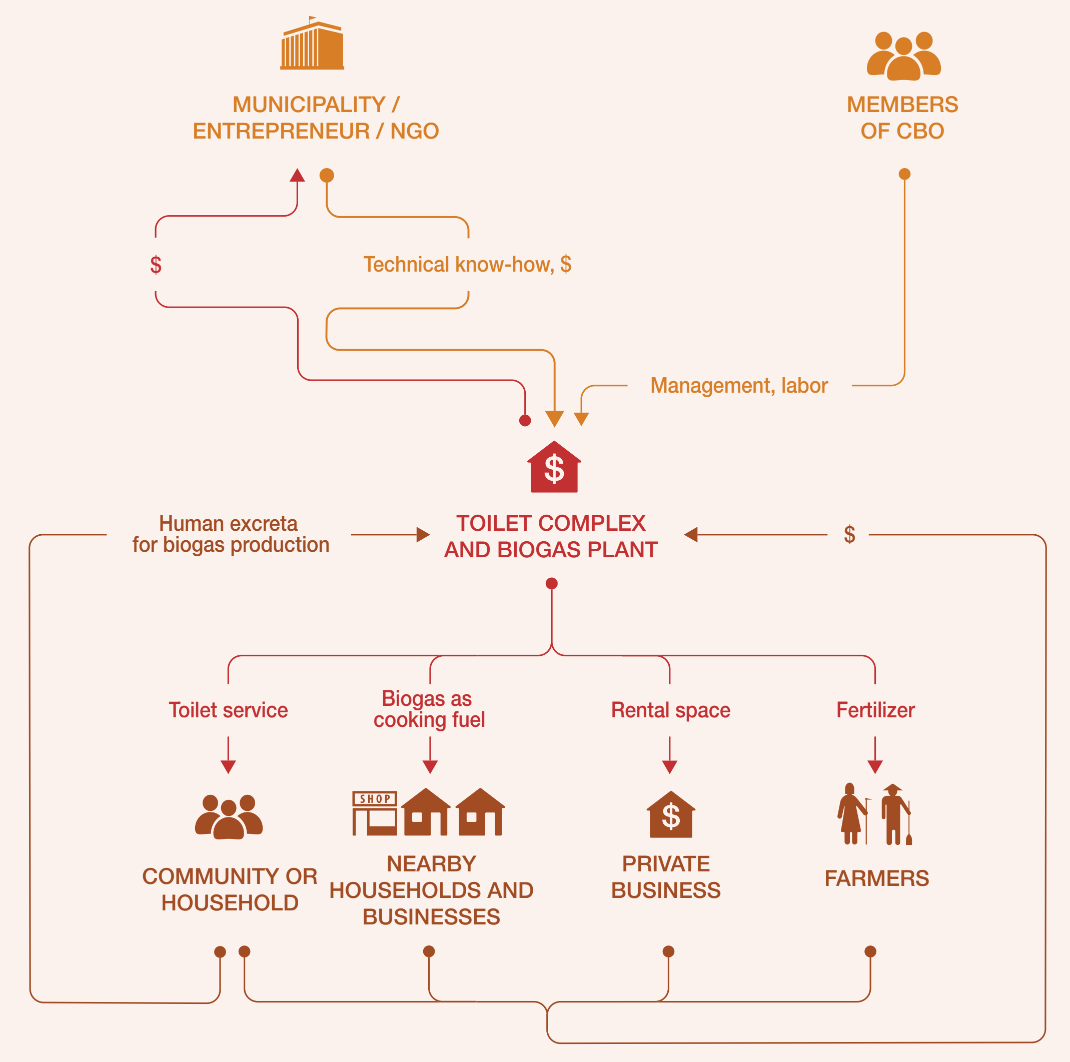
Toilet complex business model

The key stakeholders in this business value chain are the toilet users, technology supplier to install the biogas plant and its maintenance, local bodies and agencies/donors for funding the capital cost, end

users of the additional service (rental space) and value added product (biogas and potentially fertilizer) from the toilet complex (Figure 39).

The ownership and operation of toilet complex can be either by an entrepreneur, a community-based organization (CBO) or municipality. One of the roles of the municipality is to provide land for the toilet complex. Human waste from the toilet complex is fed directly to bio-digester and the biogas generated can be used within the toilet complex for lighting and heating water. The enterprise can also sell biogas to nearby households and businesses as fuel for cooking. Depending on the land space availability, the toilet complex can rent out a space within the complex to a private business such as newspaper/book stand, small neighbourhood retail store and so on. The business could potentially make fertilizer from the bio-slurry output from the bio-digester, which can be used either for landscaping purpose

FIGURE 39. VALUE CHAIN OF PUBLIC TOILET COMPLEX ON-SITE ENERGY GENERATION



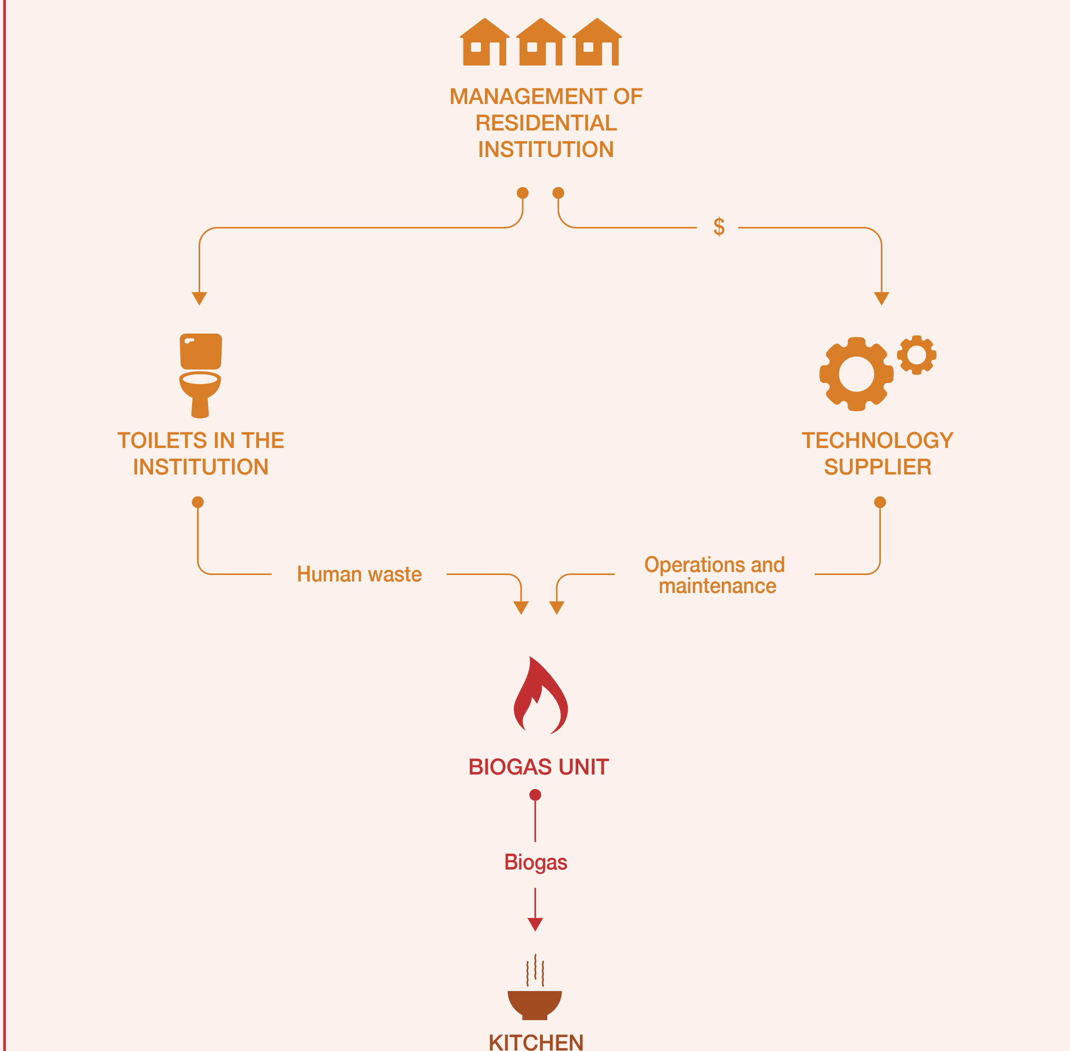
around the toilet complex or sold to farmers. However, since the product is made from human waste, the enterprise needs to take specific care to ensure the product is free from pathogens.

Residential institution business model

The key stakeholders in this business value chain are the management of the residential institution (e.g. prisons), residents (e.g. inmates of the institution), biogas operator and the kitchen management at the residential institution (Figure 40).

The concept in this business is to utilize the concentrated source of human waste generated by residents of the institution to generate biogas, which can be used within the institution premises as fuel for cooking. The process consists of sending human waste from toilets to biogas digester and the biogas produced is used in the kitchen for cooking. As an additional source of income generation,

FIGURE 40. VALUE CHAIN OF RESIDENTIAL INSTITUTION ON-SITE ENERGY GENERATION



potentially the residential institution's inmates can undertake business activity of baking or making processed food that can be sold in nearby town/city. The biogas can also be fed with other organic waste such as kitchen waste and biomass (leaf litter) generated within the institution premises. The bio-slurry from the bio-digester can be used towards landscaping or as fertilizer for growing vegetables within the institution premises under very specific and strict safety protocols.

Both the business models are eligible for sale of carbon as the biogas is generated from human waste. In both these business models, there is scope for private technology enterprise that could get into Build, Own and Operate (BOO) or Build, Own, Operate, Transfer (BOOT) arrangements. The private entity could bring all investment to set up the biogas technology while the institution provides land and sends human waste to the biogas plant. The private entity designs, constructs and maintains the biogas unit until BOOT period is expired after which it assists the institute to operate the unit.

C. Business model

The primary value proposition of the business model for both public toilet complex and a residential institution is to provide improved safe sanitation service in an environmentally responsible manner and secondary value proposition is to generate biogas from human waste. The value proposition remains same irrespective of the entity driving the business initiative which is either the public toilet complex, residential institution or private biogas technology supplier that uses BOO or BOOT approach to provide improved human waste management service to the institution along with provision of environment friendly fuel for cooking. The business model also offers value proposition of providing organic compost from bio-slurry, the output from the biogas plant.

The business model canvas is significantly different for public toilet complex and residential institution (Figure 41). In addition to the value propositions mentioned above, the public toilet complex with biogas plant can offer rental space for a business with access to a uniform group of customer segment.

Public toilet complex enterprise has multiple revenue sources. The primary revenue is from the fees collected for usage of toilet. Other revenue sources are from sale of biogas, compost and rental income. The model requires partnership with municipality or local community for access to land to build the toilet complex.

In the residential institution business model (Figure 42), the biogas is used primarily for internal consumption thereby the institution incurs substantial savings from avoided fuel purchase for cooking. The business model offers scope to sell either entire or excess biogas to nearby households and businesses. In the case of compost, the residential institution can use it internally for landscaping or growing vegetables for internal consumption. The inmates of residential institutions could be organized to undertake business activity of making processed food such as snacks and bakery product and in the process have additional revenue source from sale of these products.

Residential institution model requires developing partnership with biogas technology supplier whose assistance is critical in the initial stages towards operation and maintenance until a local labor is trained. The key activities include the production of biogas and the key resources are land, equipment, biogas technology and access to human waste.

Both these business models are eligible for carbon offset, however the biogas plant size is small to be viable to apply for Clean Development Mechanism (CDM) projects due to associated transaction costs and preferred route would be to apply for carbon offset on Voluntary Emission Reductions (VERs) market.

FIGURE 41. BUSINESS MODEL CANVAS FOR PUBLIC TOILET COMPLEX

KEY PARTNERS

- Equipment suppliers
- Municipality or community
- Carbon trading partners
- Water service providers
- International development agencies and foundations

KEY ACTIVITIES

- Sanitation service
- Processing human waste
- Biogas generation
- Distribution and sale of biogas
- Compost production
- Public campaigns and training
- Managing Voluntary Emission Reduction (VER) process

KEY RESOURCES

- Organic waste
- Equipment and technical know-how
- Land
- Labor
- Community leaders as endorsers

VALUE PROPOSITIONS

- Provision of improved, safe and affordable sanitation service
- Environment-friendly fuel for cooking/heating and lighting
- Organic compost made from bio-slurry by-product from biogas digester
- Provide a convenient space with direct access to a large customer segment of similar outlook

CUSTOMER RELATIONSHIPS

- Direct interaction

CHANNELS

- Direct sales at the enterprise
- Carbon market agents

CUSTOMER SEGMENTS

- Households in the local community
- Households and street vendors
- Farmers and household with garden
- Business
- Carbon market

COST STRUCTURE

- Investment costs – Land, building and equipment and gas distribution lines
- O&M costs – toilet facility cleaning, toilet papers and consumables, training, utilities, labor (can be intensive and skilled labor)
- Costs incurred for VER registration and carbon sale

REVENUE STREAMS

- Toilet usage fees (pay-per-use)
- Sale of Biogas
- Sale of carbon credit
- Sale of compost
- Rental space income

SOCIAL & ENVIRONMENTAL COSTS

- Potential leakage of gas
- Potential health risks for workers from direct contact with human waste
- Potential environmental risk if the human waste is not treated and disposed properly
- Using bio-slurry for crops may potentially pose health risks due to possible pathogen survival

SOCIAL & ENVIRONMENTAL BENEFITS

- Improved human waste management and treatment at the source
- Reduced local pollution from improved human waste management and treatment
- Reduced GHG emission
- Create job opportunities
- Capacity building of community
- Changing people's attitude towards use of human waste as source of energy

FIGURE 42. BUSINESS MODEL CANVAS FOR RESIDENTIAL INSTITUTION

KEY PARTNERS
- Equipment suppliers
- Carbon trading partners
- Local, central and state government agencies for partial funding

KEY ACTIVITIES
- Sanitation service
- Processing human waste
- Biogas generation
- Distribution and sale of biogas
- Compost production
- Training of staff
- Managing VER process

KEY RESOURCES
- Organic waste
- Equipment and technical know-how
- Land
- Skilled labor

VALUE PROPOSITIONS
- Provision of improved safe sanitation service
- Environment friendly fuel for cooking/heating and lighting
- Organic compost made from bio-slurry by-product from biogas digester

CUSTOMER RELATIONSHIPS
- Direct interaction

CHANNELS
- Direct sales at the enterprise
- Carbon market agents

CUSTOMER SEGMENTS
- Inmates of residential Institution
- Nearby households and businesses
- Carbon Market

COST STRUCTURE
- Investment costs – land, building and equipment and gas distribution lines
- O&M costs – training, utilities, labor (can be intensive and skilled labor)
- Costs incurred for VER registration and carbon sale
- Savings from cooking fuel and compost

REVENUE STREAMS
- Sale of biogas
- Sale of cooked food
- Sale of carbon credit

SOCIAL & ENVIRONMENTAL COSTS
- Potential leakage of gas
- Potential health risks for workers from direct contact with human waste
- Potential environmental risk if the human waste is not treated and disposed properly
- Using bio-slurry for crops may potentially pose health risks due to possible pathogen survival

SOCIAL & ENVIRONMENTAL BENEFITS
- Improved human waste management and treatment at the source
- Reduced local pollution from improved human waste management and treatment
- Reduced GHG emission
- Reduction in deforestation
- Create job opportunities

D. Potential risks and mitigation

Market risks: The market risk is different for both toilet complex and residential institution business model. Market risks hardly exist if the business is initiated by the residential institution; however, in the case of toilet complex, it has risks of community or household willing to use the toilet facility. In both the cases, there is a potential social implication of willing to use biogas and bio-fertilizers generated from human waste for cooking and landscaping purpose.

Competition risks: Biogas competes with LPG, kerosene or other traditional cooking fuels such as fuel wood and charcoal. In most developing countries, kerosene and LPG are subsidized for domestic consumption and thus biogas should be produced at a lower cost than these competing products to get buy-in from end users. For end users who use charcoal and fuelwood, there is a need for additional investment in cooking stoves for them to shift to biogas use. However, for the residential institutions with biogas plant, expense incurred for purchasing cooking fuel is reduced significantly. On a long-term basis and before the life cycle of the biogas plant, investment cost of the plant and its operation cost is completely recovered by the residential institution.

Technology performance risks: The technology used is anaerobic digestion, which is well established and mature. However, the type of digester required could potentially be sophisticated and might not be available in developing countries, and in addition the technology requires skilled labor. It is ideal for the business to transfer the technology from a market where it is widely implemented and have their staff trained in repair and maintenance of the technology. The extra care will have to be taken by operators to make sure that digested slurry is free from pathogens before using it as fertilizer.

Political and regulatory risks: In most developing countries, price of cooking fuels such as kerosene and Liquefied Petroleum Gas (LPG) are subsidized for domestic consumption. Such government policies can diminish the economic advantage offered by the biogas supplied to households and in unlikely case, if the policy is extended to commercial entities, the business model is unviable. Lately, governments are encouraging green initiatives by providing incentives such as financial assistance, concessional loans and depreciation benefits. Policies supporting green initiatives make this business model highly attractive.

Social-equity-related risks: The public toilet complex model offers greater benefits to women from increased privacy rather than defecating in the open. The biogas generated from the toilets, if used in household for cooking, would again benefit women due to use of cleaner fuel. The biogas used internally for energy savings and for residential institutions is gender neutral. Both the models mostly offer energy savings and the benefit is accrued by the institution or toilet complex. Employment opportunities, while limited, benefit the marginalized. Improved sanitation in the case of public toilet complex model benefits the underserved.

Safety, environmental and health risks: Safety and health risks to human arise when processing any type of waste but the risks are further increased when dealing with human waste. Labor in such enterprises should be provided with appropriate gloves, masks and other appropriate tools to handle the waste to ensure their safety. Ideally, the enterprise should have strict safety policies as the potential for direct human contact with human waste is very high. The risk of environment pollution is high if human waste is not treated properly and is disposed of openly leading to groundwater or surface-water pollution. The environmental risks associated with the anaerobic digestion units include possible leakage of gas and these emissions should be controlled. Compost from bio-slurry has high risks of pathogens, if not treated properly. However, if proper operation procedures are followed, the risks are reduced significantly (Table 14).

TABLE 14. POTENTIAL HEALTH AND ENVIRONMENTAL RISK AND SUGGESTED MITIGATION MEASURES FOR BUSINESS MODEL 3

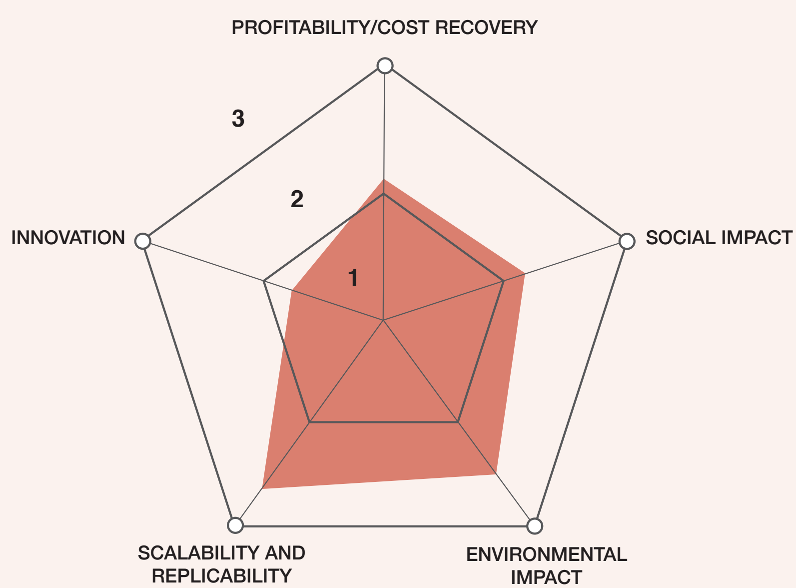
RISK GROUP	EXPOSURE ROUTES					REMARKS
	Direct contact	Air	Insects	Water/ Soil	Food	
Worker						Direct contact risks exist for workers if fecal sludge is wrongly handled, and if also compost is produced. Food produced with bio-slurry compost could have pathogen exposure and should be cooked for safe consumption.
Farmer/User						
Community						
Consumer						
Mitigation Measures						

Key: NOT APPLICABLE; LOW RISK; MEDIUM RISK; HIGH RISK

E. Business performance

This business model scores high on scalability and replicability followed by environmental impact (Figure 43). The business model has high potential for replication in developing countries and, except for the social acceptance of the product from human waste, there are no factors that limit its potential for replication. The business model offers horizontal and vertical scaling by expanding business to other sectors, such as compost and selling cooked food; however, expansion to these other businesses is a theoretical possibility. The environmental impact scores high because of high replication potential that

FIGURE 43. RANKING RESULTS FOR BIOGAS FROM FECAL SLUDGE BUSINESS MODEL



the business model offers that could result in safe management of human waste and in the process reduced pollution of groundwater and surface water resulting in lesser damage of ecosystem and its services.

The business model scores reasonably well on social impact largely from the treatment and safe management of human waste. Depending on the type of entity initiating the business, the revenue source can vary. However, even in the toilet complex business model, which offers multiple revenue source, these will remain modest, while building on cost savings based on reduced fuel expenses. The business model scores low on innovation as the technology and financing required is fairly straightforward.

CASE

Biogas from kitchen waste for internal consumption (Wipro Employees Canteen, India)

Kamalesh Doshi, Krishna C. Rao and Binu Parthan

Supporting case for Business Model 4	
Location:	Bangalore, India
Waste input type:	Food waste, kitchen waste and sewage sludge
Value offer:	Energy for cooking using biogas from kitchen waste
Organization type:	Private
Status of organization:	Operational since 2008
Scale of businesses:	Medium
Major partners:	Mailhem Engineers Pvt. Ltd (for biogas technology, plant and O&M services)

Executive summary

Established in 1945, Wipro Ltd is a large business international conglomerate, with a revenue of over USD 7.3 billion and more than 75,000 employees in India. Wipro Ltd provides comprehensive IT solutions and services, including systems integration; information systems outsourcing; IT-enabled services; package implementation; software application, development and maintenance and research and development services to corporations globally and also produces lighting, engineering, personal and medical products. Wipro operates a large canteen catering to 5,000 to 5,500 employees in their Bangalore headquarters and generates about 1,500 kg of canteen and kitchen waste per day. As a part of its corporate social responsibility, Wipro supported the initiative to convert kitchen and food waste from the employee's canteen to biogas for cooking in the canteen.

Wipro partnered with Mailhem Engineers Pvt Ltd, a waste management technology firm, to install, operate and maintain the biogas plant capable of treating three tons per day (1,095 tons/year) of canteen waste. Mailhem has indigenously developed bio-methanation technologies with modified upward anaerobic sludge blanket technology that treat all types of solid and liquid waste having large percentage of suspended solids. About 69,300 to 74,250 m^3 of biogas is produced annually. The biogas has replaced Liquefied Petroleum Gas (LPG) as the cooking fuel, saving four 19-kg LPG cylinders per day, leading to annual fuel cost saving of USD 24,480 at price of USD 17 per 19-kg cylinder for commercial applications and an increase in brand equity along with generating employment for four people. Around 108 tonnes of bio-sludge is generated annually, which is used as manure in the gardens on Wipro's campus and 3 m^3/day of overflow water is fed to sewage treatment plant in the premises.

KEY PERFORMANCE INDICATORS (AS OF 2014)						
Land use:	300 m^2 (20 m x 15 m)					
Water requirements:	1,500–1,800 L per day					
Power consumption:	25 kWh/day					
Capital investment:	USD 100,000					
Labor:	3 full-time employees and 1 part-time employee					
O&M cost:	USD 10,320/year					
Output capacity:	210–225 m^3/day of biogas; 2 tonnes/day of sludge 1,500 kg/day of canteen waste, vegetable and fruit peels + 12 m^3 of organic sludge from the existing sewage treatment plant (STP)					
Potential social and/or environmental impact:	Jobs for 4 people created, waste reused without being discharged in municipal waste; carbon emissions offset from avoided municipal waste landfill and also replacement of LPG which otherwise would have been used for cooking; carbon emissions saved 37.26 tons CO_2/year from waste recycling and 306.77 tons CO_2/year from LPG saved					
Financial viability indicators:	Payback period:	3.5 years	Post-tax IRR:	> 51%	Gross margin:	25%

Context and background

The biogas plant was initiated by Wipro in 2008 as part of its corporate social responsibility (CSR) initiative. The immediate goal was to manage the kitchen waste in the environmentally acceptable manner with long-term goal of use of waste management initiatives to reduce the company's environmental footprint and to achieve corporate sustainability. It was financed by Wipro through its internal revenues and constructed and installed by Mailhem. Collection and cooking duties are performed by Wipro, while segregation, digestion and production services are performed by Mailhem. The plant is located, adjacent to the kitchen at Wipro's headquarters in Bangalore. The input for the plant is organic canteen and food waste with 80% moisture that is generated in the employees' canteen. Before the biogas plant, it was a tedious task for staff to pack the huge amount of waste in polyethylene bags and hand them over to the civic body almost daily. It is now easy to dump this waste into the biogas plant after some segregation.

Market environment

As Wipro provides the inputs and uses the product within campus, there are no external dependency for the project. Since the project uses canteen and food waste, which otherwise needs to be disposed of, there is no cost of inputs to the project. The product, biogas, is consumed within the campus saving the cost of LPG for cooking. The price of LPG for commercial users is around USD 17 per 19 kg cylinder. LPG for corporations are not subsidized in India, and that is an additional factor motivating Wipro to invest in the technology and generate its own cooking fuel.

Macro-economic environment

There is an emerging focus on green technology in India. CSR also called corporate conscience, corporate citizenship or responsible business is a form of corporate self-regulation integrated into a business model. CSR policy functions as a self-regulatory mechanism whereby a business monitors and ensures its active compliance with the spirit of the law, ethical standards and national or international norms. With some models, a firm's implementation of CSR goes beyond compliance and engages in "actions that appear to further some social good, beyond the interests of the firm and that which is required by law." The aim is to increase long-term profits through positive public relations, high ethical standards to reduce business and legal risk, and shareholder trust by taking responsibility for corporate actions. CSR strategies encourage the company to make a positive impact on the environment

and stakeholders including consumers, employees, investors, communities and others. Wipro's primary motivation for this venture is to showcase the company's corporate social responsibility efforts, better manage its kitchen and food waste, produce biogas and use it on site to reduce its LPG consumption for cooking.

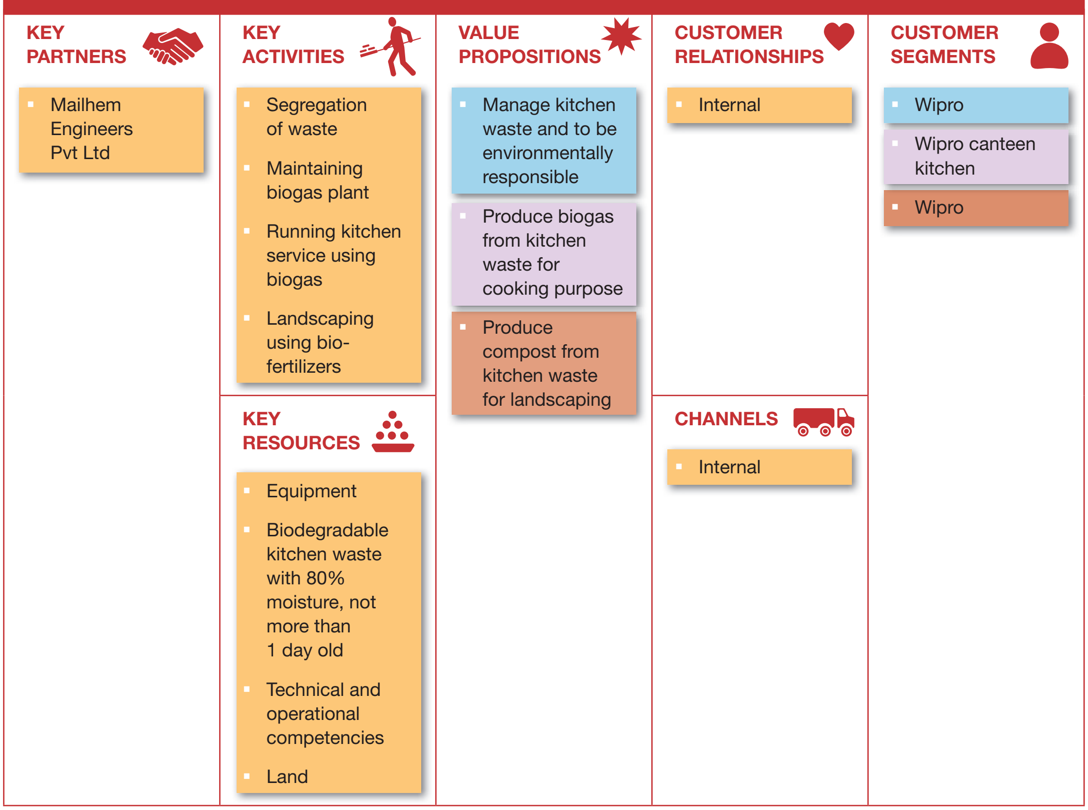
Business model

The value proposition for Wipro (Figure 44) is to minimize cost and to better manage its waste and be environmentally responsible. Wipro serves as both the customer and the producer since it is the supplier of waste and consumer of end products. The key activities include the production of biogas from food waste for use in its kitchen and produce organic compost to be used in landscaping within its campus and the key resources are land, equipment, biogas technology and sourcing of the waste. The produced biogas has resulted in substantial savings from avoided LPG purchase, has created jobs for four individuals and contributed towards reducing pollution of water bodies and natural habitats. In the event of surplus biogas and compost produced, Wipro could sell the energy to neighbouring households and compost to urban households to use them in their garden or to urban farmers. Wipro also would qualify to sell the carbon offset from this investment.

Value chain and position

The value chain consists of collection and segregation of kitchen and food waste, digestion of waste in biogas digester, production of biogas and finally the use of biogas in the kitchen for cooking and use

FIGURE 44. MAILHEM WIPRO BUSINESS MODEL CANVAS



COST STRUCTURE

- Investment cost (land, construction and machines)
- Operational cost (labor and maintenance cost)
- Depreciation
- Saving incurred from use of biogas replacing LPG and fertilizer
- Saving incurred in cost of disposal of kitchen and canteen waste

REVENUE STREAMS

- Possible sale of Certified Emission Reduction (CER) certificates

SOCIAL & ENVIRONMENTAL COSTS

- Possible exposure to pathogens
- Occupational risks from handling machinery and equipment
- Gas leakage

SOCIAL & ENVIRONMENTAL BENEFITS

- Creation of jobs for low-income workers
- Reduce pollution of water bodies
- Reduce pollution of natural habitats
- Reduce human exposure to untreated waste
- Climate change mitigation from reduction in GHG emissions

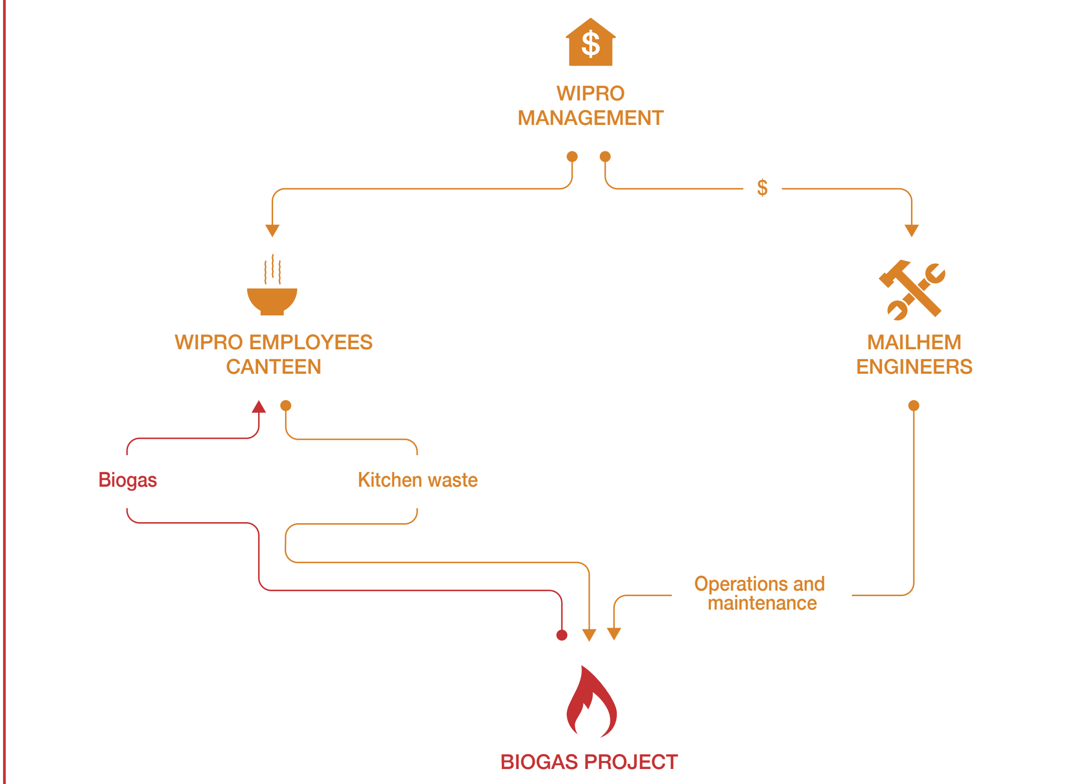
of digested slurry as organic fertilizer for landscaping in the campus. A critical relationship pertaining to the investment is with the kitchen manager and staff who make available kitchen waste with the right moisture and biodegradable content specifications and who again use the biogas for cooking food. Another important relationship is with the Mailhem engineers who supplied the technology and usually also operate and maintain the system. Wipro pays for the kitchen operation and the operation and maintenance of the system (Figure 45).

Institutional environment

In India, the concept of CSR is governed by clause 135 of the Companies Act 2013. The CSR provisions within the Act is applicable to companies with an annual turnover of USD 180 million and more, or a net worth of USD 9 million and more or a net profit of USD 0.9 million and more. The Act encourages companies to spend at least 2% of their average net profit in the previous three years on CSR activities. The government's suggested CSR activities include measures to eradicate hunger; promote education, environmental sustainability, protection of national heritage and rural sports and make contributions to prime minister's relief fund. The new rules, which will be applicable from the fiscal year 2014–2015 onwards, also require companies to set up a CSR committee consisting of their board members, including at least one independent director. The new Act requires that the board of the company shall, after taking into account the recommendations made by the CSR committee, approve the CSR policy for the company and disclose its contents in their report and also publish the details on the company's official website, if any, in such manner as may be prescribed. If the company fails to spend the prescribed amount, the board, in its report, shall specify the reasons.

While the CSR spending by the top 100 Indian companies is estimated at USD 0.86 billion per annum, the Indian Institute of Corporate Affairs anticipates that about 6,000 Indian companies will be required to undertake CSR projects in order to comply with the new guidelines, with many companies undertaking these initiatives for the first time. Some estimates indicate that the CSR spends in India could triple to USD 2.6 billion a year. This combination of regulatory as well as societal pressure has meant that companies have to pursue their CSR activities more professionally. A large number of

FIGURE 45. MAILHEM-WIPRO VALUE CHAIN



companies are reporting the activities they are undertaking in this space in their official websites, annual reports, sustainability reports and even publishing CSR reports.

The Government of India provides economic incentives in the form of accelerated depreciation benefits that can be claimed to offset tax obligations of the firm that invests in renewable energy technology. The Ministry of New and Renewable Energy Sources (MNRE) takes an active part in biogas projects and researches and provides subsidy incentives towards capital costs. The laws in the state of Karnataka mandate the management of organic waste by local bodies. Municipal solid waste management is carried out by the local bodies and not the establishments which generate the waste.

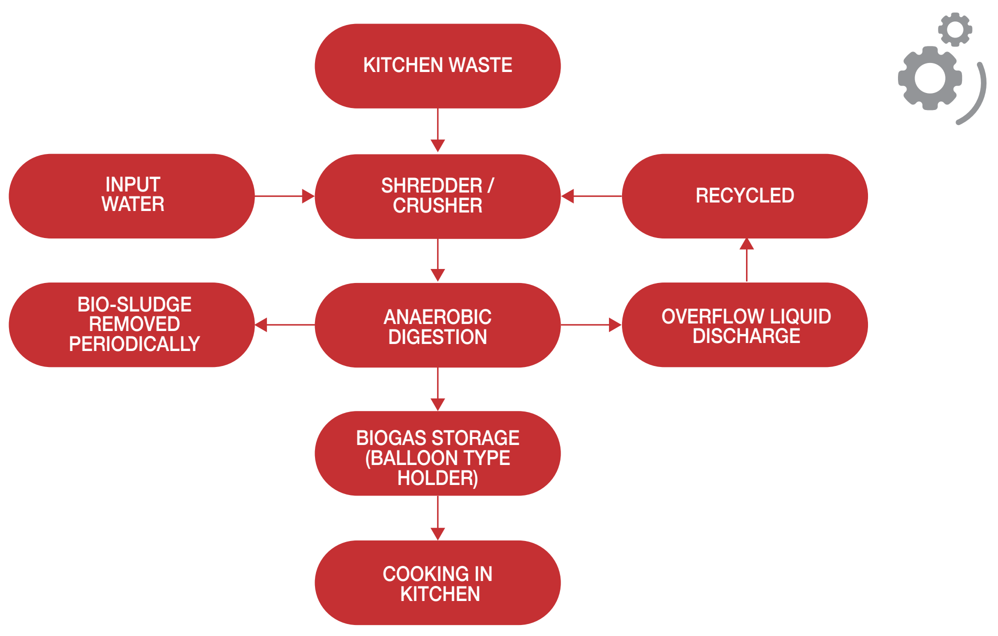
Technology and processes

Fresh (less than 1 day old) biodegradable kitchen waste with 80% moisture is used as the primary input. The facility used high-rate modified up-flow anaerobic sludge blanket (UASB) bio-methanation technology, in which the biomass is retained as a blanket and kept in suspension in the lower part of the digester. The UASB is a high-rate suspended growth in which a pre-treated raw influent is introduced into the reactor from the bottom and distributed evenly. “Flocs” of anaerobic bacteria will tend to settle against moderate flow velocities. The effluent passes upward through, and helps to suspend, a blanket of anaerobic sludge. A particular matter is trapped as it passes upward through the sludge blanket, where it is retained and digested. Digestion of the particular matter retained in the sludge blanket and breakdown of soluble organic materials generate gas and relatively small amounts of new

sludge. The rising gas bubbles help to mix the substrate with the anaerobic biomass. The biogas, the liquid fraction and the sludge are separated in the gas/solid/liquids phase separator, consisting of the gas collector dome and a separate quiescent settling zone. The settling zone is relatively free of mixing effect of the gas, allowing the solid particles to fall back into the reactor; the clarified effluent is collected in gutters at the top of the reactor and removed. Maintenance of the sludge blanket is an important factor in the efficient operation of these digesters. The plant can treat all types of solid and liquid waste having large percentage of suspended solids. The end products are biogas, organic manure and treated water for gardening. The technology is indigenously developed by Mailhem and is locally available and any component that needs to be replaced can be sourced or fabricated locally.

The design and performance of anaerobic digestion processes are affected by many factors. Some of them are related to feedstock characteristics, reactor design and operation conditions. The prerequisites for production of biogas are a lack of oxygen, a pH value from 6.5 to 7.5 and a constant temperature of 35–45 °C (mesophilic) or 45–55 °C (thermophilic). The digestion period or retention period is typically between 10 and 30 days depending upon the type of digestion employed. The anaerobic digestion systems of today operate largely within the mesophilic temperature range. The operation and management of the project is handled by Mailhem and the technicians employed for O&M have been trained and supervised by Mailhem (Figure 46).

FIGURE 46. PROCESS DIAGRAM OF MAILHEM WIPRO BIOGAS PLANT



Funding and financial outlook

The facility was set up at the Wipro campus, using equity from the company's internal finances. The plant and machinery cost USD 100,000 to set up. The primary input, kitchen waste, is sourced through Wipro's internal kitchen and is free of charge. Operation and maintenance costs amount to USD 10, 320 per year (Table 15).

TABLE 15. MAILHEM-WIPRO FINANCIALS

Key capital costs	Land building	No additional charge (uses own land)
	Plant, machinery and civil construction	100,000 USD
Operating costs	Kitchen waste and sewerage sludge costs	No additional charge (from own kitchen and sewerage treatment plant)
	Operation and maintenance	10,320 USD/year
Financing options	Equity from Wipro	100,000 USD
Outputs	Biogas and digested slurry	Supplied to Wipro free of charge and internally consumed to save cost of LPG and organic fertilizers for landscaping

The major savings is from avoided cost of LPG. The investment has resulted in onsite management of waste generated in the employees' canteen and displaces 27.36 tons of LPG, which the company would have purchased otherwise at the cost of USD 24,480 in 2014 prices per year. There are minor savings in the form of avoided purchase of manure for the garden, but these are relatively small. The internal rate of return for the investment is 27.34%. Thus, the investment of USD 100,000 is recovered within less than four years.

Socio-economic, health and environmental impact

In most of cities and places, kitchen waste is disposed in landfill or discarded which causes public health hazards and diseases like malaria, cholera, typhoid. Inadequate management of wastes like uncontrolled dumping bears several adverse consequences. It not only leads to polluting surface and groundwater through leachate and further promotes the breeding of flies, mosquitoes, rats and other disease-bearing vectors. It also emits unpleasant odor and methane which is a major greenhouse gas contributing to global warming.

As the organic fraction accounts for the larger part of the municipal solid waste, anaerobic digestion thereof at its source of generation, a decentralized level, would be an appropriate solution to reduce the amount of waste dumped and/or landfilled as it minimizes transport costs and provides renewable energy and organic fertilizer. Carbon dioxide produced after the burning of methane contributes lesser to climate change than methane. The carbon emissions saved by Wipro's biogas plant is 37.26 tons CO_2/year from waste recycling and 306.77 tons CO_2/year from LPG saved.

The efficient utilization of organic waste in biogas plants creates a cycle of economic sustainability: continuously generated by-products that can be profitably employed to produce electricity, and/or heat. This reduces the accumulation of waste which production plants would otherwise have to dispose of, often at great cost. The benefit is two-fold: The impact on the environment is reduced and the value-added chain is optimized. On top of that, the campuses can use digested slurry/residues as valuable fertilizer and displace harmful chemical fertilizers.

This and other similar initiatives have resulted in a green image for Wipro's electronic city campus, and the employees consider this initiative as a positive aspect of the company's sustainability efforts. The investment has provided full-time employment to three people and part-time employment to one person.

Scalability and replicability considerations

The key drivers for the success of this business are:

- Ease of available bio-degradable waste within the campus.
- Willingness of chefs to use biogas for cooking.
- Availability of land near the canteen within the campus.
- Strong partnership with Mailhem to install, operate and maintain the plant.
- Strong financials with shorter payback period.
- Business is incentivized by green opportunities from market and showcase its corporate social responsibility.

At the present location, the generated kitchen waste is fully utilized by the biogas plant. The digester has the capacity to process three tonnes of waste, and around two tonnes is processed almost daily. Wipro would like to replicate this model to other campuses in the long term. 'Greening' of businesses is also rapidly becoming an important consideration in corporate India, and corporate headquarters with common kitchen facilities could be motivated to uptake such efforts. The corporations and small and medium enterprises (SMEs) can consider such endeavours in the name of CSR. Modest tax breaks or accelerated depreciation offsets offered for such projects will encourage replication, thus boosting the businesses of firms that specialize in renewable energy by providing stimulus for further development of technology. However, businesses would require land for putting up such biogas plants.

Summary assessment – SWOT analysis

The key strength of this case is the sufficient resources available to support the investment and Wipro's mandate to undertake initiatives like this under its CSR program (Figure 47). The weakness is the lack of in-house technical capability to manage biogas plant and land required for the biogas plant. Wipro's biogas plant occupies 300 m^2 of land. The investment does not have any significant threats unless in unlikely situation of heavy price subsidies on LPG for commercial use. The opportunity is huge as this can be easily replicated in other Wipro campuses and also applicable to campuses of other large business corporations and institutions.

References and further readings

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Newsweek 2012. Newsweek's green rating of 500 global companies. http://www.newsweek.com/2012/10/22/newsweek-green-rankings-2012-global-500-list.html (accessed Nov. 7, 2017).

FIGURE 47. MAILHEM WIPRO SWOT ANALYSIS

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Saving in cost of transportation of waste to landfill sites ▪ Easier to maintain hygienic conditions in the premises and elimination of malodors ▪ Well-known technology ▪ Sufficient internal resources to support the waste to energy project ▪ The business model is financially attractive on the basis of avoided cost of LPG purchases ▪ Existence of a corporate sustainability strategy encouraging environment and waste management initiatives ▪ Corporate policy of having own facilities for providing food to employees responsible for central waste generation, collection, segregation and energy conversion	**WEAKNESSES** ▪ Waste management is not part of core business strategy and considerations at Wipro ▪ Lack of in-house technical capability at Wipro for managing and operating the waste to energy plant ▪ Land required for biogas plant is significant and it could be difficult during expansion of the plant if land is not easily available; replication of similar plants in other campuses are dependent upon land available ▪ Source dependent composition of waste ▪ Every biogas plant is different ▪ Negative pressure in biogas system can cause explosion ▪ High upfront cost for potential assessments and feasibility studies
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Favourable policy and regulatory environment for industrial and commercial waste in India; ▪ Renewable energy policy of India ▪ Availability of technical and management expertise and support partners for waste management in India ▪ Opportunities to replicate the kitchen-linked biogas plant in other Wipro campuses as well as other corporate campuses and institutions on a business case, rather than as part of corporate sustainability efforts ▪ Mandated requirements as per Companies Act 013, as per recent amendments	**THREATS** ▪ Changes in the price for LPG directly affect the financial attractiveness of the business; however, LPG prices are unlikely to fall ▪ Lack of awareness of biogas opportunities ▪ Direct animal feeding is an equal or favoured solution to reduce the amount of organic waste (in semi-urban or rural areas)

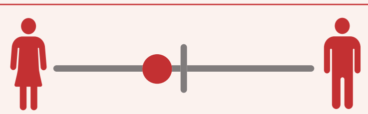
Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflects our best knowledge at the time of the assessments (2015/2016). As business operations are dynamic, data can be subject to change.

BUSINESS MODEL 4

Biogas from kitchen waste

Krishna C. Rao and Solomie Gebrezgabher

A. Key characteristics

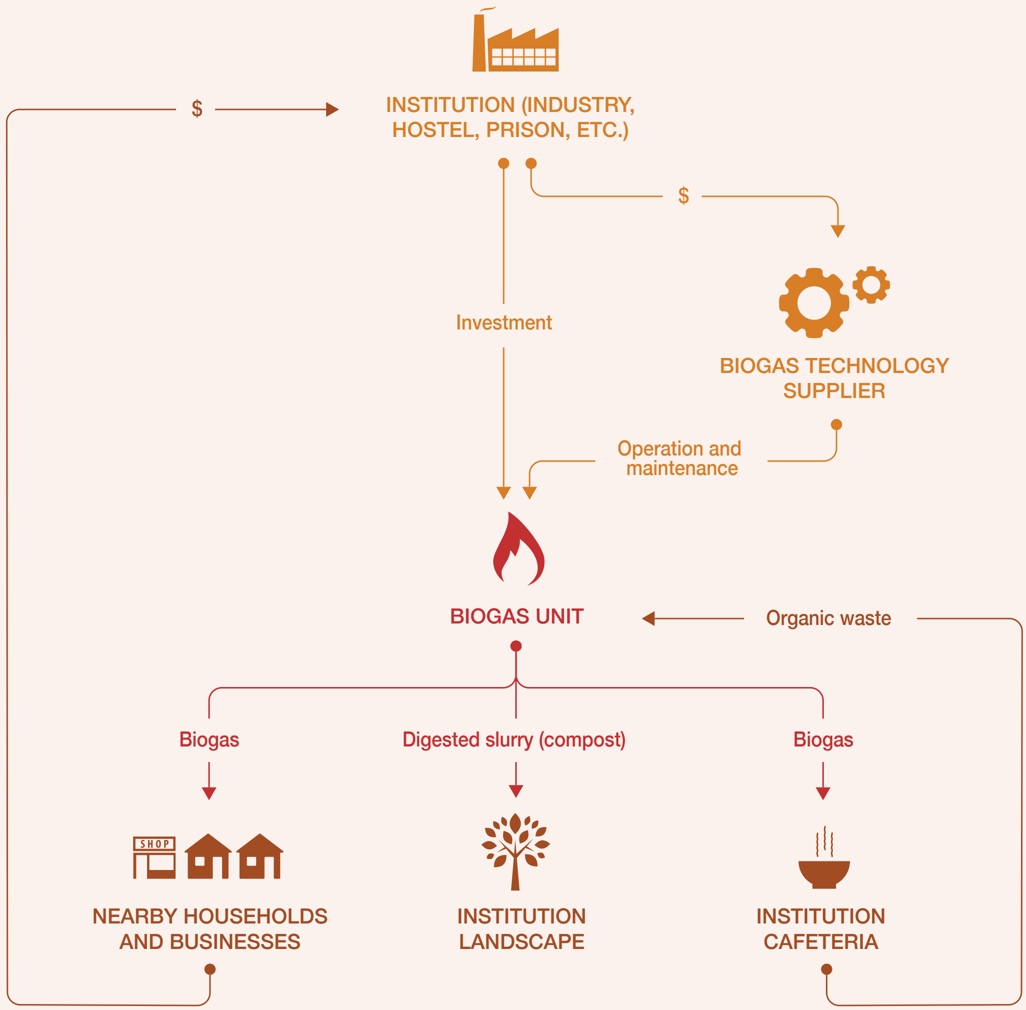
Model name	Biogas from kitchen waste
Waste stream	Kitchen and food waste
Value-added waste product	Biogas as fuel for cooking through anaerobic digestion of kitchen and food waste
Geography	Institutions with large kitchen facility to cook for large number of people
Scale of production	Medium scale; About 100–300 m^3 of biogas per day used to cook food for around 3,000 to 7,000 employees and about 1 to 4 tons/day of sludge as compost
Supporting cases in this book	Bangalore, India
Objective of entity	Cost-recovery [X]; For profit [X]; Social enterprise [ ]
Investment cost range	About USD 75,000 to 125,000
Organization type	Private
Socio-economic impact	Environment-friendly cooking fuel, reduced greenhouse gas emissions; carbon emissions offset from avoided municipal waste landfill and also replacement of LPG/coal/liquid fuel which otherwise would have been used for cooking, improved organic waste management results in reduced pollution of local water bodies and employment generation
Gender equity	Mostly gender neutral; but with benefits through improved indoor air and working environment for women operators/chefs 

B. Business value chain

The business model could be initiated by institutions such as industries, hostels, hospitals, prisons and schools with large cafeteria and kitchen facility that generate large quantities of kitchen waste and food waste. Alternatively, it can be initiated by a technology supplier who provides waste management solution to the institutions. The business concept is to process organic waste from kitchen and cafeteria to generate biogas. Biogas can be used for internal use to cook food in the cafeteria's kitchen or can be sold to nearby households and businesses. Biogas can also be used to generate electricity. The digested slurry (compost) can be used within the institution for landscaping or sold to local farmers (Figure 48).

The key stakeholders in the business value chain are the waste suppliers, institution, technology supplier and end users of the product – the institution itself or household and businesses. The biogas plant can also be fed with other organic waste such as biomass (leaf litter) and sewage sludge generated within the institution premises. The business is eligible for sale of carbon as the thermal energy for cooking is generated from sustainable biomass source instead of using LPG/coal or other liquid fuels

FIGURE 48. VALUE CHAIN OF BIOGAS FROM KITCHEN WASTE



and improved organic waste management as organic waste left in the open releases methane to the atmosphere. Alternatively, this business model can use the biogas to generate electricity especially if the institution is not connected to grid.

In the business model, there is scope for a private technology enterprise, an energy service company, who could get into Build, Own, Operate, Transfer (BOOT) arrangements with the institution. The private entity could bring all investment to set up the biogas technology while the institution provides land and kitchen waste inputs. The private entity designs, constructs and maintains the biogas unit, and sells biogas and digested slurry to the institution. This is done until the BOOT period is expired, after which it transfers ownership of the plant to the institution and assists it to operate the unit on a chargeable basis. The BOOT period can range from three to five years until the investment made by the private technology enterprise is recovered.

C. Business model

The value proposition of the business model varies to some extent with the ownership and the entity driving the business initiative. In the case where the institution is the owner and is driving the initiative, the emphasis is on the management and cost reduction, while it is more on the service provision in the BOOT case. In both cases, the value proposition is to better manage organic waste generated by the institution in an environmentally responsible manner, as well as to generate biogas from food waste for kitchen use. As mentioned above, depending on the connectivity to the grid, the model can offer either electricity or biogas as cooking fuel (Figure 49). Finally, the model also offers the provision of organic compost using the bio-slurry output from the biogas plant that can be used for internally, e.g. for landscaping or sold to local farmers.

If the institution is owner and operator of biogas unit and uses it internally, it incurs substantial savings from avoided fuel purchases for cooking. The business model has scope to sell either entire or excess biogas generated to nearby households and businesses. The model requires the development of a partnership with a biogas technology supplier whose assistance is critical in the initial stages of operation and maintenance until local labor is trained. The key activities include the production of biogas and the key resources are land, equipment, biogas technology and sourcing of the waste.

FIGURE 49. BUSINESS MODEL CANVAS – BIOGAS FROM KITCHEN WASTE

KEY PARTNERS
- Equipment suppliers
- Carbon trading partners

KEY ACTIVITIES
- Kitchen and organic waste collection and segregation
- Biogas generation and use in kitchen
- Maintenance of biogas plant
- Managing VER process
- Compost production
- Landscaping using digested slurry

KEY RESOURCES
- Consumables (MSW and peat)
- Human resource
- Capital and land
- Certification by regulator
- Equipment

VALUE PROPOSITIONS
- Improved management of kitchen and organic waste generated by the institution in environmentally responsible manner
- Environment friendly fuel for cooking
- Low-cost organic compost from bio-slurry by-product from biogas digester

CUSTOMER RELATIONSHIPS
- Direct interaction

CHANNELS
- Direct sales
- Carbon market agents

CUSTOMER SEGMENTS
- Institution, households and businesses
- Institution and potential for households with gardens/ local farmers
- Carbon market

COST STRUCTURE

- Investment costs – land, building and Equipment and gas distribution lines
- O&M costs – training, utilities, labor (can be intensive and skilled labor)
- Costs incurred for VER registration and carbon sale
- Savings – cooking fuel, compost costs and cost of disposal of kitchen and cafeteria waste

REVENUE STREAMS

- Sale of surplus biogas
- Sale of carbon credit
- Sale of surplus digested slurry (compost)

SOCIAL & ENVIRONMENTAL COSTS

- Potential leakage of gas
- Potential occupational health risks from handling machinery and equipment for workers at production facility
- Potential environmental risk if the organic waste is not treated and disposed properly, particularly possible exposure to pathogens

SOCIAL & ENVIRONMENTAL BENEFITS

- Creation of jobs for low-income workers
- Reduction of pollution of water bodies and natural habitats
- Reduction of human exposure to untreated waste
- Climate change mitigation and reduction in GHG emissions
- Improved waste management and treatment at the source contributes to reduced MSW management for the government

The business model primary revenue is from sale of biogas to nearby household and business; however, as mentioned above, when biogas is internally used, it offers operational costs savings for the institutions from avoided fuel purchase for cooking. In addition to energy, a key output from biogas plant is digested slurry (compost), which is rich in nutrients and can be processed to make organic compost that can be used for landscaping within the institution premises. Thus, there is additional savings for the institution from avoided purchase of fertilizer. The biogas model is eligible for carbon offsets. If the biogas plant size is too small to be viable to apply for Clean Development Mechanism (CDM) projects due to associated transaction costs, another preferred route would be to apply for carbon offset on the Voluntary Emission Reductions (VERs) market, or bundle with other similar projects for combined registration as CDM project.

D. Potential risks and mitigation

Market risks: The market risk does not exists if the business is initiated by the institution and the biogas and compost are used internally within the institution. However, in the case of private biogas supplier initiating the business, there is potential risk of the institutions' willingness to participate for a BOOT arrangement. Based on the economics the institution is likely to incur savings and there are no high risks associated except if the biogas plant is not treating the organic waste properly and is causing environmental pollution. If the business has high dependence on sale of carbon credit for its viability, the volatility of carbon credit market puts the sustainability of this reuse business under risk. In such scenarios, the business has to diversify its revenue streams by using biogas and compost productively so as not to entirely depend on the sales of carbon credits.

Competition risks: The business risk for the output is present if the competing fuel source provides higher economic benefits. However, in this business model, there is the cost incurred by the institution to purchase cooking fuel is reduced significantly with biogas plant installed. With short payback periods of three to five years, before the life cycle of the biogas plant, investment cost of the plant and its operation cost is completely recovered.

Technology performance risks: The technology process used is anaerobic digestion, which is well established and mature. However, the type of digester required could potentially be sophisticated and might not be available in developing countries, and in addition the technology requires skilled labor. It is ideal for the business to transfer the technology from a market where it is widely implemented and have their staff trained in repair and maintenance of the technology to mitigate the performance risks.

Political and regulatory risks: In most developing countries, price of cooking fuels such as kerosene and Liquefied Petroleum Gas (LPG) are subsidized for domestic consumption. If the government has similar policies for commercial entities and institutions, it can diminish the economic advantage offered by the biogas plant and hence making this business model less viable. Lately, governments are encouraging green initiatives by providing incentives such as concessional loans and accelerated depreciation benefits. Policies supporting green initiatives make this business model highly attractive.

Social-equity-related risks: The model does not have social equity risks. The model is mostly gender neutral and the benefits are accrued by the institution generating waste with limited or no employment creation.

Safety, environmental and health risks: Safety and health risks to humans arise when processing any type of waste. Laborers in such enterprises should be provided with appropriate gloves, masks and other appropriate tools to handle the waste to ensure their safety. The risk of environment pollution is high if leachate from kitchen waste seeps into groundwater or other natural water bodies. The waste processing technologies are not without problems and pose a number of environmental and health risks if appropriate measures are not taken. The environmental risks associated with the anaerobic digestion units include possible leakage of gas and these emissions should be controlled. Organic waste when left in open begins to decay and releases methane, which is more damaging to the environment than carbon dioxide. There is a very limited chance that the compost made from digested slurry potentially could have risks of pathogens (Table 16).

TABLE 16. POTENTIAL HEALTH AND ENVIRONMENTAL RISK AND SUGGESTED MITIGATION MEASURES FOR BUSINESS MODEL 4

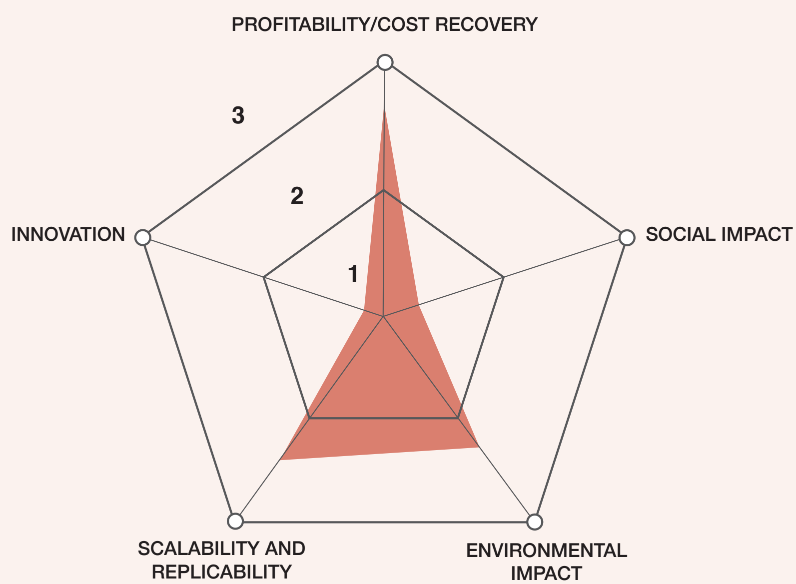
Risk group	Exposure					Remarks
	Direct contact	Air	Insects	Water/Soil	Food	
Worker						Risk to workers through direct contact with waste and compost can be mitigated using protective equipment and gear.
Farmer/user						
Community						
Consumer						
Mitigation Measures						

Key: NOT APPLICABLE; LOW RISK; MEDIUM RISK; HIGH RISK

E. Business Performance

This business model is rated high on cost-recovery and positive environment impact followed by replicability (Figure 50). The business model doesn't have a strong revenue source. However, it is based on cost recovery through savings incurred from avoided fuel expense. In addition, due to it environment friendly aspects, it offers scope for revenue from sale of carbon. The business model has a high potential for replication in developing countries with no limiting factors except for the technology. However, on scalability it scores low.

FIGURE 50. RANKING RESULTS FOR BIOGAS FROM KITCHEN WASTE BUSINESS MODEL



The environmental impact scores high because of high replication potential that the business model offers that could result in safe management of organic waste and reduced burden on the government machinery to manage solid waste. In addition, it offers reduced greenhouse gas emissions. The business model scores low on innovation and social impact. The technology and financing required is fairly straightforward. The social impact scores low due to low job creation and on a comparative basis with other business models managing solid waste, net impact on social development indicators is low.

5. BUSINESS MODELS FOR SUSTAINABLE AND RENEWABLE POWER GENERATION

Introduction

Over 1.2 billion people do not have access to electricity, a majority of them living in countries in Africa and Asia. SDG 7 thus calls to ensure access to affordable, reliable, sustainable and modern energy for all, and to increase substantially the share of renewable energy in the global energy mix by 2030, including energy derived from waste, biogas and biofuels (SDG 7.2). In developing countries, governments are promoting power generation from various agro-industrial waste and municipal solid waste (MSW) streams to improve access to energy and ensure long-term security of power supply. The recent high energy prices, coupled with environmental and financial incentives such as carbon financing and modern biomass energy options such as biomass-based energy generation, are becoming economically attractive in low-income countries. Depending on the waste source and end use of the power generated along with the ownership structure of the entity generating power, the business model can take various forms:

- **Business model 5: Power from manure** – Livestock management and the related industry are important components to the growth of the economy and an important source of livelihood in developing countries. Livestock industry results in large quantities of livestock manure, which if not managed properly pollutes waterways and generates greenhouse gas emissions. However, it also presents an opportunity to harness energy in the form of biogas or electricity on a commercial scale. Business Model 5 demonstrates that through sustainable market mechanisms, successful commercial biogas systems could be implemented.
- **Business models 6 and 7: Power from agro-waste and power from MSW –** In this business model, a social enterprise or private entity which is not a public utility generates power and sells electricity either to utilities or directly to households or businesses. The models are typically focused in regions with communities that do not have access to reliable energy and is one of the key modes to achieve SDG 7 indicators. The business cases discussed take different ownership structure and are initiated by a standalone private enterprise or are set up as social enterprise or as public-private partnerships. While there is increasing need for waste-to-energy plants, high variations in the calorific value of unsorted wet MSW make the business highly dependent on subsidies, which are justified given the large waste volume reduction. However, in this energy section, the focus is on organic waste valorization and not waste in general, thus we did not include waste incineration cases in our selection.
- **Business model 8: Combined heat and power from agro-industrial waste for on- and off-site use –** Majority of large-scale agro-industries such as sugar processing factories, cassava, palm oil and slaughterhouse industrial units in developing countries are diversifying into usage of agro-industrial waste produced during the process into a value-added by-product through co-generation. Energy generation from own agro-industrial waste also referred to as on-site energy generation model is driven by the need for agro-processing units to reduce their energy costs. In addition, these units explore new revenue streams from selling excess energy. The power generation technologies are either designed, constructed, owned and operated by the agro-industrial processing factory or are installed by an external private entity on a Build, Own, Operate, Transfer (BOOT) model. The business model offers a multi-value proposition as it not only allows agro-industries to be self-sufficient in energy while disposing of their waste sustainably, but also secures additional revenue streams by exporting excess renewable electricity to the national grid along with trading of carbon credits.

These business models have been successfully implemented in Latin American, African and Asian countries with cases presented from Brazil, Peru, Mexico, India, Kenya and Thailand. Policies, regulations and institutions play crucial roles in the successful implementation of these business models through appropriate national policies, programs and fiscal incentives. For example, a number of policy

reforms in the Kenyan power sector have liberalized the energy-generation sector thereby paving the way for independent power producers (IPPs) such as Mumias Sugar Company (MSC) to participate in power generation. A number of domestic and international programs to support bagasse-based cogeneration in India were launched which promoted the advancement of co-generation plants in India. These support programs include extension of loans for cogeneration by the Asian Development Bank (ADB) through the Indian Renewable Energy Development Agency (IREDA), capital and interest subsidies, research and development support, accelerated depreciation of equipment, a five-year income tax holiday and excise and sales tax exemptions by the Ministry of Non-Conventional Energy Sources (MNES).

The cases on livestock industry will for instance, demonstrate the role of industry such as the meat or dairy industry in promoting sustainable development in the livestock sector through the implementation of innovative financing schemes to set up biogas systems in the livestock farms to be energy self-sufficient while earning additional revenue through carbon credit market (Sadia case in Brazil). The cases will also highlight effective partnership amongst a range of stakeholders and community-led strategies coupled with market mechanisms to lead to the successful implementation of a rural electrification program.

Thus, depending on local conditions in the respective countries on renewable energy policy, institutional set-up and power purchase agreements, the cases provide a broad range of innovative partnership structure, value chain, market and pricing mechanisms.

CASE

Power from manure and agro-waste for rural electrification (Santa Rosillo, Peru)

Patrick Watson and Krishna C. Rao

Supporting case for Business Model 5	
Location:	Santa Rosillo, San Martin, Peru
Waste input type:	Livestock waste and other agro-waste
Value offer:	Biogas, manure and slurry, electricity efficient waste and water management, climate change mitigation and adaptation, Economic development through renewable Energy Increase of local food production, and added income streams
Organization type:	Public and non-government organization
Status of organization:	Owned by Municipality of Huimbayoc, Operational since 2010; plant managed by the community including its O&M
Scale of businesses:	Small electricity generation plant of 16 kW supplying power to 42 families
Major partners:	Comercial Industrial Delta SA (CIDELSA), SNV, Regional Government of San Martin, Cordaid, Fact, Practical Action

Executive summary

Santa Rosillo, a rural community in the deep jungle of the Peruvian Amazon in northern Peru, is more than 16 to 21 hours away from the nearest city, Tarapoto, and is only accessible by boat and on foot. Santa Rosillo consists of 42 households (220 people) who have an average monthly income ranging between USD 23 and USD 47. Due to the extreme remoteness of the village, prior to this project, most of the community did not have access to electricity and relied on candles, batteries and lighters for domestic lighting. Approximately 12% of the population had access to electricity through private diesel generators.

In 2010, SNV Netherlands Development Organisation (SNV), a non-profit international development organization, in partnership with the regional government initiated a rural electrification project to install two bio-digesters in the village linked to a power generator and mini-grid to provide electricity to the community. The community's primary economic activity is livestock and agriculture (cocoa), and all organic waste is fed into the two bio-digesters. The biogas generated is fed into the electricity generator and electricity is distributed to each house. The installed electrical capacity is 16 kW which provides electricity to 42 houses, the local doctor's office, the local college and public lighting for approximately

5.3 hours per day. Approximately 60% of the slurry by-product produced by the bio-digesters is then used as fertilizer to improve the soil quality of the communal grazing area, while the remaining 40% is sold to local farmers. Comercial Industrial Delta SA (CIDELSA), a Peruvian engineering company, supplied the two lagoon bio-digesters for the project.

KEY PERFORMANCE INDICATORS (AS OF 2013)						
Land use:	3,000 m^2 (including community grazing area for animals)					
Water	50,000 L/year					
Capital investment:	USD 130,519					
Labor:	1 x system operator / administrator (full-time)					
O&M cost:	USD 0.57 per kWh (total levelized cost of electricity over a life of 20 years)					
Output:	16 kW for 5.3 hours/day, supplying 85 kWh/day of electricity, Biol (solid fertilizer) and Biosol (liquid fertilizer)					
Potential social and/ or environmental impact:	42 households now have access to electricity; it has reduced the environmental pollution from manure and improved livelihood of remote community					
Financial viability indicators:	Payback period:	N.A.	Post-tax IRR:	N.A.	Gross margin:	N.A.

Context and background

The Santa Rosillo community is located in the district of Huimbayoc, 190 km from the city of Tarapoto in northern Peru. The community's main activities are agriculture, livestock and forestry, all of which generate organic waste, which was not being utilized prior to this project. Because of its remote location, the community is not connected to the national energy grid and had very limited access to gas or electricity, leaving its 42 families reliant on diesel generators or candles for power and lighting. In 2010, SNV in alliance with Practical Action and local partners commissioned the installation of two bio-digesters by CIDELSA, a company with over 10 years of experience building and installing bio-digesters. The project in Santa Rosillo was the pilot installation for SNV's rural electrification program, "BIOSINERGÍA: Access to energy with biofuels in the Peruvian Amazon." The National Public Investment System, a government investment initiative, funded the grid connecting the power generators to the village whilst the foundations CORDAID and FACT funded the installation and equipment costs for the power generators.

Market environment

Prior to the installation of the bio-digesters, only 12% of the population had access to electricity, generated through private generators and solar panels. Average usage was 2.5 hrs/day and the monthly cost ranged from USD 9.6 to over USD 465 per household/family. The families with higher costs were those that had small businesses such as a restaurant or furniture shop. The remaining 88% used battery-powered lights and candles for lighting. This project provides electricity to 100% of the community of Santa Rosillo. One of the principal advantages of this project is the anticipated low cost of electricity compared to other available forms of rural electrification. Each family is undergoing a grace period until January 2013, at which point a flat rate of USD 6 (average cost prior to project) will be charged until an exact wattage consumption has been determined. The final cost will be determined by demand, operational and maintenance costs, in addition to the population's ability to pay (approximately USD 6/month).

In Santa Rosillo, the cattle alone produce approximately 300 kg of manure daily that is now used as fuel rather than contaminating the local waterways. If this project proves successful it is intended that it will be rolled out to other rural communities throughout Peru.

Business model

The project has two key value propositions: providing electricity service to houses and businesses and providing fertilizer to farmers in Santa Rosillo (Figure 51). The municipality, donor agency and local organization played a key role in mobilizing the community and financial resource to establish electricity service provision. Since the project results in carbon offset, there is potential for generating revenue from sales of carbon.

FIGURE 51. SANTA ROSILLO RURAL ELECTRIFICATION BUSINESS MODEL CANVAS

KEY PARTNERS

- Municipality of Huimbayoc
- SNV
- CIDELSA
- Regional Government of San Martin
- Cordaid, Fact and Practical Action

KEY ACTIVITIES

- Agreement with relevant partners
- Community mobilization
- O&M of the biogas unit
- Sale of electricity and fertilizer
- Organic waste collection

KEY RESOURCES

- Land
- Capital
- Labor
- Organic waste

VALUE PROPOSITIONS

- Providing low-cost electricity service to houses and businesses in Santa Rosillo from livestock and agriculture waste
- Produce high quality solid/ liquid fertilizer

CUSTOMER RELATIONSHIPS

- Interaction with community through a local a subsidiary that manages the operation of the unit

CHANNELS

- Through appropriate agreement and self-interaction
- Direct sale of bio-fertilizer

CUSTOMER SEGMENTS

- Households and businesses
- Farmers

COST STRUCTURE

- Investment cost (Land, building, machines)
- Operational cost (raw material, labor, maintenance cost)

REVENUE STREAMS

- Sale of electricity to households/business
- Sales of fertilizer/slurry

SOCIAL & ENVIRONMENTAL COSTS

- Potential leakage of CH_4 from bio-digesters

SOCIAL & ENVIRONMENTAL BENEFITS

- Jobs creation
- Environmental benefit through reduced CO_2 emissions by generating electricity from renewable source
- Better local environmental condition by improving quality of water and reducing soil pollution and foul doors
- Reduced GHG emission (CH_4) and climate change mitigation

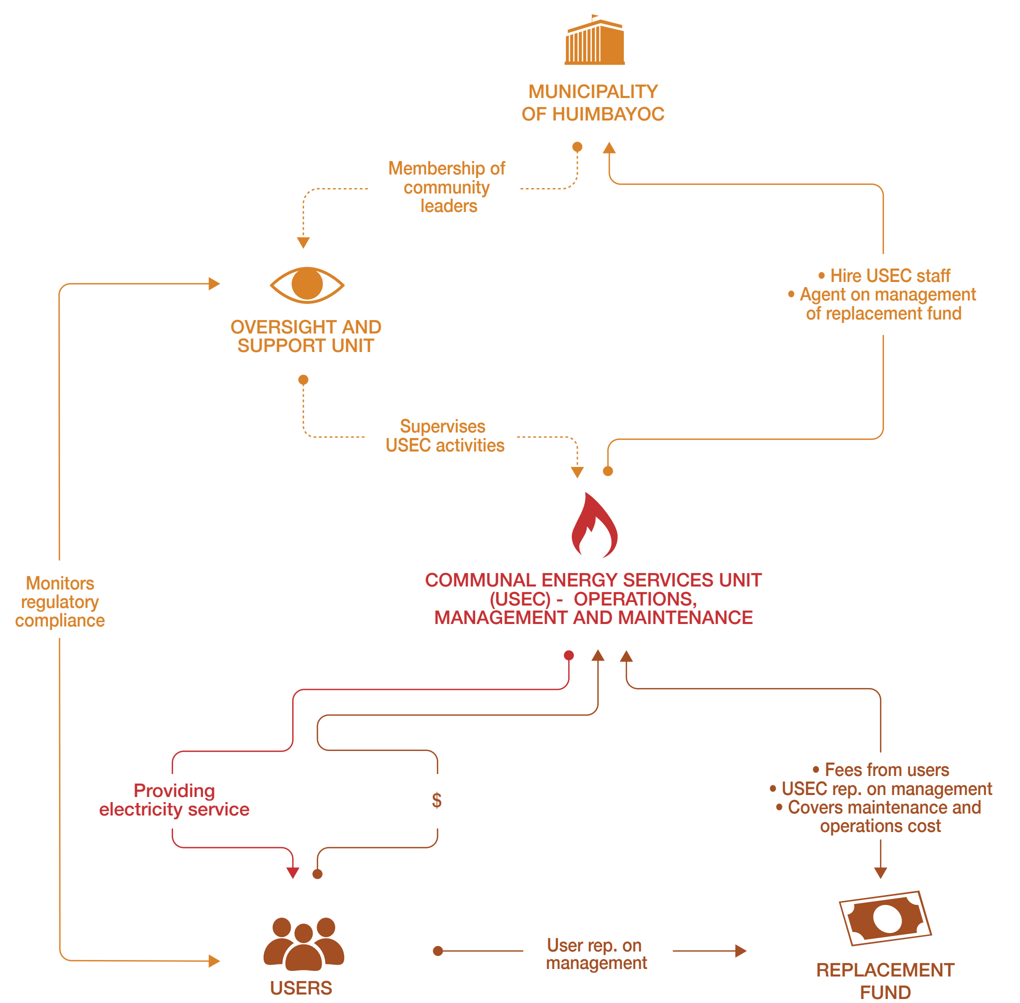
Value chain and position

Santa Rosillo's two bio-digesters are fuelled by the waste produced by the community's cattle (approximately 60), which are kept in a partial barn. Cattle spend 12 hrs/day in a communal pen, and two members of the community are responsible for collecting excrement once daily. Each cow produces approximately 5 kg of manure per day, yielding a total of 300 kg, which is loaded into the bio-digesters on a bi-weekly basis.

The project is designed as a cooperative structure to provide energy service at a cost lower than the possible alternatives. Figure 52 displays the overall management structure. The following describes the role of key actors in the process:

- Communal Energy Services Unit (USEC): The USEC team, made up of two people from the community, is responsible for operating and maintaining the system on a daily basis in direct and constant contact with both users and community authorities.

FIGURE 52. SANTA ROSILLO RURAL ELECTRIFICATION VALUE CHAIN



Note: RF = replacement fund; USEC = Communal Energy Services Unit.

- Municipality of Huimbayoc: The municipality owns the power generation and distribution system and hires USEC to maintain and operate it. The municipality voluntarily undertakes equipment inspection and maintenance checks alongside USEC and subsidizes the maintenance costs that cannot be covered by revenues from the system.
- Oversight and Support Unit: Comprised primarily of community leaders; this unit is responsible for monitoring USEC and user compliance.
- Users: The community members of Santa Rosillo, who will pay a monthly fee for electricity used, once established. Each user will have electricity meter installed in their homes and sign an electricity supply contract.

Income generated from service fees will be used to create a revolving fund designed to cover operational, management and maintenance costs. The revolving fund will be managed by three people from the USEC, a user representative and a municipal agent.

Institutional environment

Electricity access in rural Peru is challenging because of the mountainous terrain and scattered settlements. Low energy consumption and limited purchasing power per household add to the challenge. Investors are therefore not attracted to these projects unless the state provides the right financial incentives and other necessary requirements. Renewable energy is a largely unexploited market in Peru and small-scale renewable energy (biogas, biofuels, small-hydro and solar energy) provides less than 1% of national energy supply.

In 2008, the Peruvian government passed a legislative decree to promote inclusion of renewable energy, which includes biogas. This has helped renewable energy production growth exponentially. The government of Peru projects renewable energy to provide 7% of the national energy supply by 2017. The Ministry of Energy and Mines and its General Directorate of Rural Electrification (MINEM-DGER) have 437 rural electrification projects clustered into 35 groups. The total investment is estimated at USD 418 million and will benefit 1.2 million people (Mitigation Momentum, 2015). Additionally, DGER is implementing 16 other special projects which will benefit 150,000 people; approximately USD 140 million will be invested.

The government of Peru has identified rural development, environmental protection and energy security as national priorities. They have developed a legal and regulatory framework that promotes competition and investment in the sector and, more recently, have successfully developed mechanisms to promote the use of our vast renewable energy resources. The 2013–2022 National Rural Electrification Plan produced by MINEM, in concordance with an Energy Universal Access Plan, establishes a policy for the sector with the aim is to raise the rural electrification rate from 87% to 95% by 2016. The national electrification rate has increased from 55% in 1993 to 87.2% in 2012. The National Rural Electrification Plan 2013–2022 provides strategic direction to provide access to electricity to 6.2 million people in the next 10 years. Peru is undertaking efforts to increase access to energy via auctions for solar photovoltaic systems, grid extension, mini-grids with hydro, solar and wind. The Law for the Promotion of Investment in Renewable Energy Generation[3] grants competitive advantages to projects for renewables.

The following policies have been established to address these issues:

- Use of renewable energy in electricity generation (2008), amended 2011: The government is promoting the use of renewable energy resources by providing tax concessions to qualifying projects, e.g. biomass, wind, solar, geothermal, tidal and hydropower.

- Non-conventional renewable energy resources in rural areas (2005): This law provides additional tax concessions to qualifying projects that promote the use of non-conventional renewable energy in rural communities.
- Investment in electricity generation using water and other renewable resources (2008): In order to incentivize the investment in a renewable energy infrastructure, all renewable energy projects benefit from accelerated depreciation for tax purposes.

Technology and processes

The two bio-digesters, each with a 75 m^3 capacity, produce biogas for electricity (16 kW), and bio-fertilizer. Figures 53 and 54 depict bio-digesters and the power generation system, which in turn is connected to a micro power grid, extending electricity to each family.

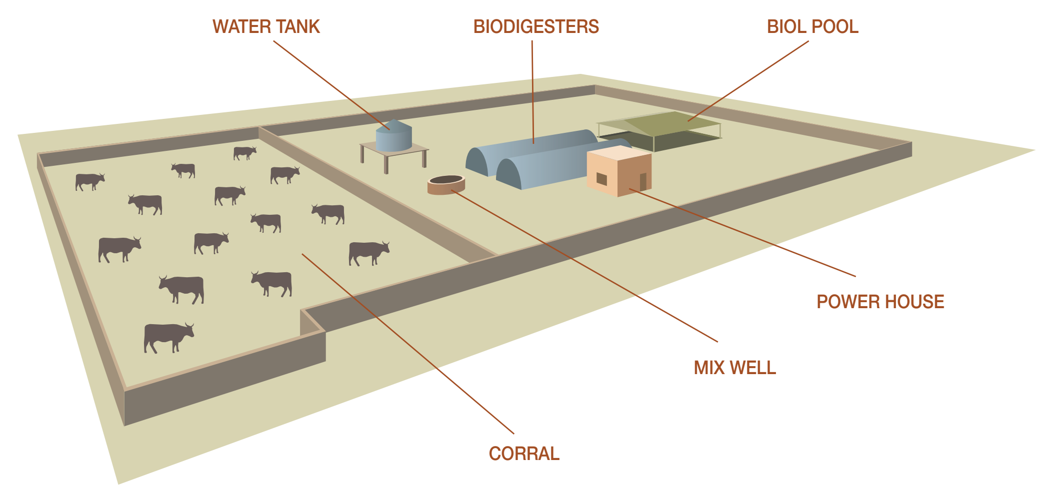
The amount of biogas generated will depend on the quality of cow manure collected, as a rough estimate 1 kg of cow manure will generate about 40 L of biogas.

Despite popular belief, the amount of waste going in the digester is almost equal to the amount coming out. However, the quality of the waste is altered for the better (less odor, better fertilizer, organic load reduced, less polluting). Waste coming out of the digester can be separated (solid/liquid): the solid part can be composted (Biol) and the liquid part can be used as liquid fertilizer (Biosol) or can be treated further and disposed.

Funding and financial outlook

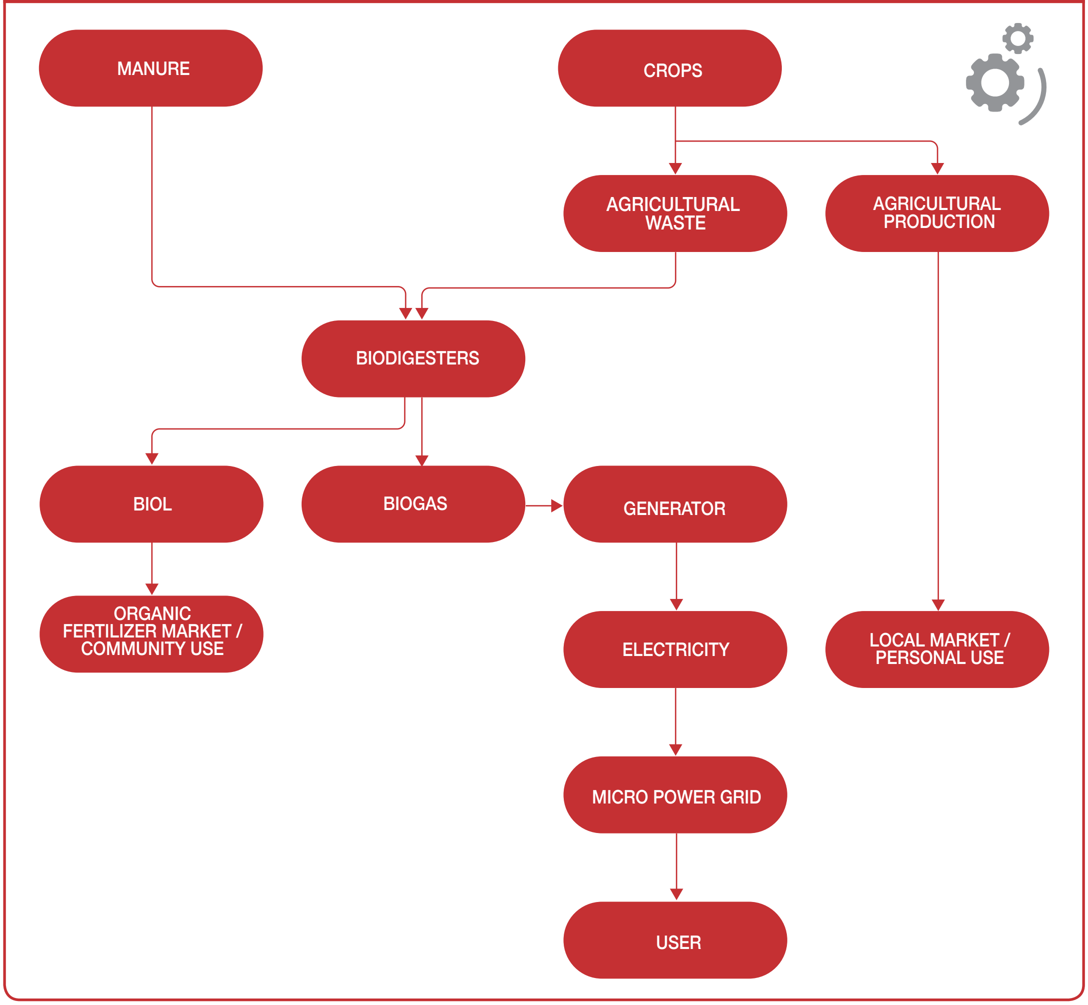
The total project cost of USD 130,519 was funded as grant through a public-private partnership between the Regional Government of San Martin (GRSM) (30%), FACT and CORDAID (68%), in addition to each beneficiary family contributing USD 59 (2%) (Table 17).

FIGURE 53. SANTA ROSILLO RURAL ELECTRIFICATION GRAPHIC



Source: Veen, 2014; modified.

FIGURE 54. SANTA ROSILLO RURAL ELECTRIFICATION TECHNOLOGY AND PROCESS



Source: Veen, 2014; modified.

TABLE 17. INVESTMENT SOURCE AND AMOUNT

ITEM	AMOUNT (USD)
Regional Government of San Martin	39,285
FACT & CORDAID	88,305
Beneficiary (USD 59/household)	2,930

Each family was given a grace period until January 2013, at which point a flat rate of USD 6 (average cost prior to project) will be charged until exact wattage consumption has been determined. The final cost will be determined by demand, operational and maintenance costs, in addition to the population's ability to pay (approximately USD 6/month). In this case, the electricity generator is created to meet a need in the community, which pays for the service. In turn, these revenues allow the proper operation

and maintenance of the company, so the service becomes sustainable over time. The sale of slurry will provide an additional income stream.

The following assumptions were built into the financial projections (Table 18):

- Total generating capacity of 619,040 kWh over a 20-year life, slowly ramping up to full capacity over the first 10 years. The generating capacity of the bio-digesters is 16 kW whereas the demand of the community is 13 kW.
- Demand for electricity will grow at a continual pace of 2.5% annually, primarily driven by population growth. Demand is expected to be approximately 17 kW by 2022, slightly higher than the capacity of the two bio-digesters (16 kW).
- Service fees are based on estimated operational and maintenance costs for equipment repairs, replacement parts and servicing. Total estimated costs are USD 3,516 in Year 1, reaching USD 5,621 by Year 20. This assumes a growth rate of 2.5% in line with demand.
- The bio-digesters can produce roughly 1,041 L of slurry per day which, with a potential sales value of USD 0.05/L, will generate a monthly income of approximately USD 1,500. It is estimated that only 40% of the generated slurry will be sold, helping to cover O&M costs that are not covered by the monthly fee income.

TABLE 18. SANTA ROSILLO FINANCIALS

PROJECT FINANCIAL SUMMARY				
USD	**YR0**	**YR1**	**YR2**	**YR3**
Investment				
GRSM	(39,284.56)			
FACT & CORDAID	(88,304.84)			
Community investment (~USD 59 per family)	(2,929.69)			
(+) Income		**11,198.21**	**11,286.10**	**11,376.18**
Annual usage income (50 families)		3,515.63	3,603.52	3,693.60
Growth rate			2.5%	2.5%
Sale of Slurry (41% total production)		7,682.58	7,682.58	7,682.58
(–) Costs		**(11,263.17)**	**(11,263.17)**	**(11,263.17)**
Operational / Maintenance		(11,263.17)	(11,263.17)	(11,263.17)
Cashflow	**(130,519.09)**	**(64.96)**	**22.93**	**113.01**

Source: Authors.

Socio-economic, health and environmental impact

The project benefits the Santa Rosillo community, its approximately 50 families. More than 220 people now have access to electricity, allowing them to improve their living conditions. Children now have more hours of light to do homework, enhancing the learning process. There are improved teaching conditions in schools, enabling the use of computers. The slurry (effluent from bio-digesters) can be used to enhance crop yields, further improving family incomes. There will also be a reduced likelihood of domestic accidents from the use of candles and better illumination in the house, as well as improved conditions in the community health centre, including the ability to now refrigerate drugs and vaccines.

By extracting methane out of waste and using it to produce heat and/or electricity, we ensure that the waste will not degrade in an open environment, therefore reducing direct methane atmospheric

emissions. By managing and reusing the livestock excrement, the project has substantially reduced pollution of the local rivers and lakes. Moreover, the energy provided by the biogas is likely to displace fossil fuel which is the main contributor to GHG emissions. By installing a digester the farmer can profit from the biogas by reducing doors and enhancing the fertilizing value of the manure. The project requires less area than aerobic compost, reduces the volume and weight of landfills, produces a sanitized compost and nutrient rich liquid fertilizers, maximizes the benefits of recycling and in the process improves the air quality through improved odor and reducing groundwater contamination.

Scalability and replicability considerations

The key drivers for the success of this business are:

- Strong financial support from municipality, donors and local agencies.
- Strong community participation.
- Simple low-cost model.
- Ease of available animal and agro-waste.

The community of Santa Rosillo is the representative of a large number of rural Amazonian villages within Peru and in other countries with similar conditions that are not connected to the electric grid or other natural resources (e.g. sun or strong water current for solar or hydro power) required for alternative micro-power solutions, but that have high volumes of unused organic waste (e.g. from agriculture or livestock). According to the Peruvian national Census (2007), there are 2.2 million households in rural areas, 36% of which do not have access to the national grid equating to approximately 800,000 households. Many such communities are heavily reliant on cattle and other livestock that produce significant waste, which traditionally causes on-going water pollution and land degradation.

Summary assessment – SWOT analysis

The key strength of the project is its low-cost alternative electricity solution for a remote region and a proven technology that can readily use abundant available waste source (Figure 55). The weakness of the project is its inconsistency in provision of reliable electricity and in addition if the community size grows and when the demand for electricity increases, the electricity generated will not be sufficient to meet new higher demand.

The key threat to the project is from the remoteness of the site. In the event of system failure, due to lack of local technical know-how and available skill, time taken to repair the unit will be longer. This can result in the community losing faith in the overall project. However, based on the success of Santa Rosillo's electrification project, it has very high potential for replication and it can help the Peruvian government define policies to ease the replication of the business with minimum obstacles.

Contributors

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FIGURE 55. SANTA ROSILLO RURAL ELECTRIFICATION SWOT ANALYSIS

	HELPFUL TO ACHIEVING THE OBJECTIVES	HARMFUL TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Simple and cost-effective example of public-private partnership that can be applied in numerous geographies and communities ▪ Provides a relatively low-cost alternative for electricity to communities that cannot gain access to the grid because of their remote location ▪ Uses an abundant waste source to generate off-grid power ▪ Utilizes very simple technology, easy to operate without significant prior technical knowledge ▪ Limited/low operational and maintenance requirements ▪ The production of fertilizer and gas is not heavily dependent on the type of excrement/waste used	**WEAKNESSES** ▪ Low cost to users is highly dependent on sale of slurry, which is anticipated to provide a subsidy ▪ Power from bio-digesters is inconsistent. The continuous supply of service requires complex infrastructure, unavailable waste volumes and costs that would exceed income ▪ Total energy capacity of 16 kWh may not be adequate if the community grows at a higher-than-anticipated rate ▪ High upfront cost may be a barrier to entry for some smaller communities/governments ▪ Payback period highly dependent on ability to sell fertilizer
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Highly replicable model in Peru, and in other countries and communities with similar dynamics (estimated 800,000 applicable households in Peru alone) ▪ Peruvian national policy promotes and provides substantial tax incentives to communities and governments seeking to partner on similar rural electrification strategies. ▪ Potential involvement of microfinance organizations to aid funding of the bio-digester roll-out ▪ Government of Peru promotes renewable energy ▪ High value bio-fertilizer for additional revenue ▪ High quality renewable fuel, biogas has several proven end-use applications ▪ Positive environmental impact ▪ Climate change mitigation and adaptation	**THREATS** ▪ Remote location of project combined with lack of local technical knowhow could lead to under maintenance of and hence failure of the system. ▪ Potential competition from large bio-fertilizer companies ▪ Possible risk from leakage of gas thus having negative perception of health risk to employees may force O&M costs higher

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Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflects our best knowledge at the time of the assessments 2015/16. As business operations are dynamic data can be subject to change.

CASE

Power from swine manure for industry's internal use (Sadia, Concordia, Brazil)

Heiko Gebauer and Solomie Gebrezgabher

Supporting case for Business Model 5	
Location:	Concórdia, Brazil
Waste input type:	Swine manure
Value offer:	Energy (Biogas to electricity and thermal energy) carbon credit and bio-fertilizer
Organization type:	Private
Status of organization:	Operational since 2003
Scale of businesses:	Large
Major partners:	Swine farmers, Brazilian Development Bank (Amazon Fund), United Nations (Carbon market), Bio-digester vendors, Espírito Santo University (for measurements of biogas)

Executive summary

Sadia is one of the world's leading producers of chilled and frozen foods with approximately 10,000 integrated poultry and pork farms, which supply raw material to its industrial plants. In order to abate the environmental impacts associated with its swine production farms and to institute sustainability into the pork meat supply chain, Sadia designed and implemented the Program for Sustainable Swine Production (3S Program) in 2003. The 3S Program provides swine producers with bio-digesters and is designed to reduce GHG emissions from the more than 3,500 swine producers in Sadia's supply chain and to qualify the emission reductions as a Clean Development Mechanism (CDM) project. Sadia installs the bio-digesters on its swine producers on a B&T (Build and Transfer) basis. The program seeks to bring sustainability to the company's supply chain by providing additional revenue from carbon credits and better working conditions for swine producers, while reducing the environmental impact associated with swine production. The biogas generated at the swine farms is used on-site and thus significantly saving operational costs for the swine farms. The program contributes to improving the local environmental condition by improving quality of water and reducing soil pollution and foul odors. Moreover, the 3S Program is expected to help disseminate environmental education among swine producers and the surrounding community. Through the design and implementation of the 3S Program, Sadia has incorporated environmental sustainability into its revenue design.

KEY PERFORMANCE INDICATORS (AS OF 2012)							
Land:	The bio-digesters installed at the individual swine farms						
Capital investments:	For the whole 3S Program USD 28 million						
Labor:	Provided by the individual swine farms						
O&M cost:	Provided by the individual swine farms						
Output:	Biogas for onsite use; In 2006 290,000 tons of CO_2-eq carbon credit sold and 2.5 million tons CO_2-eq under agreement						
Potential social and/or environmental impact:	CO_2 offset, improved working conditions of swine farms, improvement in local environmental condition, improvements in water quality and reduction of soil pollution and foul doors.						
Financial viability indicators	Payback period:	5 to 10 years*	Post-tax IRR:	N.A.	Gross margin:	N.A.	

*Depending on the value of Certified Emissions Reductions Certificates (CERCs)

Context and background

Sadia, established in 1944, is one of the world's leading producers of chilled and frozen foods in Brazil. It is one of the country's main exporters of meat-based products. As of 2008, Sadia had about 20 industrial plants that together produced over 2.3 million tons of food, including chicken, turkey, pork and beef, pasta, margarine, desserts and other products. Recognizing the increasing influence of social and environmental issues associated with swine production systems in its supply chain, Sadia designed and implemented the 3S Program in 2003. Developed and managed by the Sadia Sustainability Institute, the 3S Program seeks to institute sustainability into the pork meat supply chain by improving animal waste management while providing additional revenue to individual farmers from carbon credits.

The 3S Program provides more than 3,500 swine producers with bio-digesters and is designed to reduce GHG emissions from the swine producers and to qualify the emission reductions as a CDM project. With the program, at least three million litres of swine excrement will be processed daily, a volume equal to 5% of the total swine waste volume produced in Brazil. The voluntary program began at three of Sadia's own swine farms, functioning as prototypes to be extended to its outsourced producers.

Market environment

A significant number of swine facilities in Sadia's chain did not have an environmental permit. Environmental licenses were expensive and not all farmers were aware of their importance or how to obtain them. Most of the manure produced was disposed in groundwater, streams and rivers without adequate treatment, and as a result, nearby communities were affected by water and soil pollution, as well as by the unpleasant odor. Through the implementation of bio-digesters under the 3S Program, swine farmers are able to manage and treat swine manure and reduce GHG emissions. Swine farmers have the opportunity to diversify their income generating activities and increase their farm profits through revenues from selling carbon credits and from reduced energy costs as gases captured from the bio-digester are used by the farms. By reducing costs and creating the possibility for diversifying income sources, Sadia hopes to encourage the small producers to stay in the business.

Sadia expected that about 50% of the producers would want to participate in the 3S Program. By early 2007, 96% had signed a contract indicating willingness to participate in the program. The other 4% were large swine farms that are already prepared or were preparing to individually operate in the carbon credit market. The program is implemented in 30% of facilities. In May 2006, Sadia and

the Sadia Institute sold the first carbon credits generated by the 3S Program. Sadia sold 290,000 tons from its own farms of which 50,000 tons were sold at 11 €/ton, and the rest were based on the European Allowance Market Index. The European Carbon Fund also bought approximately 2.5 million tons of carbon from the institute to be sequestrated by the swine farms.

Macro-economic environment

Brazil is one of the major producers and exporters of pork accounting for 10% of the world pork production and exports with annual sales of over USD 1 billion. However, the intensive swine production industry resulted in significant environmental impact as a result of the higher amounts of

FIGURE 56. SADIA BUSINESS MODEL CANVAS

KEY PARTNERS

- Swine farmers
- Brazilian Development Bank
- Equipment suppliers (Sansuy and Avesuy)
- Espírito Santo University
- Government
- Data management partner
- Carbon investors

KEY ACTIVITIES

- Installation of bio-digester by Sadia on a BOT basis
- Managing CDM process and obtain emission reduction credit
- Financial management for supply chain actors regarding credits, digesters payments
- Installation of data acquisition system at individual farms and data management
- Improved instrumentation to efficiently measure carbon sequestration

KEY RESOURCES

- Bio-digesters
- Equipment to measure gas emission
- Technical know-how
- Supplier loyalty
- Financial management expertise

VALUE PROPOSITIONS

- Cost recovery from reduced energy cost and earning from carbon credit trading while ensuring better management of swine manure in accordance with regulations
- Tradable carbon credits to meet carbon emission reduction commitments

CUSTOMER RELATIONSHIPS

- Direct interaction and partnership arrangements field technicians
- Interaction with carbon trading companies and Brazilian Development Bank

CHANNELS

- Personal
- Emission trading scheme/platform
- Long-term contract arrangements

CUSTOMER SEGMENTS

- Swine farmers
- Carbon trading companies of Annex 1 countries as per Kyoto protocol

COST STRUCTURE	REVENUE STREAMS
• Investment costs (engineering, construction, equipment, commissioning) – covered by Sadia • Costs for training farmers – covered by Sadia • Operational and data management costs (labor and maintenance cost) – covered by the farmers • Maintenance costs – covered from carbon credit • Savings from energy displacement, both electricity as well as diesel-benefit to farmers	• Sales of carbon credit
SOCIAL & ENVIRONMENTAL COSTS	**SOCIAL & ENVIRONMENTAL BENEFITS**
• Potential leakage of CH_4 from bio-digesters	• Improved social and economic sustainability of swine farms • Improved animal waste management system and better working conditions • Reduced GHG emission (CH_4) and climate change mitigation • Better local environmental condition by improving quality of water and reducing soil pollution and foul doors • Dissemination of environmental education among swine producers and the surrounding community

waste generated in these operations. Swine manure has the potential to impact soil, air and water resources requiring proper management, treatment and disposal.

In a mechanism of the Kyoto Protocol, projects in developing countries that mitigate GHG emissions can apply for certificates of emission reduction, most commonly known as carbon credits. These are certificates emitted by an internationally recognized institution, e.g. the UNFCCC, which attests that a certain amount of GHG (usually measured as a ton of CO_2) has been mitigated. Once obtained, these certificates can be traded on the market and exchanged for money. The sale of carbon credits could be enough, according to Sadia's studies, to cover the cost of the bio-digesters. However, applying for the certificates was a rather difficult and expensive process. Brazil has a target to reduce its overall GHG emissions by 36.1% to 38.9% below 1990 levels in 2020. Brazil has been leading in terms of the numbers of CDM project activities after China and India.

Business model

Sadia installs the bio-digesters at its swine producers on a Build and Transfer basis (Figure 56). The participation of swine producers in the program is voluntary. One of the success factors of implementing the 3S Program is the fact that Sadia Institute was able to obtain funds from the Brazilian Development Bank, thus enabling small and medium swine producers to take part in the program. This is a good example of innovative financing mechanism in the waste reuse business. The financing arrangement is that Sadia Institute owns all the equipment installed in the farmers' facilities for the purpose of the 3S Program and is responsible for managing the CDM benefits. The institute trades carbon credits on the carbon trading market. The amount obtained is then shared with farmers, according to each potential emission reduction, after deduction of the investment made in the bio-digesters and in the program implementation and operation costs. In approximately five years, when the farmers finish

paying the Institute for it, the bio-digesters and all related equipment will change hands and be owned by the farmers. The program benefits both parties. Sadia is able to increase supplier loyalty and secure supply in the light of environmental regulation. Farmers benefit from improved management of swine manure. Moreover, in addition to creating revenues from carbon credit trading, farmers are able to benefit from cost recovery due to reduced operational costs from using energy produced from the bio-digester and also the by-product from the fermentation process can be used as crop fertilizer or as food for fish breeding.

Value chain and position

Sadia created a non-profit entity called the Sadia Sustainability Institute, an independent non-profit organization in December 2004, to manage the 3S Program and to negotiate the carbon credits (Figure 57). The institute is responsible for managing the 3S Program including unifying the swine producers and building enough carbon credits to create a CDM project. The Sadia Institute (SI) borrowed R$ 65.5 million (USD 36.11 million) from the Brazilian Developmental Bank (BNDES) for starting the implementation of the program. Sadia was the guarantor of the SI's loan for implementing the 3S Program.

The institute first identified the swine producers that could be potential participants. The role of the Sadia Institute is to provide the swine producers with information to procure the bio-digesters, identify the infrastructure needed at each facility and overall administration of the program. Two suppliers (Sansuy and Avesuy) were selected to provide the bio-digesters. Sadia also partnered with Espírito Santo University to develop new measuring equipment for measuring the gas emissions i.e. quantity of methane sequestrated and amount of CO_2 produced. Once the bio-digesters are installed, the famers are responsible for the operation of the bio-digester in their respective farms. The emission reductions qualify for the Kyoto Protocol's CDM program, under which Sadia Institute sells the carbon credits. The resulting surplus would be used to improve the social and environmental conditions of the participating farmers. Farmers pay back for the bio-digester from the carbon credit benefits on an installment basis.

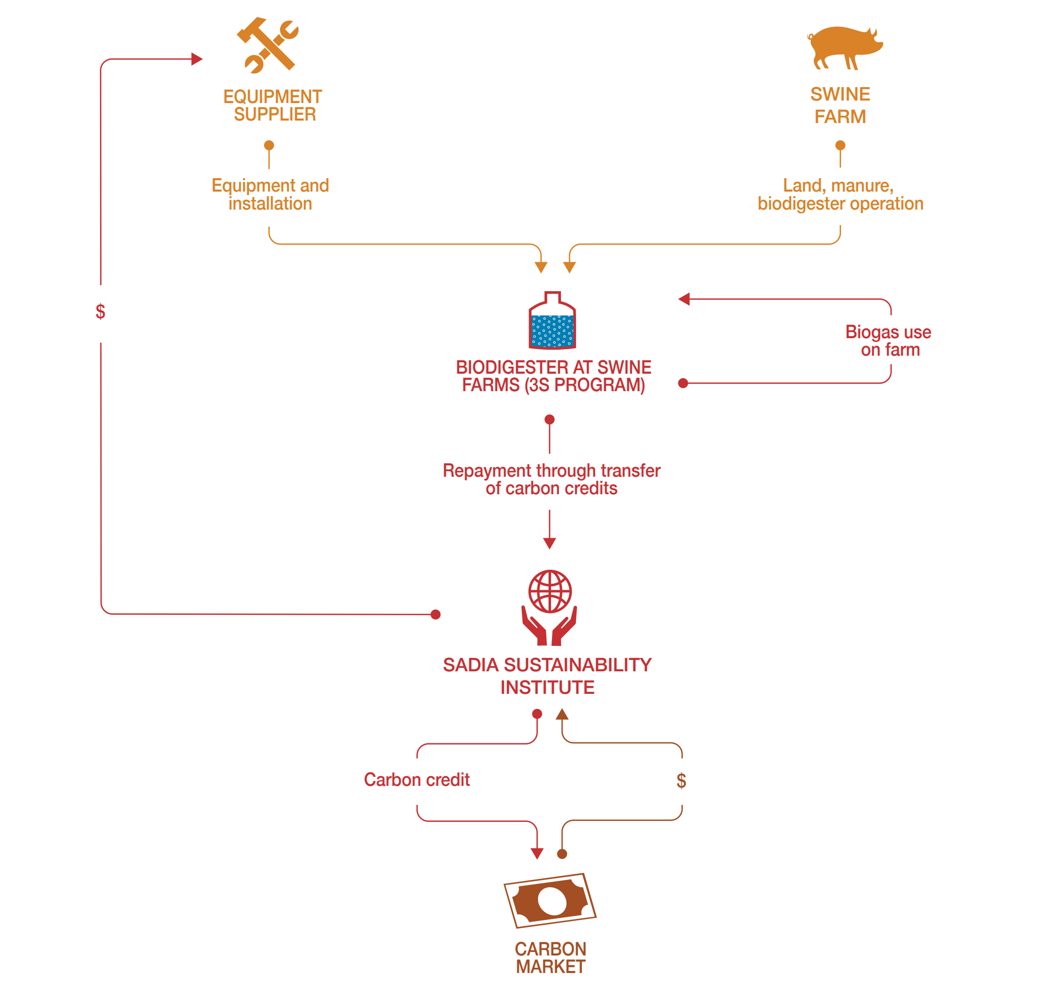
After validation of the biogas equipment by Sadia's engineers using the United Nations Framework Convention on Climate Change (UNFCCC) standards, the farmers will be able to use the biogas. However, if biogas is utilized, no CERs will be claimed for potentially displacing fossil fuels or grid electricity. The treated wastewater and mineralized sludge of the open-air lagoon is used for irrigation of surrounding crops.

Institutional environment

There are no national, state or local requirements providing for GHG emissions of agro-industrial operations (swine production) in Brazil. The state legislation on swine waste in Brazilian states determines that animal waste must have 120 days of retention in a non-permeable open-air lagoon for reduction of the organic load.

Since the 3S Program is registered as a CDM project, both the UNFCCC Kyoto protocol requirements and host country requirements apply. Along with the program implementation, auditing and verification of the program is expected. Such auditing is to be performed every semester by a designated operational entity, an independent auditor accredited by the CDM Executive Board, as determined by the UNFCCC.

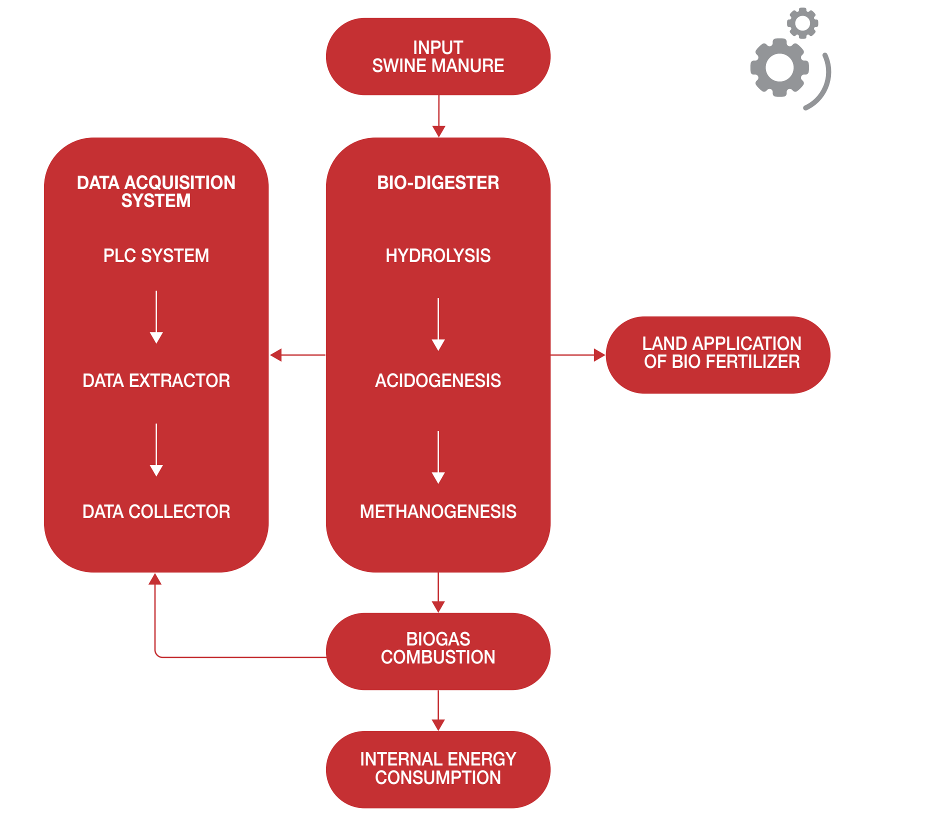
FIGURE 57. SADIA'S 3S PROGRAM VALUE CHAIN



Technology and processes

For all farms included in the 3S Program, the installed equipment follows identical standards. The technology comprises a bio-digester, a combustion system and an open-air lagoon in which to store the treated manure (Figure 58). A process for identifying each farm and data acquisition system is also installed at individual farm. A data system was developed by a software company to ensure that the information about each farm cannot be altered, manipulated or double-counted. This system works with a device called PLC (Programmable Logical Controller) that is installed in each enclosed flare system. It is responsible for the data sources (pressure, temperature, flow, farmer, maintenance and other variables) of the project and where the information is processed. This program operates the system automatically and provides all needed data for each farm. Several technologies are available for manure management in swine farms. However, the selection of a feasible technology should take into account not only technical and economic challenges but also particular farm characteristics. These include the number of housed animals, the available agricultural land for manure application and the opportunities for energy and organic fertilizer production for trading or local consumption.

FIGURE 58. SADIA'S BIO-DIGESTER PROCESS



Funding and financial outlook

The Amazon Fund, created in 2008, fosters a low-carbon economy by reducing GHG emissions, and that contributes decisively to improving not only the standard of living and preservation, but also the recovery and the rational use of its natural resources. The Amazon Fund is administered by the Brazilian Development Bank (BNDES) and aims to provide financing services for projects, which aim at the reduction of GHG emissions. This incentivizes companies, such as Sadia, to pursue CDM project activities.

The Sadia Institute (SI) borrowed money from a financial institution (R$ 60 million) from BNDES (UNDP, 2007), approximately USD 33 million) for purchasing and installing the bio-digesters and the combustion system in the outsourced farms. SI owns all the equipment installed in the farmers' facilities for the purpose of the 3S Program. In approximately five years, when the producers finish paying the institute for it, the bio-digesters and all related equipment will change hands and be owned by the swine farmers. The institute negotiates carbon credits with the operational entity under the CDM. The institute takes a percentage of the revenue from the offsets to cover operational expenses, and the remainder is allocated to the producer. Before seeing any income from the credits, the producer pays for the bio-digester; the payment is estimated to take five years of installments.

The process of certification of the carbon credits was rather complex involving several steps and actors. The volume of gas burned as well as the temperature, pressure and other measurements are registered in a computer, which would be constantly monitored by Sadia's field work technicians.

Socio-economic, health and environmental impact

The 3S Program initiated by Sadia provides additional revenue and improved working conditions for Sadia's swine producers, while reducing the environmental impact associated with swine production. The biogas generated can be used as energy in the farm, thus significantly saving operational costs. In addition, new business opportunities are created for the farmers, who can use the by-product from the fermentation process as food for fish breeding or as crop fertilizer and thus improve soil quality. The program contributes to improving the local environmental condition by improving quality of water and reducing soil pollution and foul odors. In addition, the 3S Program is expected to help disseminate environmental education among swine producers and the surrounding community.

Scalability and replicability considerations

The 3S Program was designed and implemented to reduce GHG emissions from swine producers in Sadia's supply chain and to qualify the emission reductions as a CDM project. This program can be used as a demonstration for other supply chains to replicate the program by incorporating environmental sustainability in their revenue design. In order for this program to be replicated in other developing countries with intensive livestock production, government support for projects, which aim at reducing GHG emissions coupled with innovative financing mechanism, is required.

The key drivers for the success of this business are:

- Innovative financing mechanism.
- Availability of financing organizations.
- Partnership among the different actors within the value chain.
- Foreseeing and eliminating regulatory problems relating to production permission in Sadia's swine supply chain.

SI plans to extend the program within its supply chain, including those suppliers that are not swine producers (for example, poultry and beef). SI plans to develop a "Sustainable Site Platform" in which it will give training for new agricultural commodities to be produced by its suppliers to diversify and increase their income. The platform aims to educate the producers on financial and management issues and thus creating entrepreneurs that are better prepared for the market.

Summary assessment – SWOT analysis

The key strength of Sadia is the application of innovative financing mechanism to implement the 3S Program and thus fostering strong partnership with its swine farmers (Figure 59). Availability of financing organizations such as the Amazon Fund which provide financing services for projects which aim at the reduction of GHG emissions and government support for CDM are the key opportunities for the business to further expand its 3S Program. However, sustainability of the 3S Program highly depends on carbon credit sales, the prices of which are volatile.

FIGURE 59. SWOT ANALYSIS FOR SADIA

	HELPFUL TO ACHIEVING THE OBJECTIVES	HARMFUL TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	STRENGTHS ▪ Innovative financing mechanism ▪ Strong partnership with swine farmers ▪ Ensures following environmental regulation in supply chain ▪ Intensive swine farming (abundance of swine manure) ▪ Diversified income for farmers ▪ Natural process of dry fermentation ▪ The technicians' credibility and respect	WEAKNESSES ▪ Highly dependent on carbon credit sales ▪ Farmer's lack of technical know-how to operate bio-digesters ▪ High technology cost ▪ High operation and maintenance costs ▪ A challenge to include the small producers to find a gauge to measure the gas emissions ▪ Consolidate a large number of carbon sequestrating facilities (bio-digesters)
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	OPPORTUNITIES ▪ Availability of financing organizations ▪ Government support for CDM ▪ Carbon credit market opportunities ▪ High value bio-fertilizer for additional revenue ▪ High quality renewable fuel, biogas has several proven end-use applications ▪ Country's participation in the CDM projects	THREATS ▪ Volatile carbon credit prices ▪ Possible leakage of CH4 may significantly reduce the carbon credit earnings ▪ Delay in administrative proceedings ▪ Environmental laws are not enforced ▪ Financial challenge the sale realized after the plant is commissioned ▪ Consolidate a large number of carbon sequestrating facilities (bio-digesters)

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Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflect our best knowledge at the time of the assessments (2013/2014). As business operations are dynamic, data can be subject to change.

CASE

Power from manure and slaughterhouse waste for industry's internal use (SuKarne, Mexico)

Javier Reynoso-Lobo, Krishna C. Rao, Lars Schoebitz and Linda Strande

Supporting case for Business Model 5	
Location:	Culiacan, State of Sinaloa, Mexico
Waste input type:	Animal and slaughterhouse waste
Value offer:	Biogas to electricity and thermal energy, bio-diesel, compressed Bio-gas, carbon credits and organic bio-fertilizer
Organization type:	Private
Status of organization:	Commercial-scale project under construction
Scale of businesses:	Large
Major partners:	Alberta Innovates–Technology Futures (Technology), Pro Bio (Fertilizer distributor, the group company), National Electricity Commission (Interconnection), United Nations (Carbon market), National Science and Technology Council (Research funding), IGSA (Co-investor[1]), German Biogas Company (Project design and management[2])

Executive summary

Grupo Viz (GV), a family business in the commercial cattle industry, was established in 1969 in Mexico. SuKarne, one of the five business entities of GV group, with annual sales of over USD 2 billion is the third largest feedlot grain-fed company in the world and fifth largest beef provider in North America. SuKarne's business chain produces both animal and slaughter waste, and it sells some of the waste to its affiliated companies (also owned by GV). In 2012, SuKarne began construction of a biogas pilot plant, a first for the cattle industry that uses a mixture of animal waste and residual biomass, with the lagoon's water, to produce biogas for electricity and thermal energy. At full capacity, it is expected to generate approximately 3.2 MW of electricity for self-consumption and 3 MJ to displace boiler diesel with the heat generated. It will also be possible to further treat the biogas to produce liquid fuel or compressed gas to feed the trucks used throughout the whole operation. The plant will also generate organic bio-fertilizer to be sold to an affiliated company. The project was at the time of assessment under commercial-scale development and expected for construction and commissioning in 2015, with possibilities to replicate the model in its other four facilities in Mexico. The plan is that each plant will be self-sufficient in both electricity and thermal energy. The project's feasibility study is registered

in the Clean Development Mechanism (CDM) and subject for final approval for a Certified Emission Reductions (CERs) agreement.

KEY PERFORMANCE INDICATORS FOR THE CULIACAN FACILITY (AS OF 2014)						
Water:	67,000 m^3 of slaughterhouse wastewater reutilized per annum					
Capital investment:	USD 12.5 million					
Labor:	9 employees (O&M supervisor, mechanic/electric engineers, 5 operators, 1 technician)					
O&M cost:	Approx. USD 90,000 per annum					
Output:	110,000 tons of animal waste processed per annum to generate 13 million m^3 biogas per annum, or 3.2 MW as electricity and 3 MJ as heat using a combined heat and power (CHP) unit, and approx. 35,000 tons of vermicomposting per annum					
Potential social and/or environmental impact:	Yearly savings of approx. USD 1.8 million in diesel and electricity costs, reduction of approx. 132,000 tons of equivalent CO_2 emissions per annum (US-EPA calculator), generation of a renewable source of energy for the company; Reduced soil, water and air pollution					
Financial viability indicators:	Payback period:	2.9 years	Post-tax IRR:	14.3 %	Gross margin:	USD 4.28 million

Context and background

GV is a family business established in 1969 at Culiacan, Sinaloa. Over the years, GV expanded its operation to other parts of the cattle production business value chain and now owns five subsidiary companies operating independently. The five subsidiaries of GV are: a) SuKarne Agro-industrial, a beef, poultry and pork producer, b) Rendimientos Protéicos (Renpro), specializes in processing of tallow, meat and blood meals for livestock and animal feed production, c) Productos Bioorgánicos (ProBio), specializes in the production of organic compost and vermicomposting from animal waste, d) SuKuero, specializes in leather commercialization and e) Agrovizion, an agribusiness dedicated to the promotion and commercialization of agricultural products such as corn, wheat, oats and roughage. This case study is on SuKarne, the largest producer and supplier of beef in Mexico, third largest feedlot grain-fed company in the world and fifth largest beef provider in North America. SuKarne owned at the time of assessment five production facilities around the country, located in the states of Nuevo Leon, Baja California, Michoacan, Durango and Sinaloa. These five facilities maintain a daily average of 425,000 animals confined in open feedlots through the year, and approximately 1,100,000 animals are processed per annum.

Manure is removed from the feedlots twice a year using a scraping system and disposed in piles over lands located near the operation for further degradation through composting processes. Mexican and local state legislation prohibit the unlicensed displacement and/or uncontrolled burning of animal waste, which leaves a huge amount that is left to decay on the ground, thus contributing to the greenhouse gas (GHG) emissions to the atmosphere.

A business opportunity was identified by SuKarne to develop a methane recovery project from the animal waste generated in their five facilities and generate thermal and electric energy in the form of biogas along with organic material for compost, while significantly reducing GHG emissions. In late 2012, SuKarne constructed a dry fermentation pilot plant and throughout 2013 conducted a series of trials which validated the feasibility of the technology and its waste streams for biogas production.

SuKarne is developing the commercial-scale project with Canadian biogas plant providers to construct a large biogas facility near its operation in Culiacan. Prior to this initiative, SuKarne sold its

organic waste (feedlot manure) to Pro Bio to produce organic compost and vermicomposting. This case study focuses on the business model for the biogas production facility under development. The project will use animal waste and slaughterhouse waste as feedstock to produce biogas (mainly containing methane). The biogas will be used to generate electric and thermal energy. The expected amount of GHG emissions reduction with the project is on average 132,000 tons of CO_2-eq per annum.

SuKarne's biogas operations and its end users are within its premises or with affiliated companies, and hence there is no competition for procuring waste or sale of energy. The fertilizer produced from the bio-methanation process will be exclusively sold to Pro Bio, an affiliated company in the business of producing organic compost.

Market environment

According to the Mexican Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA), 58% of Mexico's land, a total of 113.8 million hectares, is used for beef production. There is a total of 31 million cattle livestock in Mexico owned by 1.13 million breeders: 2 million dairy cattle and 29 million beef cattle. According to the Mexican Ministry of Environment and Natural Resources (SEMARNAT), livestock production has shown an accelerated growth in the past two decades, increasing by 62% in comparison with the 1990s. As a result of this progressive increase in livestock production, 83% of Mexico's emissions from agricultural sector were attributed to livestock production in 2002, equivalent to 8% of the total emissions in Mexico (Table 19). However, the consumption of fossil fuels accounts for 63% of the country's carbon emissions, and a major part of the carbon emissions are from agro-industrial operations such as meat production. There has been no significant action in terms of emission reduction from this part of the livestock sector. Other sectors such as swine farms have developed projects with the support of government programs such as Methane to Markets (M2M) and the CDM, though most account only as far as for biogas burning. So far, there are no other business models in the Mexican livestock industry that transform waste into self-supplied renewable energy at commercial-scale.

TABLE 19. MEXICO EMISSIONS IN CO_2 EQUIVALENT (GG), ADAPTED FROM "METHANE TO MARKETS." SOURCE: SEMARNAT, 2008

EMISSION CATEGORY	2002	PERCENTAGE
1) Energy	389,496.70	70.39%
1A) Consumption of fossil fuel	350,414.30	89.97%
1B) Fugitive methane emissions	39,082.30	10.03%
2) Industrial processes	52,102.20	9.41%
3) Agriculture	46,290.80	8.36%
3A) Livestock	38,527.47	83.23%
3B) Crops	7,763.26	16.77%
4) Waste	65,584.40	11.84%
Total	**553,329.40**	**100%**

Macro-economic environment

The livestock operations are prone to serious environmental impacts, such as GHG emissions, odor and water and land contamination, all a result from storage and disposal of animal waste. Confined Animal Feeding Operations (CAFOs) use similar Animal Waste Management System (AWMS) options

to store animal residues. These systems emit both methane (CH_4) and nitrous oxide (N_2O) resulting from aerobic and anaerobic decomposition processes (Clean Development Mechanism, 2007). Since approval of the Kyoto Protocol, immense interest in methane recovery has been generated amongst large-scale farms and livestock producers in Mexico, many of who have registered CDM projects.

In addition, Mexico created a strong climate change and renewable energy law in 2012 that targets 30% lower emissions compared to business as usual by 2020 and 50% by 2050.

Business model

SuKarne's methane recovery project has three key value propositions (Figure 60) – production of biogas to generate electricity and heat for self-consumption (displacing electricity purchase from the national grid and diesel costs for boilers and trucks), production of solid/liquid fertilizer from the effluent of the bio-methanation process and sale to Pro Bio and sale of carbon offset both from methane recovered and fossil fuel displacement.

It is key for SuKarne to ensure that all waste generated from its business value chain is brought to the biogas facility. SuKarne partnered with a Canadian technology research centre to help develop the biogas technology to process multiple feedstocks in the biogas digester. The most critical relationships for SuKarne in its methane recovery project is its partnership with co-investor IGSA, biogas plant providers for the design and project management of the facility construction, the national grid for interconnection and electricity supply contracts, affiliates such as Pro Bio for sale of solid/liquid fertilizer and carbon companies buying CER certificates.

Value chain and position

SuKarne manages livestock procurement and production, meat processing, distribution and commercialization (Figure 61). SuKarne captures organic waste generated from several parts of its chain and transforms it to higher-value products such as leather, animal feed, soaps, organic compost and vermicomposting, and with the implementation of this project into biogas as well. The biogas model will merge into the existing model by reutilizing the feedlot manure from the pens, corn stover from the feed mill and paunch content and wastewater from the slaughterhouse to generate renewable energy which will replace fuel and electricity supply used in one of its operations. The composting process in the value chain will shift to take place after the biogas production process.

Institutional environment

Regulatory settings in Mexico require businesses to prepare an environmental impact assessment of the proposed energy generation plants in order to demonstrate that it will not have a negative impact on the environment. This is currently regulated by SEMARNAT. Additionally, every business that intends to generate and/or sell energy must be regulated by the Electricity and Hydrocarbons Regulator (CRE). They grant permits for private self-supply generation, independent power production and co-generation. The CRE has designed several instruments which regulate the relationship between suppliers (Federal Energy Commission and Light and Power Company) and private generators.

Mexico has a progressive policy on climate change and renewable energy commitment to meet its optimistic targets. However, the government will likely have to provide more fiscal incentives. The General Law for Climate Change adopted in May 2012 sets the goal of 35% of energy generated in the country should come from renewable sources by 2024. The law creates a fund for the transition to clean and renewable energy and technologies. These legal instruments are expected to create a better framework to support renewable energy in general and also a future green economy in Mexico. Additionally, implementation of renewable energy reinforcement laws and incentives schemes as well

FIGURE 60. SUKARNE METHANE RECOVERY BUSINESS MODEL CANVAS

KEY PARTNERS

- Local breeders
- Grupo Viz subsidiaries (waste suppliers)
- Federal electricity commission
- Carbon investors
- Biogas technology developer
- Biogas plant provider

KEY ACTIVITIES

- Collection of animal and agro waste
- Production of biogas
- Electricity cogeneration and heat usage
- Production of bio-diesel or compressed biogas
- Production of organic compost
- O&M for production

KEY RESOURCES

- Slaughterhouse waste
- Dry fermentation technology
- Contracts with electricity commission
- Capital investment

VALUE PROPOSITIONS

- Recovery of methane from animal and slaughterhouse waste to create carbon offsets
- Production of biogas for heat and electricity
- Production of solid/liquid fertilizer

CUSTOMER RELATIONSHIPS

- Direct interaction carbon trading companies
- Internal and direct interaction with electricity commission
- Direct interaction and partnership

CHANNELS

- Long term contract agreements

CUSTOMER SEGMENTS

- Carbon trading company
- Grupo Viz subsidiaries (for internal consumption of electricity as well as thermal energy)
- National grid
- Fertilizer affiliate company

COST STRUCTURE

- Investment cost (engineering, construction, equipment, commissioning, cogeneration, transmission)
- Operational cost (labor, maintenance cost, energy, fuel)
- Depreciation
- Savings from energy displacement, both electricity as well as diesel

REVENUE STREAMS

- Sales of carbon offset
- Sale of surplus electricity
- Sales of solid/liquid fertilizer

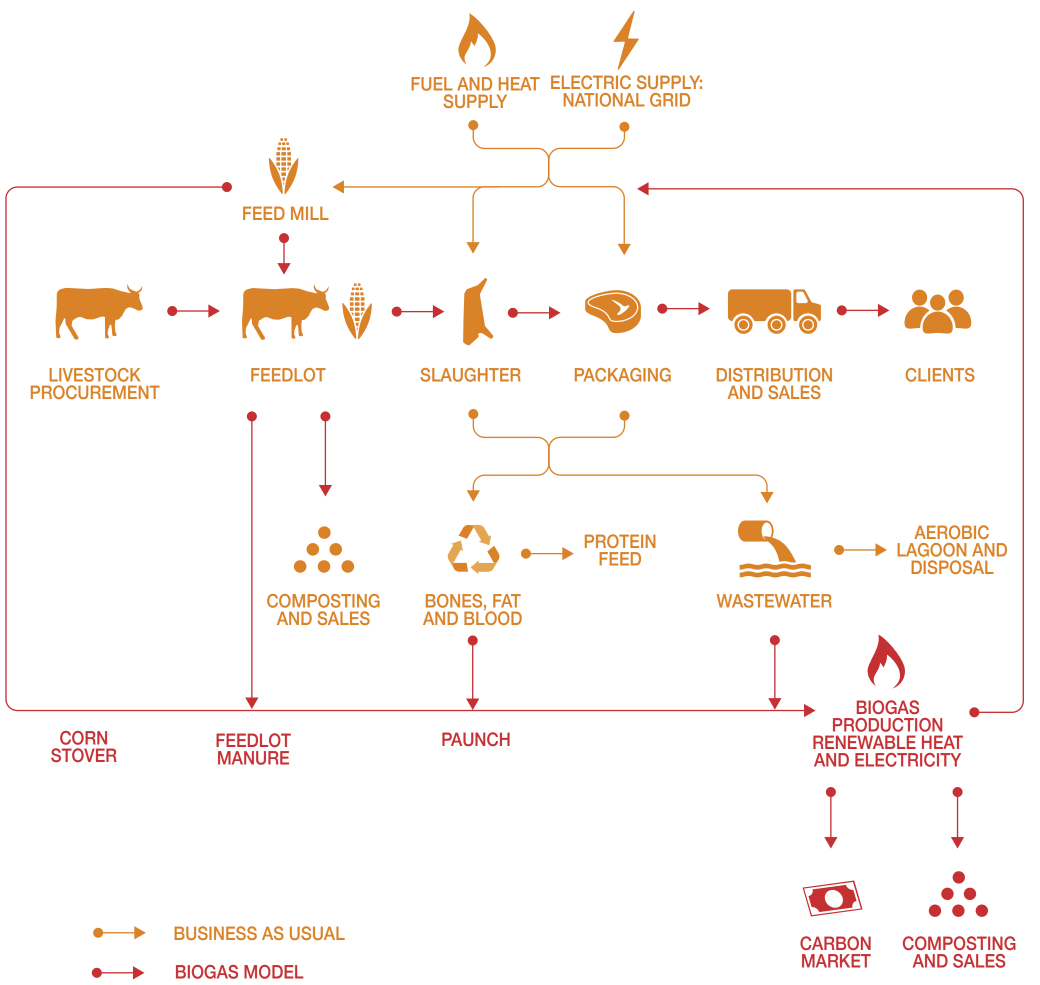
SOCIAL & ENVIRONMENTAL COSTS

- Potential leakage of methane

SOCIAL & ENVIRONMENTAL BENEFITS

- Job creation
- Reduced water, soil and air pollution
- Reduced carbon emissions
- Displacement of fossil fuel consumption (both for electricity and diesel for boilers and trucks)

FIGURE 61. SUKARNE PROCESS VALUE CHAIN, DEPICTING THE INCORPORATION OF THE BIOGAS MODEL



as the removal of subsidy on industrial diesel in 2013 in Mexico have further driven the large-scale industries such as SuKarne to adapt and develop new strategies.

Technology and processes

Slaughterhouse effluent has high Chemical Oxygen Demand (COD), high Biological Oxygen Demand (BOD) and high moisture content, which makes it well-suited to anaerobic digestion process. Slaughterhouse wastewater also contains high concentrations of suspended organic solids including pieces of fat, grease, hair, feathers, manure, grit and undigested feed which will contribute to the slowing of the process of biodegrading organic matter. The biogas potential of slaughterhouse waste is higher than animal manure and reported to be in the range of 120–160 m^3 biogas per ton of wastes.

The technology used in SuKarne's methane recovery project is a dry fermentation system including bio-digesters and a percolation tank coupled to a biogas cleaning unit and combined heat and power

(CHP) units to generate electric and thermal energy. The dry fermentation process is an anaerobic digestion technology for solid, stackable biomass and organic waste, which cannot be pumped. It is mainly based on a batch wise operation with a high dry matter content ranging from 20–50% at mesophilic temperatures. It is especially suited for application in semi-arid climates as the water consumption in the process is very low compared to conventional anaerobic digestion systems.

The biogas generated will replace the electricity bought from the national network, as well as the diesel used in boilers and trucks. The facility will consist of 900 m^3 concrete air-gas-tight chambers to manage approximately 110,000 tons of waste per year. The plants will be designed as modular solutions that are scalable according to the amount of waste that is available or energy demand. This will be the first facility of its kind in Mexico and unique worldwide in terms of feedstock characteristics, its source being a commercial cattle feedlot.

Animal waste (manure) is collected at least once every six months from the pens. Internal transport of the waste from the pens to the project site will be done in trucks carrying containers within a distance no longer than 5 km. The collected manure will be transported to the plant site to be shredded and mixed with effluents from the slaughter plant such as paunch content and wastewater to prepare an appropriate organic loading rate. Substrates such as corn stover and wood chips will be incorporated to improve material structure. Prepared substrates will be loaded into the fermentation units and digested to generate biogas. A CHP unit will be used to produce electrical and thermal energy. A biogas-cleaning unit will be incorporated before the CHP unit if necessary. Wood chips will be recovered and reutilized after the composting process.

Equipment and infrastructure required for the project:

- Dry fermentation units and components.
- Substrate mixing equipment and/or machinery.
- Biogas storage and cleaning equipment.
- Combined heat and power unit for cogeneration.
- Complementary equipment and facilities for the modular units.

Funding and financial outlook

SuKarne applied for research funding from the Mexican National Council for Science and Technology (CONACYT) and, in 2012, obtained a USD 320,000 grant for the construction and validation of a dry digestion biogas pilot plant for its Culiacan site. The investment required for the design, construction and commissioning of the large-scale biogas facility is estimated at USD 12.5 million, which will be shared between SuKarne and co-investor partner IGSA. About USD 500,000 was required to develop the mass and energy balances, feasibility study, technologies assessment and selection, pilot plant design and specialized support for the design and implementation of the chosen technology.

SuKarne's methane recovery project requires approximately USD 90,681 for operation and maintenance per annum. The revenue structure consists of savings from electricity and boiler diesel replacement from energy generation, carbon offset and sales from fertilizer. The estimated revenue potential of the plant is approximately USD 1.8 million per annum with an amortization period of 10 years. This investment is projected to result in an IRR of 14.3% with 7 years return at a discount rate of 8% (Table 20).

Note: Unit value refers to the unitary cost of every expense and income; quantity refers to the amount of supply that will be required or sold product as the technology is implemented; value is the total amount per item in US dollars; difference from business as usual (BAU) refers to the additional costs

TABLE 20. SUKARNE METHANE RECOVERY PROJECT FINANCIALS

	UNIT VALUE (USD)	QUANTITY	VALUE (USD)	DIFFERENCE BAU (USD)
Cost				
Fuel	0.54 /L	1,083,022 L/yr	584,832	–
Corn stover	49.70 /t	5,839 t/yr	290,198	48,371
CHP maintenance	0.021 /kWh	23,040,000 kWh/yr	483,840	483,840
O&M / Labor			90,681	90,681
Total				**622,892**
Saving				
Diesel	0.77 /L	701,736 L/yr	540,337	1,439,893
Electricity	0.087 /kWh	15,986,471.26 kWh/yr	–	1,390,823
Soil replacement	8.41 /t DM	23,342 t/yr	196,306	131,200
Wastewater disposal	0.25 /t	18,247 t/yr	–	4,562
Water	0.54 /t	776,783 t/yr	419,463	99,307
Total				**3,065,785**
Revenue				
Electricity	0.087 /kWh	7,053,529 kWh/yr	613,657	613,657
Compost	53.50 /t	65,702 t/yr	3,515,057	(98,058)
GHG mitigation (CERs)	10.00 /tCO_2e	132,049 t/yr	1,320,490	1,320,490
Gross margin				**4,278,982**
Payback				2.9 years
Accounting rate of return				14.3%
Capital cost			12,580,057	
Amortization period	10 years			
Interest rate	8%			

incurred by the new business model as well as savings generated, mainly from diesel, electricity and carbon credits.

Socio-economic, health and environmental impact

SuKarne's methane recovery project has high environmental benefits from reduced greenhouse gas emissions. The project ensures proper disposal of animal waste, requires less area than aerobic compost, reduces the volume and weight of landfills, produces a sanitized compost and nutrient rich liquid fertilizers, maximizes the benefits of recycling and in the process improves the air quality through improved odor and reducing groundwater contamination. It also displaces the diesel consumption in the feed mill, trucks and slaughterhouse. Additionally, the project improves the electricity burden on the regional electricity board by reducing its purchase from grid. The economic benefit from improved electricity in the region goes beyond the enterprise. In addition, SuKarne provides additional employment – nine employees for the management of biogas plant and electricity generation operations.

Scalability and replicability considerations

The key drivers for the success of this business are:

- Capital investment from administration board and co-investors.
- No barriers in accessing available in-house animal and agro-waste.

- Supportive environment for environment-friendly initiatives, with many existing livestock projects registered for CDM in Mexico; SuKarne benefits from streamlined process.
- Diesel subsidy removal.
- Favourable policies and incentives by the Government of Mexico.

SuKarne has five livestock production operations across Mexico. Based on the operational viability and profitability of its first large-scale biogas plant, SuKarne plans to separate its biogas operation into a new company and develop similar projects in all its operations across Mexico. This project has replication potential in other large livestock farms but needs to counter the challenges of adequate skilled human resources, investors that understand business risks, carbon credit markets and stable, supportive, government energy policies and financial incentives.

Summary assessment – SWOT analysis

The key strength of the project is its shorter payback period for high investment cost and strong partnership with affiliated companies (Figure 62). The weakness stems from high cost of technology that can deter its promoters from making the investment.

FIGURE 62. SUKARNE METHANE RECOVERY PROJECT SWOT ANALYSIS

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Assured supply of waste ▪ Low O&M and high revenue ▪ Strong partnership with affiliated companies ▪ Natural process of dry fermentation ▪ Food security ▪ Efficient waste and water management ▪ Climate change mitigation and adaptation	**WEAKNESSES** ▪ High technology cost ▪ Requirement of high skilled labor for this technology and research and development ▪ Too much heterogeneity among the livestock production units in relation to their size and use of technology
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Environment stress reduction offers carbon credit market opportunities ▪ Output from biogas plant is high value fertilizer which can be harnessed for additional revenue ▪ Electricity demand is growing and need for renewable energy-based electricity generation increasing in Mexico ▪ Recent changes in legislation on renewable energy control ▪ Classification and separation of waste, translate into increased opportunities for generation ▪ High-quality renewable fuel; biogas has several proven end-use applications ▪ Country's participation in the methane-to-market alliance	**THREATS** ▪ Possible human health risk may lead to investment needs ▪ Possible risk from leakage of gas may force O&M costs higher ▪ Delay in administrative proceedings ▪ Environmental laws are not enforced ▪ Weak national capabilities to design and manage projects to reduce methane emissions ▪ Lack of comprehensive schemes to address the issue of livestock waste ▪ Lack of co-generation equipment for all types of farm sizes and variable methane production

The business offers many opportunities for replication due to the high demand for electricity and heat sources as well as the opportunity to become a sustainable leader in meat industry by significantly reducing fossil fuel consumption, revoking the misconceptions of the livestock industry's contribution to GHG emissions and ultimately helping the future generations live in a cleaner and better world.

Contributors

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Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflects our best knowledge at the time of the assessments (2015–2016). As business operations are dynamic, data can be subject to change.

Notes

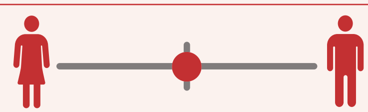
1 IGSA: http://www.igsa.com.mx
2 German partner: http://www.bekon.eu

BUSINESS MODEL 5

Power from manure

Solomie Gebrezgabher and Krishna C. Rao

A. Key Characteristics

Model name	Power from manure
Waste stream	Livestock manure, agro-waste as additional input
Value-added waste product	Biogas, energy (electricity as well as thermal energy), carbon credit, slurry/liquid and solid bio-fertilizer
Geography	Rural regions with livestock farming and large livestock industry
Scale of production	Small, medium to large scale 16 kW up to 5 MW of electricity 22,000 to 700,000 ton CO_2-eq/year
Supporting cases in this book	Santa Rosillo, Peru; Concordia, Brazil; Culiacan, Mexico
Objective of entity	Cost-recovery [X]; For profit [X]; Social enterprise [X] Community development [X]
Waste removal capacity	Manure from small (less than 600 animals), medium (600 to 1,000 animals) and large (more than 1,000 animals) livestock farms
Investment cost range	500–5000 USD/kW for capacities ranging between 1 MW to 3 MW (based on International Renewable Energy Agency or IRENA)
Organization type	Private, public-private partnership (PPP), public and non-profit organization
Socio-economic impact	GHG emission reduction (up to 700,000 ton CO_2-eq/year), improve water quality and reduce air and soil pollution, access to electricity (50 households from 16 kW plant), improved livelihood of remote communities, improved working conditions of slaughterhouse and animal farms
Gender equity	Neutral 

B. Business value chain

This business model can be initiated either by livestock processing factories such as meat or dairy processing factories with the objective of ensuring that their products have been produced in an environmentally sustainable way or by small, medium and commercial-sized livestock farms in remote communities to utilize livestock waste to produce off-grid power for rural electrification with the support of regional government and NGOs. Depending on the size of the project, the business can also be registered as a Clean Development Mechanism (CDM) project to earn additional revenue from carbon credit sales.

While the power from manure model can be implemented in different scenarios, the following sections describe power from manure model for: a) carbon credit and sustainable value chain and b) rural electrification.

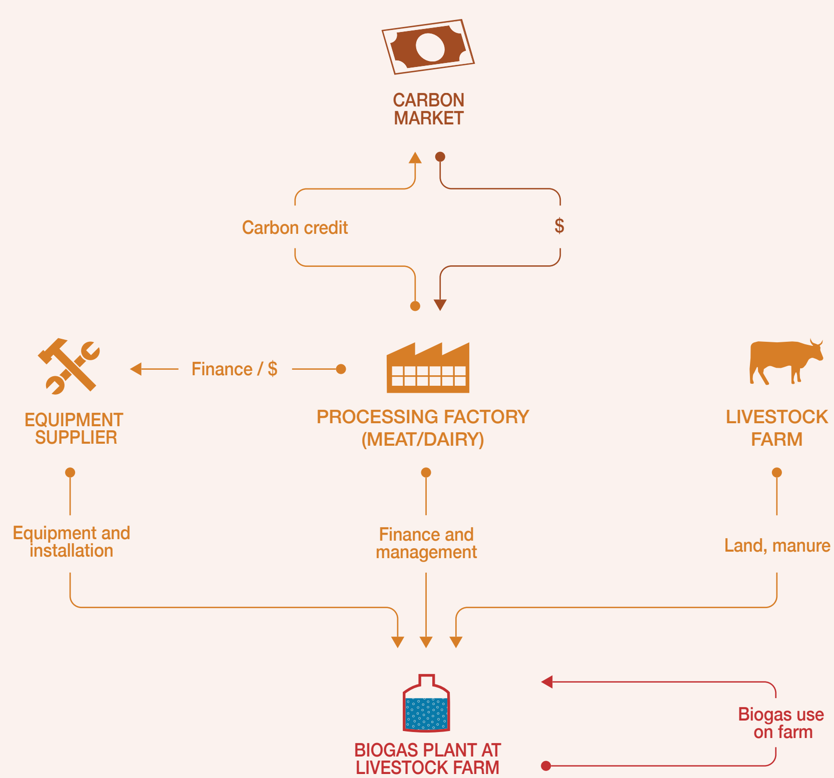
Power from manure for carbon credit and sustainable value chain

To mitigate the social and environmental impacts associated with livestock production systems, the processing factory (e.g. meat processing factory) installs bio-digesters on the animal farms within its supply chain on a Build and Transfer (B&T) basis. The factory oversees the installation of the bio-digesters on the farms, provides finance for initial capital cost, registers the project as a CDM project and manages the carbon credit revenues. The animal farm operates and maintains the bio-digesters. The factory assists the farmer in loan repayment by trading the carbon credit on behalf of the farmer. After deducting a portion of the receipts for loan repayment, the amount obtained is shared with farmers according to their potential emission reduction. The factory owns all the equipment until such time that the farmer pays back in full. The energy produced from livestock waste is used within the farms resulting in reduced farm operational costs and improved animal waste management, and the bio-fertilizer can be used on farms' own land. This business model seeks to bring sustainability to the entire supply chain by improving animal waste management while providing additional revenue to livestock farmers. In addition to cost recovery from utilizing the energy at the farm, the business model results in additional revenue for the farmer from sales of carbon credits (Figure 63).

Power from manure model for rural electrification

The business model can be commissioned by regional government in villages where there is no access to the national electricity grid or where there is very limited access to gas or electricity and where the

FIGURE 63. VALUE CHAIN FOR POWER FROM MANURE FOR CARBON CREDIT AND SUSTAINABLE VALUE CHAIN



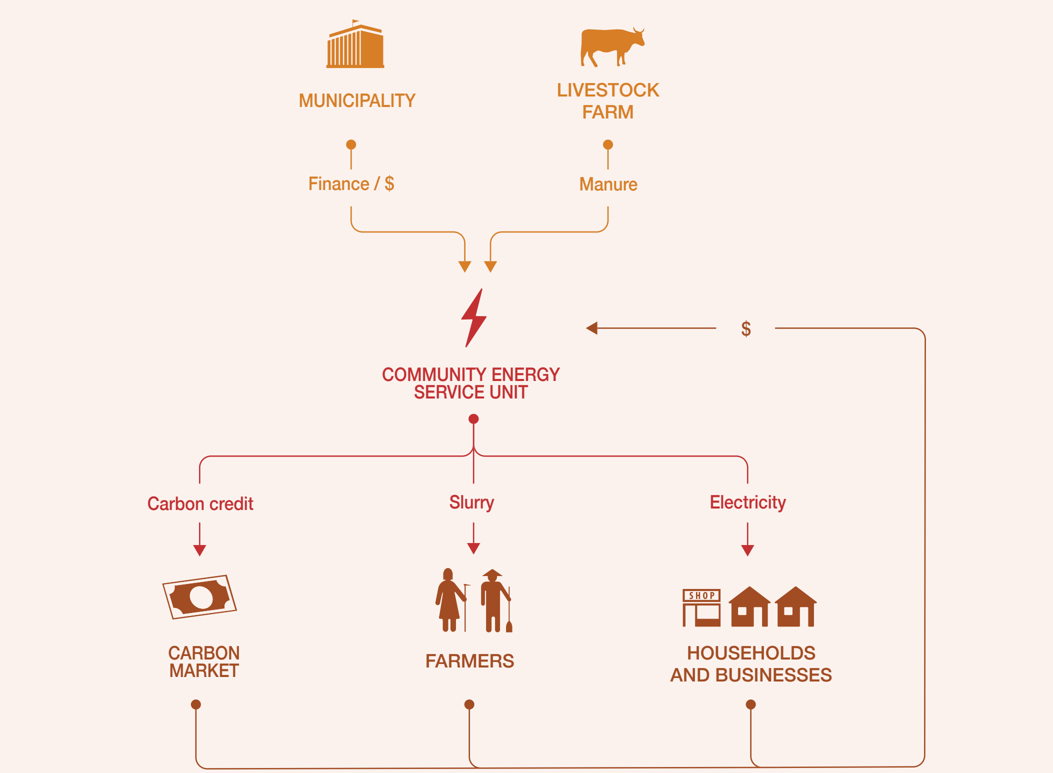
community's primary economic activity is livestock farming. This is done by installing bio-digesters, which are fed with all the livestock and other organic waste from the community to generate biogas, which in turn is fed into the electricity generator and channelled to each house through a newly-installed electricity grid. The by-product from the bio-digesters is used as fertilizer by individual farms within the community to improve the soil quality or can be sold to other local farmers. The project can be financed through a public-private partnership between the regional government and the community with the major part of the funding coming from the regional government. Although the business is financed primarily by government subsidy, the investment can be supplemented with market-based approaches. The project will sustain itself through income streams primarily from monthly electricity usage fees charged to families and secondarily from the sale of slurry. This business has also the potential to earn additional revenue from carbon credit revenues by registering the business as a CDM project (Figure 64).

C. Business model

Business model – Power from manure for carbon credit and sustainable value chain

The processing factory installs bio-digesters at its livestock farmers within its value chain on a Build and Transfer basis in order to reduce GHG emissions from the livestock producers and to qualify the emission reductions as a CDM project. The processing factory could either obtain funds from banks or use own funds to finance the small and medium animal farmers to take part in the program.

FIGURE 64. VALUE CHAIN FOR POWER FROM MANURE FOR RURAL ELECTRIFICATION



The program benefits both parties. The processing factory is able to increase supplier loyalty and secure supply in the light of environmental regulation and farmers benefit from improved management of animal manure. Moreover, in addition to creating revenues from carbon credit trading, farmers are able to benefit from cost recovery due to reduced operational costs from using energy produced from the bio-digester (Figure 65). The by-product from the fermentation process can also be used as crop fertilizer or as food for fish breeding. The processing factory owns all the equipment installed in the farmers' facilities and is responsible for managing the CDM benefits. The amount obtained from carbon trading is shared with farmers, according to each potential emission reduction and after deduction of the investment made in the bio-digesters including the program implementation and operation costs. The bio-digesters and related equipment will change ownership to the farmer ones the farmer completes payment for the investment cost on installment basis.

Business model – Power from manure for rural electrification

This business model has two key value propositions (Figure 66) – providing electricity service to houses and businesses and providing fertilizer to community farmers. The municipality, donor agency

FIGURE 65. BUSINESS MODEL CANVAS: POWER FROM MANURE FOR CARBON CREDIT AND SUSTAINABLE VALUE CHAIN

KEY PARTNERS

- Livestock farmers
- Development banks
- Financial institution
- Equipment suppliers
- University
- Government
- Carbon investors

KEY ACTIVITIES

- Installation, operation and maintenance of bio-digester
- Managing CDM process
- Financial management of supply chain actors
- Installation of data acquisition systems at individual farms

KEY RESOURCES

- Manure
- Bio-digesters
- Equipment to measure gas emission
- Technical know-how
- Supplier loyalty
- Financial management expertise

VALUE PROPOSITIONS

- Cost recovery from reduced energy cost and earning from carbon credit trading while ensuring better management of animal manure in accordance with regulations
- Tradable carbon credits to meet carbon emission reduction commitments

CUSTOMER RELATIONSHIPS

- Direct interaction and partnership arrangements field technicians
- Interaction with carbon trading companies and Development Bank

CHANNELS

- Financing arrangement for purchase of the bio-digesters and repaid through the sales of carbon credits
- Emission trading scheme/platform
- Long-term contract agreements

CUSTOMER SEGMENTS

- Livestock farmers
- Carbon trading companies of Annex 1 countries as per Kyoto Protocol

COST STRUCTURE	REVENUE STREAMS
• Investment costs (engineering, construction, equipment, commissioning) • Costs for training farmers • Operational and data management costs (labor and maintenance cost) – covered by the farmers • Maintenance costs – covered from carbon credit • Savings from energy displacement, both electricity as well as diesel-benefit to farmers	• Sales of carbon credit
SOCIAL & ENVIRONMENTAL COSTS	**SOCIAL & ENVIRONMENTAL BENEFITS**
• Potential leakage of CH_4 from bio-digesters	• Improved social and economic sustainability of livestock farms • Improved animal waste management system and better working conditions • Reduced GHG emission (CH_4) and climate change mitigation • Better local environmental condition by improving quality of water and reducing soil pollution and foul doors • Dissemination of environmental education among swine producers and the surrounding community • Displacement of fossil fuel consumption for electricity as well as thermal energy • Sale of bio-fertilizers to surrounding farmers

and local organization play key roles in mobilizing the community and securing financial resource to establish electricity service provision. Since the project results in carbon offset, there is potential for generating revenue from sales of carbon.

Alternative business model – Centralized biogas systems for carbon credit and sustainable value chain

An alternative business model is setting up centralized biogas systems owned and operated by farm cooperatives, the members being the participating manure suppliers (Figure 67). Thus, instead of installing bio-digesters at individual farms, manure from several farms within a region is supplied to a central bio-digester. Apart from the manure, the plant can receive various sorts of organic waste to increase energy yield of the system. This centralized system can be implemented by the processing factory on a Build, Operate and Transfer (BOT) model. Centralized system would benefit farmers that cannot individually construct and operate a bio-digester on their own due to capital expense or just don't have the required land, other infrastructures, sufficient number of animals and skilled labor to operate a bio-digester successfully or cost effectively.

The centralized system results in improved economic and organizational framework. It has an economy of scale advantages, and the fact that the centralized system results in a significant supply of energy is an advantage in negotiating contracts for sale of electricity to the state utility. Furthermore, the electricity produced can be supplied to the processing factory and partly used at the farms supplying

FIGURE 66. BUSINESS MODEL CANVAS: POWER FROM MANURE FOR RURAL ELECTRIFICATION

KEY PARTNERS
- Municipality
- Non-profit organization
- Community

KEY ACTIVITIES
- Agreement with relevant partners
- Community mobilization
- Organic waste collection
- O&M of the biogas unit
- Sale of electricity and fertilizer

KEY RESOURCES
- Land
- Capital
- Labor
- Manure and other organic waste

VALUE PROPOSITIONS
- Providing low-cost electricity service to houses and businesses in the community
- High quality solid/liquid organic fertilizer for self-use and sale to farmers

CUSTOMER RELATIONSHIPS
- Interaction with community through local subsidiary that manages the operation of the unit

CHANNELS
- Through appropriate agreement and self-interaction
- Direct

CUSTOMER SEGMENTS
- Household and businesses
- Farmers

COST STRUCTURE
- Investment costs (land, building and machines)
- Operational costs (raw material, labor, maintenance costs, marketing costs and R&D)

REVENUE STREAMS
- Sales of electricity
- Sales of organic fertilizer

SOCIAL & ENVIRONMENTAL COSTS
- Potential leakage of methane (CH_4) from bio-digesters

SOCIAL & ENVIRONMENTAL BENEFITS
- Jobs creation
- Environmental benefit through reduced CO_2 emissions by generating electricity from renewable source
- Improved animal waste management system and better working conditions with savings in cost of handling waste
- Better local environmental condition by improving quality of water and reducing soil pollution and foul doors
- Reduced GHG emission (CH_4) and climate change mitigation

the manure. Thus, the entire supply chain, starting from the farm to processing factory becomes energy self-sufficient. The project can be registered as a CDM project and thus earning additional revenue from carbon credit sales. Other industries or supply chains that are willing to pay premium prices for energy produced in a sustainable way can also be targeted. The bio-fertilizer produced can be used by all the participating farms as bedding for their animals or the excess sold as fertilizer and soil amendments to other farms. The drawback of centralized plants is the costly process of transporting livestock manure, and hence, a well-structured logistics is critical for the success of the business.

FIGURE 67. BUSINESS MODEL CANVAS: CENTRALIZED BIOGAS SYSTEMS FOR CARBON CREDIT AND SUSTAINABLE VALUE CHAIN

KEY PARTNERS
- Livestock farmers
- Development banks
- Financial institution
- Equipment suppliers
- University
- Government
- Carbon investors

KEY ACTIVITIES
- Installation of bio-digester on a BOT basis
- Managing CDM process
- Financial management for supply chain actors
- Installation of data acquisition system
- Improved instrumentation to efficiently measure carbon sequestration
- Logistics organization for collection and transportation of waste

KEY RESOURCES
- Bio-digesters
- Equipment to measure gas emission
- Technical know-how
- Effective logistics
- Supplier loyalty
- Financial management expertise

VALUE PROPOSITIONS
- Cost recovery from reduced energy cost and earning from carbon credit trading while ensuring better management of animal manure in accordance with regulations
- Supply of environment-friendly renewable energy
- Tradable carbon credits to meet carbon emission reduction commitments
- Low-cost organic fertilizer as soil amendment

CUSTOMER RELATIONSHIPS
- Direct interaction and partnership arrangements field technicians
- Direct communication
- Interaction with carbon trading companies and Development Bank
- Personal

CHANNELS
- Long-term contract agreements between parties
- Connection to state electricity grid
- Carbon credit trading platform
- Direct

CUSTOMER SEGMENTS
- Livestock farmers
- State utility
- Carbon trading companies of Annex 1 countries as per Kyoto Protocol
- Farmers

COST STRUCTURE

- Investment costs (Engineering, construction, equipment, commissioning)
- Costs for training farmers
- Transport costs
- Operational and data management costs (labor and maintenance cost) – covered by the farmers
- Maintenance costs – covered from carbon credit
- Savings from energy displacement, both electricity as well as diesel-benefit to farmers

REVENUE STREAMS

- Sales of electricity
- Sales of carbon credit
- Sales of organic fertilizer

SOCIAL & ENVIRONMENTAL COSTS

- Potential leakage of methane (CH_4) from bio-digesters

SOCIAL & ENVIRONMENTAL BENEFITS

- Improved social and economic sustainability of livestock farms
- Improved animal waste management system and better working conditions
- Reduced GHG emission (CH_4) and climate change mitigation
- Better local environmental condition by improving quality of water and reducing soil pollution and foul doors
- Dissemination of environmental education among producers and the surrounding community
- Displacement of fossil fuel consumption for electricity as well as thermal energy

D. Potential risks and mitigation

This section describes the potential risks and mitigation options for power from manure for carbon credit and sustainable value chain.

Market risks: The outputs from this business model are carbon credits sold in the international market, energy used by livestock farms and surrounding communities and bio-fertilizer used on farmers' own land. Market risks exist for the carbon credits as the carbon credit market is volatile which puts the sustainability of the whole reuse business under risk. Thus, the business has to diversify its revenue streams to sale of power, thermal energy and bio-fertilizers to mitigate market risks. For instance, instead of putting bio-digesters in every farm, the farmers can form a cooperative and build a centralized biogas system (alternative scenario), which collects all the manure from member farmers, processes the manure, produces and sells electricity to the national grid. The energy produced can also be supplied to the processing factories and distributed to member farmers. This ensures market for the electricity produced and also the entire supply chain, starting from the farm to processing factory becomes energy self-sufficient. Moreover, it will allow safety monitoring as well as quality control to be centralized if and where required.

Competition risks: In implementing this business model, the processing factory is incorporating environmental sustainability into its revenue design. The risk associated with output market is low. The carbon credits are sold in the international market. In the scenario where centralized biogas systems produce electricity at a large scale, competition risk can be reduced by entering into a long-term power purchase agreement with the state utility, hence ensuring a ready buyer. The electricity can also have a ready buyer when it is supplied to the processing factory and used within the farms. Moreover, other industries or supply chains that are willing to pay premium prices for energy produced in a sustainable way can be targeted.

Technology performance risks: The technologies applied for processing livestock waste are well-established and mature technologies. However, the technologies require skilled manpower to operate and maintain them. Maintaining the performance of the technologies at the standard level is very critical for the economic and environmental viability of the business as the business heavily depends on earnings from carbon credit sales. Farmer's lack of technical know-how to operate bio-digesters may result in leakages of CH_4 which will significantly reduce the carbon credit earnings. The centralized large scale plant will be easier to operate and maintain by skilled labor, which may be difficult at individual farms.

Political and regulatory risks: With the projected electricity demand set to grow, governments are encouraging green power initiatives by putting in place various incentive mechanisms such as concessional loans, feed-in tariff mechanisms and through long-term power purchase agreements. However, it is not advisable to entirely depend on government incentive mechanisms to ensure sustainability of the business. In order to ensure economic viability, the business should diversify its customer base. This can be done by supplying part of the electricity produced to the processing factory and other industries that are willing to pay premium prices for energy produced in a sustainable manner. However, this will also depend on the electricity regulation of the region where the business is operating.

Social-equity-related risks: The beneficiary of the model may change depending on the end use of the energy generated from manure. In the case of rural electrification, underserved communities are the beneficiary while in the case of livestock industry, power is generated for own use. The model offers employment opportunities which could be provided to informal laborer to mitigate any social equity risks the business model may create.

Safety, environmental and health risks: The environmental risks associated with the bio-digesters include possible leakage of CH_4. The safety and health risks to human arise when processing livestock waste.

Proper protection measures should be put in place to protect laborers (Table 21).

TABLE 21 POTENTIAL HEALTH AND ENVIRONMENTAL RISK AND SUGGESTED MITIGATION MEASURES FOR BUSINESS MODEL 5.

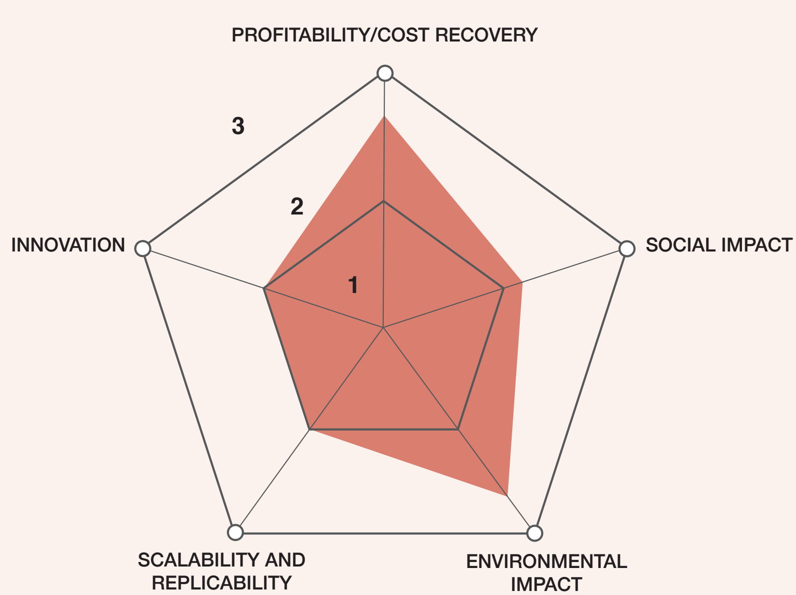
RISK GROUP	EXPOSURE					REMARKS
	DIRECT CONTACT	AIR	INSECTS	WATER/ SOIL	FOOD	
Worker						Direct contact risk relates to pathogens in livestock manure.
Farmer/user						
Community						
Consumer						
Mitigation Measures						

Key: NOT APPLICABLE, LOW RISK, MEDIUM RISK, HIGH RISK

E. Business performance

This business model is rated as high on profitability followed by environmental benefit (Figure 68). The business model is expected to result in a significant reduction of GHG emissions, which consequently is translated into carbon credit sales. Moreover, it is expected to result in promoting sustainable livestock production, generating environmental and social benefits.

FIGURE 68. RANKING RESULTS FOR POWER FROM MANURE MODEL



The business model has a potential to be implemented in regions where there are intensive livestock farms and where there is government support for CDM projects. Designing of innovative financing mechanisms and having access to finance are essential for the successful implementation of and ensuring sustainability of this business model.

CASE

Power from agro-waste for the grid (Greenko, Koppal, India)

Krishna C. Rao, Binu Parthan and Kamalesh Doshi

Supporting case for Business Model 6	
Location:	Marlanhalli, Koppal, Karnataka, India
Waste input type:	Agro-waste
Value offer:	Power
Organization type:	Private
Status of organization:	Greenko incorporated in 2006 and Ravikiran project operational since 2005 but was acquired by Greenko in 2007
Scale of businesses:	Medium
Major partners:	Investors, like e.g. Blackrock Investment Management, Aloe Private Equity, Impax Asset Management

Executive summary

Greenko Group, a environmentally-driven private Indian company, is an independent power producer utilizing new approaches to clean power, using proven, technologically-advanced systems and processes. Greenko Group has built a portfolio of clean energy projects with risk management strategies through technologically and geographically-balanced portfolio, cluster approach, leveraging the carbon market, raising finances from capital markets, financial institutions and sovereign wealth funds and balancing greenfield and selective acquisitions to generate and sell electricity to the state-owned energy utilities as well as private clients. In the financial year 2006–2007, the business acquired two biomass plants and a 50% interest in a third, including Ravikiran Power project.

The Greenko's 7.5 MW Ravikiran Power project in Marlanhalli, Karnataka state, India was commissioned in June 2005 and buys low-cost agro-waste from local farming villages using large number of biomass supply intermediaries to generate and sale electricity at pre-announced tariffs to regional electricity grid. The Greenko Group is also a part of the CDM process and generates and sells Certified Emission Reductions (CERs), Voluntary Emission Reductions (VERs) and Renewable Energy Certificates (RECs). The project has a significant positive impact on both the local community and environment from carbon offsets and increasing the incomes of local farmers. The company maintains a continuous involvement in localized projects and community programs which centres on education, health and wellbeing, environmental stewardship and improving rural infrastructure.

KEY PERFORMANCE INDICATORS (AS OF 2014)							
Land use:	NA						
Water requirement:	50 m^3/hr						
Capital investment:	USD 6 million						
Labor:	9 full-time employees						
O&M cost:	USD 2 million/year (including fuel costs)						
Output:	46 Gigawatt hours (GWh) net electricity generation at 7.5 Megawatt (MW) output level						
Potential social and/or environmental impact:	Nine jobs, 37,468 tCO_2eq/year carbon mitigation by avoiding of waste build-up and anaerobic conditions for agro-residues. Jobs created also for biomass collection and transport, an income generation for the local population by sale of agro-residues, significant indirect investment in the region by way of roads schools and civic amenities						
Financial viability indicators:	Payback period:	4.7 years	Post-tax IRR:	16%	Gross margin:	28%	

Context and background

Greenko Group was formally incorporated in 2006, founded by Anil Chalamalasetty and Mahesh Kolli, listed on the LSE and raised with a start-up capital through an initial public offering. The main operations of the group are based in India, predominantly in the central and southern states of Andhra Pradesh, Karnataka and, more recently, Chhattisgarh. The group was formed as a vehicle to take advantage of the opportunities for consolidation of the Indian renewable energy market and operate in the two markets of renewable energy supply and CER units provision. Seven of Greenko's projects generate electricity from agro-residues. The company has 289 MW of clean energy capacity from hydro, wind, gas and biomass energy. The company also has a number of projects under development and acquisition and plans to reach 1000 MW capacity in 2015 and 3 GW by 2018. In 2013, Greenko had 309 MW of power generation capacity with 51 MW being commissioned, 446 MW under construction and 1,529 MW of projects under active development.

Ravikiran Power is a 7.5 MW biomass project located at Devinagar Camp, Kampli Road, Gangavathi Taluk of Koppal District, Karnataka. The Ravikiran Power project's location was selected after surveys which indicated adequate availability of the agro-residue, primarily rice husk used by the project as well as proximity to an electrical sub-station for selling the energy generated. Koppal, Raichur and Bellary, which is also called rice bowl of Karnataka along the river Tungabhadra. The project buys 157 tons of agro-residues from local farming villages through a large number of biomass supply intermediaries and uses to assure regular supply at competitive process, providing an income-generating opportunity and a waste management solution. The project also provides employment to local villagers. The project uses rice husk, groundnut shell and bagasse as the major fuel and has a travelling grate, multi-fuel fired boiler. The electricity is sold to Gulburga Electricity Supply Company (GESCOM), which is a state-run regional electricity distribution company.

Ravikiran Power Projects Ltd, the subsidiary of Greenko Group, had entered into a PPA with Gulbarga Electricity Supply Co Ltd (GESCOM) for a period of 20 years, but the PPA was mutually terminated for the year ended March 31, 2013. The company is in discussions with various industrial and commercial customers in the state of Karnataka for the offtake of power generated by Ravikiran Power. No sales of power were made in relation to Ravikiran Power for the year ended March 31, 2014.

Market environment

The main offtaker of the electricity is the state utility. However, it is possible to sell the power directly to other 1 MW electricity consumers using the state's grid network as per the Electricity Act 2003. Such a third-party sale is a financially more attractive proposition due to the economies being driven by avoided cost of electricity supply, albeit it is slightly riskier in realization.

As a result of economic growth, the energy consumption in the country and state are increasing and the market for electricity is growing. The share of the market for the project at the regional level, the market share, is 0.02%. The total potential of biomass power in the state of Karnataka is 1,500 MW for cogeneration using sugarcane bagasse in addition to 1,000 MW from agro-residues. The state of Karnataka is linked to the southern regional electricity grid, which has power and energy deficits and the energy distribution utilities have to resort to cyclical load shedding.

CERs are a type of emissions unit (or carbon credits) issued by the CDM Executive Board for emission reductions achieved by CDM projects and verified by a Designated Operational Entity (DOE) under the rules of the Kyoto Protocol. Methodologies are required to establish a project's emissions baseline, or expected emissions without the project, and to monitor the actual on-going emissions once a project is implemented. The difference between the baseline and actual emissions determines what a project is eligible to earn in the form of credits. One CER equates to an emission reduction of one ton of CO_2 equivalent. Holders of CERs are entitled to use them to offset their own carbon emissions as one way of achieving their Kyoto or European Union emission reduction target. In August 2008, prices for CERS were USD 20 a ton. By September 2012, prices for CERS had collapsed to below USD 5.

The emergence of a secondary market for VERs outside the Kyoto Protocol is driven by corporations and individuals looking to reduce voluntarily their carbon footprint. VERs arise from projects awaiting CDM clearance, special situations (e.g. carbon capture and storage) or smaller projects.

Macro-economic environment

Electricity demand in India is likely to reach 155 GW by 2016–17 and 217 GW by 2021–22 whereas peak demand will reach 202 GW and 295 GW over the same period, respectively. At the national level, India faces an energy shortage of 10.6% and a peak power shortage of 15 GW.

Renewable energy in India comes under the purview of the Ministry of New and Renewable Energy. In order to address the lack of adequate electricity availability to all the people in the country by the platinum jubilee (2022) year of India's independence, the Government of India has launched a scheme called 'Power for All'. This scheme will ensure that there is 24/7 continuous electricity supply provided to all households, industries and commercial establishments by creating and improving necessary infrastructure. A tenfold increase in solar installation rates to 100 GW by 2022, trebling to 60 GW of new wind farms, 10 GW of biomass and 5 GW of small-scale run-of-river hydro has been targeted. In addition, India's private sector has set targets to increase its use of clean energy as a part of global efforts to reduce greenhouse gas emissions in a bid to give a push to clean energy projects in the country.

The country and the state have policies, fiscal and financial incentives to encourage independent power producers, especially those that are using renewable fuels such as agro-residues. The Government of India has provided tax incentives to renewable energy generators in the form of 10-year tax holidays from the usual rate of corporation tax, accelerated tax depreciation of assets and other fiscal incentives. In addition, the government has decided to waive transmission charges for electricity generated from renewable sources. This has been encouraged at state level by the implementation of

a tariff structure, which provides base income under long-term PPAs, typically with terms of between 15–20 years. Generation SEBs and state-owned schemes are still the dominant suppliers of energy but independent power producers and captive plants (owned by the end user) have grown significantly since liberalization of the industry began.

Business model

Ravikiran Power has two key value propositions – generation of environment-friendly electricity from crop residues and sales of carbon offset generated by the project (Figure 69). Ravikiran Power project sells the power directly to a state-run electricity distribution company. The project has the potential to have another revenue source through sales of fly ash to brick industry.

FIGURE 69. RAVIKIRAN POWER PROJECT BUSINESS MODEL CANVAS

KEY PARTNERS
- Farmers and agro-waste dealers
- Group of shareholders/ investors

KEY ACTIVITIES
- Obtaining crop residues
- Electricity generation
- Sale of electricity
- CER sales

KEY RESOURCES
- Rice husk/ agro-waste
- Local skilled staff
- Land
- Investment

VALUE PROPOSITIONS
- Environment-friendly energy security for rural Karnataka state from crop residues
- Carbon emission reductions

CUSTOMER RELATIONSHIPS
- Direct interaction with the electricity distribution company

CHANNELS
- Direct supply of electricity to the distribution company
- Direct relationship with carbon Market agents

CUSTOMER SEGMENTS
- GESCOM
- Carbon trading companies

COST STRUCTURE
- Investment cost (land, building, machines)
- Operational cost (input cost, labor, maintenance cost)
- Debt and equity payments

REVENUE STREAMS
- Sale of electricity
- Sale of CERs

SOCIAL & ENVIRONMENTAL COSTS
- Laborers' health and safety risk if no proper safety measures are present in the electricity generation unit
- Fly ash generated from the process can pose environment risks

SOCIAL & ENVIRONMENTAL BENEFITS
- Improved quality and reliability of electricity results in increased income/productivity opportunities (economic development)
- Provides employment and create livelihood
- Reduction is greenhouse gas emissions

Value chain and position

The value chain of the business consists of agricultural production, collection segregation, transport and sales of agro-residues, conversion of agro-waste to energy, transmission of energy, and distribution and sales of energy (Figure 70). The critical relationships the enterprise has are with the agro-residue suppliers who ensure availability of adequate quantity of biomass with good quality at prices that make the business viable. The Ravikiran Power project has partnered with multiple biomass dealers who procure agro-residues from local farmers. The other significant and important relationship the enterprise has is with investors who finance the capital and operating costs and who expect a healthy return on their investments. The project's relationship with a local distribution company that buys the electricity at a contract price plays a significant role in keeping the operation costs of the company lower. However, with only a single buyer of the electricity and also with other energy sources available in the market, there could be a significant threat from substitutes, but with the electricity shortage, it is not applicable. In addition, the project will generate 33,000 CERs per year. A flow-chart illustrating these relationships are given below.

The project is able to offer a good price for agro-residues which otherwise has a low economic value and is able to contribute to meeting the energy and power deficit in the electrical grid, providing additional developmental benefits. The catchment area of the project has enough agro-residues – primarily rice husk and also groundnut shell, arecanut husk and plywood waste. Greenko has secured a proportion of its feedstock supply locally to reduce transport costs through a combination of building relationships with local suppliers and developing its own fast-growing stocks on surplus or adjoining land at its biomass plants. The project processes about 157 tons/day of dry waste with less than 10% moisture content with specific consumption of about 1.23 kgs of waste/kWh. The cost of feedstock used to run a biomass plant represents approximately 50% of power revenue generated. Over time, the company intends to grow up to approximately 30% of its feedstock requirements. This should reduce Greenko's dependency on external providers of feedstock and reduce fuel supply risks.

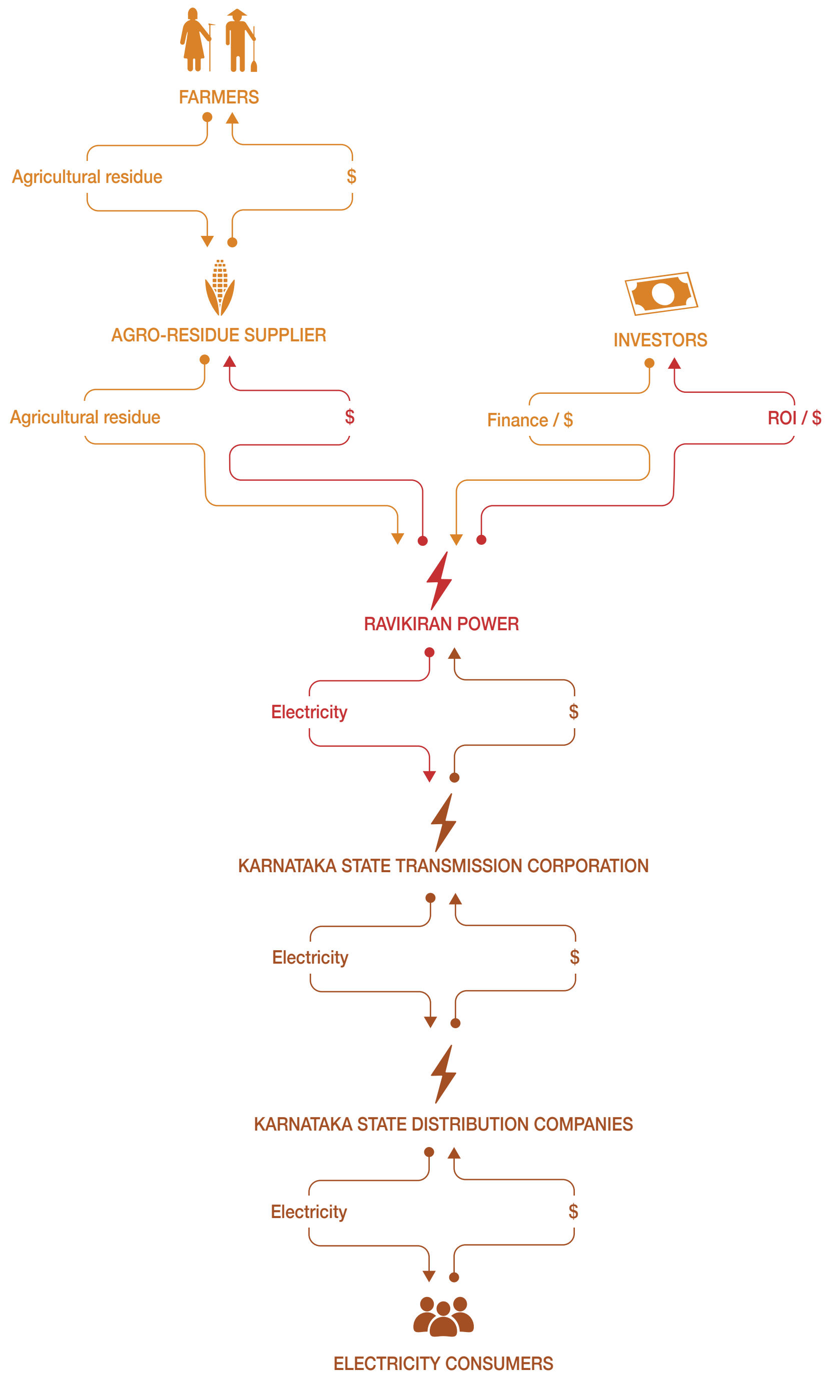
The fly ash is a lightweight particle captured in exhaust gas by electrostatic precipitators installed before flue gas chimney at the plant. Fly ash is very fine with cement-like properties and has long been used as an additive in cement, concrete and grout, as filler material and as ingredient for bricks. Fly ash bricks now account for about one-sixth of India's annual brick production, saving energy, soil and carbon emissions and putting a toxic waste product to beneficial use.

Institutional environment

The legal and regulatory framework, with implementation of Electricity Act 2003, National Electricity Policy, the National Tariff Policy and the Accelerated Power Development and Reform Program, is conducive for waste-to-electricity projects in Karnataka and generally in India. Electricity generation projects do not require to obtain license to set up, have guaranteed open access to the grid and offered an attractive electricity purchase price and also open access to consumers over 1 MW. There are no regulatory issues relating to the sourcing of the agro-residues. The policy of the Karnataka state environmental agency – Karnataka State Pollution Control Board (KSPCB) covers hazardous waste, battery waste, e-waste and plastics and does not cover agro-residues that are the waste input to the power plant. However, KSPCB environmental policy does cover fly ash, which the plant generates.

The Ministry of New and Renewable Energy has implemented a wide range of programs for the development and deployment of biomass-based power generation. To encourage investment in the sector, fiscal and financial incentives have been provided that include capital/interest subsidy, accelerated depreciation, concessional duties and relief from taxes, apart from preferential tariff for grid power being given in most potential states. To facilitate the development of renewable energy sources

FIGURE 70. RAVIKIRAN POWER PROJECT VALUE CHAIN



in the state, the Government of Karnataka established Karnataka Renewable Energy Development Ltd (KREDL) on March 8, 1996. KREDL will be responsible for laying down the procedure for inviting of proposals from Independent Power Producers (IPPs) and DPR and evaluation of project proposals, project approvals, project implementation, operation and monitoring. Single-window clearance will be provided. Gulbarga Electricity Supply Company Ltd (GESCOM) has the responsibility for the distribution of electricity in Bidar, Gulbarga, Yadgir, Raichur, Koppal, Bellary districts and purchases power from the project.

Technology and processes

The technology used for waste-to-electricity conversion is the steam cycle with biomass combustion which is proven and used in a large number of thermal (coal, nuclear and biomass) power plants around the world. Biomass combustion is generally suitable for large capacity (few MW and above) and grid-connected applications, whereas biomass gasifier and bio-methanation-based power plants are more suitable for sub-megawatt level and decentralized applications. The agro-residues are combusted in a multi-fuel, travelling grate-water tube boiler to produce steam. The steam passes through a condensing, impulse turbo generator, which generates electricity which is exported at 110 kV to the state grid network. The risks associated with the technology have primarily to do with management of high-temperature steam in the boiler and in the turbo generator. The technology and equipment was locally sourced and spare parts, technicians, operators and technical expertise to service the technology is locally available.

The biomass power projects are normally designed to handle multi-fuel (biomass) along with conventional fossil fuels like coal. Due to poor bulk density, the volume of biomass to be stored and handled poses challenges. The lighter particles of ash flying in furnace get carried away through flue gases and get collected in hoppers below economizer, air pre-heater, duct and electrostatic precipitator. From these hoppers the ash is either collected manually on tractor/lorries or dry ash conveying is carried out. See Figure 71 for Ravikiran Power project's process flow.

Funding and financial outlook

Greenko was incorporated in 2006 and raised its equity through initial public offering by getting listed on the London Stock Exchange. Greenko Group has raised an equity of USD 1.8 million and debt of about USD 4.18 million and plans to raise further its equity in the near future. Ravikiran Power project is one of Greenko's electricity generation projects under its portfolio financed from the debt and equity raised. See Table 22 on financials. In addition, the Ravikiran Power project also benefits from an interest subsidy of 2% on debt from public financial institutions. The total investment cost of the project is about USD 6 million, and plant and machinery is the major cost. The annual total cost of production incurred by the project is about USD 2 million. The fuel and agro-residue cost forms 50% of its operations, followed by debt payment and labor and maintenance. The Ravikiran Power project pays USD 15/ton of agro-residue.

FIGURE 71. PROCESS DIAGRAM OF RAVIKIRAN POWER PROJECT

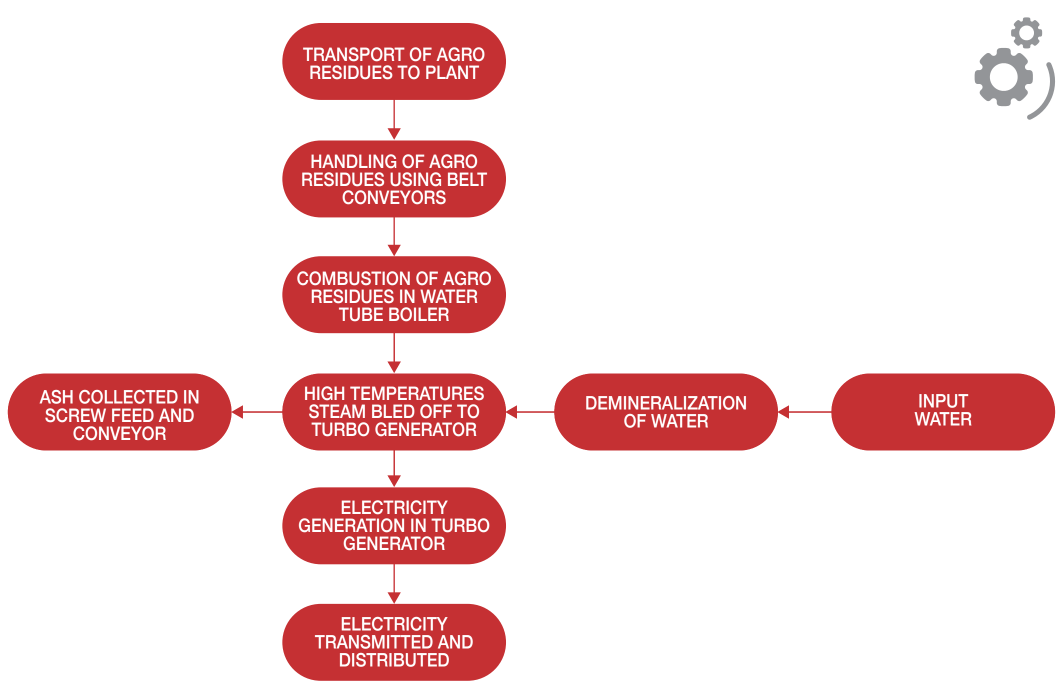


TABLE 22. GREENKO FINANCIALS (IN MILLION USD)

Key capital costs (2006)	Land building and civil costs	0.56
	Plant and machinery	4.5
	Miscellaneous fixed assets	0.16
	Preliminary and pre-operative expenses	0.6
Operating costs	Fuel/agro-residue costs	1.0
	Operation and maintenance	0.24
	Interest on debt	0.49
	Depreciation	0.29
Financing options	Equity from equity investors	1.8
	Debt from the state bank of India	2.0 at 12%/year interest
	Debt from HUDCO	2.18 at 12%/year interest

Ravikiran Power project has two revenue sources – energy sales and CER sales. Revenue generated from annual CER sales is about USD 0.24 million for 37,468 tCO_2eq/year carbon mitigation. Its annual revenue from sales of energy is an upwards of USD 2.53 million. Taking assumption of net revenue increase of USD 0.05 million every year, Greenko has a payback period of 4.71 years on its investment made in Ravikiran Power project. The investment has an internal rate of return of 16% and gross margin of 28%.

Socio-economic, health and environmental impact

The Ravikiran Power project has a significant economic development impact to the region both from improving the local availability of electricity and by infusing money into the local economy especially to farmers by offering a value of about 15 USD/ton of agro-residue and contributing USD 1 million to the local economy. The project has also created direct employment for nine people and resulted in local job creation in biomass residue collection and transport, in shops and restaurants and in the area. The electricity generated will primarily be used in the local area which can power local agro-industries and commercial establishments. The project directly reduces greenhouse gases which otherwise would have been emitted in the absence of the project. Applying the UNFCCC-approved methodologies for baseline setting, monitoring and verification of emission reductions, it was found that the project resulted in emission reductions of 37,468 tCO_2eq/year. The project has a role in regulating ecosystem services by mitigation of climate change through emission reductions.

Scalability and replicability considerations

The key drivers for the success of this business are:

- Management team with extensive project development, financial and corporate management skills.
- Location of plant near low-cost crop residue and sub-station to sell electricity.
- Support from the Indian government for independent power producers.
- Incentives for renewable energy.
- Electricity shortage and unserved areas.

Greenko has already replicated similar biomass energy projects in six other locations with plants ranging in capacity from 6–8 MW, totalling 34 MW. There are opportunities for scaling up the business but the opportunity would be constrained by the availability of agro-residues within the catchment area of the business. However, the business has considerable scope for replicating the projects in other parts of India.

Summary assessment – SWOT analysis

The key strength of Ravikiran Power project is its resource expertise in managing the power plant (Figure 72). The business has limited weaknesses and it should continue to reduce its reliance on a specific crop residue, e.g. its reliance on rice husk dominates over other crop residues. The business threat is from biomass availability and price fluctuation of biomass residues. The business has an opportunity to replicate the projects in other regions, and in addition, the government of India provides a favourable policy and regulatory environment for independent power producers.

FIGURE 72. RAVIKIRAN POWER PROJECT SWOT ANALYSIS

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Cluster approach to project development to optimize use of resources and expertise ▪ Combination of greenfield and selective acquisitions to grow the portfolio of projects ▪ Effective resource mobilization strategy from the capital markets, institutional investors and sovereign wealth funds ▪ Plant location closer to both input and customer. ▪ Avoidance of GHG CO2 emissions ▪ Positive view of the project by local community ▪ Additional income for rural farmers ▪ Nucleus for other economic activities	**WEAKNESSES** ▪ Plant breakdowns and loss of operating time and revenues ▪ Complex material handling due to different types of agro-residues ▪ Changes in feedstock prices and its seasonal availability could have a significant impact on profitability ▪ Shortage of skilled manpower ▪ Weak biomass availability assessments
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Favourable policy and regulatory environment and incentives for independent power producers in India ▪ Attractive power purchase rates for electricity generated from renewable energy sources ▪ Availability of agricultural waste in the catchment area of the power plant ▪ Availability of financing organizations ▪ Direct third-party sale ▪ Continuing high demand for energy	**THREATS** ▪ Low demand and very low prices for emission reductions from late 2012 onwards ▪ Fluctuations in availability and prices of biomass residues for the power plant ▪ Depreciation of the Indian currency against Euro ▪ Uncertainty in tariff policies ▪ Poor grid stability with prolonged forced or planned outages ▪ Long delays in issue of permits/ approvals by authorities ▪ Currency non-convertibility or instability ▪ Channeling of agro-waste for other uses

References and further readings

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Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflects our best knowledge at the time of the assessments (2015–2016). As business operations are dynamic, data can be subject to change.

CASE

Power from rice husk for rural electrification (Bihar, India)

Krishna C. Rao, Hari Natarajan and Kamalesh Doshi

Supporting case for Business Model 6	
Location:	Bihar, India
Waste input type:	Primarily rice husk; Currently testing other biomass waste
Value offer:	Electricity to households and small businesses and biochar
Organization type:	Private
Status of organization:	Operational since 2007
Scale of businesses:	Medium
Major partners:	Shell Foundation, Acumen Fund, Bamboo Finance, International Finance Corporation, LGT Philanthropy, CISCO, Ministry of New and Renewable Energy, Government of India, Farmers

Executive summary

Founded in 2008, Husk Power Systems Inc. (HPS) is promoted by first generation entrepreneurs Gyanesh Pandey, Ratnesh Yadav, Manoj Sinha (natives of Bihar, India) and Charles Ransler (USA). It has won several business plan competitions and secured foundation grants in the United States. As a rural empowerment enterprise, HPS has a mission to provide renewable and affordable electricity to rural people in a financially sustainable way. Most of rural Bihar suffers from poor access to modern energy with majority of households relying on either kerosene for lighting or other low-quality energy source, such as candle or batteries. HPS owns, installs, operates and manages decentralized rice husk/biomass gasifier-based 25–100 kW generation and distribution systems to deliver lighting and electrification services to 200–600 households on a "fee for service" basis to households and 5–10 irrigation pump sets and small businesses in rural Bihar. HPS procures rice husk/feedstock at negotiated rates. The consumers prepay a fixed monthly fee, ranging from USD 2–3 to light two fluorescent lamps and one mobile charging station which is at least 30% cheaper than the cost of kerosene and diesel and enables savings of up to USD 50 for each household every year. HPS uses a franchisee-based business model and uses three distinct approaches to deliver electricity services: a) Build-Own-Operate (BOO) b) Build-Own-Maintain (BOM) – operation is managed by a local partner or entrepreneur and c) Build-Maintain (BM) – a local partner/entrepreneur owns and operates the plant. At the time of this assessment, the company had more than 84 plants, enough to provide electricity to over 250,000 people across 300 villages and hamlets and employing 350 people across the state of Bihar.[1]

KEY PERFORMANCE INDICATORS (AS OF 2014)							
Capital investment:	USD 1,300/kW						
Labor:	Full-time: 3; Part-time: 5–10						
O & M cost:	Estimated to be less than USD 0.15 /kWh						
Output:	25–100 kW of electricity						
Potential social and/or environmental impact:	Each unit serves about 200–600 households, 5–10 irrigation pump sets and small businesses; improved energy access and cleaner local environment, reduction in GHG emissions, employment generation						
Financial viability indicators:	Payback period:	6–8 years	Post-tax IRR:	N.A.	Gross margin:	45%	

Context and background

Despite significant efforts and resources deployed by the Government of India towards rural electrification, about 480 million citizens residing in about 125,000 villages in India (45% of the total population) do not have access to reliable power. Of those who do, almost all find electricity supply intermittent and unreliable. When grid rationing takes place, villages often receive power only after midnight when "priority" demand from cities and industry is low. This is of little use to rural households and businesses. The Indian government has designated several thousand villages as "economically impossible" to reach via conventional grid. Without electricity, these villagers are forced to live at the whim of natural forces and lack basic communication, education and healthcare infrastructure. Common energy supply options, such as kerosene lanterns or diesel generators, are uneconomical, inefficient and environmentally unfriendly.

The state of Bihar is third largest with 82.9 million population and 12th largest with 94,163 km^2 geographical size in India. Only 52.8% of villages and 6% of households of the state are electrified, leaving about 85% of the population with no access to electricity. Even the villages connected to grid have frequently interrupted poor quality of power supply. However, Bihar is blessed with fertile soil and good rainfall. It has several geographic and climatic advantages to harness renewable energy. The decentralized electricity generation is the possible solution to reduce transmission losses and to provide electricity to densely populated villages with scattered but large number of small-scale commercial activities. The decentralized power generation can make use of readily-available biomass, which is typically transported out of state. Bihar is a part of the rice belt of India, producing about 4.7 million metric tons of rice per year, generating about 1 million tons of rice husk which is underutilized and is a good source for fuel. Each 32 kW gasifier installed by HPS requires approximately 60 kg of rice husk per hour or 15,000 kg rice husk per month assuming eight hours of operation per day. It was in this context that HPS initiated its operations in 2007, using rice husk as fuel to generate electricity to provide safer, better and cleaner lighting solution at an affordable cost to rural households in Bihar.

Market environment

HPS has identified 25,000 villages as feasible sites within India's rice producing area (Bihar and neighbouring states) for its projects. Promotion of the plants is largely by word-of-mouth and also through local press and media, and their benefits are now well known in Bihar. HPS receives several hundred enquiries about installations each year.

While the minimum services offered by HPS to a household is two light connections and one mobile charging point, a small percentage of households in each mini-grid request and obtain additional

supply to power household appliances, such as a fan, television, radio, etc. The cost of services offered by HPS is significantly higher than that of the state utility, but the grid is practically non-existent across Bihar. Even if the grid were to penetrate these areas in future, HPS plants can feed its energy to the grid with minimal additional investment. Also the state of Bihar has numerous private diesel-generator-run electricity providers whose service provision is similar to services offered by HPS. With rising diesel prices, in the long run, it would be difficult for them to compete with HPS.

The residue from gasification is a carbon-rich ash, or biochar, is rich in alkaline components (Ca, Mg and K) high in silica, and this may contribute to the neutralization of soil acidity and to a decrease in the solubility of the phytotoxic metals such as aluminium in the soils. Biochar can bind and release nutrients (N, P, K and Ca) and could reduce nutrient leaching to the subsoil. It also retains water in soils with low plant-available water and helps draining flood-prone areas. It can be used to improve the fertility of the soil for growing rice or vegetables. *Biochar also has appreciable carbon sequestration value. These properties are measurable and verifiable in a characterization scheme, or in a carbon emission offset protocol.*

Macro-economic environment

India has been promoting biomass gasifier technologies in its rural areas to utilize surplus biomass resources such as rice husk, crop stalks, small wood chips and other agro-residues. The goal was to produce electricity for villages with power plants of up to 2 MW capacities. During 2011, India installed 25 rice husk-based gasifier systems for distributed power generation in 70 remote villages of Bihar.

The Electricity Act 2003 de-licenses power generation completely and the techno-economic clearance from the Central Electricity Authority (CEA) has been done away with for any power plant, except for hydroelectric power stations above a certain amount of capital investment. The Independent Power Producers (IPP) can sell electricity to any licensees or where allowed by the state regulatory commissions to consumers directly. However, the act provides for imposition of a surcharge by the regulatory body to compensate for some loss in cross-subsidy revenue to the SEBs due to this direct sale of electricity by generators to the consumers. As per the Act, 10% of the power provided by suppliers and distributors to the consumers has to be generated using renewable and non-conventional sources of energy so that the energy is reliable.

The Government of India launched the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) – Programme for creation of rural electricity infrastructure and household electrification in April 2005 for providing access to electricity to rural households. As on 30.04.2012, against the targeted coverage of 1.10 lakh[2] un-electrified or de-electrified village and release of free electricity connections to 2.30 crore[3] Below Poverty Line (BPL) households, electrification works in 1.05 lakh un-electrified or de-electrified villages have been completed and 1.95 crore free electricity connections to BPL households have been released under RGGVY. Under RGGVY, electrification of un-electrified BPL households is provided free electricity service connection. Infrastructures created under RGGVY can be used for providing connections to Above Poverty Line (APL) by respective distribution utilities by prescribed connection charges, and no subsidy is available for this purpose. On one side, the program improves access to energy, while on the other side, it creates further problems for India's electricity sector. In addition to RGGVY, there are subsidies provided by the Ministry of New and Renewable Energy for renewable energy projects such as biomass gasification.

Business model

The business offers multiple value propositions, and the primary value proposition is to provide high-quality electricity service to household and businesses in rural areas that have either no access

to electricity or it is unreliable (Figure 73). The enterprise uses rice husk from rice farmers and rice mills to generate electricity using biomass gasification technology. The enterprise partners with local community and the government. HPS uses a franchisee-based business model through three distinct approaches to deliver electricity services: a) Build-Own-Operate-Maintain (BOOM), b) Build-Own-Maintain (BOM) – operation is managed by a local partner or entrepreneur and c) Build-Maintain (BM) – a local partner/entrepreneur owns and operates the plant.

Value chain and position

The rice husk (or hull) is the outermost layer of the paddy grain that is separated from the rice grains during the milling process. Around 20% of paddy weight is husk which is largely considered a waste product with no commercial value and is often burned or dumped in the rivers or on landfills. As per estimates, about 1.8 billion kg of rice husk are produced every year in Bihar. The franchise partners procures rice husk from local rice farmers. HPS is dependent upon farmers and rice mills for rice husks and to mitigate any potential shortfall, HPS reaches out to more farmers/rice mills (Figure 74).

The cost of rice husk is approximately USD 0.02–0.025/kg. HPS faced significant challenge in procuring rice husk for the gasifier for a suitable price. At one point suppliers – rice mill operators and farmers – started demanding higher price. HPS countered this by establishing its own rice mills, where it offered milling services at no cost in return for the rice husk. This forced the suppliers to enter long-term contracts at a fixed price. HPS is exploring other input feed stocks such as wheat husk, mustard stems, corn cobs, wood chips, etc. HPS business suffers from substitutes and new entrants.

HPS's value proposition lies in making the plants so simple to operate and maintain that high-school-educated people from the village can be trained to manage and run them. Tars and other particulates in the producer gas can damage equipment, in particular engines, so a key factor for successful operation is the rigorous HPS maintenance program. HPS also requires high safety standards and detailed monitoring. It is through this attention to maintenance and monitoring that HPS plants achieve over 93% availability.

Electricity fees start at USD 2.2 per month for a basic connection of two lights and one mobile phone charging. "Pay for use" service approach is being followed by HPS for raising revenue and supplying electricity at a low cost. Low-cost prepaid meters have been installed that can efficiently regulate the flow of low-watt electricity and reduce electricity theft to less than 5%. One month's deposit is required when a customer signs the supply contract with HPS. The local HPS collector goes from house to house to collect the fee each month in advance and checks that everything is working well. All complaints are logged and followed up. Under the terms of the contract, HPS agrees to provide service for at least 27 days every month and pro-rates the fees if this level is not met. However, average provision is now over 28 days per month (93% availability). All customers are trained in safe use of electricity. The biochar, the residual waste from the plant, is used in making incense sticks, rubber and manure. About 1,200 women have been employed in incense-stick manufacturing.

HPS has set up a first-of-its-kind 'Husk Power University'. The university will serve as a training facility where new recruits and existing staff will be trained in large engine repair and maintenance, facility management and continuous improvement processes. It will help in job creation for Bihar youths, particularly those living in rural areas, and also in enhancing health and safety conditions at the existing operational sites located in rural areas. HPS has developed significant public support in the local community since it not only provides access to electricity but also creates local employment opportunities either through direct employment in the plant or in the making of incense sticks.

FIGURE 73. HUSK POWER SYSTEMS BUSINESS MODEL CANVAS

KEY PARTNERS

- Local community and businesses
- Entrepreneur
- Government of India, donors and private investors to fund the enterprise
- Rice farmers and rice mills in Bihar

KEY ACTIVITIES

- Obtaining the rice husk
- Biomass gasification for electricity generation
- Electricity distribution
- Bill collection
- Community mobilization
- Maintenance of existing plants
- Franchise management
- Selling of biochar

KEY RESOURCES

- Developed technology
- Rice husk/ agro-waste
- Partnerships
- Local staff
- Mini-grid

VALUE PROPOSITIONS

- Residents and businesses of rural Bihar get higher quality electricity services for a fair price
- Opportunity to start a business based on proven technology in partnership with a successful company
- Additional income source for households making incense stick from biochar
- Carbon offset

CUSTOMER RELATIONSHIPS

- Direct interaction with the users
- Direct relationship with franchisee, technology transfer, maintenance services, and continuous support
- Direct

CHANNELS

- Mini-grid maintained by HPS
- Direct contact to reach potential franchisee
- Biochar from gasification process of rice husk is given away by HPS to businesses making incense stick

CUSTOMER SEGMENTS

- Rural residents and businesses in Bihar
- Local entrepreneurs
- Incense stick makers
- Carbon trading companies

COST STRUCTURE

- Investment cost (land, building, machines)
- Operational cost (input cost, labor, maintenance cost)
- Debt repay and equity

REVENUE STREAMS

- Sale of electricity
- Subsidies
- Build – Maintenance fee from franchise
- Sale of biochar for incense stick making
- Sale of CO2 offset

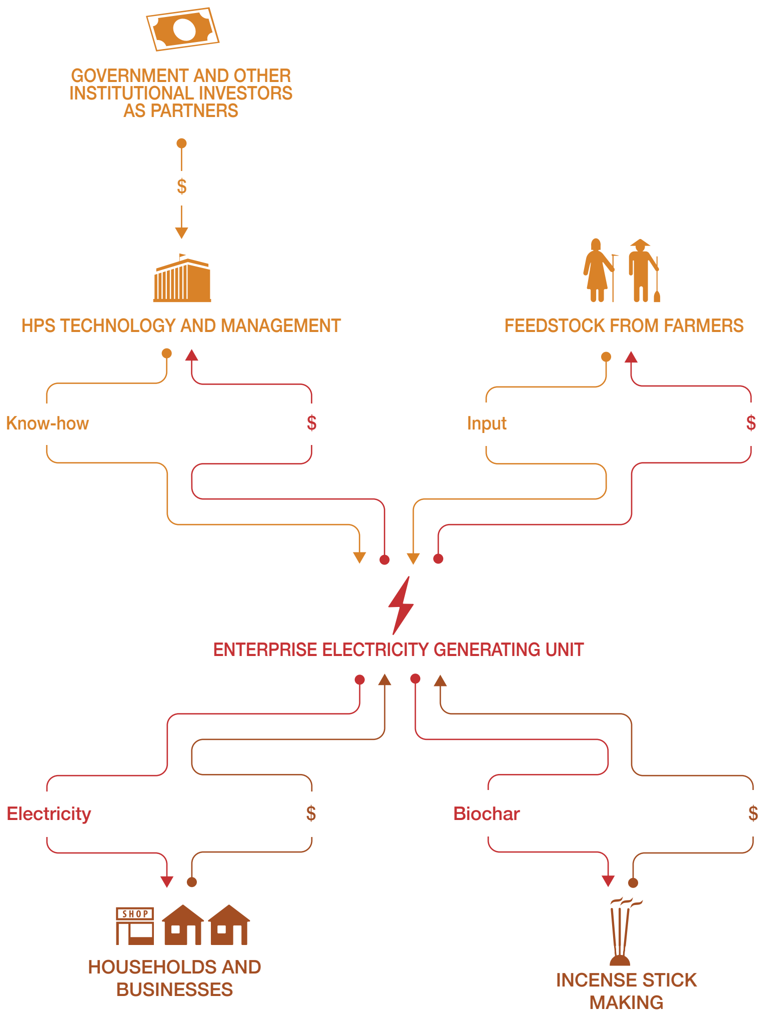
SOCIAL & ENVIRONMENTAL COSTS

- Potential laborers' health and safety risk if no proper safety measures are present in the electricity generation unit
- Potential safety issues on handling of biochar

SOCIAL & ENVIRONMENTAL BENEFITS

- Improved quality of electricity results in increased income/productivity opportunities (economic development) and healthier environment through reduction on kerosene usage for lighting
- Provides employment and create livelihood
- Reduction is greenhouse gas emissions

FIGURE 74. HUSK POWER SYSTEMS VALUE CHAIN



Institutional environment

The Ministry of New and Renewable Energy (MNRE) is promoting multi-faceted biomass-gasifier-based power plants for producing electricity using locally-available biomass resources such as wood chips, rice husk, cotton stalks and other agro-residues in rural areas. The biomass-gasifier programs of MNRE supports distributed or off-grid power for rural areas, captive power generation applications in rice mills and other industries as well as tail-end grid-connected power projects up to 2 MW capacities. The program envisages implementation of such projects with involvement of Independent Power Producers (IPPs), Energy Service Companies (ESCOs), industries, cooperatives, Panchayats, SHGs, NGOs, manufacturers or entrepreneurs, industries, promoters, developers, etc. Bihar Renewable Energy Development Agency (BREDA) promotes all renewable energy projects and programs in the state. The ministry is implementing a program for providing financial support for electrification of those

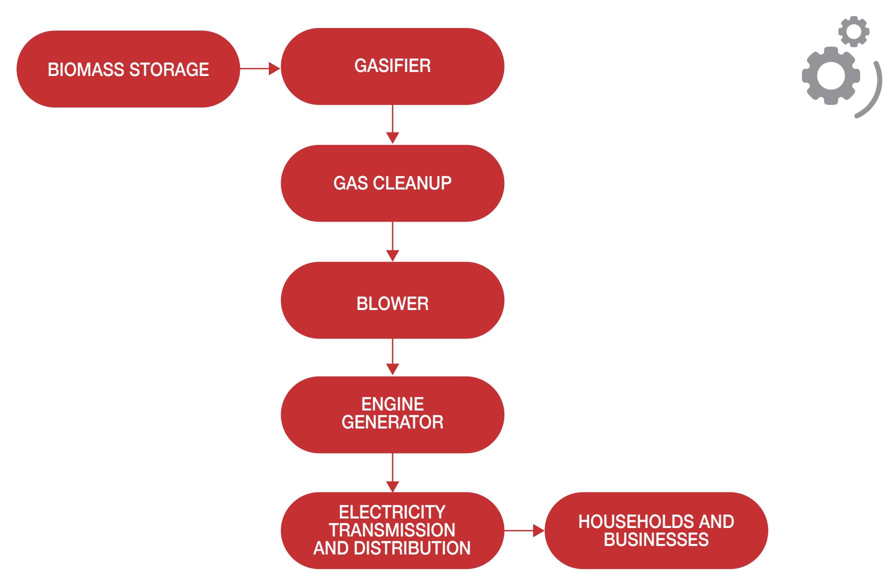
remote un-electrified Census villages and un-electrified hamlets of electrified Census villages where grid extension is either not feasible or not cost-effective and not covered under RGGVY.

About 150 MW equivalent biomass gasifier systems have been set up for grid and off-grid projects. More than 300 rice mills and other industries are using gasifier systems for meeting their captive power and thermal applications. In addition, about 70 biomass gasifier systems are providing electricity to more than 230 villages in the country. A system of cross-subsidization is practiced based on the principle of 'the consumer's ability to pay'. In general, the industrial and commercial consumers subsidize the domestic and agricultural consumers. Furthermore, government giveaways such as free electricity for farmers, partly to curry political favour, have depleted the cash reserves of state-run electricity-distribution system. This has financially crippled the distribution network and its purchasing power to meet the demand in the absence of subsidy reimbursement from state governments.https://en.wikipedia.org/wiki/Electricity_sector_in_India - cite_note-140 This situation has been worsened by state government departments that do not pay their electricity bills.

Technology and processes

Biomass gasification is thermochemical conversion of biomass into a combustible gas mixture (producer gas) through a partial combustion route with air supply restricted to less than that theoretically required for full combustion. The HPS solution consists of a gasifier, filters and a gas engine connected to a generator (Figure 75). The gasifier is a down-draft type, where the sack loads of rice husk is loaded from the top into the hopper every 30–45 minutes through to the combustion chamber. Air is drawn through the top, and partial combustion occurs under a restricted supply of oxygen to give energy-rich producer gas, which comprises of hydrogen, carbon monoxide and methane. The residual char drops to the bottom of the chamber and is subsequently removed. The gas that is generated is water-cooled and cleaned through a series of filters made of char or rice husk and finally a cloth filter to eliminate particulate matter. The clean combustible gas is available for power generation in

FIGURE 75. TECHNOLOGY PROCESS OF HUSK POWER SUPPLY



diesel-gen-set or 100% producer gas engines, which generates electricity at 240 V, single phase. Thus, electricity generated is distributed at the same voltage level through a single-phase-insulated cable system mounted on bamboo poles (for reduced costs). The distribution network is extended to a maximum of 2 km to keep the losses and voltage drops to acceptable levels. HPS has also developed low-cost prepaid meters (less than USD 8) that allow for better control and reduced theft.

The basic connection provides a household with two 15-W compact fluorescent lights and mobile-phone charging throughout the period each day the plant runs (up to eight hours in the evening). Sometimes, poorer households share a basic connection and get one light each. If a household or business wants to pay more for a higher-power connection, then this can be provided. A fuse blows if the customer attempts to use more than their agreed power.

The key advantages of HPS solution is that the various components of the system have been locally manufactured/adapted, rugged and durable and are simple to operate and maintain. HPS is still conducting research on the technology front to deal with the undesirable tar content of rice husk to explore other potential feedstock and alternative applications and uses of the resultant biochar. HPS has also recently implemented low-cost remote monitoring of its plants for better control and management of the same and shifted to solar - biomass hybrid mini-grids for 24/7 power supply (this information was not available when analyzing the case).

Funding and financial outlook

The capital cost (inclusive of installation) of each plant is less than USD 1,300/kW, and the operational cost is estimated to be less than USD 0.15/kWh. The gross margin at the plant level is expected to be around 45%, but sale of carbon off-sets and sale of biochar towards incense making is expected to each add 10% to the total revenues of a plant. Social enterprises, such as HPS, which step in to address the electricity gap in rural areas of India, are typically funded by a combination of grant and equity, with some support from the government by way of subsidy. HPS received significant grant support to the tune of approximately USD 2 million over four separate tranches from its strategic partner, Shell Foundation which contributed towards the early R&D costs, subsidized a portion of the costs of its high-profile management team, helped ramp up the rate of deployment and attract additional financing. In addition, HPS also raised funding (equity investment) of USD 1.65 million in 2009–2010 from Acumen Fund, Bamboo Finance, LGT Venture Philanthropy, Draper Fisher Jurvetson, CISCO and the International Finance Corporation. HPS also receives a government subsidy of approximately USD 7,100 for each plant from MNRE and the Government of India. Alstom Foundation recently announced a EUR 90,000 grant to upgrade 65 existing power plants by retro-fitting gasifiers using dry cleaning and cooling systems at the plants. The immediate positive impact of implementing the system would be dramatic reduction in water usage – by almost 80% – and also reduce operational cost considerably.

Socio-economic, health and environmental impact

Husk Power Systems has made a tremendous impact in the lives of rural people by supplying affordable electricity. The good quality lighting enables children to study properly and families to relax in the evening, as well as reducing snake and dog bites and petty crimes. Shops and businesses have lower costs and can work more easily even after dark without the need for diesel generators, and some new businesses have started. In one village, mobile-phone ownership increased from 10% to 80% of households after the HPS supply was installed, because previously, people had to go out of the village to have their phones charged. HPS is also using its plants as a channel for promoting and marketing other relevant products from different companies and foundations.

Furthermore, HPS is delivering economic and environmental benefits, as switching from traditional sources of energy by reduction in kerosene use by 6–7 L/month, saving about USD 4.40 per month or twice the cost of a basic connection. The overall portfolio of plants provides direct employment to over 350 people, with additional temporary work created during plant construction. HPS is starting businesses that use the char left over from rice-husk gasification, including that from the manufacture of incense sticks. As of now, more than 1,200 women have been trained (at two plant sites) for manufacturing incense sticks. This enables household to earn up to USD 16 per month and save USD 2.3 on kerosene costs while paying only USD 1.2 for electricity.

The HPS plant makes use of rice husk that is abundantly available but, until recently, was considered as waste. Rice mills are paid about USD 25 per ton of rice husk, so they earn an extra USD 3,000 per year by supplying an HPS plant as well as solving a disposal problem. The burning of rice residues in fields causes severe air pollution in some regions. The alternative, residue incorporation into the soil, in turn causes methane emissions from rice fields, contributing to climate change. Each megawatt of power generated from rice-husk plants has resulted in reduction of CO_2 emissions by about 25,800 every year. These reductions in emissions can be attained with the implementation of 32–33 rice-husk plants. Each plant serves around 400 households, saving approximately 42,000 L kerosene and 18,000 L diesel per year, significantly reducing indoor-air pollution and improving health conditions in rural areas. HPS has also offset a total of 2.2 million units of CO_2 by 2013. Further saving CO_2 from reduced use of diesel.

HPS is developing a program of activities for CDM to gain carbon credits. Moreover, processed wastewater and tar tank water is collected in a settling tank and recycled, which ensures that there is no water pollution. Rice husk char and tar and used filter media are mixed and stored on the ground. HPS is also working to reduce the water consumption in its char removal systems.

HPS makes sure that customers understand how to use electricity safely and that every member of the household agrees to abide by safety rules. HPS has facilitated the education of children of local communities by paying school-fee of USD 0.75 per month. Figure 76 summarizes the social impact of the project.

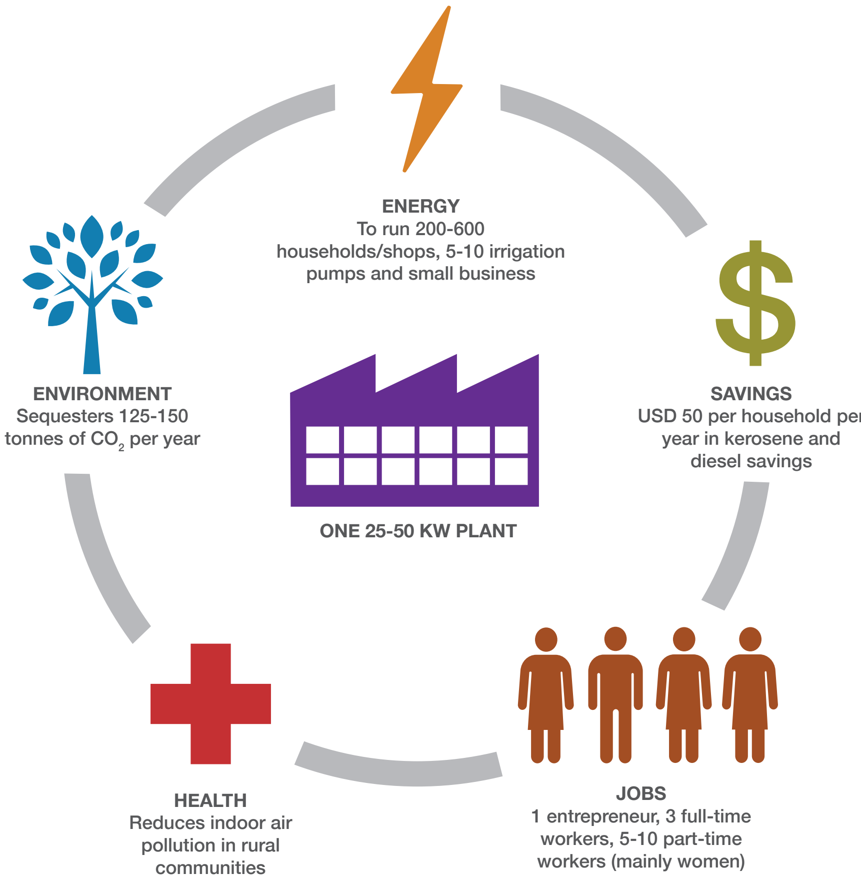
Scalability and replicability considerations

The key drivers for the success of this business are:

- High demand for electricity.
- Strong partnership with the Government of India.
- Central and state policy that promotes renewable energy and provides good incentives.
- Strong financial support from multiple institutional investors.
- Good availability of uniform fuel input (rice husk).

Given that HPS offers a decentralized, low-cost solution, which leads to lower transmission and distribution losses and makes use of a resource available locally which was earlier considered as waste. It has an immense potential not just across the state of Bihar but also across the entire country and the developing world, where over 1.6 billion people still do not have access to electricity/lighting. HPS has identified 25,000 villages as feasible sites within India's rice-producing belt (Bihar and neighbouring states) for establishing rice-husk-based power plants. Rice husk is a plentiful resource in India and many other countrie., Bihar alone produces 3 million tons/year of paddy, which could provide sufficient husk to supply electricity to 3 million households. HPS technology could therefore be used in many other rice-producing areas, as well as places with other biomass residues. HPS is exploring other avenues to increase its revenue other than fees collected for electricity service. Monetizing carbon offsets from biomass gasifier plant (125–150 tons CO_2/year per gasifier).

FIGURE 76. SOCIAL IMPACT OF THE PROJECT



Source: Husk Power Systems; modified.

HPS is planning to build a training centre and also provide some training by distance learning. New ideas under development and testing include programmable prepayment meters, char removal systems that cut water use and automated plant monitoring. Other ways of adding value to char are also under investigation.

The conditions across most parts of India, South Asia and sub-Saharan Africa, with regards to access to electricity in rural areas though not as severe, are quite similar, thereby offering significant potential for replication of the solution and business model offered by HPS. HPS started looking for funding to the tune of USD 6–8 million, to help achieve its ambitious target of establishing 3,000 plants to address the electricity needs of 10 million people across 10,000 villages.

Summary assessment – SWOT analysis

The key strength of HPS is its strong partnership with government, institutional investors along with buy-in from households and farmers (Figure 77). The weakness of HPS is its heavy dependence on rice husk as feedstock and subsidies from government. The business has a significant threat from government electrification programs and, in the event of flood or drought, it might not have access

FIGURE 77. SWOT OF HUSK POWER SUPPLY

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Strong government partnership to finance infrastructure investment for rural electrification ▪ Strong partnerships, also with donors and social venture finance to fund company's soft costs ▪ An inclusive business model ▪ More than one revenue source (sale of electricity, biochar, franchisee fees and carbon credits) ▪ Local buy-in ▪ Robust technology	**WEAKNESSES** ▪ Too much dependence on rice husk for input feedstock ▪ Technological adaptation required for different biomass inputs ▪ Strong dependence on one revenue source while HPS is diversifying to incense stick production and CO2 credits sales ▪ Heavy dependence on government subsidy for capital cost ▪ Lack of trained work force at the local level
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Low penetration of rural electrification ▪ Carbon credit market opportunities ▪ Huge potential for scaling and replication in India and other developing countries ▪ Rising crude oil prices weaken competitors ▪ The Government of India incentives to electrify un-electrified areas ▪ Locally available biomass (rice husk) ▪ A severe energy crunch in India ▪ Poor rule of law economic growth	**THREATS** ▪ Threat of entrants and substitutes, especially solar units and cheaper electricity by utilities under rural electrification program ▪ Business operations effected by poor rule of law ▪ Unavailability of rice husk in case of drought or floods ▪ Rice husk popularity could potentially drive up prices of inputs, undermining the business proposition

to rick husk. The business has opportunity to scale up and scale out and is already scaling using franchising model. It could improve its business stability by increasing its revenue source from sale of carbon credits and sale of biochar.

Contributors

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Jasper Buijs, Sustainnovate; formerly IWMI

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Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflects our best knowledge at the time of the assessments (2013–2014). As business operations are dynamic, data can be subject to change.

Notes

1 Towards 2017, HPS increased its promotion of solar - biomass hybrid mini-grids for 24/7 power supply (this information was not available and considered when writing the case).

2 One lakh = 100,000.

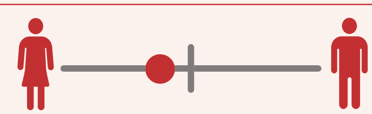
3 On crore = 10,000,000.

BUSINESS MODEL 6

Power from agro-waste

Krishna C. Rao and Solomie Gebrezgabher

A. Key characteristics

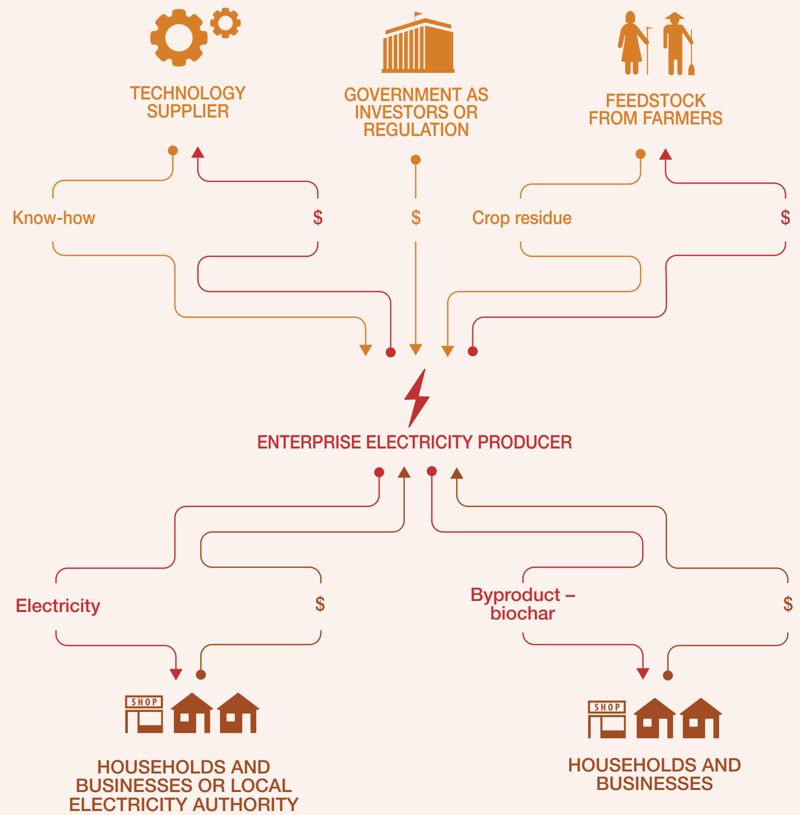
Model name	Power from agro-waste
Waste stream	Agro-waste (from farmers and agro-industries)
Value-added product	Power (through biomass gasification or combustion)
Geography	Rural areas with large acres of crop cultivation for ease of procurement of crop residues
Scale of production	Small to medium scale; 25–100 kW (gasification) and up to 8 MW (combustion)
Supporting cases in this book	Koppal, India; Bihar, India
Objective of entity	Cost-recovery [X]; For profit [X]; Social enterprise [X]
Investment cost range	Approx. USD 1,000 to USD 1,400 per kW
Organization type	Private
Socio-economic impact	Improved energy access resulting in increased local income and productivity, cleaner local environment, reduced greenhouse gas emissions and employment generation
Gender equity	Clean air working environment supports in particular women where it is replacing kerosene lamps 

B. Business value chain

The business model is initiated by a standalone private enterprise, social enterprise or agro-industries such as coffee processing units or rice mills that generate large quantities of crop residues as waste (Figure 78). The business concept is to process crop residues like wheat stalk, rice husk, maize stalk, groundnut shells, coffee husks, sawdust, etc. which has no commercial value and is often burned or dumped in the rivers or on landfills to generate electricity. The electricity can be consumed internally or sold to households, business or local electricity authority or combinations thereof.

The key stakeholders in the business value chain are the suppliers of crop residue: farmers and agro-industries, government as a regulator and/or investor, technology supplier and end users of the product – household and businesses directly or through the local electricity authority. Generating electricity from agro-waste or crop residue can be from one of the following processes: anaerobic digestion through biogas, gasification through producer gas and combustion/incineration through steam. Biomass combustion is generally suitable for large capacity and grid-connected applications, whereas biomass gasifier and bio-methanation-based power plants are more suitable for sub-megawatt level and decentralized applications. The business is eligible for sale of carbon as the electricity is generated from sustainable biomass source. In this business model description, the process used is gasification where crop residue is used as a feedstock for making syngas or producer gas, which contains carbon

FIGURE 78. VALUE CHAIN OF POWER FROM AGRO-WASTE



monoxide and hydrogen and can be used to generate electricity using modified diesel or gasoline engine generators.

The ownership and operation of the enterprise generating electricity can take different forms. The plant can be designed, constructed, owned and operated by a standalone private enterprise such as agro-industrial processing factory, community-based organization, social enterprise and individual entrepreneur, either on a Build, Own and Operate basis or on a Build, Own, Operate, Transfer (BOOT) basis. In the latter scenario, the private entity brings investment to set up the energy production technology, while the concessionaries i.e. the agro-industrial factories or community provides land and inputs. The private entity designs, constructs and maintains the energy production unit until BOOT period is expired after which it assists the host company to operate the unit. The business model can use BOOT approach and franchise its model to scale up its business operations.

C. Business model

The primary value proposition of the business model (Figure 79) is to be a reliable provider of electricity from sustainable biomass source (agro-waste/crop residue). Depending on the ownership structure, the primary motive of the enterprise varies. This would in turn result in significant differences in the operations and management of the business.

FIGURE 79. BUSINESS MODEL CANVAS – POWER FROM AGRO-WASTE

KEY PARTNERS
- Government
- Equipment suppliers
- Farmers and agro-industries
- Carbon trading partners
- Investors/Donors

KEY ACTIVITIES
- Collection of crop residue
- Contractual agreements
- Electricity generation and distribution
- Community mobilization
- Meter, billing and collection
- Managing Clean Development Mechanism (CDM) process

KEY RESOURCES
- Crop residue
- Technical know-how
- Land and skilled local labor

VALUE PROPOSITIONS
- Reliable provision of environment-friendly electricity at a fair price from a sustainable biomass source
- Environment-friendly, low-cost biochar
- Carbon emission reductions

CUSTOMER RELATIONSHIPS
- Direct interaction with the community and electricity authority
- Direct interaction
- Direct interaction with carbon market agents

CHANNELS
- Emission trading platform
- Direct electricity connection to community
- Direct sales or network of distributors

CUSTOMER SEGMENTS
- Households and businesses
- Electricity authority
- Industries household
- Carbon market

COST STRUCTURE
- Land costs
- Investment costs – building and equipment, transmission and distribution lines
- O&M costs – training, input cost (crop residue), utilities, labor (can be intensive and skilled labor)
- Debt and equity payments
- Costs incurred for CDM/Voluntary Emission Reductions registration and carbon sale

REVENUE STREAMS
- Sale of electricity
- Sale of activated carbon or charcoal (by-product)
- Sales of carbon credit

SOCIAL & ENVIRONMENTAL COSTS
- Potential leakage of gas
- Laborers' health and safety risk if no proper safety measures are present in the electricity generation unit
- Potential safety issues on handling of biochar

SOCIAL & ENVIRONMENTAL BENEFITS
- Improved social and economic sustainability through improved access to electricity
- Reduced GHG emission
- Create job opportunities

Social enterprise or community business model

A community-based organization or a social enterprise would run such an enterprise with the primary motive of providing reliable electricity to remote and underserved households and small businesses as a service while trying to achieve operational sustainability. This type of business model requires the enterprise to mobilize the community, procure agro-waste from local sources, develop appropriate and agreed pricing and establish transmission and distribution lines to reach out to every customer. The key activities for this business model are labor intensive, as it requires regular maintenance of transmission and distribution lines along with monthly meter, billing and collection activity for each customer. The business on a per capita basis is higher on capital and operation cost. From a cost recovery perspective, the business model is dependent on subsidies from government and donors to cover at the least its capital cost, but it has high potential to be financially viable and recover its operational cost including making marginal profits. Typical electricity generated under this model are in the range of 25–100 kW. The electricity generated is too small in size to be viable to apply for CDM projects unless the business does franchising of its model and bundles these transactions. However, it can access carbon offset on VERs market.

For-profit private business model

A private enterprise with profit maximization motives would get into a power purchase agreement with a local electricity distribution company. The electricity generated is directly fed to a local grid, and the local electricity distribution company pays an agreed price per unit to the enterprise as per the long-term power purchase agreement (PPA). The burden of transmission and distribution of electricity is transferred to the local electricity distribution company. The enterprise is not as labor-intensive as the social enterprise business model on per capita of electricity generated. In addition, this business model installs larger electricity generation plants of up to 8 MW. This is large enough and viable to apply for CDM.

In both the business models described above, it is important for the enterprise to have a strong partnership with farmers and agro-industries to ensure reliable supply of crop residues at an agreed price. The common key activities are procurement and processing of crop residue, electricity generation and sales. To improve the production efficiency, training of farmers can be a useful activity so that farmers provide high-quality crop residue and store-crop residue in appropriate manner to reduce moisture content. Sales of electricity is the primary revenue source with some additional revenue if the enterprise is able to tap into the carbon market.

Gasification process results in a by-product called biochar, which is rich in carbon. Biochar has multiple applications, as it can be sold to household or businesses as fuel to industries to produce activated carbon, and it is also an excellent fertilizer. The business model could potentially increase its revenue through sales of this by-product. The combustion process has fly ash as its waste product, which is used in brick manufacturing.

D. Potential risks and mitigation

Market risks: The electricity generated from processing crop residue is mainly sold to local electricity grid on a long-term power purchase agreement or to household and businesses through a social enterprise or community-based model. In the latter, community mobilization and product pricing are key activities before the enterprise is established, and hence this risk is addressed significantly. In the business model where electricity is sold to local electricity grid, since the demand for electricity is continuing to grow in developing countries and local electricity distribution companies are trying to manage to bridge the gap between demand and supply, the risks are lower. However, in environments where the electricity sector is regulated and the state utility is the sole buyer, the bargaining power

of the business producing and selling electricity will be low. If the business has high dependence on sale of carbon credit for its viability, the volatility of carbon credit market puts the sustainability of the business under risk. In such scenarios, the business has to diversify its revenue streams so as not to entirely depend on the sales of carbon credits.

Competition risks: The business risk for the output (electricity) is relatively low. The social enterprise business model has risks from competitive products like solar home lighting system while the for-profit business model selling electricity to local grids has to compete with businesses generating electricity from cheaper fuel source such as coal and hydropower. The business has higher risk in procuring inputs (crop residue) at a price suitable for the business' financial viability. With time, as they realize the revenue potential from crop residue, the farmers are likely to demand higher price. To mitigate this risk the enterprise should target different types of farmers cultivating different crops or have longer-term agreements with farmers. The enterprise can also create its own plantation or agro-processing unit (rice mills) to secure its supply of agro-waste.

Technology performance risks: The technology used is gasification, which is well-established and mature for decentralized applications. The technology has been widely used commercially and is proven. However, the technology requires skilled labor.

Political and regulatory risks: In most developing countries the demand for electricity is projected to grow and governments are encouraging green initiatives by providing incentives such as concessional loans, feed-in tariff mechanisms and through long-term power purchase agreements. However, in regions where electricity is dominated by public sector and regulations do not allow sale of electricity, the business model cannot be established.

Social-equity-related risks: The model is considered to have relatively more advantages to women especially in underserved communities having clean working environment from clean indoor air by replacing kerosene used for lighting with modern energy. The social enterprise business model is geared to ensure no social equity risk arises in the community. However, the same cannot be said about for profit-private business model. The power generated is fed to the grid and this additional power might be used to improve energy reliability in existing regions rather than providing energy to underserved areas. Both social enterprise and for-profit models provide employment opportunities and additional revenue for farmers from sale of crop residues.

Safety, environmental and health risks: The waste-processing technologies are not without problems and pose a number of environmental and health risks if appropriate measures are not taken. The environmental risks associated with the gasification units include possible leakage of gas, and with the combustion unit's emission of flue gas and fly ash. These emissions should be controlled within acceptable limits by putting in place suitable equipment. Organic waste when left in open begins to decay and releases methane, which is more damaging to the environment than carbon dioxide. The safety and health risks to workers are present, and thus standard protection measures should be put in place (Table 23).

TABLE 23. POTENTIAL HEALTH AND ENVIRONMENTAL RISK AND SUGGESTED MITIGATION MEASURES FOR BUSINESS MODEL 6

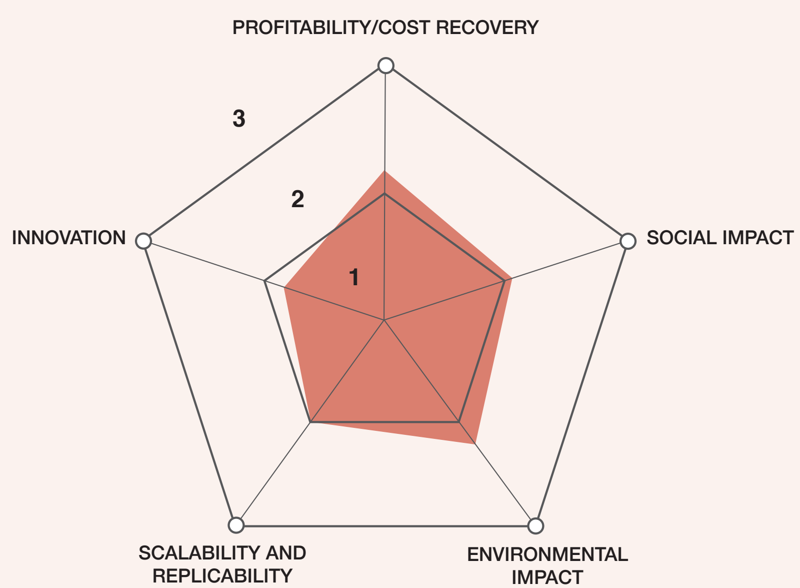
RISK GROUP	EXPOSURE ROUTE					REMARKS
	DIRECT CONTACT	AIR	INSECTS	WATER/ SOIL	FOOD	
Worker						Risk from crop residues can be more physical (sharp edges) than of other nature.
Farmer/user						
Community						
Consumer						
Mitigation measures						

Key: NOT APPLICABLE · LOW RISK · MEDIUM RISK · HIGH RISK

E. Business performance

This business model is rated high on environmental impact followed by profitability (Figure 80). The environmental impact scores high from the large-scale impact potential that the business model offers along with reduced greenhouse gas emission. The business model has a strong revenue source and

FIGURE 80. RANKING RESULTS FOR POWER FROM AGRO-WASTE BUSINESS MODEL



offers potential for additional revenue source from sale of carbon (VERs) and biochar. The social impact of the business model is dependent upon the customer segment served for provision of electricity. If the electricity is provided to underserved communities, the impact will be higher.

The business model has a high potential for replication in developing countries with availability of waste, technology and institutional capabilities. It can be scaled horizontally and has a potential for vertical scaling by expanding into the business of adding value to biochar for domestic and industrial use. It has a strong potential to be implemented in agriculture intensive regions. The business model scores relatively low on innovation as it is fairly straightforward with no sophisticated technology requirements. However, it may require innovative partnership and financing arrangements.

CASE

Power from municipal solid waste at Pune Municipal Corporation (Pune, Maharashtra, India)

Krishna C. Rao, Binu Parthan and Kamalesh Doshi

Supporting case for Business Model 7	
Location:	Pune, Maharashtra, India
Waste input type:	Municipal solid waste (MSW)
Value offer:	Biogas to electricity
Organization type:	Public
Status of organization:	Biogas plant operational since 2009
Scale of businesses:	Medium
Major partners:	Mailhem Engineers Pvt Ltd, Solid Waste Collection and Handling (SWaCH), Janwani, Cummins India, MITCON, Kirloskar and Maharashtra Plastic Manufacturers Association (MPMA)

Executive summary

The case demonstrates power generation from organic fraction of MSW in Pune Municipal Corporation (PMC) through generation of biogas. With population of more than 31 million, area of 243 km^2 and 48 zones, Pune is the seventh largest metropolitan area in India and the second largest in the state of Maharashtra. The biogas from MSW initiative in Katraj Gaon region in Pune is part of a larger Zero Waste Electoral Ward Initiative. The biogas plant provides street lighting services for about 4 km long Katraj–Kondhwa road in Pune. The bio-sludge is used as a manure in the 112 municipal parks and gardens maintained by PMC. The project is with a partnership between PMC; the Solid Waste Collection and Handling (SWaCH), an NGO, for door-to-door collection of waste and Mailhem Engineers Pvt Ltd, a waste management technology firm to process the MSW collected to produce biogas, electricity and bio-sludge. SWaCH has employed waste pickers to collect segregated waste from households and ensuring it reaches the secondary collection system, while PMC is providing support in various ways.

KEY PERFORMANCE INDICATORS (AS OF 2014)						
Land use:	0.03 ha					
Water requirement:	1.25 m^3/day					
Capital investment:	180,000 USD					
Labor:	4 persons, 3 persons at full-time employment and 1 person at half-time employment					
O&M cost:	18,000 USD/year					
Output:	300–325 m^3/day processing 5 tons/day and electricity generation of 144 MWh/year, 180 tons/year of bio-sludge used manure					
Potential social and/ or environmental impact:	Created 4 jobs, processing a significant share of municipal solid waste of Pune and providing municipal lighting services; Project also reduces 76.1 tCO_2eq of GHG emissions by reducing electricity consumption.					
Financial viability indicators:	Payback period:	Approx. 6 years	Post-tax IRR:	16%	Gross margin:	62%

Context and background

The average annual MSW generated in India is 120 kg/capita/year. PMC generates 2,550 tons/day of MSW, with 40% to 60% organic matter, and hence is useful for generating energy. Most of the cities in India collect only 60% to 70% of waste actually produced, have insufficient landfill sites and find it difficult to locate new sites at affordable transportation distances. The composition of MSW varies greatly from municipality to municipality (country to country) and changes significantly with time. There is no single approach that can be applied to the management of all waste streams.

The term "digestible wastes" defines organic waste materials which can be easily decomposed by the anaerobic digestion process. The digestible household waste, such as food and kitchen waste, green waste, and most paper waste, includes not only waste from households, but also from institutions, digestible municipal park and garden trimmings, vegetable residues and discarded food from markets and catering businesses, out-dated food from supermarkets, etc. Not all of this organic waste would be suitable for anaerobic digestion. Wood and other lignin containing waste materials are typical examples of organic wastes that are not suitable for anaerobic digestion. PMC is the civic body responsible for providing waste collection and management service to its residents and has initiated a number of waste management projects. Katraj Gaon, as part of admin ward of Dhankawadi, is among the largest electoral wards in terms of area and has population of 15,377 with the blend of high and low-income and nearly 12,000 commercial establishments. Every day about nine tons of waste is collected by waste pickers organized as SWaCH. Nearly three tons of wet waste segregated by waste pickers is sent to biogas plants. Because of the project, the burning and dumping of waste on open plots and public spaces has also reduced considerably. Dry waste collection has also gone up as a result of the efforts and a lot more dry waste is now being sold for recycling. A substantial amount of waste consisting of dry non-saleable and low-value waste and mixed waste, however, still has to be sent to the landfill.

Market environment

The output of the project is biogas, electricity and sludge slurry. Biogas is a methane-rich gas (45–80% methane content), which can be used as renewable fuel for direct combustion for heating applications in commercial and communal kitchens in the city, co-generation (renewable electricity and/or heat generation) or upgraded to bio-methane (typically>94% CH_4) and injected into the gas grid or used for vehicle fuel. Electricity generated in this way will then be used to power streetlights and water and sewerage pumps through a distributed generation-based model. Katraj biogas plant is able to light only 140 street lights which are limited by waste availability. The liquid sludge rich in plant macro and

micro nutrients can be used as soil improver and as fertilizer for plants, provided that it meets the strict quality requirements imposed for such application. Its application to land brings humus and slow-releasing macro and micro nutrients to the soil, contributes to moisture retention and improves soil structure and texture. Using compost made from recycling, such as organic wastes, is considered environmentally sustainable.

If a sustainable zero waste system is successfully put to test in such an area, its replicability would be high. PMC has 144 electoral wards, and in 2012, it had 22 biogas plants in operation. The market share is relatively small, and the waste management to municipal street lighting is only provided in one out of 144 electoral wards in Pune. There is a need for more waste management solutions for Pune including composting. PMC spends a considerable amount of resources on municipal street lighting and is looking for waste to energy solutions like the Katraj project. The attractiveness of the opportunity increases with passing time as the waste generation in the city is on the increase as well as the energy prices. One of the challenges for the waste input is segregation and making sure that only the organic waste is sent to the biogas plant.

There are also opportunities for similar waste-to-energy solutions for other cities in India. Competition for this business model is primarily from the energy utilities as the competing product is electricity. However, following historical trends, it is likely that the electricity tariffs will only increase in the future making biogas to electricity from MSW even more attractive. The impact of waste prevention and resource efficiency initiatives is likely to increase in the future, and food waste per capita may well start to decrease.

Maharashtra has an assessed potential to generate 637 MW from MSW, industrial waste and sewerage (out of the country's 3,400 MW potential in the sector). Of this, Maharashtra has achieved just 22.51 MW, and the new grid-connected renewable energy policy, which was approved by the state cabinet recently, aims at generating another 300 MW from such waste.

Macro-economic environment

As per the rules by Central Pollution Control Board (CPCB), every municipal authority shall be responsible for collection, storage, segregation, transportation, processing and disposal of MSWs. Municipal authorities shall adopt suitable technology or combination of such technologies to make use of wastes so as to minimize burden on landfill. The biodegradable wastes shall be processed by composting, vermicomposting, anaerobic digestion or any other appropriate biological processing for stabilization of wastes. Landfilling shall be restricted to non-biodegradable, inert waste and other waste that are not suitable either for recycling or biological processing. All of the Municipal Corporation, including PMC, spends a substantial amount of their annual budget on waste collection and transportation. With the dual objective of catering to the ever-increasing demand for electricity as well as the promotion of environmentally-friendly renewable energy technologies, the State Government of Maharashtra had issued guidelines to encourage power generation from MSWs into electricity. Apart from the pollution it causes, disposal of waste has also become a major problem with the continued depletion of potential landfill sites. As a result, 52.88 MW proposals in four cities in Maharashtra are under active consideration through private sector participation using municipal solid waste as raw material.

The Government of India launched Jawaharlal Nehru National Urban Renewal Mission (JnNURM), a massive city modernization scheme under which state governments and city municipalities can apply for funds to improve city infrastructure. Pune is eligible under this scheme and could potentially access these funds to install the biogas to electricity from MSW at other 143 electoral wards.

Business model

The business model canvas is from the perspective of the entity managing the biogas plant to generate electricity. PMC biogas plant in Katraj Gaon has several interlinked value propositions (Figure 81): production of biogas to generate electricity to provide street lighting services to Katraj–Kondhwa Road in Pune and organic compost produced from slurry and waste output from the biogas plant for landscaping of electoral wards within the Pune municipality. The biogas plant contributes to carbon offset, and therefore there is potential to realize revenue from sales of carbon. Janwani, an initiative of the Mahratta Chamber of Commerce Industries and Agriculture along with PMC, Cummins India Ltd, SWaCH Cooperative, Lions Club and Maharashtra Plastic Manufacturers Association is working towards a common goal and supports the project.

FIGURE 81. MAILHEM-PMC BIOGAS PLANT BUSINESS MODEL CANVAS

KEY PARTNERS

- Mailhem Engineers Pvt. Ltd.
- Janwani (NGO)
- Mahratta Chamber of Commerce Industries and Agriculture
- Cummins India Ltd.
- SWaCH Cooperative
- Lions Club
- Maharashtra Plastic Manufacturers Association

KEY ACTIVITIES

- Collecting and segregating waste
- Maintaining biogas plant
- Generating and transmitting electricity
- Supply of compost
- Landscaping

KEY RESOURCES

- Equipment
- Organic waste
- Technical and operational competencies
- Land

VALUE PROPOSITIONS

- Provide a cost-effective solution to process organic component from MSW
- Produce biogas to generate electricity and provide reliable street lighting
- Production of compost from output waste generated by biogas plant

CUSTOMER RELATIONSHIPS

- Internal

CHANNELS

- Internal

CUSTOMER SEGMENTS

- Pune municipality and its residents
- Residents and businesses in Katraj–Kondhwa road
- Electoral wards of Pune municipality

COST STRUCTURE

- Investment cost (land, construction and machines)
- Operational cost (labor and maintenance cost)

REVENUE STREAMS

- Savings from electricity for street lighting
- Savings from fertilizer for landscaping
- Savings from manpower and transportation of waste to the landfill and via extended landfill lifetime

SOCIAL & ENVIRONMENTAL COSTS

- Possible exposure to pathogens
- Occupational risks from handling machinery and equipment

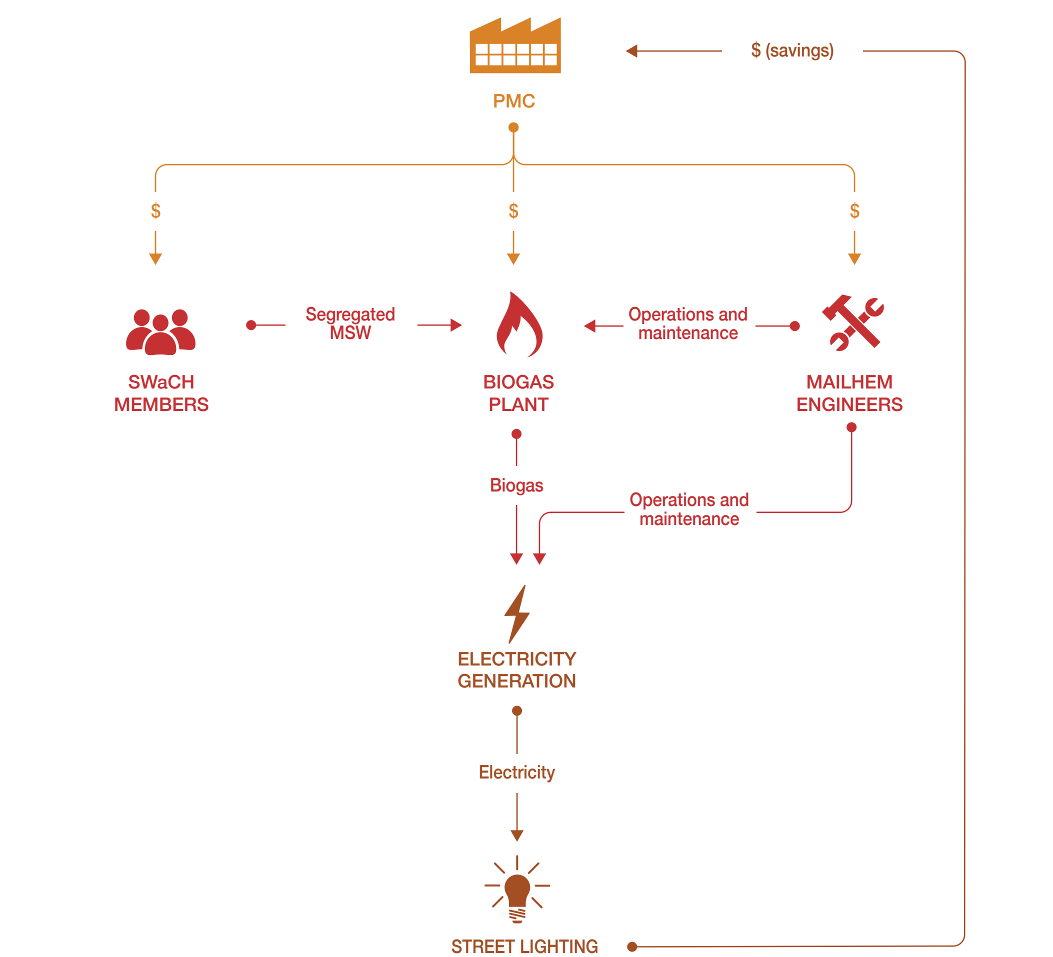
SOCIAL & ENVIRONMENTAL BENEFITS

- Creation of jobs for low income workers
- Reduce pollution of water bodies and natural habitats

Value chain and position

The value chain consists of waste collection, waste segregation, waste-to-energy conversion and street lighting (Figure 82). The citizens helped by initial segregation of their waste. The waste is then collected and further segregated by SWaCH, which has signed a memorandum of understanding with PMC under which an annual payment is made by PMC for waste management. Each household also pays a fee to SWaCH on a monthly basis for waste collection. Solid waste other than MSW, i.e. garden waste, domestic hazardous waste, e-waste, biomedical waste, hazardous waste, construction and demolition waste, animal carcass, street sweeping, etc. was to be collected by SWaCH for additional user fees. PMC provided equipment, slum subsidy, push-cart maintenance amount, sorting centre and admin desk/office space to SWaCH. Post-segregation of waste, members of SWaCH deliver organic content of the waste collected to the PMC biogas plant, which is linked to electricity generation facility. This electricity is used to provide street lighting to Katraj–Kondhwa Road of the municipal area and also as back-up power for the municipal administration building. PMC does not have required skills or expertise in maintenance of waste-to-energy conversion and municipal street lighting. PMC engaged

FIGURE 82. PMC BIOGAS TO ELECTRICITY VALUE CHAIN



with Mailhem to install waste-to-energy infrastructure and contracted Mailhem for operation and maintenance of the biogas digester and electricity generator.

The main challenge was to teach citizens to separate biodegradable and non-biodegradable waste, because the two kinds of waste are treated differently, and to collect user fees from citizens/waste generators. Janwani used tools like home visits, announcements from vehicles and street puppet theatre to deliver its message. A second challenge was to create value from the waste by processing all organic or wet waste within the ward and by recycling dry waste. Dry trash like plastic, glass and paper is sold for recycling by the waste-pickers.

Institutional environment

The solid waste management in developing countries has received lesser attention from policymakers and researchers than other environmental problems, such as air and water pollution. However, the legal and regulatory framework in India mandates the treatment of solid waste. According to governmental policies, the organic waste component of MSW has to be bio-digested or composted and the inorganic portion landfilled. There are a number of other relevant waste management policies for controlling hazardous waste, plastics, construction and demolition waste, e-waste, battery waste and MSW. The State Government of Maharashtra has banned the sale and use of plastic bags across the state since 2006 after the Mumbai floods of 2005.

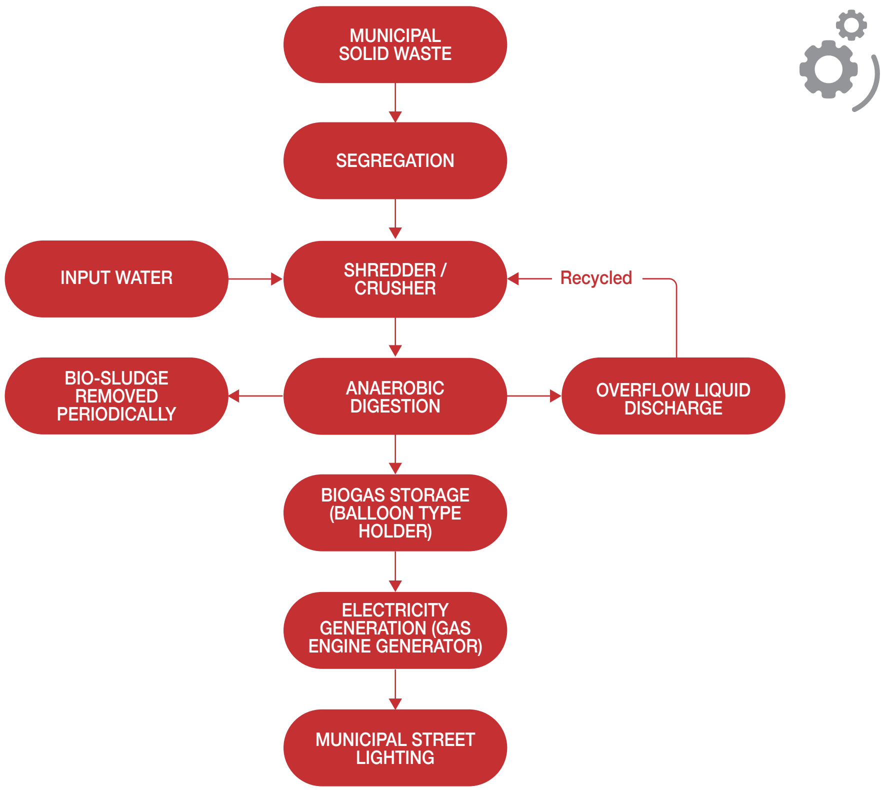
The Government of India has established JnNURM with an aim to encourage reforms and fast-track planned development of identified cities. Focus is to be on efficiency in urban infrastructure and service delivery mechanisms, community participation and accountability of ULBs/parastatal agencies towards citizens. Assistance under JnNURM is additional central assistance, which would be provided as grant (100% central grant) to the implementing agencies. The sectors and projects eligible for JnNURM assistance includes sewerage and solid waste management. The Ministry of New and Renewable Energy (MNRE) promotes power generation from MSW projects by providing a capital subsidy for power generation from MSW of USD 0.3 million per MW, with max of USD 1.55 million per project. Each proposal will be examined and concurred by Integrated Finance Division of the Ministry on a case-to-case basis. The Maharashtra Electricity Regulatory Commission (MERC) has also been very proactive in promoting energy generation from renewable energy sources. MERC has been in the forefront of determining preferential tariffs for renewable energy technologies, with its first tariff order for non-fossil fuel based co-generation projects issued even before the enactment of Electricity Act 2003.

Technology and processes

Anaerobic digestion is a collection of processes by which micro-organisms breakdown biodegradable material in the absence of oxygen. The best practice for bio-degradable waste is separation at source, as they need to be of high quality (i.e. free from physical impurities) in order to ensure stable operation of the anaerobic digestion process. The chemical and biological pollutants, contaminants, toxins, pathogens or other physical impurities must also be strictly monitored and limited to allow safe and beneficial utilization of sludge as fertilizer. Anaerobic digestion can be single stage, multi stage or batch process. Based on the content of total solids (TS) of the substrate to be digested; the anaerobic digestion processes can be low solids (LS), containing less than 10% TS; medium solids (MS), containing about 15–20% TS and high solids (HS), ranging between 22–40% TS (Verma, 2002). The industrial process takes places in a specially designed digester tank, which is part of a biogas plant.

The technology employed for anaerobic digestion is modified up-flow anaerobic sludge blanket. The technology is proven and is used in waste management systems around the world (Figure 83).

FIGURE 83. PROCESS DIAGRAM OF MAILHEM-PMC BIOGAS PLANT



Maintenance of the sludge blanket is an important factor in the efficient operation of the reactors. The biogas produced is combusted in gas engine coupled to an electrical generator to produce electricity for street lighting. The operation of the technology requires segregated MSW with only the organic portion with 80% moisture. Therefore, segregation of MSW is an important aspect, and the technology may not work properly when the input biomass deviates from the specifications.

The technologies – the biogas digester and electricity generator – are locally available and components that need replacement can be fabricated locally. The operation and maintenance of the plant is managed by Pune-based Mailhem, and the technicians employed have been trained and supervised also by Mailhem. The intellectual property rights for the specific digester construction and commissioning lies with Mailhem.

Funding and financial outlook

The operations of biogas plant at Katraj Gaon electoral ward in Pune started in 2009. The land and building costs were covered by the municipality at an existing facility. Investment was towards plant and machinery cost which was USD 180,000 with PMC financing the entire investment (Table 24). on financials. The annual operation and maintenance cost incurred is about 18,000 USD/year. PMC has a contract with SWaCH to deliver organic waste from MSW, and as a part of providing waste management service to households it pays an agreed amount. There is no additional amount given

TABLE 24. MAILHEM PMC BIOGAS PLANT FINANCIALS

Key capital Costs	Land building	No costs (uses PMCs own land)
	Plant and machinery and civil costs	180,000 USD
Operating costs	MSW costs	No costs
	Operation and maintenance	18,000 USD/year
Financing Options	Equity from PMC	180,000 USD
Revenue	Savings from electricity	About 15,840 USD/year
	Savings on manpower and transportation	About 21,000 USD/year
	Savings on manure	About 10,800 USD/year

to SWaCH for supplying organic waste to the plant. Therefore, no cost is considered for MSW input. In Katraj, Cummins India gave USD 45,000 to Janwani and offered 3,000 employees as volunteers, helping Janwani to create awareness. PMC biogas has indirect revenue sources in the form of savings from electricity and fertilizer. Based on these savings, PMC biogas plant has a payback period of 19 years on its investment with an internal rate of return of 2%. PMC can generate revenue from annual carbon sales. It offsets 76.1 tCO_2eq per year.

Socio-economic, health and environmental impact

Poor solid waste management is a threat to public health and causes a range of external costs. Mixed wastes from municipalities are often landfilled. Landfill deposits pose the risk of uncontrolled air, soil and water pollution. Left to degrade naturally in landfill sites, organic wastes from households and municipalities have very high methane production potential; thus, have a negative impact on the environment. Methane has a very high global-warming potential. Over a period of 100 years, each molecule of methane (CH_4) has a direct global warming potential which is 25 times higher than that of a molecule of carbon dioxide (CO_2). Anaerobic digestion can save up to 1,451 kg CO_2/t of waste treated compared to 1,190 kg CO_2/t in the case of composting. Source separation helps divert organic wastes from landfill, thus reducing the overall emissions of greenhouse gases and the negative environmental and health effects related to these waste disposal methods. In order to decrease the environmental and health effects associated with landfilling, waste management is nowadays moving away from disposal and towards waste prevention, reuse, recycling and energy recovery.

PMC biogas plant has a positive impact on socio-economic, health and environment for the region. It provides full-time employment to three people and part-time employment to one person. The waste collection and street lighting efforts have resulted in residents of Katraj electoral ward getting waste management as well as street lighting services. The waste picking members of SWaCH have increased their daily earnings and has improved their social and economic stature. The plant effectively manages municipal solid waste generated within the Katraj Gaon ward which is one of the biggest divisions in Pune, therefore providing environmental benefits as well as health benefits from proper waste management. The project also displaces electricity for street lighting in Katraj–Kondhwa Road and displaces 144 MWh/year of electricity purchases by PMC otherwise. It also mitigates 76.1 tCO_2eq/year of GHG as a result of the avoided electricity consumption.

Scalability and replicability considerations

The key drivers for the success of this business are:

- Partnerships with SWaCH/NGO to deliver segregated organic waste to the plant.
- Technology partnership for operation and maintenance of the plant.

- Demand for end products – electricity and compost are internal and hence no significant competition risks.
- Government policy toward renewable energy.
- Rising electricity tariffs.

If the Katraj zero-garbage model proves itself, Janwani plans to set up a biogas plant in every ward. The potential for replication is high within the PMC and also in other metropolitan areas in India. The increasing quantities of MSW generation and rising electricity tariffs are likely to make replication opportunities further attractive.

Summary assessment – SWOT analysis

The key strength of the business model is its arrangement to secure reliable supply of organic solid waste for the biogas plant and the operation owned by a large urban body that can easily finance such investments (Figure 84). The business can be easily replicated. With an ever-increasing volume of household waste generated, the business has a high opportunity for replication to other areas of a city and to other cities in India. The weaknesses stem from its low rate of financial returns as the key

FIGURE 84. MAILHEM-PMC BIOGAS PLANT SWOT ANALYSIS

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Established arrangements with reliable partners for waste collection and delivery and operation and maintenance of the waste-to-energy plant ▪ Large urban body with significant internal financial resources for waste management activities, which makes financing of the effort easy ▪ Use of an innovative public-private partnership (PPP) model for waste management	**WEAKNESSES** ▪ Government body as the key partner in the business model and subject to bureaucratic delays ▪ Financial model not attractive based on the avoided cost of electricity and bio-fertilizers purchases ▪ Households only pay a small contribution towards waste management significantly below the cost of waste management ▪ Non-availability of suitable land ▪ Inadequate manpower with the municipal corporation for implementation and compliance verification with MSW rules
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Favourable policy and regulatory environment for waste management and independent power producers in India ▪ Significant opportunities exist for replication of the model to other divisions/ parts of the urban civic body ▪ Availability of an ever-increasing volume of household waste and expected increase in power tariff in other parts of India ▪ Increased yields and beatification of city parks using bio-fertilizers	**THREATS** ▪ Changes in the composition and volume of household waste and the challenge of effective segregation of the waste ▪ Increased public awareness and active commitment and participation of citizens in local collection schemes required

revenue is from electricity savings, which is a relatively small amount in comparison to the amount investment. Therefore, investment does not look financially attractive.

The success of the project requires increased public awareness and active commitment and participation of citizens in local collection schemes. Some of the other constraints are non-availability of suitable land, lack of technical awareness of citizens with respect to waste processing technologies, inadequate waste pickers and manpower with the municipal corporation for implementation and compliance verification with MSW rules. The business model faces significant threat from any changes in composition and volume of input waste.

Contributors

Mailhem Engineers Pvt Ltd

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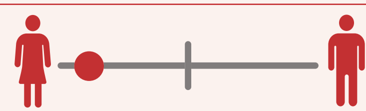
Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflects our best knowledge at the time of the assessments (2015/2016). As business operations are dynamic, data can be subject to change.

BUSINESS MODEL 7

Power from municipal solid waste

Krishna C. Rao and Solomie Gebrezgabher

A. Key characteristics

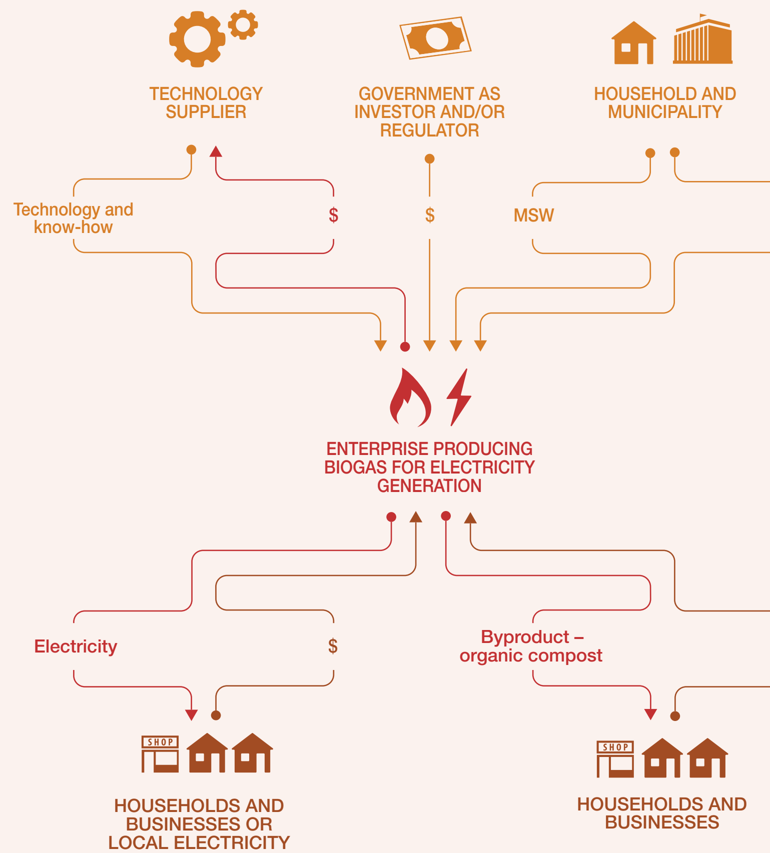
Model name	Power from municipal solid waste (MSW)
Waste stream	Organic waste – Organic component of MSW
Value-added waste product	Anaerobic digestion of organic waste to produce biogas to generate electricity and produce organic compost
Geography	Applicable to cities and towns that generate large quantities of organic solid waste
Scale of production	Medium to large scale; About 145 MWh/year to 9 GWh/year of electricity and 180 tons/year to 12,000 tons/year of organic compost
Supporting cases in this book	Pune, India
Objective of entity	Cost-recovery [X]; For profit [X]; Social enterprise [X]
Investment cost range	About USD 180,000 for lower size plant to USD 11 million of large size plant
Organization type	Private and public-private partnership (PPP)
Socio-economic impact	Improved and reliable electricity resulting in increased income and productivity, reduced greenhouse gas emissions, improved MSW management and processing and employment generation
Gender equity	Clean air working environment for women where kerosene lamps are replaced; and waste collection jobs for women 

B. Business value chain

The business model is initiated by a standalone private enterprise or a public-private partnership (PPP) where a private entity partners with the municipality to manage the solid waste generated by the city. The business concept is to collect, segregate and process organic component of MSW to generate electricity and compost. The electricity and compost can be sold to households, business or local electricity authority (Figure 85).

The key stakeholders in the business value chain are the waste suppliers, either household or the municipality; regulators-government; investors – municipality or private enterprise; technology supplier and plant operator – private enterprise and end users of the product–household and businesses or municipality. The process of generating electricity from MSW can be done through either incineration to produce heat and steam, gasification or anaerobic digestion. In this business model, the technology process used is anaerobic digestion where the organic component of MSW is segregated and sent to a digester to produce biogas, which is used to generate electricity. The business is eligible for sale of carbon as the electricity is generated from sustainable organic source with improved MSW management as MSW left in the open releases methane to the atmosphere.

FIGURE 85. VALUE CHAIN OF POWER FROM MSW



The contractual agreement of the PPP and role of private and public entities can take many forms. There are multiple options for the ownership of the plant. The plant can be owned by the municipality or the private enterprise with the concession from municipality to provide land and MSW. If it is owned by private enterprise, it may be on Build, Own, Operate (BOO) basis which is also called energy service company (ESCO) or on Build, Own, Operate, Transfer (BOOT) basis. Under BOOT, the private entity designs, constructs and maintains the energy production unit until BOOT period is expired after which it assists the municipality to own and operate the unit.

C. Business model

The primary value proposition of the business model is to reliably provide electricity from MSW. However, it would vary for a PPP as the primary mandate would be to provide waste collection and waste management service (Figure 86). The model also offers value proposition of providing organic compost which is a by-product of the process.

The business will have to collect MSW from the municipal landfill site or have the municipality garbage trucks deliver MSW to the plant. The business can also organize collection of MSW directly from households, and this would require a larger labor force. The enterprise would sell the electricity either

FIGURE 86. BUSINESS MODEL CANVAS – POWER FROM MSW

KEY PARTNERS
- Government
- Municipality
- Technology and equipment suppliers
- Carbon trading partners

KEY ACTIVITIES
- MSW collection and segregation
- Contractual agreements
- Electricity generation and distribution
- Managing CDM process
- Compost production

KEY RESOURCES
- MSW
- Equipment
- Partnership, technical know-how and operational competencies
- Land and skilled local labor
- Agreement with electricity authority

VALUE PROPOSITIONS
- Reliable provision of environment-friendly electricity from a sustainable biomass source
- Waste collection and management service
- Organic compost from the by-product of anaerobic digestion

CUSTOMER RELATIONSHIPS
- Direct interaction with the community and electricity authority
- Direct interaction with household and municipality
- Direct interaction

CHANNELS
- Direct
- Direct collection from household or municipality
- Direct sales or via distributors
- Via carbon market agents

CUSTOMER SEGMENTS
- Households and businesses
- Electricity authority
- Households and municipality
- Recycling industries
- Farmers and landscapers
- Carbon market

COST STRUCTURE
- Investment costs – Building and equipment, transmission and distribution lines
- O&M costs – Training, utilities, labor (can be intensive and skilled labor)
- Costs incurred for CDM/VER registration and carbon sale

REVENUE STREAMS
- Sale of electricity
- Sales of carbon credit
- Waste collection and management fees
- Sale of recyclables
- Sale of compost

SOCIAL & ENVIRONMENTAL COSTS
- Potential leakage of gas
- Potential health risks for workers at production facility
- Potential environmental risk if the waste is not treated and disposed properly

SOCIAL & ENVIRONMENTAL BENEFITS
- Improved social and economic sustainability through improved electricity access
- Reduced GHG emission and pollution of water bodies and natural habitats
- Contributes to improved MSW management with reduced human exposure to untreated waste
- Create job opportunities

to household or businesses or to a local electricity distribution company. Other key activities for this business model are regular maintenance of transmission and distribution lines along with monthly meter, billing and collection. However, it is preferred by the enterprise to get into a power purchase agreement with the local electricity distribution company and feed the electricity to local grid at an agreed price per unit. The burden of transmission and distribution of electricity is as such transferred to the local electricity distribution company.

Sale of electricity and waste collection and management are the key revenue source. The enterprise is also eligible for carbon offset and since the electricity generated is substantial, it will be viable to apply for Clean Development Mechanism (CDM). MSW consists of inorganic waste such as plastics, paper and glass that have high resale value and sale of recyclables is another revenue source for the business model. In addition to above mentioned revenues, key outputs from the biogas plant are bio-slurry and sludge, which are rich in nutrients and can be processed to make organic compost. The enterprise can sell the compost to farmers and landscapers. Compost can be delivered to the customers either through direct sales, network of distributors or micro-franchising. The direct sales would involve managing a large human resource base for sales and marketing staff.

D. Potential risks and mitigation

Market risks: The electricity generated from processing MSW is primarily sold to local electricity grid on a long-term power purchase agreement. Since the demand for electricity is continuing to grow in developing countries and local electricity distribution companies are trying to bridge the gap between demand and supply, the market risks associated are lower. However, in environments where the electricity sector is regulated, with the tariff decided by the regulatory commission and the state utility is the sole buyer, the bargaining power of the business producing and selling electricity will be low. If the business has high dependence on sale of carbon credit for its viability, the volatility of carbon credit market puts the sustainability of this reuse business under risk. In such scenarios, the business has to diversify its revenue streams so as not to entirely depend on the sales of carbon credits. The business model also sells compost to farmers and landscapers. The market demand for compost can be low in urban areas, but in rural areas there is always high demand from farmers. However, sales in rural areas might significantly increase its transportation cost. The business needs to find the right balance between its urban and rural market.

Competition risks: The business risk for the output (electricity) is relatively low. The business model has to compete with other businesses generating electricity from cheaper fuel source such as coal. The business has higher risk in procuring MSW if it is not able to obtain a contract with municipality. To mitigate this risk the enterprise will have to undertake door-to-door collection of household waste. In the case of compost, competing products are chemical fertilizers, which are subsidized in developing countries; hence, the challenge for compost to be price competitive. The business should diversify its customers across different types of farmers including plantations and agro-forestry that will likely have higher demand for compost. The business could also produce varieties of compost products suitable for different types of crops. However, this in an unlikely scenario if the revenue stream is minor.

Technology performance risks: The technology process used is anaerobic digestion, which is well-established and mature. However, the type of digester required could potentially be sophisticated and might not be available in developing countries, and in addition, the technology requires skilled labor. It is ideal for the business to transfer the technology from a market where it is widely implemented and have their staff trained in operation, repair and maintenance of the technology.

Political and regulatory risks: In most developing countries, the demand for electricity is projected to grow and governments are encouraging green initiatives by providing incentives such as concessional loans, feed-in tariff mechanisms and through long-term power purchase agreements. However, in regions where electricity is dominated by public sector and regulations do not allow sale of electricity, the business model cannot be established. The risks to compost from political and regulatory aspects are similar to electricity. If the regulation does not allow compost from MSW for crop production, it can hamper business viability and restrict the application of such compost to a very specific market and customer segment such as forestry or landscaping.

Social-equity-related risks: The model does not have any social equity risks. The model is considered to have more advantages for women due to clean working environment from clean indoor air by replacing kerosene used for lighting and offering women jobs in waste collection. The employment opportunities are limited for non-skilled workers. The model could potentially improve the working environment of informal workers especially women engaged in waste collection.

Safety, environmental and health risks: Safety and health risks to human arise when processing any type of waste. The risks are even higher when processing MSW. Laborers in enterprises handling such waste should be provided with appropriate gloves, masks and other appropriate tools to handle the waste to ensure their safety. The risk of environment pollution is high if leachate from MSW is untreated and seeps into groundwater or other natural water bodies. The waste processing technologies are not without problems and pose a number of environmental and health risks if appropriate measures are not taken. The environmental risks associated with the anaerobic digestion units include possible leakage of gas (methane) and these emissions should be controlled. Organic waste when left in open begins to decay and releases methane which is more damaging to the environment than carbon dioxide (Table 25).

TABLE 25. POTENTIAL HEALTH AND ENVIRONMENTAL RISKS AND SUGGESTED MITIGATION MEASURES FOR BUSINESS MODEL 7

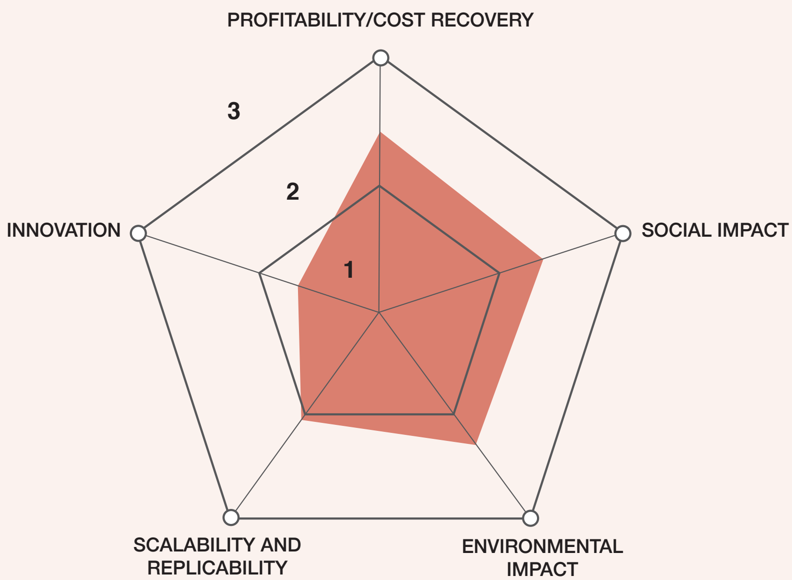
RISK GROUP	EXPOSURE					REMARKS
	DIRECT CONTACT	AIR	INSECTS	WATER/ SOIL	FOOD	
Worker						Air exposure if RDF is burnt (incl. organic and non-organic waste) Food based risks if slurry is chemically contaminated, which requires compost monitoring for chemical contaminants
Farmer/User						
Community						
Consumer						
Mitigation measures						

Key: NOT APPLICABLE — LOW RISK — MEDIUM RISK — HIGH RISK

E. Business performance

This business model is scores high on profitability, followed by social impact and environmental impact indicators (Figure 87). The business model has multiple revenue sources: sale of electricity, waste collection and management fees, sales of recyclables and potential for sale of carbon and compost, and the model serves a diverse customer base. Since the business model is involved in MSW management and offers multiple value propositions, it provides direct jobs to about 20 people, and the number is higher if the business is also involved in the collection of waste from households. The environmental impact scores high from the large-scale impact potential that the business model offers from safe MSW management along with reduced greenhouse gas emissions.

FIGURE 87. RANKING RESULTS FOR POWER FROM MSW BUSINESS MODEL



The business model has high potential for replication in developing countries. It can be scaled horizontally and has potential for vertical scaling by expanding into the compost business. It has a strong potential to be implemented in agriculture intensive regions. The business model scores low on innovation. However, one needs to acknowledge that despite the process is well-known, there is need for a sophisticated technology tailored to specific characteristics of MSW in developing countries and the model requires innovative financing arrangements.

CASE

Combined heat and power from bagasse (Mumias Sugar Company, Mumias District, Kenya)

Solomie Gebrezgabher, Jack Odero and Nancy Karanja

Supporting case for Business Model 8	
Location:	Mumias District, Western Kenya
Waste input type:	Bagasse (Sugarcane waste)
Value offer:	Clean and renewable electricity
Organization type:	Private
Status of organization:	Operational since 1972 (Co-generation unit since 2009)
Scale of businesses:	Large
Major partners:	Out-growers, PROPACO (French development agency)

Executive summary

Mumias Sugar Company Ltd (MSC) generates electricity from its bagasse-based co-generation plant. MSC was primarily established to produce sugar for local production and export. Over the years, the company has created additional revenue from its bagasse-based co-generation plant. The company generates about 34 MW of electricity, 26 MW of which is sold to Kenya Power and Lighting Company (KPLC) based on a long-term power purchase agreement (PPA), while the remaining is used for factory needs and domestic use in the staff quarters. MSC's business model is cost-driven and is based on its strategic access to input from its nucleus estates and out-growers. This guarantees the company reliable and low-cost supply of input. Since the commissioning of the co-generation plant, MSC has experienced stability in electricity supply to run its operations as opposed to the unreliable supply from the national grid. In addition to enabling MSC to be energy self-sufficient, the co-generation plant contributes to mitigating environmental pollution by replacing fossil-based energy production while satisfying the energy demand of the country. The co-generation plant is also beneficial to local populations by contributing to expanding access to electricity supplies in areas otherwise distant from the grid.

KEY PERFORMANCE INDICATORS (AS OF 2012)						
Land:	0.6 ha (for the co-generation plant)					
Capital investment:	USD 63 million (boiler costs USD 28 million and generator USD 14 million)					
Labor:	20–25 persons full-time and 5 persons on a contract basis (for the co-generation plant)					
O&M costs:	1 million USD/year					
Output:	34 MW of electricity and 100 tons/day of ash					
Potential social and/or environmental impact:	Mitigation of environmental pollution by reducing GHG emissions, reducing fossil fuel dependence, employment generation, expanding access to electricity for rural areas					
Financial viability indicators:	Payback period:	17	Post-tax IRR:	3%	Gross margin:	30%

Context and background

MSC is a registered agro-based publicly-listed company in Kenya that is involved in the growing and processing of sugarcane to produce sugar. In 2014, its ownership is 36% local corporate, 56% local individuals and 8% foreign investors. The company started its operations in 1972 and became the largest sugarcane processor in Kenya both in terms of profitability and scale of operations, crushing (depending on supply) between 1.1 and 2.4 million tons of sugarcane annually and producing 70,000–260,000 tons of sugar. MSC was primarily established to produce sugar for local production and export. Over the years, the company has created additional revenue streams from electricity generation. Construction of the power co-generation plant started in 2007 and was completed in 2009, with an initial finance of USD 35 million provided by the French development agency, PROPARCO. The initial and long-term goals of the co-generation plant were waste management and electricity production, which varied in the last years between 21 and 34 MW of electricity per year.

Market environment

Kenya has an electricity demand of 1,191 MW and installed power capacity of 1,429 MW of electricity. Peak demand load is projected to grow to 2,500 MW by 2015 and 15,000 MW by 2030. The demand for electricity in Kenya outstrips supply despite imports from Uganda. With the projected electricity demand set to grow, the government is encouraging green power initiatives such as co-generation units. Though on-site power production through bagasse co-generation is on the increase, its potential is not fully exploited in the industry.

The Kenya Electricity Generating Company (KENGEN) generates approximately 80% of electricity consumed in the country, while the balance is produced by independent power producers (IPPs), such as MSC. In 2013, MSC sold about 26 MW of electricity to KPLC, which distributes the power through the national grid. KPLC buys power from generators like KENGEN and MSC and is responsible for the transmission, distribution and retail of electricity throughout the country.

MSC with its CDM initiative has also concluded purchase agreements with financial group Japan Carbon Finance Ltd (JCF). Launched in late 2004, the financial group has received committed funds of approximately USD 140 million for its Japan GHG Reduction Fund (JGRF). In addition to JGRF, JCF has established second and third funds to purchase further carbon credit for some of fund providers in JGRF. JCF plans to use the fund to purchase emission reductions credits from CDM and joint implementation (JI) projects in developing and “in transition” economies around the world. JCF has assisted development of various types of CDM/JI projects, such as renewable energy, energy efficiency and waste management, and concluded purchase agreements in more than 30 projects worldwide, including cogeneration plant of MSC.

Macro-economic environment

The Kenyan power sector is characterized by the heavy reliance on hydroelectricity, frequent power outages, low access to modern energy and high dependence on oil imports. With the enactment of the Electric Power Act in 1998, the KPLC was unbundled into three entities: the KPLC that was to carry out transmission and distribution functions to meet demand, the KENGEN to carry out the generation function and the Electricity Regulatory Board (ERB) to regulate the power sector. The Act also allowed IPPs to enter into PPAs with KPLC to add more power into the grid. KPLC has, however, retained the transmission and distribution functions all over the country which hinders the emergence of decentralized IPPs and independent power distributers.

Kenya leads in exploiting renewable energy (RE) sources to meet the challenges of growing demand and addressing the related environment concerns to complement the realization of Vision 2030: "accelerating transformation of the country into a rapidly industrializing middle-income nation by the year 2030". The incentives for RE power include 0% import duties and value-added tax exemption on renewable energy materials, equipment and accessories, feed-in tariffs at a price level that attracts and stimulates new investment in the renewable energy sector. These will have direct impacts on the development of renewable energy in Kenya and on the available energy that KPLC can supply to regional populations. The IPPs were introduced into the sub-sector as a means of redressing the challenge of capacity shortfalls. At least 174 MW of power is supplied by IPPs. MSC generates 34 MW, 26 MW of which is dispatched to the grid. The government has identified the unexploited potential of up to 300 MW from other sugar factories.

Business model

MSC is essentially a sugar factory with a co-generation plant that processes bagasse to produce and sell electricity to KPLC through a long-term PPA (Figure 88). MSC employs a cost-driven business model. Since commissioning of the co-generation plant, MSC has experienced more stability in electricity supply to run its operations, and thus reduced operational costs compared to the unreliable supply from the national grid that it was previously relying on.

Value chain and position

MSC sources its sugarcane from its nucleus estates and its out-growers. Bagasse, produced after sucrose extraction from sugarcane, is used as fuel in the boilers to generate high-pressure steam, which runs generator to produce electricity. Ash, generated by the cogeneration plant, is applied as a soil conditioner in the company's sugarcane plantation (Figure 89).

Although MSC is vertically integrated and owns its nucleus estate, it still heavily depends on out-growers for its input, and thus the supplier power is high. In recent years, MSC has experienced a declining supply of sugarcane from both its nucleus estate and out-growers. This has been to a large extent attributed to the declining soil productivity of the cane fields due to continuous mono-cropping of sugarcane. This situation has led to production that is well below the installed plant capacity and has forced the company to reduce cane crushing and sugar milling to one or two times a week, down from the efficient all-week year-round production. Since MSC waste re-use operations are a direct result of cane crushing, there has been an associated decline in outputs for electricity generation.

MSC has a PPA with KPLC to provide 26 MW of electricity to the national grid. KPLC is responsible for the transmission, distribution and retail of electricity throughout the country, which gives it a high bargaining buyer power. The terms of the PPP are such that if MSC fails to provide the agreed 26 MW, it is penalized by KPLC which deducts a percentage of the revenues accruing to MSC. The company has also been forced to procure sugarcane from far areas and from out-grower farmers and bagasse

FIGURE 88. MUMIAS SUGAR COMPANY BUSINESS MODEL CANVAS

KEY PARTNERS
- Out-growers
- PROPARCO (French development agency)

KEY ACTIVITIES
- Operate co-generation plant
- Sales of electricity

KEY RESOURCES
- Equipment
- Long-term PPA with KPLC
- Sugarcane, bagasse
- Technical and operational competencies
- Capital
- Nucleus estates

VALUE PROPOSITIONS
- Competitively priced and renewable energy based electricity through processing of bagasse in environmental-friendly way
- Use of ash as soil enrichment in cane sugar plantation

CUSTOMER RELATIONSHIPS
- Long-term PPA

CHANNELS
- Connection to KPLC national grid

CUSTOMER SEGMENTS
- KPLC
- Nucleus estate (internal use)

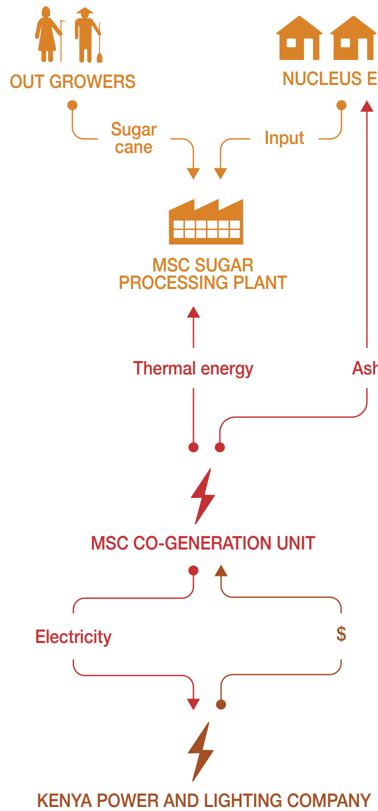
COST STRUCTURE
- Capital investment cogeneration – Financed by debt
- Operational cost (labor cost, water repairs and maintenance)
- Reduced operational costs from using own electricity and thermal energy
- Minimized transport costs
- Interest on borrowed fund
- Tax = 16% VAT

REVENUE STREAMS
- Electricity sales
- Improved soil productivity and yield
- Sales of carbon credits

SOCIAL & ENVIRONMENTAL COSTS
- Possible contamination of water source

SOCIAL & ENVIRONMENTAL BENEFITS
- Contribute to mitigating environmental pollution
- Contribute to the economy of local community
- Generate employment opportunity
- Contribute to improved waste management
- Expanding access to electricity supplies to local communities

FIGURE 89. MSC CO-GENERATION UNIT VALUE CHAIN



from other sugar companies not producing power/electricity to complement supplies from the nucleus estate and the out-growers. To mitigate this situation, MSC is researching on developing a cane variety that can survive nutrient-depleted soils to ensure sustained supply of sugarcane for crushing. An energy balance initiative has also been commissioned aimed at improving energy consumption to further enhance the export of green energy to the national grid.

The co-generation plant is a CDM project, which qualifies for Carbon Emissions Reduction (CER) certificates. MSC estimates an annual production of 130,000 tons of CERs. Under purchase agreement with JCF as well as the provision of Article 12 of the Kyoto Protocol on CDM, MSC is allowed to sell and JCF to purchase CER certificates. In 2010, MSC was the first Kenyan firm to sell carbon credits, making Ksh 22 million (about USD 270,000).[1]

Institutional environment

In 2008, Kenya launched Vision 2030, a development blueprint aimed at making Kenya a newly industrialized middle-income country providing a high quality of life to all its citizens in a clean and secure environment. Addressing climate change is a top priority of the Government of Kenya. Kenya's Intended Nationally Determined Contribution (INDC) includes an ambitious mitigation contribution of a 30% reduction in GHG emissions by 2030 relative to the business as usual scenario. The plan

was developed through a cooperative and consultative process that included stakeholders from governments, private sector, civil society and development agencies.

Kenya's power sector reform was initiated following the enactment of the Electric Power Act 1997 whereby the policy formulation function was retained by the Minister for Energy, while regulatory functions were passed on to an autonomous regulator: Electricity Regulatory Board (ERB) and commercial functions in respect of generation, dispatch, transmission, distribution and supply to various commercial entities. The government amended the Electricity Act to enable the reform and restructuring of the sub-sector in order to prepare it to attract adequate funding, especially from the private sector, for operations and development and to improve financial and technical efficiency of entities involved. With the implementation of reforms, KPLC is now transformed from the de facto vertically integrated structure into a single buyer (purchasing egency) model in which it purchases bulk power from IPPs and the public sector generation company under long-term bilateral PPAs.

The government has been encouraging and supporting green power initiatives such as wind power and co-generation such as the one undertaken by MSC, all with the goal of increasing the installed power capacity of Kenya. The RE department is responsible for leading the planning, development, implementation, promotion and execution of structures for the development and regulation of the RE and energy efficiency through research and planning, development of standards and regulations, compliance and enforcement. RE portal provides easy access to relevant information about entry requirements and procedures for operating a RE power plant, the legal and regulatory framework for such investments (such as tariff regulation) and relevant market information.

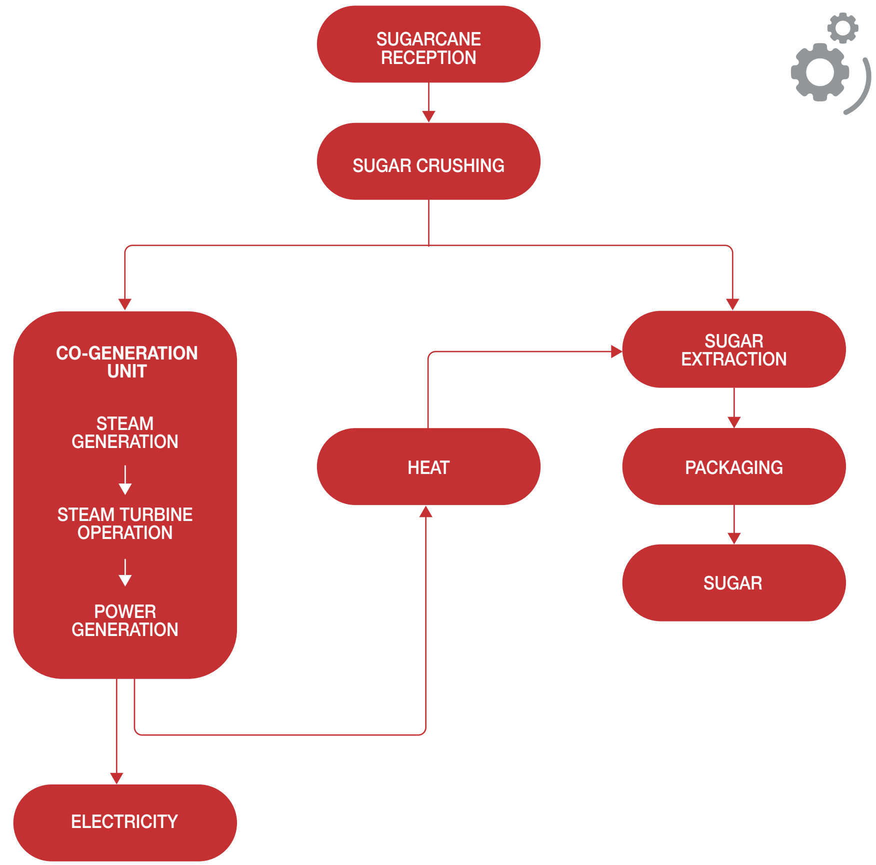
Technology and processes

Co-generation is the production of electricity and heat from a single fuel source. For MSC, the fuel source is bagasse. Bagasse produces sufficient heat energy to supply all the needs of a typical sugar mill, with energy to spare. To this end, a secondary use for this waste product is in co-generation, the use of a fuel source to provide both heat energy used in the mill and electricity, which is typically sold on to the consumer electricity grid. Bagasse is the fibrous matter that remains after sugarcane is crushed to extract its juice. The high moisture content of bagasse, typically 40–50%, is detrimental to its use as fuel. Bagasse is an extremely inhomogeneous material, making it particularly problematic for paper manufacture. In general, bagasse is stored prior to further processing. For electricity production, it is stored under moist conditions, and the mild exothermic reaction that results from the degradation of residual sugars dries the bagasse pile slightly.

Figure 90 depicts MSC sugar and co-generation unit process. Bagasse produced after sucrose extraction from sugarcane is used as fuel in the boilers to generate electricity. There are three main steps involved in co-generation power production:

- Steam generation – Bagasse's chemical energy is converted into heat by burning. The heat energy is used in boilers to heat water to produce steam at specified pressures and temperatures.
- Steam turbine operation – Steam from boilers is used to drive the turbines, which convert the heat energy into mechanical energy. This provides the power to turn the equipment for power generation at controlled speeds.
- Power generation – The turbines are used to turn electrical power generators. All the major capital equipment including the boiler and generator were imported.

FIGURE 90. MSC SUGAR AND CO-GENERATION UNIT PROCESS DIAGRAM



Funding and financial outlook

The total investment cost of the co-generation unit was USD 63 million, with the boiler and generator taking bulk of the capital costs at USD 28 million and USD 14 million respectively. There was no land acquisition since the power plant was built on a yard that had an old sugar production line. Initial finance of USD 35 million for the co-generation plant was provided by PROPARCO in 2007 as a loan at an annual interest of 6.24%, one-off arrangement fee of 1% and commitment fee of 0.5%. The total amount repayable, loan plus interest and fees, amounts to USD 39.8 million. The loan was repayable over 10 years after a three-year grace period and was used to finance phase one of the project. The second phase of the project was financed by banks in 2009 lending a total of USD 28 million repayable after 10 years following a three-year grace period. The company successfully commissioned the 34 MW co-generation project effective May 11, 2009, leading of sale of 26 MW of power to grid. The commissioning of the power sub-station and the transmission line was done simultaneously. Production, sales and costs of electricity from the co-generation plant are shown in Table 26. The figures for the years 2013 to 2015 were at the time of the case assessment still reported projections.

Taking the steady annual profit of USD 3.68 million and the initial capital of USD 63 million, the plant's payback period is approximately 17 years and assuming useful life of 25 years, Internal Rate of Return

TABLE 26. FINANCIAL DATA OF MSC FOR 2009–2015

YEAR	2009	2010	2011	2012	2013	2014	2015
Electricity exported (kWh)	25,000	25,000	25,000	25,000	25,000	25,000	25,000
Electricity sales (Million USD)	11.93	12.27	12.27	12.27	12.27	12.27	12.27
Cost of electricity (Million USD)	8.36	8.59	8.59	8.59	8.59	8.59	8.59
Profit from electricity sales (Million USD)	3.57	3.68	3.68	3.68	3.68	3.68	3.68
Payback period	17 years						
IRR	3%						

*Assuming useful life of 25 years and discount rate of 10%.

(IRR) is 3%. In addition to the direct income from sale of electricity, MSC further realizes cost savings from using their own generated 8 MW of electricity at a cheaper cost compared to the cost they could have incurred if electricity was supplied from the main grid. The company is also in advanced stages of negotiating with the Japan Carbon Finance Company for sale of carbon credits and projects that it will earn an annual income of USD 800,000 from the sale of credits due to its green initiatives. Besides the power generated, the company also collects the ash from the burnt bagasse that is used as a soil conditioner and applied on the company's nucleus estate. In addition, MSC is planning to introduce new products such as ethanol production, expanding co-generation, new packages for various market segments, capacity expansion and modernization, investment in computer technology and improved supply chain management for overall efficiency in the company.

Socio-economic, health and environmental impact

As sugar mills tend to be located in rural areas (Mumias is a rural town) near sugarcane plantations, co-generation is beneficial to local populations by contributing to expanding access to electricity supplies in areas otherwise distant from the grid. Co-generation, in addition to enabling MSC to be energy self-sufficient, contributes to mitigating environmental pollution by replacing fossil-based energy production while satisfying the energy demand of the country. As it is a locally sourced fuel, bagasse increases the reliability of electricity supply by diversifying sources and reducing fossil fuel dependence. As a biomass fuel, bagasse supplies a raw material for the production of natural, clean and renewable energy, enabling its use to further government targets for renewable energy use. The CO_2 emissions by burning of bagasse are less than the amount of CO_2 that the sugarcane plant absorbed from the atmosphere during its growing phase, which makes the process of cogeneration GHG-neutral.

Furthermore, it boosts employment for neighbouring communities and allows operational personnel to develop skills in operating the equipment and technologies. The co-generation plant employs between 20 and 25 people on regular basis and another five on contract basis. In order to safeguard employees' health and safety, MSC provides personal protection equipment, annual medical check-ups for all staff and safety signs are put at all entrances. Furthermore, to ensure minimal release of pathogens from the burnt bagasse, it has re-engineered the plant.

MSC had experienced difficulties in disposing the bagasse by direct dumping into forests and water bodies before the co-generation project. Not only was the bagasse-making the land derelict, dry bagasse occasionally ignited and caused fire resulting into loss and destruction of property. However, this

problem was nipped after commissioning of the power plant since the bagasse produced after crushing is fed directly into the power plant to fire the boilers. Reuse of bagasse has freed up space/land which can now be used productively. The project complies with local environmental and safety standards and aims to be as close as possible to international reference standards.

Scalability and replicability considerations

The key drivers for the success of this business are:

- Reliable supply of inputs as MSC is vertically integrated.
- Strategically situated near the sugarcane source.
- Securing of long-term PPA.
- Government encourages green power initiatives.

The co-generation plant is best suitable where there already exists some infrastructure i.e. a sugar company that is already generating bagasse, with the power co-generation initiated as a plant within the sugar factory. It may not be feasible to set up the co-generation plant as an independent plant that relies on bagasse from external sources. Given the initial high capital costs, such a project requires the involvement of development agencies that can provide finance to offset the initial capital expenditure. This project has the potential to be replicated in countries where there are large sugar manufacturing companies and where there is a government support for RE initiatives. Issuing longer-term licenses and PPAs with good feed in tariffs allow for sufficient time for the investor to pay off project financing debts as well as provides adequate amortization period for the equipment. MSC is planning to expand its sugar production facilities with corresponding co-generation plant by development of a new sugar factory with capacity to crush 6,000 tons of cane a day or acquiring one or more state-owned sugar factories in Kenya, Uganda and Tanzania.

Summary assessment – SWOT analysis

Key strengths of the business are securing of long-term purchase agreement with the state utility while ensuring energy self-sufficiency (Figure 91). Declining supply of sugarcane due to declining soil productivity is a key threat to the business. There is a threat that failure of MSC to deliver agreed electricity to KPLC may result in penalty and loss of income. To mitigate these problems, MSC has the opportunity to register the project as CDM and earn from sales of carbon credits. Furthermore, MSC has the opportunity to explore the development of a cane variety that can survive nutrient-depleted soils.

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FIGURE 91. SWOT ANALYSIS FOR MSC

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Long-term power purchase agreement ▪ Diversified revenue streams ▪ Energy self-sufficient ▪ Clean and renewable energy generation ▪ Nucleus estates provide some guarantee of input ▪ Community support of sugarcane farmers as well as nearby villages	**WEAKNESSES** ▪ Declining sugarcane production due to mono-cropping led to production below installed capacity ▪ Technical dependency on sugar cane ▪ Internal revenue stream dependency on sugar sales and electricity sales ▪ High initial cost with long payback periods
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Earnings from sale of carbon credits ▪ Register as CDM and earn from sales of carbon credits ▪ Development of a cane variety that can survive nutrient depleted soils ▪ Growing electricity demand ▪ Sourcing bagasse from other nearby sugar companies not producing electricity ▪ Potential of decentralize power generation and distribution in remote villages	**THREATS** ▪ Declining supply of sugarcane, and hence bagasse due to declining soil productivity ▪ Failure of MSC to deliver agreed electricity to KPLC may result in penalty and loss of income

Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflect our best knowledge at the time of the assessments 2015. As business operations are dynamic, data can be subject to change.

Note

1 https://www.standardmedia.co.ke/business/article/2000208079/government-to-support-nse-introduce-carbon-credits-trading (accessed 18 January 2018).

CASE

Power from slaughterhouse waste (Nyongara Slaughter House, Dagorretti, Kenya)

Jack Odero, Krishna C. Rao and Nancy Karanja

Supporting case for Business Model 8	
Location:	Dagorretti, Kenya
Waste input type:	Slaughterhouse waste (solid and liquid) form
Value offer:	Biogas, power and bio-fertilizer
Organization type:	Private
Status of organization:	Operational since 2011
Scale of businesses:	Small
Major partners:	United Nations Industrial Development Organization (UNIDO), Kenya Industrial Research and Development Institute (KIRIDI) and United Nations Environment Programme (UNEP)

Executive summary

The Nyongara Slaughter House is located in Dagorretti on the outskirts of Nairobi. Dagorretti is an area famous with the presence of slaughterhouses that supply meat to different regions in Nairobi and its environs. The waste generated by the slaughterhouse was polluting Nairobi River and the National Environmental Management Authority (NEMA), an environment regulatory body, was closing slaughter-house units that were not meeting the regulatory norms of treating their waste. This catalysed partnership between Nyongara Slaughter House and UNEP, UNIDO and KIRIDI through the Ministry of Environment to develop and demonstrate a solution to not only treat the waste to produce biogas but also provide monetary benefits to the slaughterhouse units. The biogas operations began in 2011 with biogas used for heating and to generate electricity primarily for refrigeration and lighting purpose. The slurry output from the plant is high in nutrients and is used in cultivation of tomatoes within the slaughterhouse. Based on the success of Nyongara biogas plant, the proprietor of Nyongara Slaughter House wants to set up a business of treating waste from other slaughterhouse units in Dagorretti, Kenya to generate biogas and sell the electricity to slaughterhouse units.

KEY PERFORMANCE INDICATORS (AS OF 2012)						
Water requirement:	4,000 L/day wastewater input from the slaughterhouse					
Capital investment:	USD 35,000 to 60,000					
Labor:	1 full-time for composting; 2 part-time for biogas plant operations					
O&M cost:	NA					
Output:	25 cubic meter per day of biogas generating 10 kVA electricity and bio- fertilizer					
Potential social and/or environmental impact:	1 full-time and 2 part-time jobs, a cleaner environment through reduced water pollution and CO_2 emissions, reduction of GHG emissions					
Financial viability indicators	Payback period:	3–5 years	Post-tax IRR:	N.A.	Gross margin:	N.A.

Context and background

Dagorretti is a suburb of Nairobi well known for its slaughterhouses, employing over 5,000 people, which were almost shut down in 2009 due to untreated slaughterhouse waste polluting the Nairobi River. The surroundings were stinking, emitting large quantities of methane, and the blood and wash water were seeping into the groundwater. Unreliable grid electricity forced the slaughterhouses to depend on diesel generators, increasing their high-energy bill, accounting for up to 40% of their total cost of production.

Based on the request of the Ministry of Environment, Government of Kenya and as a part of cleaning of the Nairobi River Initiative, UNEP requested UNIDO to develop solutions to manage slaughter-house waste. At the same time, the proprietor of Nyongara Slaughter House was looking out for a solution to manage its waste and comply with NEMA regulations. This led to the collaboration between Nyongara Slaughter House, UNIDO, UNEP, KIRDI under a public-private partnership for this pilot project.

A 15-kW biogas plant was installed at the Nyongara slaughterhouse, with a high-performance temperature-controlled digester (using solar heating), replacing the diesel generator and recovering waste heat to replace wood and charcoal for hot water to clean the slaughterhouse. The generated electricity is consumed for lighting and powering water pumps and compressors for cold storage and processing of hides and skins while mitigating the pollution of Nairobi River. At the time of the interview, the proprietor of Nyongara Slaughter House was planning to initiate conversation with the owners of other slaughter-house units to process their waste and sell electricity to those units and neighbouring households and enterprises.

Market environment

At the time of the assessment, Nyongara biogas plant processed about 300 kg of solid waste per day and generated electricity for four hours in a day. Dagorretti recorded more than 15 slaughter-house units, and on an average, each unit produces about four tons of solid waste and 4,000 L of wastewater per day. Based on the total quantity of waste (60 tons of solid waste + 60,000 L of wastewater) generated from all the slaughter-house units in Dagoretti, it has the potential to meet the electricity demand of all the units and generate surplus electricity. A typical slaughterhouse requires electricity for refrigerating units, water pumping, heating, slaughtering appliances, office equipment and lighting. At the time of the interview, majority of the slaughter-house units were shut down by NEMA, and these slaughter-house units were looking at Nyongara to provide them with a solution

to meet the environment regulations and reopen their business. Key competitor for Nyongara biogas plant is from a local electricity authority in Dagoretti. However, the electricity authority is struggling to meet public and private demand. Dagoretti area suffers from severe electricity shortage and majority of the slaughterhouses invest in diesel generators from backup power supply.

Macro-economic environment

Only 25% of the population in Kenya has access to electricity with less than 5% in rural areas. Installed capacity in 2011 was only 1,590 MW, which is very low for a country of 40 million people (40 W per capita – South Africa's figures are roughly 40,000 MW for 50 million people or 800 W per capita). The main problems in the sector are that existing capacity is barely able to meet demand, especially when hydrological conditions dip. There are independent power producers (IPPs) providing around 27% of the generated energy. Small-scale renewables contribute about 3% of installed capacity and is expected to grow to 6% by 2018.

Kenya's Vision 2030 ambition is to be a middle-income country in 18 years' time. This will require system capacity to grow to 15,000 MW by 2030. Rapid growth in capacity is required both to underpin the GDP growth targets and to allow universal access to electricity to be achieved. However, the present situation remains dogged by problems. Severe power shortage and electricity blackouts are putting pressure on the economic growth. While government plans to significantly add new generation capacity, initiatives such as the biogas plant at Nyongara Slaughter House, is a drop in the ocean that is still an urgent need not just from electricity access but also from environment perspective.

Business model

The Nyongara biogas plant exhibits three value propositions (Figure 92): treating waste from slaughter-house units to enable them to meet environmental regulations, generating electricity from the waste and producing bio-fertilizer. The electricity generated is consumed by the unit and surplus is sold to adjacent slaughter-house units and neighbouring households. The outlet slurry from the biogas plant is rich in nutrients and has the potential to be sold as bio-fertilizer.

Value chain and position

Nyongara biogas plant accepts 300 kg of waste per day, generating 9 kWh of electricity at the Nyongara Slaughter House. However, the proprietor plans to treat waste from other slaughter-house units to generate and provide electricity and thermal energy (Hot water for cleaning). The value chain analysis (Figure 93) is based on future plans. The value chain consists of procuring waste from other slaughter-house units and supplying electricity to slaughter-house units and neighbouring households and enterprise. The project will reduce dumping of slaughterhouse waste, and hence lower methane emissions to the atmosphere.

Since other slaughter-house units are looking for a solution to treat their respective waste, the supplier power is low. The slaughter-house units have existing investments in diesel generator, so unless the Nyongara biogas plant can provide electricity at lower costs, buyer power is prominent. In addition, the enterprise has threat from new entrants. The enterprise has potential to add another revenue source through production and sales of nutrient-rich bio-fertilizer from the slurry output of the biogas plant. The slurry is in the meantime used to irrigate the compound, thus providing the hundreds of workers with a cleaner and greener working environment.

FIGURE 92. NYONGARA BIOGAS PLANT BUSINESS MODEL CANVAS

KEY PARTNERS

- UNIDO, UNEP, KIRDI for providing know-how

KEY ACTIVITIES

- Procuring and treating waste from slaughterhouses
- Biogas to electricity conversion
- Organic fertilizer production from biogas outlet slurry
- Sales

KEY RESOURCES

- Financial resources
- Land, building, equipment, labor
- Agreement with slaughterhouse units
- Slaughter-house waste

VALUE PROPOSITIONS

- Treating waste produced by slaughter-house units to enable them to meet local environmental regulations
- Electricity for slaughterhouse operations and cooking for household
- Organic fertilizer for crop cultivation (potential)

CUSTOMER RELATIONSHIPS

- Direct

CHANNELS

- Direct sales

CUSTOMER SEGMENTS

- Slaughter-house units
- Slaughter-house units, neighbouring households and enterprise for energy service
- Farmers

COST STRUCTURE

- Investment cost (land, building, briquetting machines)
- Operational cost (labor, maintenance cost)
- Energy savings

REVENUE STREAMS

- Sale of electricity
- Sale of organic fertilizer

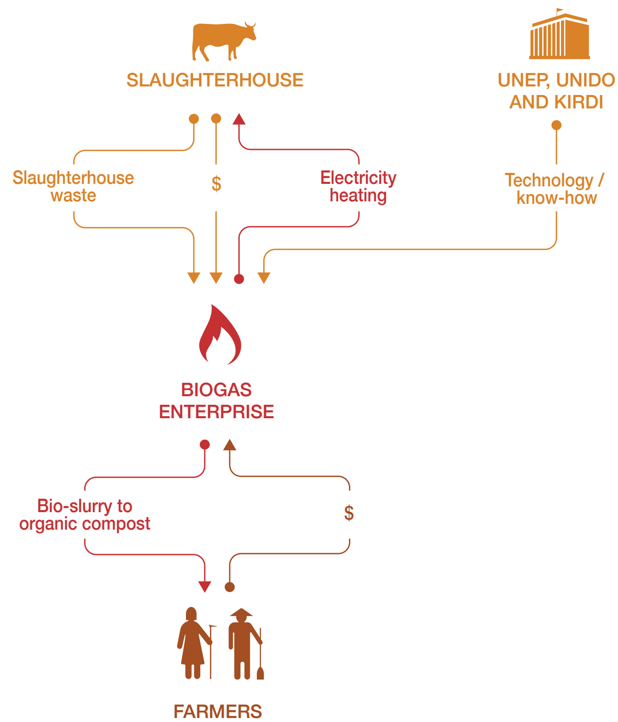
SOCIAL & ENVIRONMENTAL COSTS

- Possible human health hazard from direct contact to pathogens that may still exist from the organic fertilizer
- Laborers' health risk due to contact with slaughterhouse waste
- Environmental risks from biogas leakage to the atmosphere

SOCIAL & ENVIRONMENTAL BENEFITS

- Waste from slaughterhouses treated reduces pollution of Nairobi River
- Reduction of human health problems (and related costs) in the locality due to reduction of pollution of water bodies
- Creation of jobs

FIGURE 93. NYONGARA BIOGAS PLANT VALUE CHAIN



Institutional environment

The project was developed to address NEMA, a national environmental agency regulation that mandates appropriate treating of the waste generated by slaughterhouses. The project plans an expansion phase to treat waste from other slaughter-house units, and it has buy-in from the Ministry of Energy and Petroleum (MEP), thus showing an acceptance from the government for such operations. The 2006 Energy Act sets up the Energy Regulatory Commission (ERC), an independent regulator meant to formulate licensing procedures, issue permits, make recommendations for further energy regulations, set and adjust tariffs, approve power purchase agreements (PPAs) and prepare national energy plans.

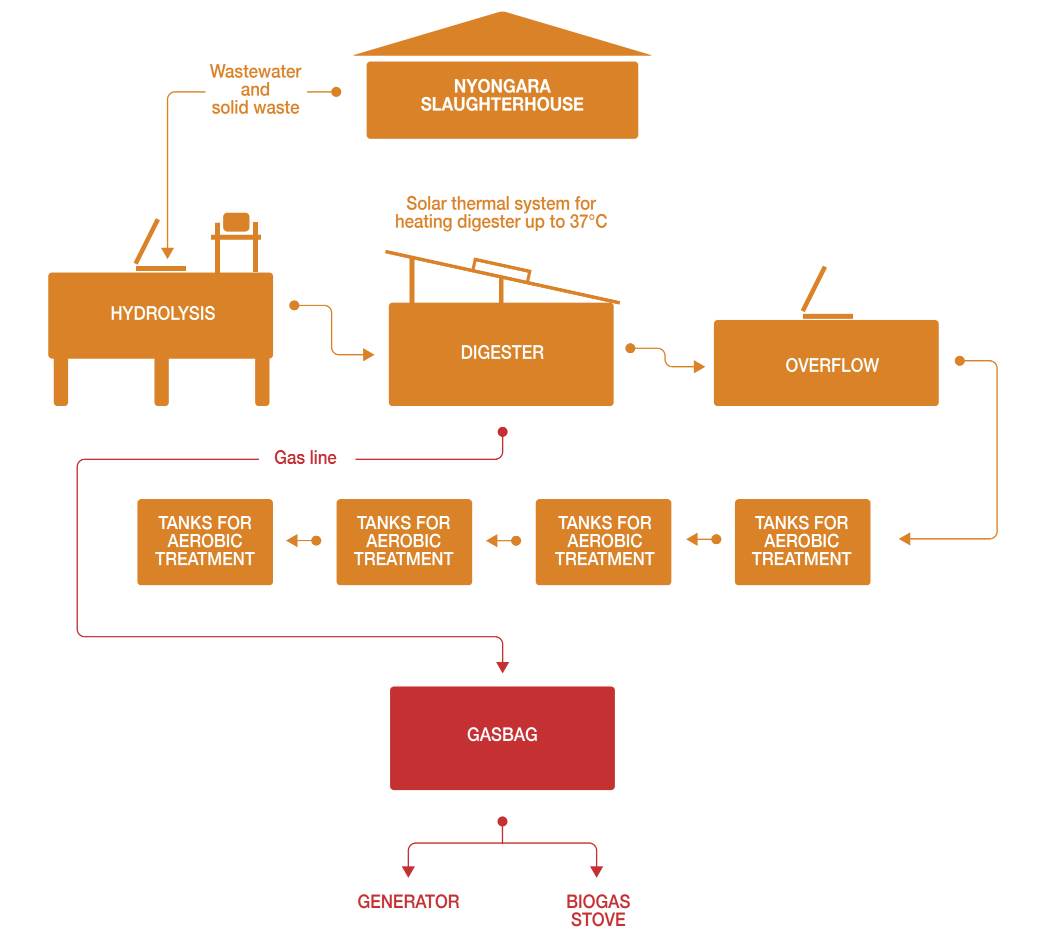
The Energy Act entrusts the MEP to elaborate sustainable renewable energy production, distribution and commercialization frameworks with emphasis on the expansion of local manufacturing sectors and provide specific incentives to existing renewable markets such as bio-digesters, solar systems and hydro-turbines. Renewable energy frameworks will also encourage biomass co-generation – heat and power – and alternative fuel production from sugar mills. The MEP shall also improve levels of international cooperation in the field of technology transfer and financial support. The broad objective of the directorate of renewable energy, one of the four technical directorates of the MEP, is to promote the development and use of renewable energy technologies. Renewable energy support tools included in the Energy Act are income tax holidays for relevant generation and transmission projects; full custom and import duties exemption for exclusive renewable energy equipment. In May 2008, a feed-in tariffs policy on wind, biomass and small hydro-resource-generated electricity was implemented by the MEP.

The feed-in tariff for biomass derived electricity up to 40 MW is USD 0.07 for firm power and USD 0.045 for non-firm power per kWh at interconnection point.

Technology and processes

UNIDO identified, based on the previous implementations at the Bungoma municipal slaughterhouse and the Homa Bay municipal slaughterhouse, the high-performance temperature-controlled (HPTC) biogas digester model marketed by Rottaler as most suitable to process the waste from slaughterhouse (Figure 94). Wastewater and solid waste from Nyongara Slaughter House is transferred daily to the hydrolysis tanks of the biogas plant where complex carbon chains (carbohydrates, proteins and fats) in the organic materials are decomposed into lower organic compounds (amino acid, sugar and fatty acids), which is the main substrate for the methane producing bacteria. These lower compounds are then released into the digester. The digester is an anaerobic (airtight) system in which the methanogens have the best living conditions (37°C) to produce methane out of organic material. Biogas produced in the digester is collected in a balloon (gas holder) from which it is fed either into the generator for

FIGURE 94. PROCESS DIAGRAM FOR NYONGARA BIOGAS PLANT



Source: http://www.kirdi.go.ke

electricity or into the gas compressor to send pressurized gas to the burners. Along with newly-installed solar panels, enough biogas-electricity is being generated to power the slaughterhouse including its cold-storage facilities. The biogas yield of a plant depends not only on the type of feedstock, but also on the plant design, fermentation temperature and retention time. One cubic meter of biogas can be converted only to around 1.7 kWh.

The output slurry from the digester can be further sterilized after the aerobic treatment and used for surface irrigation. Through adding oxygen into the system the BOD and the bacteria can be reduced to an amount which is not effecting the environment and groundwater. Generator operated with 100% biogas supplies the slaughterhouse as well as biogas plant with electricity. Whereas using the gas for direct combustion in household stoves or gas lamps is common, producing electricity from biogas is still relatively rare in most developing countries.

Funding and financial outlook

The capital cost for the Nyongara biogas plant was financed by UNDP, UNIDO, KIRDI and the proprietor of the slaughterhouse. Information on the total investment cost was not provided by the entity. However, it was estimated to be about USD 40,000. Based on limited data provided by the enterprise and from the literature, approximate savings from biogas was calculated. The opportunity cost of using biogas instead of electricity was taken into consideration. In Kenya, 1 kWh of electricity is priced at approximately 16 Kshs (0.2 USD, at an exchange rate of 1 USD = 80 Kshs). Therefore, the 72.6 kWh electricity generated from the biogas will result in daily cost savings of 1,161 Kshs (15 USD) and 34,848 Kshs (436 USD) per month or 5,227 USD per year, with payback period of less than eight years. If the value of heat energy used and revenue by sale of bio-fertilizer is added, the payback period is expected to be in the range of 4–5 years.

Socio-economic, health and environmental impact

The wastes arising from blood and ingesta combined with the large volume of water used to wash off these wastes constituted the greatest proportion of environmental hazards associated with day-to-day slaughterhouse activities. Slaughterhouse wastes pose a serious threat to the environment and the general population at large because of poor waste-management practices which results into adverse impacts on water, land and air (water being the most affected). The adjacent land of most slaughterhouses is often marshy due to improper drainage of wastewater arising from washings in the slaughterhouses. Land pollution occurs when solid wastes such as hides, hooves, horns and ingesta/dung are left unattended on open land. When the rain falls, these wastes are washed into nearby sewerage channels or streams. The project was initiated to assist slaughter-house units to meet the environmental regulations, and thus reduce pollution of Nairobi River. NEMA had closed down all the slaughter-house units in Dagorretti for flaunting environmental regulations. The biogas plant now provides solutions for the closed down units to treat their waste and meet NEMA's requirements.

The economic benefits include reducing the cost of energy from USD 0.20 to USD 0.09 per kW. The biogas produced is used for electricity generation of about 30 KW resulting in reduction in GHG emissions and improving the energy security for the region. The project has cut CO_2 emissions by 108 tons per year. This will not only help to stop deforestation as people look to cleaner, greener sources of fuel but will also assist the country to cut GHG gases and hence their devastating effects.

The biogas plant provides employment in operation and maintenance. Reopening of these closed units will result in restoration of lost jobs. Additionally, if the enterprise gets into production of organic fertilizer from the slurry output, it provides additional benefits to the environment by improving soil quality and carbon offset in comparison to chemical fertilizers.

Scalability and replicability considerations

The key drivers for the success of this business are:

- Strict implementation of environmental regulations from NEMA and closure of slaughter-house units.
- Technology transfer from Germany by UNIDO and financial assistance from UNEP and KIRDI.
- Electricity shortage in Kenya.
- Government promotes renewable energy.

The project could be a blueprint for slaughterhouses across the continent and an important example of how to reduce water pollution from industrial sector. As mentioned earlier, the proprietor of Nyongara biogas plant is planning to scale up the biogas plant and its operations to process waste from all the slaughter-house units. The initial pilot unit is realizing savings from reduced electricity usage and achieving cost recovery. This solution has high replication potential where all slaughter-house units can have an individual retrofit unit within their respective premises. This solution is applicable not only for waste from slaughter-house units but also other organic solid waste. The company is now looking to other products and employment opportunities including poultry feed and pet food as it seeks to be a zero-waste operation. Scientists and engineers from the KIRDI were involved in the implementation from the very beginning of the activity, which enabled UNIDO to transfer the know-how and skills to local technicians, so that the maintenance, replication and up-scaling process would be very smooth.

The two-stage biogas digester technology is widely used for commercial power generation in Europe and the USA. The design was adapted by UNIDO to meet local African requirements (ease of replication, up-scaling and maintenance) and can be implemented in any place where organic waste (food waste, market waste, fish waste, slaughter-house waste, agro-waste, chicken or animal manure) is available. This is the third HPTC biogas project UNIDO is completing in Kenya and, with the support of Government of Kenya through the Ministry of Industrialization, UNIDO would like to implement this model of biogas digesters as a standard in all mid-size slaughterhouses in Kenya. UNIDO will also look into establishing mini tanneries to process raw hides and skin to wet blue, which would further facilitate effective waste treatment as well as energy and employment generation in and around the slaughterhouses. Almost all well-known biogas power plants in developing countries depend on financial support from a third international party. Many new studies come to the conclusion that biogas power plants are not commercially viable without subsidies or guaranteed high prices (approx. 0.20 USD) for the produced outputs.

Summary assessment – SWOT analysis

The key strength Nyongara biogas plant is the reliable technology that can treat the waste to required local environmental norms. In addition, demand for electricity generated is high (Figure 95). The weakness is the investment required is high and financial assistance is needed for small enterprise. The business has the opportunity to both scale up and scale out, and scaling would require increased effort in building sound partnerships. The biggest threat for the business is from competition. The competition is not only from local electricity authority, but also once other slaughterhouse units have access to the technology, they can plan for a similar business approach and eat into Nyongara's market.

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FIGURE 95. NYONGARA BIOGAS PLANT SWOT ANALYSIS

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Availability of waste ▪ Low labor requirement and potentially lower O&M ▪ Able to process waste to meet environmental regulations ▪ Strong technology partnership	**WEAKNESSES** ▪ Dependence on one type of waste and buy in from other slaughterhouse units if they plan to scale up ▪ Significant land required ▪ Potentially financing constraint for additional investment ▪ Import of technology and equipment required ▪ Lack of skilled technicians and engineers ▪ High maintenance cost
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Environment stress reduction offers market opportunities with other slaughterhouse units ▪ High potential for scaling in a cluster set up and can also be easily replicated ▪ Favourable regulatory framework and feed-in tariffs for renewable energy power ▪ Cost-effective internal use of electricity ▪ Electricity shortages and frequent power blackouts	**THREATS** ▪ Possible human and environment health risk from biogas outlet slurry may lead to need for additional investment ▪ Other slaughterhouse units can install their respective biogas plants and sell electricity ▪ Political instability in Kenya ▪ Lack of awareness and local capacity ▪ Lack of finance

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Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflects our best knowledge at the time of the assessments 2013/2014. As business operations are dynamic, data can be subject to change.

CASE

Combined heat and power and ethanol from sugar industry waste (SSSSK, Maharashtra, India)

Solomie Gebrezgabher and Hari Natarajan

Supporting case for Business Model 8	
Location:	Someshwarnagar, Maharashtra, India
Waste input type:	Bagasse, molasses, spent wash (Distillery effluent)
Value offer:	Electricity/heat, ethanol, pressed mud and bio-fertilizer
Organization type:	Cooperative society
Status of organization:	Operational (since 1962), co-generation unit (since 2010)
Scale of businesses:	Large
Major partners:	Sugarcane farmers (Cooperative society), Government of India, Maharashtra State Government

Executive summary

Shri Someshwar Sahakari Sakhar Karkhana (SSSSK) is a cooperative sugar factory located at Someshwarnagar, taluka Baramati, dist. Pune, Maharashtra that produces sugar from sugarcane grown by its farmer members. In the process producing sugar, it produces bagasse and molasses as waste products. In order to address fluctuations in profits in the sugar unit itself, SSSSK has made additional investments in a distillery unit producing ethanol using molasses; a biogas unit generating biogas using spent wash from the distillery; a cogeneration facility generating combined heat and power using bagasse and biogas and bio-fertilizer using press mud from biogas plant. There is significant demand for the ethanol from companies producing alcoholic beverages as well as pharmaceutical companies. The government has also put in place a requirement of 5% ethanol blending of fuel, which has created a demand for ethanol from petroleum companies. The biogas produced is used internally as input fuel to the boiler while the bio-fertilizer (the discharge from the biogas unit), which is high in organic matter, is distributed at no cost to the farmers in proportion to the cane supplied by them. The electricity generated by the cogeneration unit partially used internally and surplus is sold to the state electricity utility by way of a long-term power purchase agreement at a pre-determined incentive tariff that has been set by the MERC. SSSSK assists the member cane growers to increase cane growth by providing quality seed and tissue culture plantlets, introducing modern techniques of cultivation, integrated nutrient management, irrigation water management and pest management and providing bio-fertilizers to its members. SSSSK's operations have led to significant socio-economic benefits

for the local community in terms of the creation of livelihood for member farmers, job creation and improving the quality of basic infrastructure such as roads and access to healthcare and education. Moreover, the whole process results in CO_2 offset due to use of non-fossil fuel for electricity generation.

KEY PERFORMANCE INDICATORS (AS OF 2012)							
Land:	60 ha						
Water requirement:	130 m^3/hr						
Capital investment:	Co-generation unit = USD 20.8 million, Distillery unit = USD 4.4 million, Biogas unit = USD 0.53 million						
Labor:	150 full-time and approximately 50 temporary/seasonal persons						
O&M cost:	2.5% of capital costs (643,000 USD/year)						
Output:	18 MW electricity/year, 5 million L of alcohol/year						
Potential social and/or environmental impact:	20,000 farmer members benefit, 200 jobs in the local community, overall socio-economic development in the community – Roads, healthcare and education, CO_2 offset						
Financial viability indicators	Payback period:	3–5 years for co-generation distillery	Post-tax IRR:	N.A.	Gross margin:	10–12%	

Context and background

The cooperative ownership structure, prevalent in the sugar industry in Maharashtra, India, enables to undertake activities with a common goal by formation of non-profit economic enterprises for the benefit of their members. SSSSK is a cooperative sugar factory in taluka Baramati, dist. Pune that produces sugar from sugarcane grown by its more than 20,000 farmer members across 40 villages and four talukas. It was established in 1961 with a crushing capacity of 1,016 tons of cane crushed per day (TCD), which has since been increased to 3,600 TCD.

In order to improve the utilization of the waste streams from the process of making sugar, SSSSK has made various investments since its establishment, which include a distillery unit producing ethanol using molasses; a biogas unit generating biogas using spent wash from the distillery and a co-generation facility generating combined heat and power using bagasse and biogas and bio-fertilizer using press mud from biogas plant. The co-generation plant was commissioned on May 21, 2010. In 2011–2012, SSSSK generated 99 million kWh, consumed 29 million kWh and sold 70 million kWh to the grid.

Market environment

Sugar is India's second largest agro-processing industry. There are more than 500 sugar factories with about 5 million hectares of land under sugarcane with an average yield of 70 tonnes per hectare. Biggest problem the sugar industry facing today is surplus production, from 10 lakh (1 million) tonnes in 1950 to over 200 lakh (20 million) tonnes in more recent years. While consumption of sugar is increasing at a steady pace of 4–5% per annum, it does not match the increase in production. As a result, prices of sugar have been steadily sliding over years. With the advancement in the technology for generation and utilization of steam at high temperature and pressure, the sugar factories can also produce significant surplus electricity for sale to the grid using same quantity of bagasse. For example, if steam generation temperature/pressure is raised from 400 °C/33 bar to 485 °C/66 bar, more than 80 KWh of additional electricity can be produced for each ton of cane crushed. The sale of surplus power generated through optimum cogeneration would help a sugar mill to improve its viability, apart from adding to the power generation capacity of the country.

One of the fastest-developing countries in the world today, with economy in transition, India consumes 12.18 quadrillion Btu (Quads) of power, with over 8–10% growth per annum. India's annual per capita energy consumption of 0.7 tonnes of oil-equivalent and its electricity consumption of roughly 835 TWh is less than one-seventh of that of developed countries. It is of utmost importance for business and industry to have adequate, economical, reliable, high-quality power supply. The market for SSSSK's electricity is the state electricity grid. There is significant demand for electricity, given that the state of Maharashtra has been suffering from an energy shortage in excess of 10% for the past decade. In order to address the energy gap, the state electricity regulator (MERC) established an incentive tariff for cogeneration units in 2002 to maximize generation from existing resources. SSSSK's cogenerating unit is capable of generating 18 MW power, 15.8 MW of which is exported to electricity grid based on a long-term power purchase agreement. The incentive tariff set by the regulator is 0.096 USD/kWh. Bagasse-based co-generation of power in India has come to a take-off stage. The lessons learned during the last decade have been extremely useful for achieving accelerated growth in the near future.

There is also a significant demand for alcohol from companies producing alcoholic beverages as well as pharmaceutical and petroleum companies. The government has put in place a requirement of 5% ethanol blending of fuel, which has created a demand for ethanol from petroleum companies. SSSSK is benefiting from government incentives for co-generation units and government regulations in relation to ethanol blending of fuel. The biogas plant has capacity of 14,787 m^3/day which contributes up to 5% input requirements of the boiler, although it was established primarily to address the concerns of the pollution control board with regards to discharge of the spent-wash from the distillery unit.

Macro-economic environment

Bagasse co-generation

The Indian government has set the challenging goal of increasing its electricity capacity six to eight-fold in the next 30 years in the context of significant capacity shortfalls and a financially-ailing electricity sector. The potential from about 575 operating sugar mills spread over nine major states has been identified at 3,500 MW of surplus power by using bagasse as the renewable source of energy. Given that the installed capacity of the total biomass/bagasse-based distributed generation is only 20% of the total estimated resource, the potential benefits of more projects is vast.

The conditions that support the growth of the bagasse-based cogeneration in India started 1992 when a number of domestic and international programs was launched to support the dissemination of bagasse-based cogeneration technology. These support programs include:

- The launching of a national program on promotion of bagasse-based co-generation by the Ministry of Non-conventional Energy Sources (MNES) in 1992 by offering capital and interest subsidies, fiscal incentives, research and development support, accelerated depreciation of equipment, a five-year income tax holiday and concessional import duty, excise and sales tax exemptions.
- Extension of loans for cogeneration by Asian Development Bank (ADB) through the Indian Renewable Energy Development Agency (IREDA).
- International funding for bagasse co-generation from the United States Agency for International Development (USAID).
- The on-going power sector reforms, unbundling of utilities and the enactment of the Electricity Bill 2003, provide further opportunities to sugar mills to emerge as power producers.
- Adoption of Electricity Bill 2003 by states.
- State subsidies and support provided by Maharashtra Energy Development Agency (MEDA).
- Innovative financial mechanisms, including trade of emission reductions from these projects under CDM of the Kyoto Protocol.

- The conducive Central and State Electricity Regulatory Commission's orders on preferential feed-in tariffs.
- Trading of energy in form of renewable energy certificate are allowed since 2010 for which CERC as well as the state ERCs have promulgated various regulations.

There are however barriers to accelerated growth of the bagasse co-generation sector in India such as the non-availability of sustainable policy and regulatory framework regime across different sugar-producing states and no opportunity of exporting electricity outside the state.

Ethanol from molasses

India's transport sector is growing rapidly and accounts for over half of the country's oil consumption whilst the country has to import a large part of its oil needs. In 2002, the government mandated that nine states and four federally-ruled areas will have to sell E-5 (5% ethanol blending) by law from January 1, 2003 which boasted the production of ethanol from sugar factories. The price of ethanol from sugar factories has been set by the government. However, ethanol pricing in India is complicated by differences in excise duty and sales tax across states, and the central government is trying to rationalize ethanol sales tax across the country. This has made ethanol production an uncertain venture and hence hindered the growth of ethanol production.

Business model

The electricity generated by the co-generation unit is purchased by the state electricity utility by way of a long-term power purchase agreement at a pre-determined incentive tariff that has been set by the state electricity regulatory commission (Figure 96). This provides the enterprise a reliable source of revenue for the length of the contract. The incentive mechanisms coupled with the power purchase agreement can make the resulting electricity competitively priced on the open market. The alcohol is sold to producers of alcoholic beverages as well as pharmaceutical and petroleum companies. The biogas produced is used internally as input fuel to the boiler. The discharge from the biogas unit which is high in organic matter is distributed at no cost to the farmers in proportion to the cane supplied by them in order to increase farm productivity, and hence increase reliability and consistency of sugarcane supply to the enterprise.

Value chain and position

SSSSK is vertically integrated and owns its raw materials for the main product (sugarcane) and for its energy-producing units (Figure 97). However, there is a threat that fluctuating sugar prices might force farmer members to shift to other crops. Since area allotted to factory is fixed by the government so as to ensure consistent supply of cane, it becomes all the more important to develop harmonious and good relations with these growers so that they do not switch to alternate cash crops. Hence from Porter's five forces lens, the supplier power is medium.

SSSSK's main buyers are the Maharashtra state utility for its electricity and the petroleum, pharmaceuticals and alcohol companies for its alcohol. The state utility is the only buyer of SSSSK's electricity based on a long-term power purchase agreement. However, the feed-in tariff is decided by the MERC with its terms and conditions, bringing the bargaining power of state utility to medium level. The substitutes for electricity from co-generation unit are electricity from fossil fuel and other renewable energy sources such as biogas, hydropower, wind, solar energy, etc. In the short term, the threat of substitutes is low as SSSSK has a long-term power purchase agreement with the state utility.

The alcohol from the distillery is sold to various industries and buyers with the introduction of the government requirement for 5% ethanol blending of fuel. However, the price of ethanol from sugar

FIGURE 96. SSSSK BUSINESS MODEL CANVAS

KEY PARTNERS

- Sugarcane farmers
- Maharashtra State Cooperative Bank

KEY ACTIVITIES

- Build, operate, own and maintain co-generation, distillery and biogas unit
- Sales of electricity and ethanol
- Distribution of the digested solids to the farmers as organic fertilizer

KEY RESOURCES

- Equipment
- Bagasse, water
- Technical and operational competencies
- Capital
- Agreement with the Maharashtra State Electricity Distribution Company
- Reliable yield at sugarcane fields

VALUE PROPOSITIONS

- Electricity produced based on a waste-to-energy approach, contributing to environmental protection and reducing the energy gap in the region
- Distillate of various grades of alcohol for production of goods
- Organic fertilizer for increasing yield at the sugarcane fields

CUSTOMER RELATIONSHIPS

- Direct
- Recurrent purchase based on client satisfaction
- Agreement with suppliers of sugar cane that receive organic fertilizer in proportion to the cane supplied by them

CHANNELS

- Connection to the state electricity grid
- Direct sales of distillates
- Direct transport of fertilizer to the sugarcane farmers

CUSTOMER SEGMENTS

- Maharashtra State Electricity Distribution Company (MSEDCL)
- Petroleum, alcohol and pharmaceutical companies
- Sugarcane farmers

COST STRUCTURE

- Capital investment (95% financed by debt): Co-generation unit; Distillery unit; Biogas unit
- Repayment of debt and dividends on equity
- Input cost (bagasse)
- Interest on borrowed fund
- O&M
- Marketing and sales (alcohol)

REVENUE STREAMS

- Sale of electricity
- Sale of alcohol/ethanol

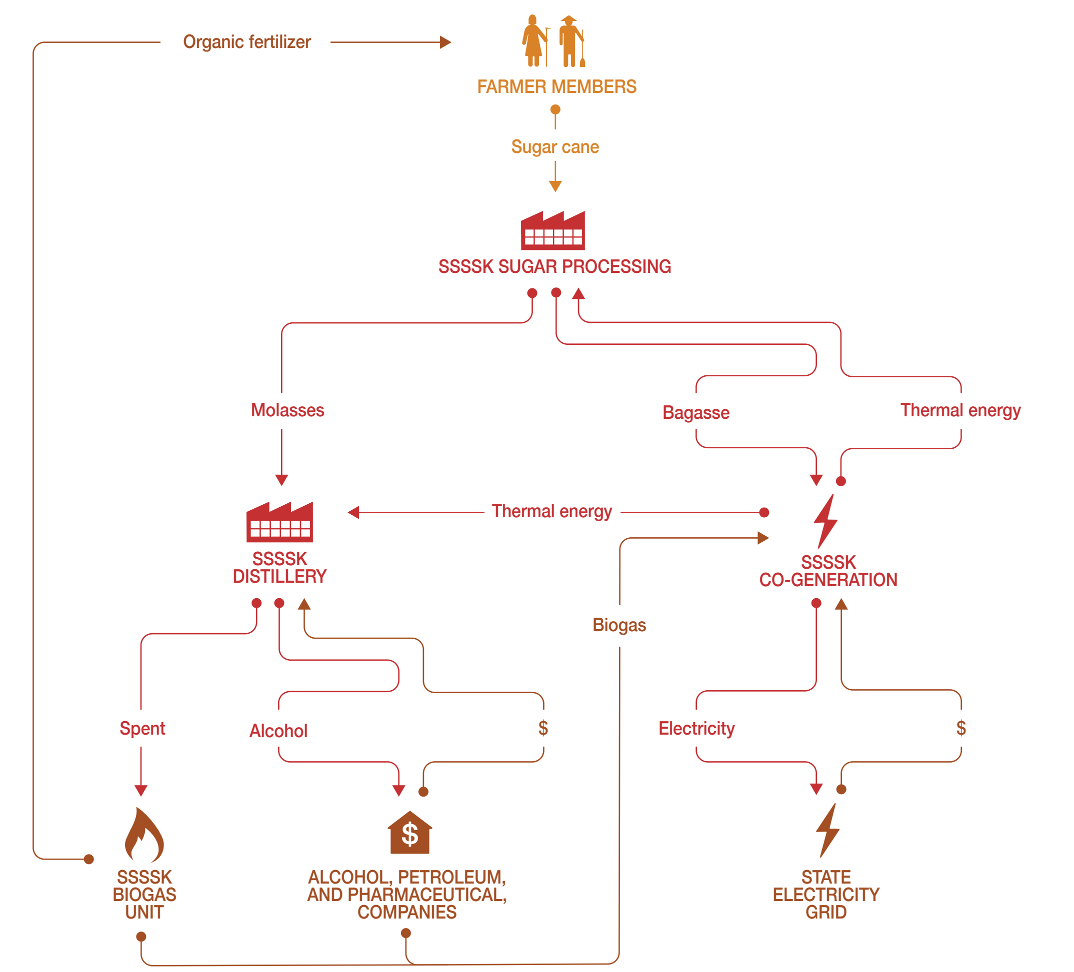
SOCIAL & ENVIRONMENTAL COSTS

- Flue gas emissions and fly ash from the boiler
- Significant water requirement

SOCIAL & ENVIRONMENTAL BENEFITS

- Livelihood, advise and support to farmer members
- Creation of jobs
- Climate change mitigation through use of non-fossil fuels
- Contribute to improving quality of basic infrastructure (roads, access to healthcare and education) in rural areas benefitting members

FIGURE 97. SSSSK VALUE CHAIN



factories is set by the government due to which SSSSK has medium bargaining power. The competition among existing companies is low; however, the competition in the sugar commodity market is high due to surplus production. While consumption of sugar is increasing, it does not match the increase in production and this drives sugar price down. The performance of the cogeneration unit is also highly dependent on government subsidy. By-products from the boiler are boiler ash and flue gas for which there are prescribed standards by pollution control board so as to minimize damage to the environment.

Institutional environment

Indian sugar industry comprises of a mix of private and cooperative units and is highly regulated by central and state government bodies across the entire value chain including sugarcane procurement area, pricing of sugarcane and production of alcohol under the Essential Commodities Act 1955 (subsequently amended in 2003). The government has established various support structures, such as the Sugar Development Fund, which provides concessional loans for upgrading and modernization

efforts as well as for establishing ethanol plants and power-generation units. Hence, both the co-generation and distillation approaches are well encouraged by the government.

The electricity generated by the co-generation unit is purchased by the state electricity utility by way of a long-term power purchase agreement. The Electricity Bill 2003 enacted subsequently by the Government of India has provided major impetus. The bill has recommended that the states should generate a minimum 10% of energy from renewable sources. It also gave supreme powers to the State Electricity Regulatory Commissions (SERC) for deliberating and deciding tariffs and other terms and conditions for all renewables, including bagasse co-generation. IREDA, a Government of India enterprise and the lending arm of MNES, has provided promotional/development finance for harnessing biomass energy in India over the last 10–12 years.

Industry associations like the Cogeneration Association of India, financial institutions and other stakeholders are pursuing the Central Electricity Regulatory Commission (CERC) to guide SERC to adopt a uniform tariff order for bagasse co-generation in the entire country.

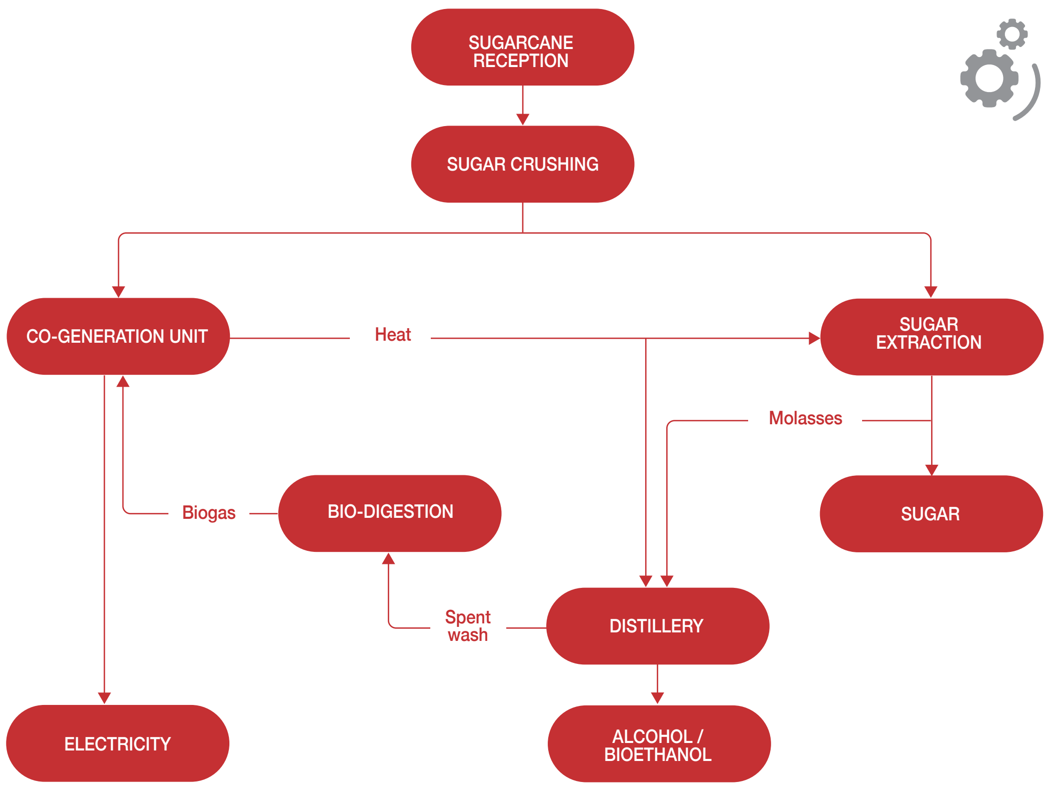
Technology and processes

Sugarcane needs to be crushed within 24 hours of harvesting, else it starts deteriorating resulting in reduced recovery of sugar from the sugarcane. The sugar industry is an energy-intensive industry. Therefore, apart from sugarcane, steam and electricity are essential for running the mill. For this reason, most of the sugar mills have a co-generation unit for supply of steam and electricity. The efficiency of co-generation plant is in the range of 75–90%, as compared to the conventional plant of 35%, because the low-pressure exhaust steam is used for heating purposes in the factory.

The typical recovery of sugar from cane during the process of making sugar is 12%. The balance sugar is available in the molasses, which is a by-product of the process (Figure 98). SSSSK's distillery unit processes the molasses to produce various grades of alcohol such as rectified spirits, extra neutral alcohol, impure alcohol and ethyl alcohol. The distillery unit consists of a multi-stage fermentation process, which is then distilled through separation columns to obtain various grades of alcohol. This unit has a capacity to produce up to 30,000 L of alcohol (95% pure) per day and requires approximately 500,000–600,000 L of water per day. The spent wash from the distillation process, which is high on fructose, is passed on to the biogas plant (18,000 m^3/day equivalent to 40–45 tons of bagasse (input requirements of the boiler for one hour). The biogas contributes up to 5% of the input fuel requirements of the boiler and is generated through a two-stage process comprising of an acid preparation stage followed by methanogenesis. Compost fertilizer is prepared from press mud and spent wash by adding microbial culture with the help of mixing cum aeration machine.

The original setup of the co-generation unit had two low-pressure boilers (16 kg/cm^2 and 21 kg/cm^2) that generate heat to meet the internal process requirements and was capable of generating approximately 2.75 MW power. SSSSK later replaced the low-pressure boilers with a multi-fuel capability, high pressure 100 TPa, 87 kg/cm^2, 570 °C boiler. The input to the boiler includes 42–45 tons/hour of bagasse (supplemented by 18,000 m^3/day of biogas) and 25 m^3/hr of treated water, which is obtained from a reverse osmosis system. The steam generated in the boiler drives a steam turbine, which is connected to a synchronous generator capable of generating 18 MW of power during crushing season. Steam is also extracted at different stages of the turbine to meet the process heat requirements of the sugar and distillery units. Suitable suppliers of equipment were locally available for all the above technologies, with a consultant providing turnkey services for installation, commissioning and preliminary testing.

FIGURE 98. SSSSK TECHNOLOGY PROCESS FLOW



Funding and financial outlook

The 18 MW co-generation unit was established at a capital cost of USD 20.8 million. The distillery unit was established at a capital cost of USD 4.4 million. The biogas unit was established at a capital cost USD 0.53 million. The investment for these units was funded predominantly through debt with approximately 5% equity contribution. The loans were obtained under the Sugar Development Fund established by the government, which provided concessional term loans at 4% interest rate and up to 8–10 years duration, and the Maharashtra State Cooperative Bank, which offered standard term loans at market rates. SSSSK has not faced any significant challenges in raising funds to meet its investment needs.

Apart from the revenues from sales of sugar, the revenue streams of SSSSK include sales of electricity from its co-generation unit and alcohol from its distillery unit (Table 27). Out of the 18 MW power generated by the co-generation unit, 15.8 MW is exported to the state electricity grid by way of a

TABLE 27. REVENUE STREAMS OF SSSSK

REVENUE STREAM	QUANTITY	AMOUNT (MILLION USD/YEAR)
Sale of electricity	15.8 MW	7.45
Sale of alcohol	5,000,000 L	4.27

long-term power purchase agreement at a pre-determined incentive tariff of 0.096 USD/kWh. The market price for ethanol has been fixed by the government at 0.5 USD/L, whereas the price for other grades of alcohol could be as high as 0.8 USD/L. In the case of pharmaceutical companies, although the demand is small and not regular, the rates could range from USD 1 to USD 2 per litre.

The operating and maintenance cost for the first year is assumed to be 2.5% of the capital cost. The input cost of bagasse is 36.6 USD/ton. The payback period for the co-generation unit is five years, assuming six months of operation and 100% off-take of the surplus energy generated by the state electricity utility. The payback period for the distillery unit is three years. The CERs from such projects can be sold to international emission reduction buyers generating additional revenue.

Socio-economic, health and environmental impact

In addition to the livelihood provided to over 20,000 farmer members and employment opportunities within the factory to over 150–200 staff, SSSSK has been largely responsible for the socio-economic development in the immediate vicinity. SSSSK provides advice and support on sugarcane cultivation to its farmer members, such as nutrient management, irrigation management, pest control and access to subsidized seeds and fertilizers. SSSSK has also improved the quality of the basic infrastructure such as roads, access to healthcare and education. SSSSK has established six schools, a junior college and a professional science college, which provides preferential admission and reduced fees (50%) to the children of its farmer members.

Moreover, the whole process results in CO_2 offset due to use of non-fossil fuel for electricity generation as well as for transportation. The blending of renewable ethanol in petrol reduces vehicle exhaust emissions and also reduces import burden of the country. The Indian project promoters can sale the CERs internationally and ensure additional financial benefits every year. However, there are also potential environmental costs associated with the operation of the business such as issues related to water usage and flue gas emissions from the boiler. The water requirement for the entire operation, at 130 m^3/hr, is quite high and has posed some challenges on account of insufficient release of water from dams/irrigation canals, especially during poor monsoon seasons, due to competing use for irrigation. Another issue is with respect to the flue gas emissions and fly ash from the boiler. These emissions are controlled within acceptable limits with suitable equipment.

Scalability and replicability considerations

The key drivers for the success of this business are:

- Electricity shortage and concurrent government support mechanisms such as provision of concessional loans and feed-in-tariff mechanisms.
- Government regulations stipulating alcohol blending for fuel.
- Securing of long-term power purchase agreements.
- Consistent supply of input for energy producing units as SSSSK is vertically integrated.

SSSSK is an example of the implementation of well-established and mature technologies in the sugar manufacturing industry. These technologies enable the organization to improve the efficiency of the process, reduce waste and improve the overall economics of the entire operation. This business case also highlights the advantages of a cooperative ownership structure, which leads to significant socio-economic benefits for the local community. SSSSK operates in a highly-controlled and regulated environment, which poses some challenges so far as scaling up prospects and profitability is concerned, but the profitability has been enhanced through investments in cogeneration and distillery units which have been made possible through concessional sources of finance and feed-in tariff schemes available through mechanisms established by the government. This business has the

potential to be replicated in other similar sugar factories in the state, within India and other countries where there already exists some infrastructure such as a sugar manufacturing company, and the co-generation, distillery and biogas plant could be initiated as a plant within the sugar factory. In order for this business to be replicated in other countries, government support mechanisms are essential.

Summary assessment – SWOT analysis

Key strengths of the business are its application of well-established technologies, which enabled the business to be energy self-sufficient as well as diversify its revenue streams (Figure 99). However, the processes are water intensive and the profitability of the energy producing units depends on government incentives. The latter is not an immediate threat as government support for renewable sources of energy is likely to increase. Fluctuating sugar prices which may force sugarcane growers to shift to other crops and competition from other sugar producing countries such as China and Brazil threaten SSSSK. The energy producing units might result in reduction of GHG emissions, and this presents opportunities for SSSSK to earn carbon credit sales by registering the business as a CDM project.

FIGURE 99. SWOT ANALYSIS FOR SSSSK

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Power purchase agreement ▪ Well-established and mature technologies ▪ Diversified revenue streams ▪ Zero-waste process ▪ Reliable sustainable and self- sufficient energy ▪ Vertically integrated ▪ Business arrangement allows competitive pricing ▪ Implied social benefits	**WEAKNESSES** ▪ Significant water requirement ▪ Dependent on government incentives ▪ Inadequate capacity of various players including sugar mills, financial institutions and regulators ▪ Slow adaptation of modern technologies and modernization of old sugar mills ▪ Weak management of existing facilities
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Demand for electricity is growing and government support for energy from renewable sources is likely to increase ▪ Opportunity for registering the project as a CDM and earn additional revenues from sales of carbon credits ▪ High value products for downstream industries ▪ Huge potential to increase productivity of sugarcane and sugar recovery rate	**THREATS** ▪ Fluctuating sugar prices may force sugarcane growers to shift to other crops and decreasing sugar prices may disrupt business ▪ Competition from other sugar producing countries (China, Brazil) ▪ Competition from fossil-fuel-based energy ▪ Insufficient availability of water from dams due to competing uses for irrigation may pose risk of production stoppage ▪ Ethanol production an uncertain venture due to complex sales tax ▪ Procedural delays of ERCs, SEBs and other agencies ▪ Reduction in yields of sugarcane due to single crop cultivation with overuse of fertilizers and pesticides ▪ Poor financial health of power distribution companies

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Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflect our best knowledge at the time of the assessments (2015–2016). As business operations are dynamic, data can be subject to change.

CASE

Combined heat and power from agro-industrial wastewater (TBEC, Bangkok, Thailand)

Louis Lebel and Krishna C. Rao

Supporting case for Business Model 8	
Location:	Bangkok, Thailand
Waste input type:	Wastewater from agricultural industries (starch, palm oil and ethanol)
Value offer:	Build, Own, Operate and Transfer (BOOT), one-stop shop to treat agro-industrial effluent and generate electricity from biogas and CER certificates
Organization type:	Private
Status of organization:	Founded in September 2003
Scale of businesses:	Large – TBEC has processed 6,200,000 m^3 of wastewater/year, generated 38,360,000 Nm^3 of biogas/year, and 26,500,000 kWh of electricity/year by multiple projects
Major partners:	The Private Energy Market Fund (PEMF), Finland and Al Tayyar Energy (ATE), Morocco (Head office in the United Arab Emirates) (provided investment) and Provincial Electricity Authority (purchased electricity)

Executive summary

Thai Biogas Energy Company (TBEC), founded in 2003, is a one-stop shop for premium biogas Build Own Operate and Transfer (BOOT) projects with strong emphasis on high biogas yield, safety, quality of construction and quality of its human resources. It has implemented a number of biogas projects in Southeast Asia to treat effluents from agro-industrial units, such as palm oil and cassava processing plants. The biogas generated from treating wastewater is used to generate electricity, which is sold to the Thai electricity grid via a provincial electricity authority. Some projects have also received carbon credits for contributing to reductions in GHG emissions. These credits are purchased by companies in Europe. The treated wastewater also has useful mineral and nutrients for plants and is sometimes reused to irrigate rubber trees, or more typically released into public canals. Through its business model, TBEC's investment results in employment of local labor for biogas plant construction. TBEC also shares its revenue, technology and expertise with the host company and provides training to facilitate easy transfer of the project at the end of BOOT period. Since 2016, TBEC has been managed

by Asia Biogas Group. It has 8 power plants in Thailand and 1 in Lao PDR. TBEC projects produce 44 million m^3 of biogas or 88 GWh equivalent of biogas annually, and reduce greenhouse gas emissions by 320,000 tCO_2e per year.

TBEC is certified ISO 9001, ISO 14001, and follows the guidelines of the International Finance Corporation (IFC) of Thailand on global warming. TBEC is the market leader in the Mekong area for biogas projects for cassava wastewater in Rayong, Kalasin, Saraburi in Thailand, and for the palm oil and rubber industry in Surat Thani. The TBEC Tha Chang Biogas Project won many awards, including Best Biogas Project in Asia Selling Electricity to the Grid at the ASEAN Energy Award in 2010, the Crown Standard from the Thailand Greenhouse Gas Management Organization (TGO) and the designated national authority (DNA) of Thailand and Gold Standard by the World Wide Fund.

KEY PERFORMANCE INDICATORS (AS OF 2013)						
Land:	Land is provided by concessionaries/industry owners					
Water requirements:	Most is 'wastewater' output – 25,000 m^3 of treated wastewater/day					
Capital investment:	Highly project-specific depending on scale, location, labor and benefit sharing arrangements with concessionaires, but as an illustration installing a 1.4 MW biogas power plant involves investment costs of approximately 3.5–3.9 million USD in 2008					
Labor:	116 full-time employees (including O&M of multiple plants)					
Output:	25,000 m^3 of treated wastewater/day; Across several projects, TBEC has processed 6,200,000 m^3 of wastewater/year, converted 97,250,000 kg COD/year into around 38,360,000 Nm^3 of biogas/year, 26,500,000 kWh of electricity/year and 250,000 tCO_2e/year of CERs					
Potential social and/or environmental impact:	Reduced dependence on imported fossil fuels for power generation; CO_2 emission reduction; local jobs in construction of plant; skilled jobs in operation and maintenance; reduced nuisance odors and water pollution					
Financial viability indicators:	Payback period:	N.A.	Post-tax IRR:	N.A.	Gross margin:	N.A.

Context and background

Recognizing the need to reduce GHG emissions to mitigate climate change, TBEC promotes use of cost-effective and environmental-friendly renewable energy such as biogas generated from agro-processing wastewater. TBEC have hired Waste Solutions Ltd, a New Zealand firm of technology developers and consulting engineers, to design the plants. TBEC adopts a BOOT model, bringing in investment to set up biogas plants that treat wastewater from agro-industry factories that provide land and inputs. TBEC finances, designs, constructs, operates and maintains the plant until BOOT term expires. TBEC recovers its costs by producing electricity and selling it to a provincial electricity authority. Training is provided to help the host company after transfer of project. The business has operated projects in Thailand and in Lao PDR and is developing ones in Myanmar, Cambodia and Vietnam. The TBEC has installed and is operating six projects at starch units and three projects at palm oil mills. Examples of plants installed and operated by TBEC include Rayong, starch plant (15,000 m^3/day biogas, 1.4 MW of power); Kalasin, starch plant (30,000 m^3/day, 2 MW); Saraburi, high fructose syrup from cassava (25,000 m^3/day and 1 MW in Lao) and Thachang project at palm oil mill and concentrated latex plant (35,000 m^3/day and 2.8 MW). The Thachang project has targeted CO_2 emission reduction of 51,823 tons/year. The construction of the Thachang project started in January 2007 and commissioned in November 2008. Operation started in January 2009, and registration with UNFCCC was in September 2010.

TBEC raised finance from the Private Energy Market Fund (PEMF) in Finland and Al Tayyar Energy (ATE) in Morocco for setting up these plants. PEMF is a private equity fund for alternative energy development and power conservation. It holds about 70% of TBEC. Al Tayyar Energy (ATE) is a clean power development and investment company founded by HRH Prince Moulay Hicham Ben Abdallah Al Alaoui of Morocco. It has head office in the UAE. The company primarily focuses on bio-energies, such as biofuels, biogas and biomass. It also invests in solar, wind and hydroelectric project companies.

Market environment

Thailand is the world's third largest producer of crude palm oil and has one of the largest tapioca processing industry. Most agricultural production processes have significant amounts of organic residue output as a by-product. There are also many underutilized agro-processing waste sources not only in Thailand but also around the region. Due to increasing pressure to reduce GHG emissions, such agro-processing units, the customers of TBEC are looking for ways of treating wastewater from such processing of agricultural products including palm oil or starch from cassava. The waste-to-biogas and power business of TBEC contributes to greater use of renewable energy, allowing the firm to make a profit by selling electricity at preferential prices, as well as carbon credits while improving the environment. The electricity generated is directly sold to the grid of the Provincial Electricity Authority (PEA). Electricity demand is expected to continue to grow over the coming decades despite significant efforts in improving efficiency. Electricity prices are regulated by the government to ensure electricity is priced at a rate which is accessible to both residential and industrial users.

With high quality and safety standards, TBEC is a premium product company with around 10 competitors. For instance, Asia Biogas Company Ltd, Prapob Company and several other newcomers. Most of the new enterprises contract for construction of biogas plants and do not invest and operate the plant. As of 2008, 21 CDM projects in the palm-oil sector were registered with the Thai Greenhouse Gas Management Organization (TGO). The number of approved CDM projects in Thailand is still limited due to the high level of burdensome bureaucratic procedures involved.

Macro environment

The fossil fuels account for 80% of the total energy supply in Thailand. The Government of Thailand targets to increase the share of alternative energy from 6.4% at present to 20.3% of commercial primary energy by 2022, as per the Renewable Energy Development Plan. To achieve the above targets, the Government of Thailand supports the projects by several incentives such as subsidization, soft loan, tax incentive, Board of Investment (BOI), Energy Service Company (ESCO) Fund, CDM, adder cost, etc.

Thailand, with its abundant and varieties of biomass and agricultural wastes, has the great challenge and opportunity for the waste-to-energy projects to supply renewable energy-based electricity. Thailand's Ministry of Energy estimates that the potential of power generation in Thailand from biomass, MSW and biogas is 3,700 MW. Bio-based renewable energy (RE), such as agricultural residues, crops, biogas from biomass and wastes, MSW and biofuels, has shared in a large portion of RE more than 90% of potential RE in Thailand. For example, with 64 palm-oil mills, Thailand had a potential of more than 5 million m^3 of biogas/year from palm oil mill effluent (POME) that can generate more than 50 GWh of electricity/year.

Business model

TBEC develops, designs, finances and operates biogas projects on a Build-Own-Operate-Transfer (BOOT) while the concessionaries provide land and inputs and operates the plant after expiry of BOOT period (Figure 100). The BOOT period is flexible and depends on type and characteristics of individual

FIGURE 100. TBEC BUSINESS MODEL CANVAS

KEY PARTNERS
- Wastewater producers
- PEMF, Finland
- Al Tayyar Energy, Morocco
- Provincial Electricity Authority

KEY ACTIVITIES
- BOOT biogas projects
- Selling the biogas to the boiler for drying process
- Selling renewable electricity
- Marketing carbon offsets
- Producing and selling fertilizer (future option)
- Training BOOT customers as part of quality services

KEY RESOURCES
- Wastewater
- Land
- Capital
- Skilled labor
- Experienced top management team
- Technology
- Government policies
- Longer-term agreements with suppliers
- Long-term power purchase agreement with the Electricity Authority

VALUE PROPOSITIONS
- Wastewater treatment for agro-industries through well-serviced BOOT model
- Renewable electricity supply to the Thailand state electricity
- Carbon offset generation
- Organic fertilizer (future option)

CUSTOMER RELATIONSHIPS
- Agreements with agro-industries
- Direct PPA with PEA
- Direct with carbon trading markets

CHANNELS
- Direct to biogas plant from the host company
- Connect to national grid
- Carbon trading markets

CUSTOMER SEGMENTS
- Agro-industry that process cassava, palm oil or ethanol
- Provincial electricity authority
- European institutions purchasing carbon offset
- Farmers (future option) needing fertilizer

COST STRUCTURE
- Infrastructure investment (high)
- O&M cost (high)
- Training

REVENUE STREAMS
- Sale biogas to the host company for drying process
- Sale of electricity to provincial electricity authority
- Sale of CO_2 offset through CDM
- Sale of fertilizer (future option)

SOCIAL & ENVIRONMENTAL COSTS	SOCIAL & ENVIRONMENTAL BENEFITS
• In case of leakage of gas, there are consequences to the environment	• Jobs creation • Indirectly increase income to the farmers • Reduce the odor of the wastewater • Environmental benefit through reduced CO_2 emissions by generating electricity from renewable source and reducing pollution (fossil fuels substitution)

projects. It normally takes between 15 to 17 years before the transfer is made to the host company. Thus, key customers are the agro-industrial unit and the entity purchasing electricity which is the Provincial Electricity Authority (PEA) in Thailand. TBEC's unique selling point is quality of product and service, appealing to higher-value markets.

Value chain and position

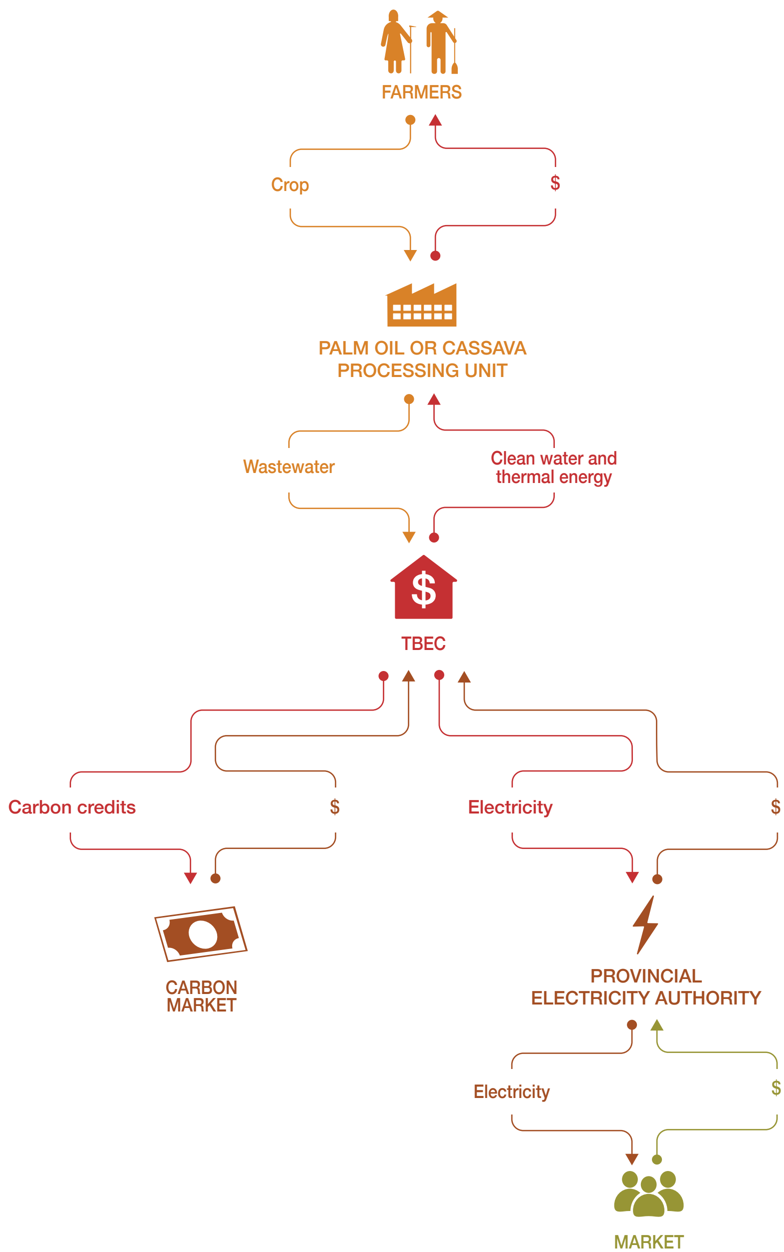
Figure 101 describes the relationship between some of the key value chain actors in a typical TBEC project. TBEC treats wastewater from agro-processing units (like palm oil) to generate electricity. The major supplier of the plant's raw material is the agro-industry with which TBEC has an agreement to treat waste from the process. Threat to supply of effluent does not exist due to such agreements. The biogas it generates from treating wastewater is used to produce electricity, which is sold to the Thai electricity grid. TBEC has a PPA with the electricity authority, and thus threat of buyer power is low. Electricity as well as thermal energy (heat) could also be sold back to host agro-processing units directly under energy purchase agreement. Carbon credits may be purchased by companies in Europe. The BOOT agreements cover sale of concessions to partners. Thus, the specific role of TBEC in a project can be substantial over time and has certain challenges. Biogas power plants are quite complicated and require careful supervision. Unprofessional management can reduce cost-effectiveness and increase risks. Seasonality of biogas production can cause trouble with production planning.

TBEC develops a project under CDM to obtain CERs and successfully completed United Nations Framework Convention on Climate Change (UNFCCC) registration of all its projects as CDM projects. For example, the actual GHG emission reductions or net anthropogenic GHG removals by sinks achieved during the period of January 1, 2013 to December 31, 2014 were 91,678 tCO_2e against the estimated amount of 51,823 tCO_2e for Thachang project. The examples of the biogas yield from different dry substrates are as follow: 200–400 m^3/ton of cattle manure and dung, 250–450 m^3/ton of pig and chicken dung, 350–700 m^3/ton of energy crops and 700–900 m^3/ton of POME (FNR, 2007 and 2009). A value-added option is to turn the biogas into green gas by removing CO_2 and other gaseous components (H_2S, H_2O) content and increasing the percentage of methane. Compared to the biogas, the green gas and natural gas contain 29% more methane.

Institutional environment

Thailand is one of the first countries in Asia to have a policy to encourage biofuels, cogeneration, distributed generation and the generation of power from renewable energy. Co-generation and the production of power from renewable energy is implemented under the Small Power Producer Program (SPP) of 10–90 MW capacity and Very Small Power Producer Program (VSPP) of less than 10 MW capacity. It became a very effective policy instrument in promoting investment in renewable energy and co-generation. Private power producers sell electricity to the electric utilities under power purchase agreements at a price determined based on avoided cost or users located nearby. The VSPP has a more

FIGURE 101. TBEC VALUE CHAIN



lenient set of requirements and less complicated power purchase arrangement of 'net metering'. The SPP and VSPP regulations have been amended to be more investor-friendly and practical, including changes to the criteria for qualifying facility, calculation of the avoided cost and interconnection requirements. In addition, the government also launched a program to encourage the renewable energy SPPs by providing an additional tariff for a period of 5–10 years from the Energy Conservation

Fund. The "adder" was determined through a competitive bidding system, which resulted in approval of 14 projects with average "adder" of 0.18 baht per kWh (US¢ 0.56), representing approximately 5% increase from the normal tariff. Financial incentives through soft loans and investment subsidies were expanded in amount and coverage for selected types of renewable energy projects, in particular biogas in pig farms and factories producing tapioca starch, palm oil, rubber sheet, ethanol and other types of agro-industry, municipal wastes and micro hydro. This has given an enormous boost to a number of marginal projects, particularly biogas and municipal waste projects.

The PEA is a government enterprise with prime responsibility concerned with the generation, distribution, sales and provision of electric energy services to the business and industrial sectors, as well as to the general public in provincial areas, with the exception of Bangkok, Nonthaburi and Samut Prakran provinces. The PEA has expanded electricity supply to all areas covering 73 provinces, approximately 510,000 km^2, accounting for 99% of the country's total area.

Technology and processes

TBEC applies a robust, flexible and highly productive Covered Lagoon Bio-Reactor (CLBR) technology suitable for changing volumes and quality of wastewater discharged from industrial factories. Wastewater passes through an anaerobic digestion process through which organic substances such as proteins, carbohydrates and fats are digested by bacteria in a suitable environment and are finally transformed into biogas. The CLBR has uniquely designed mixers, baffles and a thick high-density polyethylene (HDPE) cover with optimized contact with anaerobic bacteria to convert organic matter into biogas. Temperature is a key factor in planning a covered lagoon. Warm climates require smaller lagoons and have less variation in seasonal gas production. Cover materials must be: ultraviolet resistant; hydrophobic; tear and puncture resistant; non-toxic to bacteria and have a bulk density near that of water. The recovered biogas can be used to produce space heat, hot water, cooling or electricity. The biogas is collected in pipes, cleaned and stripped of condensate, dust and hydrogen sulphide and compressed and fed to dedicated biogas engines if used for power generation. The GE Jenbacher engine is designed specifically for gas applications and is characterized by particularly high efficiency, low emissions, durability and high reliability. The engine is designed with a knock control system which increases reliability and availability through control of firing point, output and mixture temperature. The engines gas mixer has been optimized to meet the requirements of modern gas engines and ensure trouble-free operation with biogas. In case of any excess build-up of biogas, the surplus gas will be combusted or flared. The effluent released from the digester is either recycled or sent to a small settling pond where sediment is settled and returned to the digester. The treated waste leaving the treatment system boundary is then pumped to existing water treatment lagoons.

A typical 200 tons-per-day starch factory can produce as much as 25,000 m^3 of methane (4.5 MW) from the cassava wastewater and 16,000 m^3 of methane (2.8 MW) from the cassava pulp. This is equivalent to 40,000 L of heavy fuel oil (HFO) per day or can be used to produce up to 7.3 MW of electricity per hour. Some of the areas of focus for new development are reactor configuration, process control, modelling and optimization for improving biogas yield; use of other feedstock such as solid residual, and energy crops; pre- and post-treatment for digestibility improvement and nutrient recovery; improved biogas clean up processes and upgrading biogas to high value/rich methane gas for fuel cell, vehicle, CNG, etc.

Funding and financial outlook

The investment costs covering project development, design, construction and start-up system depend on the size, location and duration of contract for individual projects. The major investment costs are plant machinery/equipment with minor cost of building and small cost of engineering services

and other infrastructure. It should be noted that land and material costs are covered by concession partners. Historically, a key constraint has been reluctance of Thai domestic financial institutions to finance waste-to-energy products. Most financial institutions still define waste-to-energy business as a high-risk business. Unfamiliarity and trust that carbon credits can be saleable to European countries is part of the explanation. For that reason, partners invested their own money in order to initiate the business in 2003. At present, some Thai financial institutions offer refinance since they now realize the business potential.

The main revenue streams are from the sale of biogas and electricity and construction and maintenance under BOT schemes. Carbon credits are still relatively modest. Overall conditions that effect revenue streams include government policies, seasonality and prices. Seasonality is important as unusual seasons or weather conditions have an impact on inputs to the commodity processing factories that, in turn, produce wastes that are turned into energy. Table 28 shows the indicative cost structure of operations expressed in terms of approximate percentage of annual investment cost.

TABLE 28. OPERATIONAL AND MAINTENANCE COSTS OF TBEC

COST ITEM	OPERATIONS COSTS AS A % OF INVESTMENT COST
Equipment (depreciation)	*Approx. 65%*
Labor	*Approx. 10%*
Maintenance	*Approx. 15%*
Electricity	*Approx. 5%*
Building	*Approx. 5%*

The financial parameters of the typical project (based on Thachang project) are as follows:

1)	Capacity of plant	2.8 MW
2)	Term of BOOT contract	10 years
3)	Investment cost	USD 3.9 million
4)	O&M cost	USD 0.2 million
5)	Electricity sold to grid per year	9,644 MWh
6)	Average tariff per kWh	USD 0.076
7)	Escalation in O&M cost per year	2%
8)	Increase in tariff per year	2%
9)	Average CERs per year	48,694 tons
10)	IRR (without CERs)	4.44%
11)	IRR (with CERs)	20.60%

Socio-economic, health and environmental impact

The project will create an indigenous renewable electricity resource, replacing power from coal, diesel and natural gas, and will contribute to the development of the region, as well as national economy by reducing Thailand's deficiency of power and need to import fossil fuels. In terms of environmental benefits, the project reduces existing levels of pollutants in wastewater; air pollution; GHG with positive impact on the health of those living around the plant and mitigates global warming by trapping methane. TBEC hires local labor for the construction and operation of biogas plant. The project will directly create more than 10 new jobs, and thus increase stakeholder incomes. It will improve human capacity and diversity of employment opportunity by training project managers, lab technicians and operators.

Scalability and replicability considerations

Key drivers to the success of this business are:

- Strong partnership among different institutions – technology developer, agro-processing businesses and electricity authority and financing institutions.
- Ability to raise finance to set up effective BOOT schemes for various agro-industries.
- Expertise in biogas plant operation.
- The government policy and interest in promoting renewable energy based power.

TBEC already has experience in taking its technology and business model from core operations in Thailand into Lao PDR. TBEC is also in talks with agricultural enterprises in Vietnam and Indonesia to produce biogas from cassava. A bank overseas has already lent EUR 10 million (THB 416 billion) for new projects. They have replicated the model with multiple agro-industries. As the technology can process any organic matter, the business model has potential to reach out to municipalities to process the organic component in the MSW as well.

Summary assessment – SWOT analysis

The key strengths of the business are setting up of effective BOOT schemes, expertise in biogas plant operation and strong partnership with agro-industry (Figure 102). TBEC is branded as a premium

FIGURE 102. SWOT ANALYSIS OF TBEC

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Assured supply of wastewater due to secured rights ▪ Effective BOOT scheme ▪ Strong partnership with agro-industry ▪ Expertise in biogas plant operation ▪ Securing of long-term power purchase agreement ▪ Highly robust technology	**WEAKNESSES** ▪ Complex biological processes ▪ High cost of technology ▪ Requirement of high skilled labor makes recruitment of staff difficult ▪ No immediate market for treated water ▪ Time taken for agreement and partnerships for every new project
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Environmental stress reduction offers environmental credit market opportunities ▪ Treated wastewater has potential for fertilizer due to the process ▪ Expansion potential to other agro-processing plants such as sugar, ethanol and liquor production due to highly robust technology ▪ Electricity demand is growing and need for renewable-energy-based electricity generation increasing in Thailand ▪ Good potential of foreign investment if the incentive policy is retained	**THREATS** ▪ Possible human health risk may lead to investment needs ▪ Possible risk from leakage of gas, thus having negative perception of health risk to employees may force O&M cost up ▪ Seasonality regards biogas production ▪ Volatility of international carbon market

product-service company as it puts more emphasis on quality and safety. However, the technology is high-priced and requires highly-skilled labor. There is no market yet for treated wastewater, but there is an opportunity to use the treated wastewater for agriculture. Growing electricity demand and application of the technology to other agro-processing plants such as sugar, ethanol and liquor production present opportunities for TBEC to expand.

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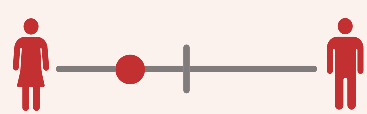
Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflects our best knowledge at the time of the assessments (2015/2016). As business operations are dynamic, data can be subject to change.

BUSINESS MODEL 8

Combined heat and power from agro-industrial waste for on- and off-site use

Solomie Gebrezgabher and Krishna C. Rao

A. Key characteristics

Model name	Combined heat and power from agro-industrial waste for on- and off-site use
Waste stream	Agro-industrial waste – Bagasse from sugar processing factories; Effluent (solid and liquid waste) from agro-industrial units like cassava starch, palm oil and slaughterhouse
Value-added waste product	Electricity, biogas, thermal energy, carbon credit, bio-fertilizer
Geography	Regions with larger agro-industries
Scale of production	Small to large scale 15 KW of power from slaughterhouse waste; 1.4 MW–2.8 MW of electricity annually from effluent from cassava starch and palm oil mills 12 MW–34 MW of electricity from sugar-processing factories
Supporting cases in the book	Mumais district, Kenya; Maharashtra, India; Bangkok, Thailand
Objective of entity	Cost-recovery [X]; For profit [X]; Social enterprise [ ]
Waste removal capacity	About 1.3 million tons of bagasse from crushing 3–4 million tons of sugarcane; 4,000 L/day of wastewater from slaughterhouse; 25,000 m^3/day of wastewater from agro-industrial units
Investment cost range	1.16–1.85 million USD/MW of electricity from sugar-processing factories 2–2.6 million USD/MW of electricity from agro-industrial effluent
Organization type	Private
Socio-economic impact	Reduce environmental pollution by substituting fossil fuel based energy (1.4–34 MW) and by providing better waste management/reducing effluent, reduce fossil fuel dependence, employment generation (5–200 jobs depending on scale)
Gender equity	Access to electricity to local community by replacing kerosene used for lighting resulting in clean working environment for women from clean indoor air 

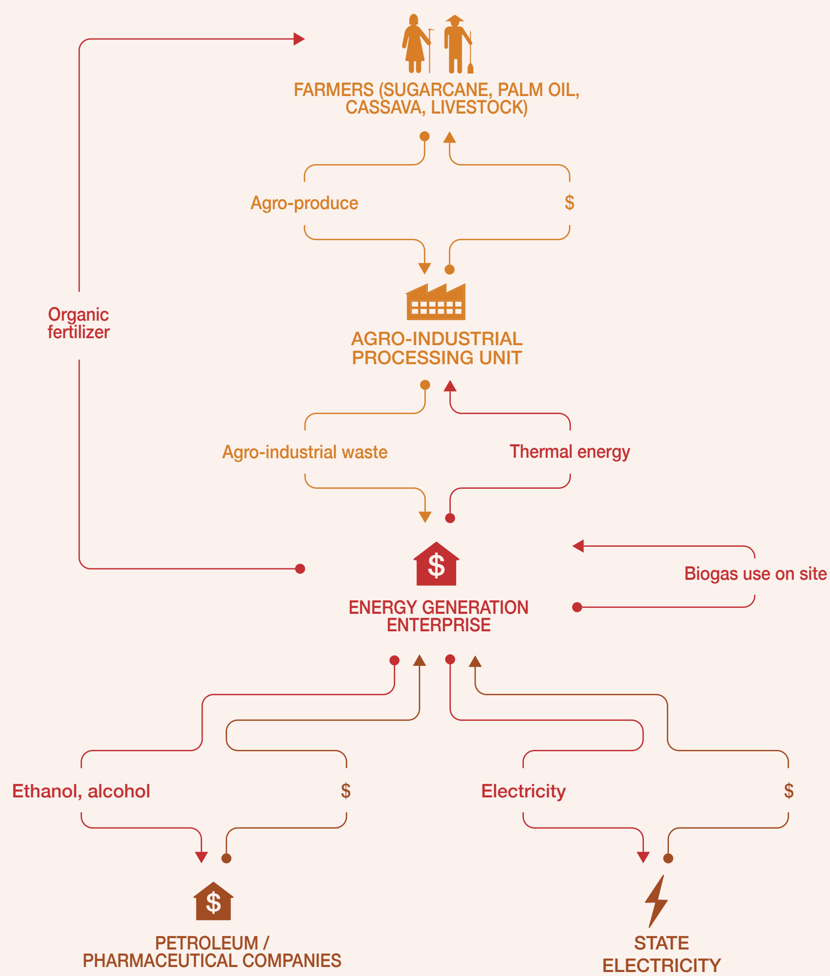
B. Business value chain

This business model can be initiated by industrial factories in order to create additional value and revenue by generating energy from their organic waste by-products. By-products include agro-industrial waste such as bagasse and molasses from sugar-processing factories, and wastewater from cassava, palm oil and slaughter-house industrial factories. The technologies applied and the resulting energy products vary depending on the type of waste processed. These include co-generation units to produce electricity and thermal energy, distillery units to produce ethanol/alcohol and biogas units

to produce electricity and thermal energy/heat. Production technologies such as combustion and covered lagoon bio-reactor are suitable for processing bagasse and wastewater to produce biogas. Figure 103 depicts the value chain for on-site energy generation from an agro-industrial waste business model. The electricity produced by the co-generation unit or by the covered lagoon bio-reactor is sold to the state utility on a long-term power purchase agreement. The alcohol/ethanol produced from the distillery unit of sugar-processing factories is sold to petroleum and pharmaceutical companies, while the energy produced by the biogas unit is used on-site as input fuel to the co-generation unit. The discharge from the biogas unit, which is high in organic matter, can be distributed to farmers to be used as bio-fertilizer.

The ownership and operation of the energy-producing units take different forms. The energy-production technologies are either designed, constructed, owned and operated by the factory or are installed by an external private enterprise on a BOOT model. In the latter case, the enterprise brings investment to

FIGURE 103. GENERIC VALUE CHAIN FOR COMBINED HEAT AND POWER FROM AGRO-INDUSTRIAL WASTE FOR ON- AND OFF-SITE USE MODEL



set up the energy production technology while the concessionaries i.e. the factories provide land and inputs. The enterprise designs, constructs, trains and maintains the energy production unit until the BOOT period expires, after which it assists the host company in operating the unit.

C. Business model

This business model involves processing of waste by-products from an agro-industrial factory in order to generate and sell electricity to the national grid through a long-term power purchase agreement (Figure 104). By-products are heat which can be fed back into the industrial process, resulting in energy savings, and ethanol which can be sold to petroleum and pharmaceutical companies. Additional revenue can be generated from registering the model as a CDM project and earning money from selling certified carbon emission reductions.

D. Potential risks and mitigation

Market risks: The outputs, electricity and alcohol (ethanol), are sold to different markets and hence face different market risks. The electricity is mainly sold to state electricity grid on a long-term power purchase agreement, while ethanol is sold to petroleum or pharmaceutical companies. The growing demand for electricity in developing countries reduces the market risks in terms of ensuring sales.

FIGURE 104. BUSINESS MODEL CANVAS – COMBINED HEAT AND POWER FROM AGRO-INDUSTRIAL WASTE FOR ON- AND OFF-SITE USE

KEY PARTNERS
- Out-growers
- State government
- Concessionaries
- Technology developers

KEY ACTIVITIES
- Build, operate, own and maintain energy producing unit
- Sales of electricity and ethanol
- Managing CDM process and obtain emission reduction credit

KEY RESOURCES
- Equipment
- Agro-industrial waste
- Technical and operational competencies
- Capital
- Power purchase agreement
- Improved farmers' productivity

VALUE PROPOSITIONS
- State utility obtain competitively-priced renewable electricity
- Petroleum, alcohol and pharmaceutical companies obtain alcohol and ethanol for blending
- Farmers obtain fertilizer rich in organic matter
- Tradable carbon credits to meet carbon emission reduction commitments

CUSTOMER RELATIONSHIPS
- Long-term contract
- Long-term contract
- Personal
- Dedicated web interface for registering CDM project online (Semi-automated)

CHANNELS
- Connection to state electricity grid
- Alcohol/ethanol purchase agreement
- Direct
- Carbon credit trading platform

CUSTOMER SEGMENTS
- State electricity grid
- Petroleum, alcohol and pharmaceutical companies
- Farmers
- Annex 1 countries

COST STRUCTURE

- Capital investment (co-generation unit, distillery and biogas unit)
- Input cost
- Interest on borrowed fund
- O&M
- Marketing for alcohol/ethanol sales
- Reduced operational costs from using own electricity and thermal energy
- CDM administration-related costs

REVENUE STREAMS

- Sale of electricity
- Sale of alcohol/ethanol
- Sale of compost
- Sales of carbon credit

SOCIAL & ENVIRONMENTAL COSTS

- Possible flue gas emissions and fly ash from boilers
- Significant water requirement
- Possible contamination of water source
- Possible human health hazard from direct contact to pathogens that may still exist from the organic fertilizer
- Laborers' health risk due to contact with agro-industrial waste
- Environmental risks from biogas leakage to the atmosphere

SOCIAL & ENVIRONMENTAL BENEFITS

- Climate change mitigation through use of non-fossil fuels
- Livelihood, advice and support to out-grower farmer members
- Creation of jobs
- Expanding access to electricity to local communities
- Reduced environmental pollution from waste effluents

However, in environments where the electricity sector is regulated and the state utility is the sole buyer, the bargaining power of the business producing and selling electricity will be medium. In such situations, the feed-in tariff policy announced by the government will protect the interest of the renewable-energy-based power producers. Ethanol/alcohol is sold to various industries and with the introduction of government requirements for ethanol blending of fuel, ethanol will have various buyers and less market risks. However, in countries where ethanol blending is not mandatory, the business will face competition from other fossil-based substitute products. In sharp contrast to the ensured sales of electricity to state utility, the carbon credit market is considered to be volatile and this puts the sustainability of the whole reuse business under risk if carbon credit sale is the major revenue stream. In such scenarios, the business has to diversify its revenue streams so as not to entirely depend on the sale of carbon credits.

Competition risks: The risk associated with output market is low. The electricity is sold to state utility on a long-term contract, and hence has a ready buyer. With the introduction of government requirement for ethanol blending, ethanol has various buyers and less competition risk. Competition risks exist in the input market. In the case of sugar-processing factory, the cogeneration units are designed to process only a specific kind of input, i.e. the by-product from processing sugarcane and its operations depend heavily on the continuous supply of sugarcane from its suppliers. In scenarios where the inputs are sourced from the sugarcane growers, the competition in the sugar commodity market will affect the decision of sugarcane growers. For instance, fluctuating sugar prices might force farmers to shift to other crops, and this will affect the operations of the cogeneration and distillery units of the sugar-processing factory. This risk can be mitigated by forming a cooperative sugar factory which is vertically integrated and owns the raw materials and agro-waste.

Technology performance risks: The technologies applied for processing agro-industrial waste from sugar-processing factories as well as for processing wastewater are well-established, robust and mature with high flexibility to changing wastewater volumes and quality. However, the technologies require skilled labor for construction as well as O&M of the plant.

Political and regulatory risks: With the projected electricity demand set to grow, governments are encouraging green power initiatives by putting in place various incentive mechanisms such as concessional loans, feed-in tariff mechanisms and through long-term power purchase agreements. Thus, the risk is fairly low.

Social-equity-related risks: The model is considered to have more advantages to women if excess electricity generated by these agro-industries is supplied either for rural electrification or fed to the grid. Since access to electricity to local community will help replace kerosene used for lighting resulting in clean working environment for women from clean indoor air. Modern energy access will also benefit the community from increased productivity. If the energy generated is used for agro-industries internal use, then the model is gender neutral. The social-equity risks from the model are limited; however, the agro-industry could consider under their corporate social responsibility to improve energy reliability in neighbouring community.

Safety, environmental and health risks: The environmental risks associated with co-generation units include possible leakage of gas and emission of flue gas and fly ash. These emissions should be controlled within acceptable limits by putting in place suitable equipment. The safety and health risks to human arise when processing waste from agro-industry, especially meat production. Proper mitigation measures should be put in place to protect laborers, farmers, consumers and surrounding communities (Table 29). Another issue is with respect to the water requirement for the energy-producing units. The water requirement can be high, and thus competes with uses for other purposes such as irrigation. This has important implications in terms of evaluating trade-offs for competing uses.

TABLE 29. POTENTIAL HEALTH AND ENVIRONMENTAL RISKS AND SUGGESTED MITIGATION MEASURES FOR BUSINESS MODEL 8

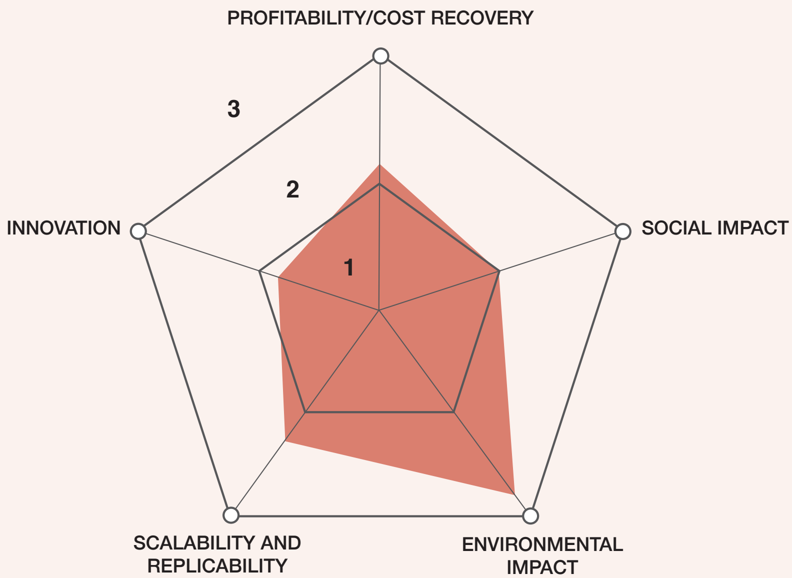
RISK GROUP	EXPOSURE ROUTES					REMARKS
	DIRECT CONTACT	AIR	INSECTS	WATER/ SOIL	FOOD	
Worker						Risks apply to the use of slaughterhouse waste, and its management, including fly control
Farmer/User						
Community						
Consumer						
Mitigation measures						

Key: NOT APPLICABLE · LOW RISK · MEDIUM RISK · HIGH RISK

E. Business performance

The business model scores high on environmental impact as it avoids environmental pollution from large agro-industrial factories and generates renewable energy on a large scale, substituting fossil-fuel-based energy sources, and thus resulting in reduced GHG emissions (Figure 105). This business model is scalable and replicable in countries where there are large agro-industrial factories and where there is government support such as provision of concessional loans and feed-in tariff mechanisms for renewable energy initiatives and government's directive on blending of ethanol with petrol/gasoline as transportation fuel. The ranking of other factors scores significantly low in comparison to environmental impact.

FIGURE 105. RANKING RESULTS FOR ON-SITE COMBINED HEAT AND POWER FROM AGRO-WASTE BUSINESS MODEL



6. BUSINESS MODELS ON EMERGING TECHNOLOGIES/ BIO-FUEL PRODUCTION FROM AGRO-WASTE

Introduction

There has been a significant effort to develop a potentially cost-effective process to produce bio-fuel from cellulosic sources. In our typology of waste covered in this book, important cellulosic sources could be identified for example in agro-industrial waste. Cellulosic bio-fuel sources have the potential to offer greater energy return on investment in comparison to grains (which might better support food security) while they provide environmental benefits by reducing dependency on fossil fuels.

The **Business model 9: Bio-ethanol and chemical products from agro and agro-industrial waste** described in this section highlights production of bio-fuel (bio-ethanol) from agro-industrial waste produced by mills processing cassava, rice, wheat, coffee and so on. The case examples are from Latin America (Venezuela and Mexico). One of the case highlights successful and economically-viable production of ethanol from residual plant waste (yare) associated with cassava flour production. Yare, the juice from the cassava pulp, is poisonous due to its cyanide content and requires proper waste disposal unless there are resource recovery options. The second case study shows a fuel recovery option from a waste generated during alcohol (ethanol) production.

For the presented model to work, since the technology is new and the business cases are in their nascent commercialization stage, it is critical that the patent laws are strong for safeguarding enterprises R&D efforts on the technology and incentives given to competing products such as ethanol from sugarcane or other sources are similar so as to provide a level playing field to all.

CASE

Bio-ethanol from cassava waste (ETAVEN, Carabobo, Venezuela)

Patrick Watson and Krishna C. Rao

Supporting case for Business Model 9	
Location:	ETAVEN, Carabobo, Venezuela
Waste input type:	Cassava waste
Value offer:	Bio-ethanol (as additive to petrol/ gasoline as transportation fuel)
Organization type:	Private
Status of organization:	Established in 2007, Business operational since 2012
Scale of businesses:	Medium
Major partners:	University of Carabobo, Ministry of Science and Technology, Libertador Municipality Mayor's Office

Executive summary

ETAVEN C.A. (ETAVEN) is a private Venezuelan company established in 2007 that has patented a process for producing ethanol "Yarethanol" using proprietary rights for the strain of bacteria for fermentation from yare, a by-product of cassava processing. Yarethanol is an ecological, non-fossil, non-poisonous, non-polluting and high demand, renewable fuel. It is produced at 50% of the market price through the patented process with a high yield of 50%.

ETAVEN is situated in the cassava-flour-processing region of Venezuela, which allows it to easily and cost-effectively purchase sub-optimal cassava that cannot be used for other commercial purposes, as well as residual plant waste (yare) associated with cassava flour production. By purchasing and using this waste, ETAVEN has had a significant positive impact on both the local community and environment, reducing the pollution associated with high cyanide run-off from improper disposal of cassava into local rivers and lakes, reducing GHG emissions and increasing the incomes of local cassava farmers by up to 50%. It has a very high social impact due to creation of jobs (>1,500 jobs) fostering agriculture. The company began Yaretanol production in the third quarter of 2012, and through franchise model, it seeks to expand its market beyond Venezuela.

KEY PERFORMANCE INDICATORS (AS OF 2012)						
Land use:	5 ha					
Water requirement:	8,000 L monthly (water is reused to wash cassava)					
Capital investment:	USD 2.5 million (Site utilized the existing infrastructure of a former sugar cane refinery)					
Labor:	50 plant employees; and 12 university volunteers to analyze and improve the process					
O&M cost:	Approx. USD 375,000 per annum (forecast 2013)					
Output:	30 tons/ day of Yaretanol					
Potential social and/or environmental impact:	Reduced water pollution previously caused by improper yare waste disposal into local rivers, reducing GHG emissions by substituting petrol used for transportation, creation of jobs, Improved incomes of approx. 300 local cassava farmers					
Financial viability indicators:	Payback period:	< 2 years	Post-tax IRR:	> 50%	Gross margin:	99%

Context and background

The cassava is one of the most drought-tolerant crops, capable of growing on marginal soils. The average yield of cassava crops worldwide was 12.5 t/ha in 2010. The cassava plant gives the third highest yield of carbohydrates per cultivated area among the crop plants, after sugarcane and sugar beets. The plant must undergo processing immediately after harvest (within 48 hrs) to remove compounds that generate cyanide. Yare is a regional name for the milky juice arising from pressing bitter cassava that has a high cyanide content. Venezuela produces 60,000 tons of yare per year which traditionally goes unused and improperly discarded.

Until now, the yare is not used in Venezuela as a source of ethyl alcohol (as bio-fuel). ETAVEN undertook research and laboratory experiments for two years and obtained 50% yield of ethanol from yare. Cassava is one of the richest fermentable substances for the production of alcohol. The fresh roots contain about 30% starch and 5% sugars, and the dried roots contain about 80% fermentable substances which are equivalent to rice as a source of alcohol. ETAVEN uses the sub-optimal cassava that cannot be used for other commercial purposes, as well as residual plant waste (yare) associated with cassava flour production. Cassava processing produces annually big quantity of wastes, and if they are not properly managed, they can cause a serious pollution to the environment and human life.

Ethanol has been known to slightly improve gas mileage. It has a high-octane rating of 113 and improves performance while keeping the engine clean. Ethanol also contains 67% more energy than it takes to produce, so it is efficient for your car and for the environment. An important advantage of biofuels is that they can easily be integrated into the existing transport infrastructure, thus avoiding the significant investment costs associated with other renewable options for the transport sector.

In 2008, ETAVEN patented an engineered yeast strain that efficiently produces Yaretanol or ethanol from yare. In early 2012, ETAVEN completed construction of its pilot ethanol plant and began producing ethanol in Q3 of 2012. It then produced approximately 30 tons of ethanol per day, roughly 1% of Venezuela's national consumption of ethanol. ETAVEN ethanol plant is located in Western Venezuela in the Libertador Municipality, which has a robust cassava processing industry, comprising more than 150 producers and over 300 farmers who supply cassava for bread making. However, small cassava roots or diseased plants cannot be used to produce cassava flour for bread, resulting in approximately 40%

of the local cassava going to waste. Unused cassava was traditionally discarded in local waterways (rivers and streams) where it was left to rot and release toxins. Yare is high in cyanide that can leach into the water supply, while plant decomposition releases methane into the atmosphere. ETAVEN procures yare from either farmers or cassava-flour-making units to produce ethanol, which is sold to oil companies in Venezuela to blend it with gasoline.

Market environment

Ethanol production from yare is dictated by both availability of yare and demand for ethanol. Cassava is the third most common source of food in tropical countries after rice and maize with total production reaching approximately 250 million tons in 2011, according to the UN. Within Latin America, Brazil is the dominant player, accounting for approximately 70% of regional production. Considering the high comparative ethanol yield from yare and that it can be used alongside food production, rather than competing with it, there is a significant opportunity in all cassava-producing countries to increase the potential incomes of cassava farmers.

Global consumption of ethanol has surged during the last 10 years, driven by greater environmental awareness, advances in technology that have made ethanol cost-effective and suitable for fuel and growing national interest in energy independence and security. Furthermore, government subsidies and mandates have driven ethanol's growing popularity. A number of additional countries have begun to require a minimum ethanol blend in gasoline. In addition, there has been significant public investment into the ethanol distribution infrastructure to accommodate this increasing production and demand. Global consumption of ethanol increased during 2002–2012 by approximately 500% reaching 1.4 million barrels per day, led by the U.S. and Brazil who accounted for over 85% of total ethanol production and consumption in 2012.

The two key sources of competition for Yaretanol are: 1) other ethanol producers and 2) the oil industry (for petroleum). Approximately 90% of the ethanol used in Venezuela is imported from Brazil at twice the price of Yaretanol, while 1% is produced by ETAVEN and the remaining 9% by other domestic producers. Other sources used to create ethanol are sugarcane and corn.

Though ethanol is a viable substitution of petroleum in combustion engines, it is used only if mandated by the government. In 2006, Petroleos de Venezuela S.A. (PDVSA), the Venezuelan state-owned oil company, announced their "Ethanol Agro-energy Development Project", a USD 1.3-billion initiative. To increase the production of ethanol, PDVSA plans to build 14 ethanol distilleries by 2012 with an output of 20,000 barrels per day of the biofuel. Venezuela imports ethanol to mix in gasoline. The plan's focus has been to double the amount of land used for sugarcane cultivation over the next five years competing with Brazilian sugarcane imports.

Macro-economic environment

ETAVEN is aware of potential obstacles from vested interests including the PDVSA (with their direct interest in sugarcane ethanol), the Government of Venezuela (due to reduction in tax revenue in dollars), importers of ethanol from Brazil and manufacturers of ethanol from Brazil. Hence, ETAVEN is planning to focus on expanding into Latin America (Costa Rica, Panama, Dominican Republic and Peru) and a number of African countries rather than expansion of their market locally. Many countries are striving for energy independence by way of biofuels that do not come from foodstuffs. Significant research has begun to evaluate the use of cassava as the ethanol biofuel feedstock. On December 22, 2007, the largest cassava ethanol fuel production facility was completed in Beihai in China, with an annual output of 200,000 tons, which would need an average of 1.5 million tons of cassava. In November 2008, China-based Hainan Yedao Group reportedly invested USD 51.5 million (£ 31.8 million) in a new

biofuel facility that is expected to produce 33 million US gallons (120,000 m^3) a year of bioethanol from cassava plants (https://en.wikipedia.org/wiki/Cassava; accessed 18 January 2018).

Business model

ETAVEN's key value propositions (Figure 106) is the production of bio-ethanol from yare for blending with petrol, in the process reducing environmental hazard of pollution of water bodies through leaching of cyanide and reducing in methane emission from natural decomposition. ETAVEN spent initial years in developing technology to process yare to ethanol. Once the technology was ready for commercial production, it formed partnerships to secure procuring of cassava and its by-products from farmers and cassava-processing mills. ETAVEN does not use any middlemen and takes direct responsibility of delivering ethanol to petroleum companies. There is potential for the business model to create additional value making cassava flour and selling cassava shells as animal feed.

Value chain and position

Yaretanol has higher octane rating than petrol as fuel. It is an octane booster and anti-knocking agent, reducing country's dependence on petroleum, source of non-oil revenue for the producing country, and reducing adverse foreign trade balance. ETAVEN has patented its technology and process of producing ethanol from cassava and yare (Figure 107). The company buys cassava directly from approximately 300 local farmers, who sell diseased or small roots unsuitable for use in bread making, or it buys yare produced during pressing for flour production from small-scale cassava flour producers. Both supplier groups provide ETAVEN with waste that cannot be sold or used otherwise; therefore, supplier power is relatively low. Cassava is delivered directly to the plant, while yare is collected by ETAVEN through its fleet of collection tanker trucks. ETAVEN also relies on about 12 university volunteers each month, who evaluate and monitor operations, as well as provide staff training and write key operating manuals.

ETAVEN sells its ethanol to two key clients, Venezuelan petrochemical companies Solven and Inproin. In the context of Venezuela, though the demand for ethanol is high, there is significant buyer power as oil and gas companies can choose whether or not to blend petrol with ethanol. It is yet not mandatory by the Government of Venezuela. If ETAVEN is able to supply consistently necessary amount to oil companies, the buyer power will remain lower as long as they are willing to blend petrol with ethanol. The primary substitute for Yaretanol is ethanol produced from other products, such as sugar cane or corn. It is unlikely that buyers have a propensity to buy ethanol derived from any particular feedstock; therefore, the threat of substitutes is relatively high. Yaretanol has the lowest production cost of USD 0.18 /L, in comparison to USD 0.35 for corn and USD 0.22 for sugarcane. Therefore, it is very competitive on a cost basis.

The ETAVEN can also use starch and ethanol as a base for biopolymers and plastic extract as a base for bio-combustibles. The fermentation by-products with other waste streams, including animal manure and human excrement, can further be anaerobically digested to produce biogas and biological fertilizers. The ethanol can also be used as cooking fuel using specially-designed efficient cook stoves. The project is recognized as CDM to generate carbon credits. The cassava peels can be used with livestock manure as inoculum to generate biogas.

Institutional environment

Though Venezuela is the fifth largest oil exporting country in the world and the industry is a significant source of wealth for the country, the Government of Venezuela has promoted ethanol as a substitute for lead additives in gasoline. The Government of Venezuela did express an interest in 2006 to expand ethanol production (from sugar cane). However, it has not as yet made it mandatory to blend for domestic usage. ETAVEN has patented its proprietary strain of yeast in Panama, since Venezuela exited

FIGURE 106. ETAVEN BUSINESS MODEL CANVAS

KEY PARTNERS

- Farmers and flour-mill processing cassava
- University of Carabobo
- Ministry of Science and Technology
- Libertador municipality mayor's office

KEY ACTIVITIES

- Marketing to petroleum companies
- Farmer training
- Collection of yare and cassava and its by products
- Making ethanol from yare

KEY RESOURCES

- Yare from farmers producing cassava and processing units
- Capital
- Skilled labor
- Patent-protected IP

VALUE PROPOSITIONS

- Production of bio-ethanol from yare for blending with petrol, and in the process reducing environmental hazard

CUSTOMER RELATIONSHIPS

- Direct interaction with petroleum companies

CHANNELS

- Direct supply to petroleum companies

CUSTOMER SEGMENTS

- Petroleum companies

COST STRUCTURE

- Investment cost (Land, building, machines)
- Operational cost (Raw material cost, fuel and products to clean cassava, labor, utilities and maintenance cost)
- Marketing cost
- Depreciation
- IP maintenance
- R&D
- Training

REVENUE STREAMS

- Sale of ethanol

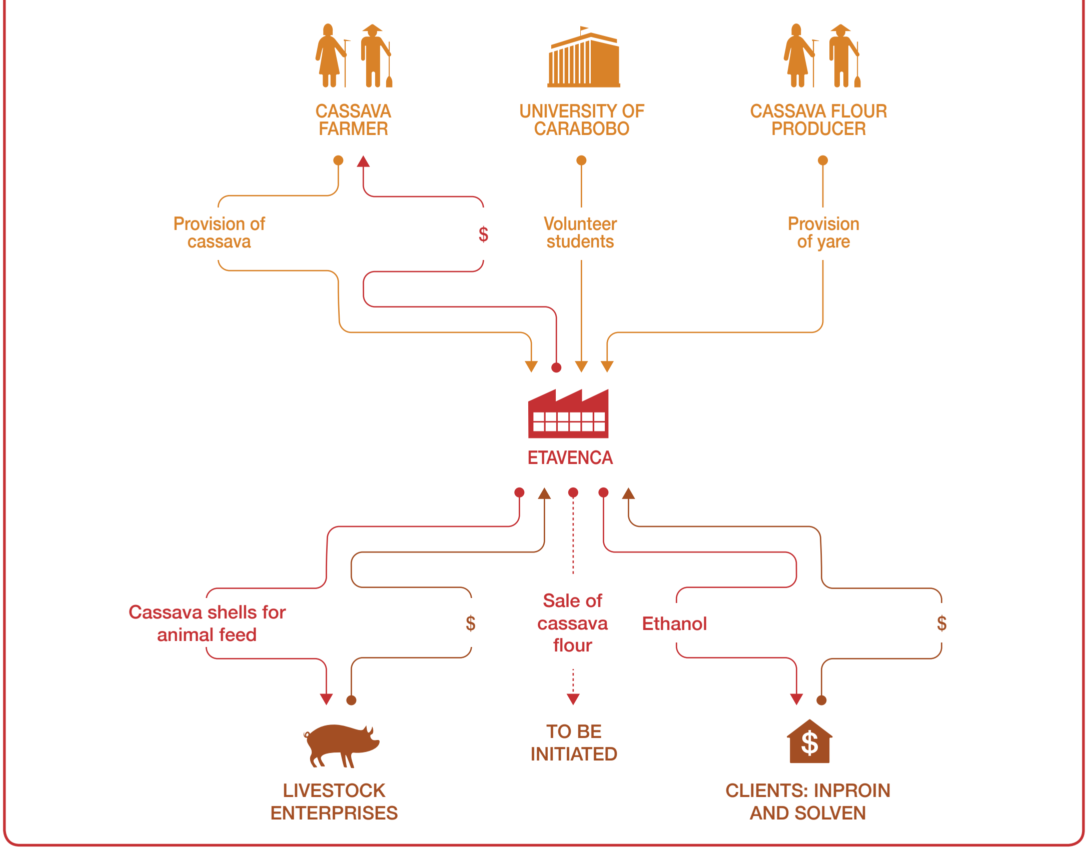
SOCIAL & ENVIRONMENTAL COSTS

- Potential cyanide exposure in local environment

SOCIAL & ENVIRONMENTAL BENEFITS

- Job creation
- Environmental benefit through processing of cassava by-product "yare" that can cause water pollution from improper disposal of cassava into local rivers and lakes
- Environmental benefit through reduced CO_2 emissions by using ethanol from renewable source blended into petrol

FIGURE 107. ETAVEN VALUE CHAIN

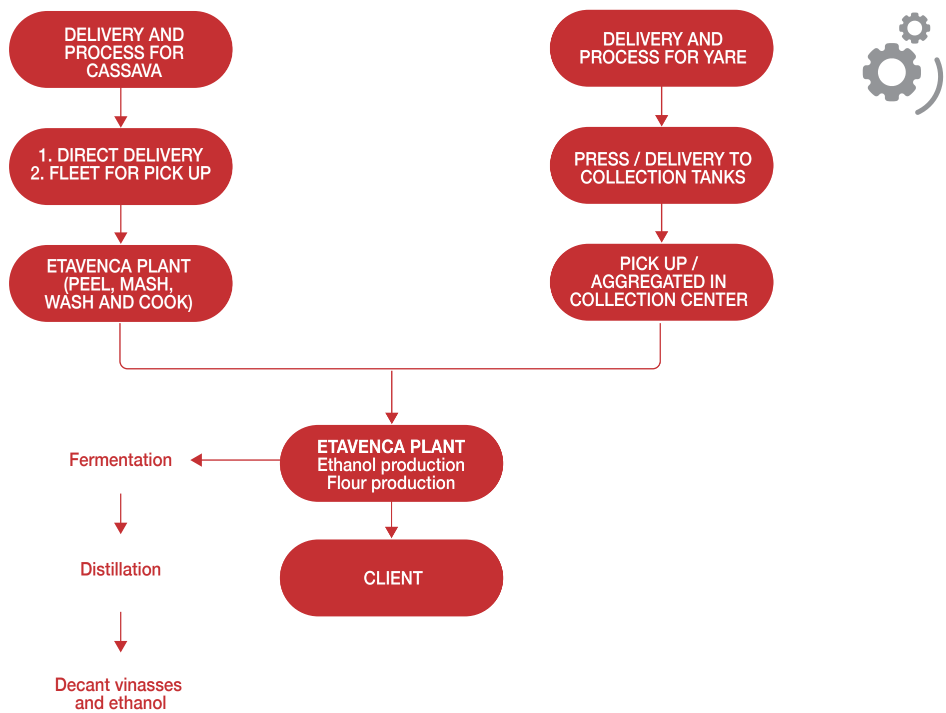


the Andean Community of Nations (CAN) in 2006, and thus, patents established in Venezuela cannot be legally enforced. Blends of E10 (petroleum with 10% ethanol added) or less have been mandated in over 20 countries, spearheaded by the US; however, a required blend has not been implemented yet in Venezuela. The National Council of Scientific and Technological Research (founded in 1967) and the state Ministry of Science and Technology direct and coordinate research activities in Venezuela.

Technology and processes

ETAVEN patented process for producing ethanol from the yare and cassava is as follows (Figure 108): ETAVEN receives two forms of feedstock: 1) yare from the cassava farmers that produce flour and 2) cassava directly from farmers. For cassava farmers that deliver yare, farmers are required to manually press the cassava to extract the liquid and deliver it to nearby collection tanks. ETAVEN owns a fleet of approximately 15 vehicles used to collect yare from each of its collection tanks that are situated near the farms and deliver to a collection center whereby it is aggregated and fed into the plant. In the case of cassava received directly from the farmers, ETAVEN receives the cassava through two different methods; 1) directly from the farmers delivering it to deposits at the plant or 2) utilizing their fleet of vehicles to pick it up directly from farms. For the collected cassava, it is peeled, mashed and then heated up with water to help with the conversion of the starch molecules into sugar, then strained. The cassava skin from peeling process is given away to be used for animal feed. The process of ethanol fuel production involves yeast fermentation of sugars, distillation and dehydration.

FIGURE 108. PROCESS DIAGRAM OF ETAVEN



The liquids extracted from cassava is fermented with the ETAVENCA strain of yeast in fermentation tanks and undergo distillation process which results in both ethanol and vinasses (residual waste left after distillation) being separated out. The resulting ethanol is then ready to be sold to clients, and the vinasses is treated and disposed. The yield of conversion is about 70–110 L of absolute alcohol per ton of cassava roots depending on the variety and method of manufacture.

There are other optional technologies available for treating cassava-processing waste (from small and large factories). These options include: landfilling, use as animal feed, ensiling of solid residue, fermentation of cassava peel, use of wastewater for irrigation, infiltration of wastewater into the soil, storage in aerobic or anaerobic lagoons and anaerobic digesters. One way is to build anaerobic and aerobic lagoons (ponds) to treat the waste before its disposal. In the condition of anaerobic digestion of cassava waste, cyanide is released in the form of liquor and then liberated by enzymatic and non-enzymatic reactions. This system is very effective and environmental sound but requires a large area of land and large capital investment and therefore is suitable only for the large processing plant. In case cassava processing is of small to medium scale, wastewater can be treated through channelling the waste into shallow seepage areas. The areas, however, should be situated away from natural water sources. Cassava-processing wastewater can also be effectively utilized as a liquid fertilizer, if it is well treated. However, if the waste is not properly treated resulting in its high HCN content that can have a negative effect on plant growth, the use of wastewater for irrigation or as a source of fertilizer should be restricted.

Funding and financial outlook

ETAVEN was established in 2007 by four founding partners who each invested approximately USD 650,000 for a total investment of USD 2.5 million (Table 30) to convert a former sugarcane refinery into the ETAVEN ethanol plant. Total cost was lower than the cost to purchase and restore a brown-field site, in part, because a number of the pre-existing fittings and equipment could be re-used. The most significant capital expenditure items after the land and sugar cane refinery were the four distillation towers, costing approximately USD 75,000 each.

The key production costs for ETAVEN are electricity and raw materials; however, both are low, allowing the company to achieve operating margins in excess of 85%. The feedstock is bought at nominal value (USD 0.02 /L) as it cannot be used for any other purpose, and ETAVEN effectively serves as a waste collection service improving conditions for surrounding farms. The most significant operational cost (approximately 45% in 2012) is for staff wages as the firm employs a substantial workforce of 50 employees. However, only 19 of those employees are officially recorded because the remaining 31 are considered temporary for legal purposes (both are included in the numbers below). From the remaining operational costs, the most significant line items are for fuel (approximately 14% in 2012) and products used to clean the cassava and disinfect equipment (approximately 17%). In addition, ETAVEN runs a significant education budget used to train the *cassaveros* (cassava farmers) in farming best practices and to train staff (approximately 12%).

Production began in June 2012 with monthly sales starting at USD 300,000 and increasing steadily throughout the year to USD 350,000 in December. ETAVEN is forecasting sales to continue growing strongly for the medium term, averaging about 50% growth per annum for the next three years. Due to the low cost of sales, ETAVEN achieved strong operating margins of 99% for the first six months of operation. The net profit margin is forecast to remain stable at about 56% over the forecast period as costs grow in line with revenues.

Socio-economic, health and environmental impact

ETAVEN estimates that their operations have improved the incomes of local cassava farmers and small-scale flour producers by up to 50%. The actual payments to farmers from ETAVEN for cassava and yare are minimal (USD 0.02/L). Therefore, their positive social impact has been primarily through

TABLE 30. ETAVEN FINANCIALS

SUMMARY FORECAST P&L						
USD	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Initial Investment	(1,000,000)	(1,000,000)	(500,000)			
Sales			2,287,161	4,190,891	5,573,885	8,249,350
Cost of Sales			(8,922)	(36,786)	(48,925)	(72,409)
Gross Profit			**2,278,239**	**4,154,105**	**5,524,960**	**8,176,941**
Operating and Financing Costs			(230,219)	(450,515)	(601,462)	(847,430)
Human Resources			(107,350)	(216,285)	(216,285)	(216,285)
Profit Before Tax			**1,940,669**	**3,487,306**	**4,707,213**	**7,113,227**
Tax			(659,828)	(1,185,684)	(1,600,452)	(2,418,497)
Net Profit			**1,280,842**	**2,301,622**	**3,106,761**	**4,694,730**
Payback Period from Yr 1 Revenues: <2 years						
IRR: 50%						

indirect channels. By improving the disposal of waste, local farming operations are perceived as more sanitary by larger cassava buyers, who are now willing to purchase cassava from small holder farmers previously viewed as unsuitable suppliers. In addition, through ETAVEN's educational programs for local farmers, small holders have learned to bypass intermediaries to sell their goods directly to buyers who offer higher prices. Finally, the collection and use of waste cassava (approximately 40% of total yield) and yare diverts substantial (approximately 60 tons per day) cyanide-rich waste from local water sources and reduces methane emission that results from the slow rot of cassava in public spaces.

Scalability and replicability considerations

The key drivers for the success of this business are:

- Patented technology and process for making ethanol from cassava and its by-products.
- Lower production cost of ethanol from cassava in comparison to other feedstock such as sugar cane and corn.
- Ease of access to cassava waste and no value or competition for procuring this waste.
- Underdeveloped national ethanol production, inviting price leadership.

ETAVEN's ethanol production process and sourcing model is highly scalable to developing markets where cassava is grown. Yaretanol production technology is relatively simple and cost-effective to implement, requiring only three key steps: extraction, fermentation and distillation before decanting the ethanol and vinasses. Furthermore, cassava is a hardy crop suitable for growth in arid, nutrient-deficient soil, making it popular in sub-Saharan Africa, where there is already a developed cassava industry. ETAVEN intends to franchise its process, targeting Central and South American countries in phase one and further rolling out to Africa and Asia in phase two. The largest potential untapped reserves of cassava are in Nigeria, Thailand, Brazil and Indonesia.

Cassava-to-ethanol plants have already been established in several countries, such as NDZiLO in Mozambique and TMO Renewables in China proving feasibility of the technology. In England, TMO Renewables announced they have advanced to demonstration scale on cassava stalk feedstock with major Chinese fuel and food producers. TMO is now processing an initial shipment of cassava stalk delivered from China, an inexpensive, abundant feedstock underutilized in 2G bio-ethanol. Improved efficiencies at TMO's 0.1-ha demonstration facility are projected to produce ethanol for less than USD 2 per gallon, marking a crucial step toward commercialization. Utilizing cassava stalk, TMO's conversion process will yield 70 to 80 gallons of 2G ethanol per ton of feedstock. The ETAVEN's business is capable of being reproduced at the international scale in tropical climates on the arid soils that are poor in nutrients.

Summary assessment – SWOT analysis

The key strength of ETAVEN is its simple process, low production cost and use of a feedstock that has hardly any other strong alternative uses (Figure 109). The weaknesses of ETAVEN are its unfavourable business environment and limited awareness on ethanol from cassava among policy makers. Due to the limited awareness, there is strong potential for policy makers to give priority for ethanol from sugarcane and corn. Therefore, ETAVEN has significant threat from other established producers of ethanol in its market shed. ETAVEN has strong opportunities to expand its market to other regions in developing countries where cassava is the staple food. In addition, it can further stabilize its business and increase its profitability by vertically scaling its business to capture value from both upstream and downstream parts of its value chain by getting into cassava-flour processing and selling of cassava shells as animal feedstock.

FIGURE 109. ETAVEN SWOT ANALYSIS

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Patented technology and process ▪ Relatively simple and cheap process to roll out ▪ Higher ethanol yield from cassava than any other commercially-used feedstock ▪ Uses sub-optimal feedstock thereby not competing with food production ▪ Plant is situated close to a cluster of flour mills and cassava producers helping to reduce operating costs ▪ Have achieved extremely high operating margins on pilot plant, therefore allowing considerable flexibility in potential costs for future expansion	**WEAKNESSES** ▪ Business model reliant on nominal value for purchased cassava; cost feasibility for international expansion would need to be assessed based on market prices ▪ Patented technology virtually invisible; difficult patent enforcement in case of infringement
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Potential of expansion in a number of other cassava-producing countries through franchising ▪ Significant potential for domestic expansion in Venezuela, assuming improved government support for all ethanol production (not just sugarcane) ▪ Potential for vertical scaling and having additional revenue source by getting into cassava-flour making and sales of cassava shells as animal feed ▪ Underdeveloped national ethanol production provides room for maneuver	**THREATS** ▪ Competition or entry into market from other, more established cassava-to-ethanol producers ▪ Domestic pressure from incumbent sugar cane refineries in Venezuela, and government bias toward sugarcane-based ethanol ▪ Unfavorable business environment in Venezuela for ETAVEN ▪ Limited awareness of cassava-to-ethanol opportunity among policy makers and governments who could further benefit from the technology

Contributors

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Cinthya Pajares, I-DEV International

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Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflects our best knowledge at the time of the assessments (2015/2016). As business operations are dynamic, data can be subject to change.

CASE

Organic binder from alcohol production (Eco Biosis S.A., Veracruz, Mexico)

Patrick Watson, Krishna C. Rao and Kamalesh Doshi

Supporting case for Business Model 9	
Location:	Veracruz State, Mexico
Waste input type:	Vinasse waste (from alcohol production)
Value offer:	Clean water and chemical additive (for cement)
Organization type:	Private
Status of organization:	Established in 2011, business operational since March 2013
Scale of businesses:	Pilot plant for Mexican domestic market
Major partners:	Client and supplier of vinasse for plant, Universidad del Medio Ambiente (UMA), Gecco Corp., Industrias ADVIEE, San Jose de Abajo distillery, BiD Network, Green Momentum, New Ventures Mexico.

Executive summary

Eco Biosis S.A (Eco Biosis) is a private Mexican company established in 2011 that has patented an innovative process for producing a chemical additive, an organic binder (BioDisperSis VC®) from the vinasse waste generated in alcohol production. It has launched its pilot factory in March 2013 in Veracruz Ignacio de la Llave in Mexico and is providing BioDisperSis VC® to the construction industry for use as a plasticizer in cement. The Eco Biosis plant is situated alongside an alcohol distillery that provides the vinasse waste remaining after sugarcane alcohol distillation. Eco Biosis receives the vinasse from the distillery free of charge because it offsets the cost of disposal. By utilizing the vinasse waste, Eco Biosis has a significant positive impact on both the local community and environment, reducing the pollution associated with run-off and improper disposal by the refineries into local rivers and lakes. Furthermore, all water extracted from the vinasse during the Eco Biosis process is fed back to the distilleries, thereby reducing overall water usage. This will help the distilleries to earn an environment-friendly enterprise certificate.

KEY PERFORMANCE INDICATORS (AS OF 2014)						
Land use:	Pilot Plant: approx. 300 m^2; Expansion plant: approx. 3,000 m^2					
Water requirement:	The water used in open circuit cooling system, cleaning system for evaporator and 2 t/hr steam and condensation system is recycled; small quantities of make-up water to recoup losses is used by the plant					
Capital investment:	Pilot plant: USD 150,000 for installation of rented equipment and other process equipment and capex (additional USD 700,000 required to buy the plant); Expansion plant (Q2 2015): approx. USD 1,200,000					
Labor:	Pilot plant: 12 full-time employees; Expansion plant: 14 full-time employees					
O & M cost:	Pilot plant: USD 123,000 per annum; Expansion plant: USD 900,000 per annum					
Output:	BioDisperSis VC® production; Pilot plant: 600 tons per annum; Expansion plant: 9,000 tons per annum					
Potential social and/or environmental impact:	Employment generation (for 12 employees in pilot plant, 14 in the expansion plant and up to 35 in stage 2 of expansion plant); Reduced water pollution (previously caused by improper vinasse waste disposal into local rivers); Reduced use of water by distillery (as water extracted from vinasse is returned to plants); Substitution of a non-eco-friendly product used today by the cement industry; Simplified logistics result in lower carbon footprint					
Financial viability indicators:	Payback period:	1.5 years	Post-tax IRR:	34%	Gross margin:	22%

Context and background

The alcohol industry in Mexico produces approximately 650 million L of alcohol per year. It also produces about 15–17 L of liquid waste, known as vinasse, for every litre of alcohol produced. Vinasse is the residual effluent left after distillation of the ethanol from fermented wines. It has a low solid content of less than 10% undissolved solids but high content of dissolved solids, organic matter and ashes and has high viscosity, very acidic pH (3.5–6) and very high BOD (17,000–50,000 mg/L). In most cases, it is discharged at very high temperatures (around 90 °C). Vinasse is a potentially highly-polluting effluent that can cause serious health issues, diminish aquatic life, affect productivity of land, contaminate aquifer found lands, and emit methane into our atmosphere if not managed properly.

It is very difficult and costly to treat and dispose of vinasse. Different forms of utilization, treatment and final disposal have been sought for the economical and environmentally-sustainable treatment and disposal to avoid environmentally negative impacts of vinasse. Because of the large quantities of vinasse produced, alternative treatments and uses have been developed, such as recycling of vinasse in fermentation, concentration by evaporation and yeast and energy production. Physical and chemical treatment options of the residue have not been very successful until now, though the high organic content of the residue make it well suitable for biological treatment, especially for anaerobic fermentation. There has been limited success due to the high cost of treating the vinasse before it can be processed. It has unfavourable carbon to nitrogen ratio, lack of important trace elements (like nickel, copper, zinc, etc.) and high content of sulphur reducing the conversion of organic materials into biogas.

The on-site disposal of vinasse by combustion and incineration has also been tried. It generates potassium-rich ash which can be sold commercially. However, it requires considerable amount of energy during pre-evaporation and has difficulties of foaming, salt crystallization and ash fusion. It has been used as organic fertilizer in the cane plantations but can cause salinity problems. Vinasse at lower concentrations may also be used as fodder or as a compost ingredient. In higher concentrations, its chemical properties may affect negatively soils, rivers and lakes if frequently discharged over a longer period of time.

There is no simple, existing way to get rid of vinasse. For this reason, many members of the alcohol industry in low and middle-income countries have chosen to set the problem aside and dispose its waste in an unlawful manner, dumping it into rivers, sewage pipes and land and causing often grave social and/or environmental problems. Thus, green approaches are in demand to address the challenge, building on the hidden resources vinasse offers.

In 2009, Eco Biosis started working on the technology to treat vinasse in collaboration with the Universidad del Medio Ambiente, New Ventures, Fundacion E. and Green Momentum. In 2011, Eco Biosis submitted the patent for a multi-stage dehydration process for treating vinasse and converting it into a commercially valued product, called BioDispersis that is easy to handle and distribute. It acts as a natural dispersing and plasticizing agent that can be used as a substitute for lignosulfonates. The main by-product of the process is clean water, which can be reintegrated in the alcohol production process, helping it achieve greater sustainability standards.

In March 2013, Eco Biosis completed the construction of its pilot plant and began converting vinasse to BioDisperSis VC® (BioDispersis). It expects to operate at 100% capacity producing up to three tons per day for 25 days a month (approx. 600 tons per annum). This is the first of a series of plants the company anticipates building to use its patented technology. Eco Biosis's plant is located in eastern Mexico in the Veracruz state, one of the leading sugarcane-producing and alcohol-refinery states in Mexico. The plant is situated within the site of a sugarcane refinery plant, which produces up to 250 m^3 of vinasse on a daily basis. The refinery provides water, air, electricity, steam and vinasse free of charge to Eco Biosis, because Eco Biosis offers a cost-effective way to dispose of unwanted waste.

Market environment

The organic binder (chemical additive) being produced by Eco Biosis is an ecological substitute for lignosulfonates, water-soluble anionic polyelectrolyte polymers that have a broad range of applications across many industries including cements, agriculture, pesticides, mining, leather tannery, crude industry, livestock, concrete, binding and adhesive and dyes and pigment industries.

The annual global consumption of lignosulfonates in 2013 was approximately 1.24 million tons and grew annually by about 1.5% during the last 13 years. The construction sector leads in demand for lignosulfonates, which are used as a plasticizer for concrete, allowing the concrete to be made with less water while maintaining the ability to flow. In Mexico, the consumption of concrete lignosulfonate is 55,000 tons per annum, which is expected to continue growing by about 2.5–4.5% per annum. Eco Biosis anticipates operations producing 600 tons of lignosulfonates from the pilot plant or approximately 1% of the Mexican market and up to 5,000 tons by 2014 or roughly 10% of the market.

The competitive landscape in Mexico is dominated by Norwegian company Borregaard LignoTech, which has over 60% of the market and produces speciality chemicals for the agro and construction industries. The other key players are Tembec and WestRock (created by merger of Mead Westvaco and RockTenn) which produce lignosulfonates using wood as the primary raw material. The Eco Biosis lignosulfonate substitute, however, has competitive advantages of indigenous supply at fraction of the cost and its green credentials as all of Eco Biosis' competitors use non-sustainable timber as their primary raw material.

Macro-economic environment

The alcohol industry is expected to exceed USD 1 trillion in 2014, with market volume expected to reach approximately 210 billion litres, according to market research firm Market Line. Mexico alone

produces over 10 billion litres of vinasse annually, which must be disposed of in accordance with government requirements. Due to the quantity of vinasse produced and high disposal costs, a large amount of run-off ends up in the lakes and rivers causing a significantly negative environmental impact. The regulation around vinasse waste disposal has therefore tightened in recent years, increasing the disposal cost for alcohol distilleries and reducing operating margins. Due to which the domestic alcohol production has fallen in recent years and import of ethanol has increased.

Only a handful of the largest alcohol refineries in Mexico are disposing of vinasse legally, which has led to significant investment into R&D to improve disposal methods. The most common method for disposing of vinasse is through the use of anaerobic reactors and burning the gas or utilizing filtration systems and landfill; however these methods are costly and/or not effective. The Eco Biosis technology provides a profitable solution to disposal methods used by alcohol refineries, in addition to producing a versatile chemical additive that can be used in a number of different industries. Eco Biosis' model provides a solution to vinasse disposal that can be easily replicated on a global scale.

Business model

The key value proposition of Eco Biosis (Figure 110) is to produce lignosulfonates substitutes with superior environmentally-safe moieties from vinasse waste generated during alcohol production, and in the process save water and reduce environment pollution. After spending initial years in developing technology to process vinasse waste to lignosulfonate substitutes, Eco Biosis is running a pilot plant in partnership with an alcohol distillery. Lignosulfonates has multiple applications and Eco Biosis can target multiple customer segments such as concrete, cement, chemical, mining and energy companies. At the time of the interview, Eco Biosis has a contract with a multinational company to supply 100% of BioDisperSis produced during the next six years starting after 2014.

Value chain and position

The key players in the Eco Biosis value chain are alcohol producers as supplier of vinasse, water, utilities and infrastructures, partners for developing technology and business development and clients who will buy BioDisperSis (Figure 111). The San Jose de Abajo distillery provides vinasse for the pilot plant and provided land to Eco Biosis to construct its plant within its factory premises. The distillery's gas, electricity and steam supply are provided free of charge to Eco Biosis operations. Earlier, the distillery was dependent upon water from sugarcane to dilute the waste for its operations, and it had to stop its distillery operations after every harvest. Incorporating the Eco Biosis plant into the distillation process allows the distillery to continue production uninterrupted throughout the year as water recovered from treatment of vinasse by Eco Biosis is sent back to the distillery, therefore positively impacting the profitability of the business. For the expansion plant, Eco Biosis is in negotiations with a number of businesses and hopes to secure a larger and more stable source of vinasse.

Developing the process of treating vinasse to produce lignosulfonate substitute required Eco Biosis to consult with different agencies for technical assistance, product development, use of equipment to start the plant and refine the process. In addition, it also received business development assistance from incubation programs such as BiD Network, New Ventures, Green Momentum and UMA, and in the process gained exposure to investors/funding and overcome legal issues.

Eco Biosis' one key client is committed under contract for the next six years (starting 2014) to buy the entirety of the production of BioDispersis. Eco Biosis is also in advanced conversations with a number of other potential clients who are interested in their product in the long run.

FIGURE 110. ECO BIOSIS BUSINESS MODEL CANVAS

KEY PARTNERS

- Universidad del Medio Ambiente
- Gecco
- Industrias ADVIEE
- San Jose de Abajo distillery
- BiD Network
- Green Momentum
- New Ventures Mexico
- Mexican national Council for Science and Technology (CONACYT)

KEY ACTIVITIES

- BioDisperSis VC° production, storage and sales
- R&D of the product
- Quality control

KEY RESOURCES

- Land
- Capital
- Skilled labor
- Agreement with distillery for supply of vinasse and utilities
- Patent-protected IP
- Green brand image

VALUE PROPOSITIONS

- Producing environment-friendly lignosulfonate substitute from alcohol distillation by-product waste and reduce environment pollution

CUSTOMER RELATIONSHIPS

- Direct interaction with user industries

CHANNELS

- Appropriate agreement and self-interaction

CUSTOMER SEGMENTS

- Construction and chemical companies
- Agricultural companies (in future)
- Livestock feeding companies
- Specialized product-distributing companies
- Mining companies
- Energy companies

COST STRUCTURE

- Investment cost (land, building, machines)
- Operational cost (fuel, labor, utilities, maintenance cost)
- Marketing & sales cost
- R&D
- Patent maintenance costs (substantial: approx. 250,000 over the lifetime of a worldwide patent)

REVENUE STREAMS

- Sale of BioDisperSis (lignosulfonate)

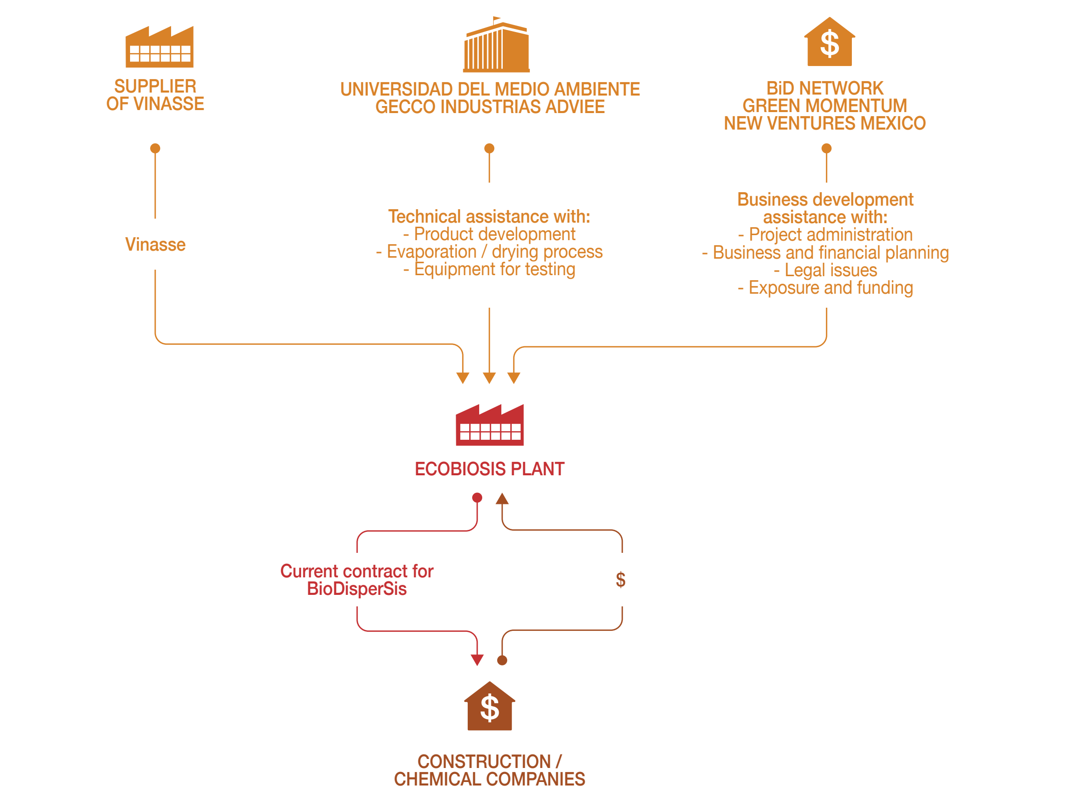
SOCIAL & ENVIRONMENTAL COSTS

- Possible risk of water pollution and environmental hazard if the removal of pathogens and pollutants during the process is not complete and it is discharged into the open

SOCIAL & ENVIRONMENTAL BENEFITS

- Job creation
- Environmental benefit through processing vinasse which can otherwise cause water, land and air pollution
- Environmental benefit from consuming BioDisperSis rather than lignosulfonates made from wood pulp
- Carbon footprint reduction from the local purchase of lignosulfonates instead of importing them

FIGURE 111. ECO BIOSIS VALUE CHAIN



Eco Biosis business has supplier power prominence as the source of vinasse is dependent upon the San Jose de Abajo distillery continuing to supply it to the Eco Biosis plant, in addition to funding the operational costs of the plant. However, supplier prominence is weakened if Eco Biosis plant reduces the operational costs of the distillery. Buyer power prominence and substitutes exist as there is an established market for lignosulfonates. Eco Biosis' hopes to counter it by pricing its product 70% lower than its competitors. The threat of new entrants, using the same process, is limited due to patent protection; however, there are other existing methods of treating vinasse, which could compete with Eco Biosis.

Institutional environment

Prevention and management of waste: Mexico is working on environmental waste reduction to achieve better management of waste through an environmental policy. The president has made policies to reduce global warming a special and personal issue of his administration. In spite of the attention given to the issues, Mexico continues to face serious environmental challenges largely because even when anti-pollution legislation exists, much of it is not being applied and enforced. The Mexican Department for Environmental Affairs implemented a law in 1996 restricting the contamination of national water bodies (NOM-001-ECOL-1996), which proposed a set of contaminant limits for liquids being disposed of. The sample analysis of sugarcane vinasse done by Eco Biosis indicated a total suspended solids content 50 times higher than that specified by the contaminant limits.

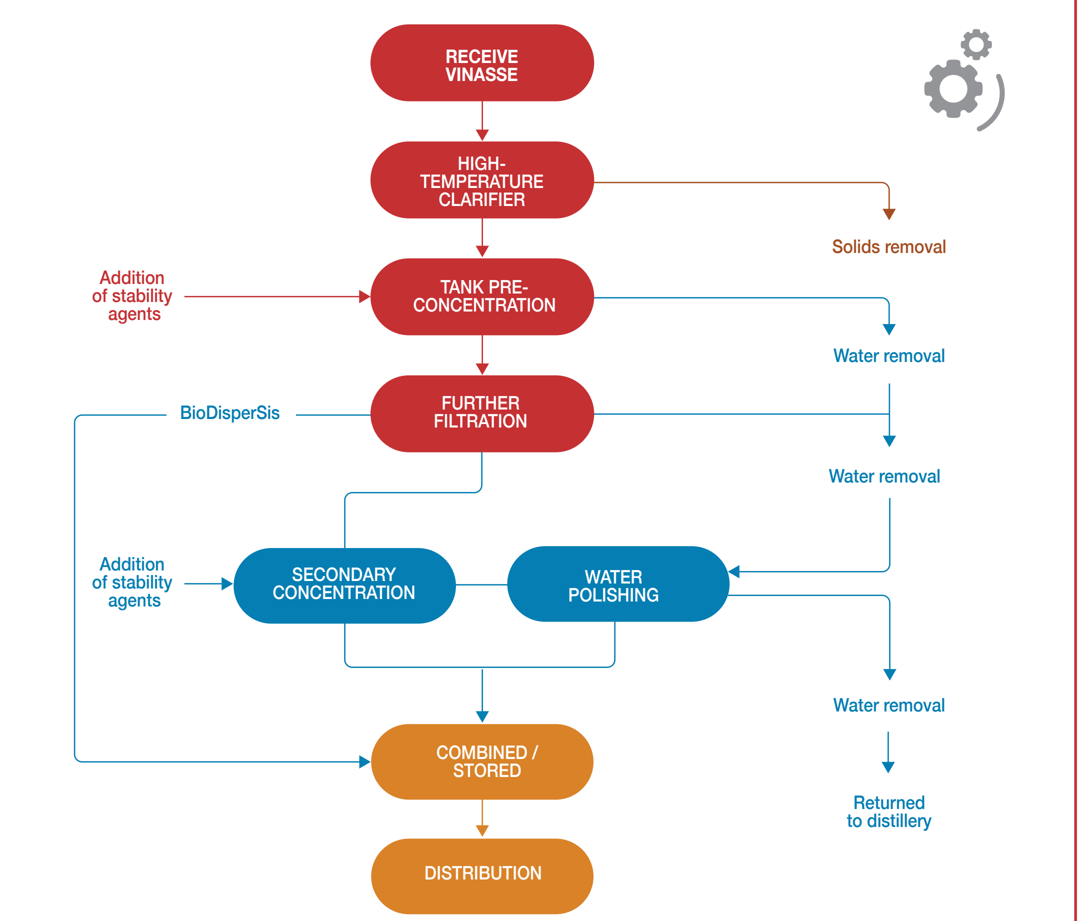
Because the technology is untested on an industrial scale, Eco Biosis has encountered certain resistance within the government to build the pilot plant. Eco Biosis has opted not to be classified as a waste treatment service provider, but rather decided to register as a manufacturing company subject to manufacturing sector regulations. Eco Biosis is therefore subject to a different frequency of operating audits than it would otherwise be under the waste treatment classification and has to obtain different more practical permits prior to initiating production.

Technology and processes

Eco Biosis initiated the patenting process for manufacturing BioDisperSis in 2011. Patent approval is pending. Figure 112 presents the process involved in production of BioDisperSis.

Vinasse is received into the plant through a pipeline from the distillery and is passed through a high-temperature clarifier to extract suspended solids (fibres, mud and yeast) before being stored in a tank to start the pre-concentration process. During the pre-concentration process, water is removed and stability agents are added for required physical properties needed for BioDisperSis. The solution then goes through a further filtration process to extract any remaining water. Three products are

FIGURE 112. PROCESS DIAGRAM OF ECO BIOSIS



derived from this process: water, BioDisperSis and vinasse that needs to go through an additional process of concentration. Water extracted is treated to improve its quality before being returned to the distillery for reuse in the alcohol distillation process. The vinasse passes through an additional low temperature concentration process where other agents are added to the solution before it is ready to be stored and dispatched. The vinasse batch that has gone through the secondary concentration and the BioDisperSis are re-combined and a number of chemical agents are added to the liquid in order to preserve the product quality and durability. The remaining BioDisperSis is then checked for quality control, stored under the appropriate conditions and distributed via the Eco Biosis fleet of distribution trucks.

Funding and financial outlook

The implementation and construction cost for the pilot plant was approximately USD 150,000 and 100% funded by the directors, one other private angel investor and the Mexican National Council for Science and Technology. The total amount spent on the pilot plant does not, however, reflect a standalone build-out of the plant as Eco Biosis utilized second-hand and rented machinery, in addition to renting out the plant, which would have otherwise cost an additional USD 700,000 to acquire (Table 31). The most significant expense items were machinery (USD 80,000), installation (USD 25,000), vehicles (USD 25,000) and electrical costs (USD 10,000). The total investment to date has been approximately USD 400,000; however, the vast majority of this has gone into product R&D. The pilot plant is expected to make a small profit of approximately USD 35,340 on an annualized basis, with revenues of about USD 158,000. The key operational costs for the pilot plant are machinery rental, chemical process and labor, contributing to approximately 79% of the total running costs.

TABLE 31. ECO BIOSIS FINANCIAL SUMMARY

PILOT PLANT FINANCIAL SUMMARY									
USD/MONTH	M1	M2	M3	M4	M5	M6	M7-12	Y1	Y2
Initial Investment	(13,333)	(13,333)	(13,333)					(40,000)	
Revenue (Unit: USD 240)				13,205	13,205	13,205	79,230	118,845	158,460
Costs									
Labor				(1,843)	(1,843)	(1,843)	(11,058)	(16,587)	(22,116)
Chemical Process				(3,850)	(3,850)	(3,850)	(23,100)	(34,650)	(46,200)
Evaporator: Rent				(2,400)	(2,400)	(2,400)	(14,400)	(21,600)	(28,800)
Telephone				(189)	(189)	(189)	(1,134)	(1,701)	(2,268)
Plant Rental and Petty Cash				(1,137)	(1,137)	(1,137)	(6,822)	(10,233)	(13,644)
Distribution				(841)	(841)	(841)	(5,046)	(7,569)	(10,092)
Total Costs				**(10,260)**	**(10,260)**	**(10,260)**	**(61,560)**	**(92,340)**	**(123,120)**
Net Margin				**2,945**	**2,945**	**2,945**	**17,670**	**26,505**	**35,340**
Payback period from pilot plant: 4.5 years									
IRR*: 34%									

*IRR only taken for first 2 years as the pilot plant is not intended to be run on a continual basis but used as a model on which to launch the expansion plant

The pilot plant is being used to prove the quality of BioDisperSis and secure a number of larger-scale contracts in order to start construction of the expansion plant. Eco Biosis is therefore looking to expand (Table 32) from this in two key phases: 1) an initial expansion plant with production capacity of 9,000 tons in 2015–2016 and 2) a full expansion plant coming on-stream in 2017–18 with production capacity of 27,000 tons. Eco Biosis will invest USD 2.6 million in the expansion plant, which will have revenues of USD 1.7 million and breakeven at approximately 45% production capacity. The fully-operational plant will require a further investment of USD 5.4 million and increase potential revenues by up to 300%, with breakeven production of approximately 55%.

TABLE 32. ECO BIOSIS FINANCIALS PROJECTIONS

EXPANSION PHASES FINANCIAL SUMMARY							
USD	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Investment	2,587,589		5,368,968				
Revenue		1,668,734	1,768,265	6,332,350	6,710,043	7,110,264	7,534,355
EBITDA		780,143	839,613	3,316,631	3,556,095	3,811,249	4,083,077
Net Profit		**368,120**	**406,656**	**1,324,082**	**1,430,042**	**1,663,888**	**1,909,755**

Eco Biosis has already secured approximately USD 0.8 million in funding for its expansion plant from a number of developmental agencies.

Socio-economic, health and environmental impact

From an environmental perspective, the technology has a significant positive impact as it reduces the contamination of local water bodies through converting unused vinasse into lignosulfonate substitute, and in addition, indirectly improves the livelihood of the local population. Furthermore, Eco Biosis has a negative net water usage as it extracts more water from the vinasse received than it uses in the conversion process, thereby returning water for reuse to the alcohol distilleries and preserving an already scarce supply of potable water. Eco Biosis provides employment to 12 local workers in the pilot plant; however, this will increase to approximately 14 in the expansion plant and up to 35 in the fully-operational plant which is planned to come on-stream in 2018.

Scalability and replicability considerations

The key drivers for the success of this business are:

- Patented technology and process for making BioDisperSis from vinasse.
- Partnerships with alcohol distilleries, allowing extreme low-cost sourcing of inputs.
- Viable lower-cost alternative for vinasse treatment in compliance with regulatory requirement.
- Awareness and market for clean technology solutions.
- Higher-priced substitutes (Lignosulfonates are imported).
- Tightening vinasse disposal regulations.

The Eco Biosis pilot plant feasibility is from multiple factors. Most important is the plant's location within an existing distillery, and in addition receiving services free of charge which would otherwise have had a significant impact on the operational costs. Operational cost savings incurred assist in making a small-scale pilot plant viable. The two key considerations for scaling Eco Biosis are: 1) availability of vinasse as a raw material and 2) demand for lignosulfonate substitute. With continued support of anti-pollution legislation in Mexico, Eco Biosis provides a cost-effective approach to disposing of vinasse legally and can therefore secure significant quantities of the vinasse waste at relatively low cost, enabling it continued domestic expansion.

On a global scale, the alcohol industry continues to grow strongly, expecting to reach USD 1 trillion in 2014, representing almost 210 billion litres. This represents a significant opportunity for the Eco Biosis technology to be utilized in other countries to counter the pollution from vinasse. The demand for lignosulfonate substitutes will continue to grow in the construction industry as it provides an environmental-friendly alternative to wood-pulp-derived lignosulfonates. Furthermore, Eco Biosis can export its product to foreign markets demanding lignosulfonates.

Summary assessment – SWOT analysis

The key strengths of Eco Biosis are the benefits drawn by alcohol distillery and an environmentally-friendly alternative for producing lignosulfonates substitute from vinasse in comparison to mainstream methods of using wood pulp as key input (Figure 113). The weakness of Eco Biosis is high investment required for its expansion. In its future expansion, Eco Biosis might require to alter its process based on the quality of raw material input and could further increase its investment costs. Eco Biosis once has commercially proven and has successfully run its operations for few years. It has strong opportunities to expand both domestic and overseas.

FIGURE 113. ECO BIOSIS SWOT ANALYSIS

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ A proprietary cost-effective solution to significant global environmental problem ▪ Patent pending that will reduce threat of competition ▪ Beneficial for distilleries as disposing of unwanted waste and getting clean water back ▪ BioDisperSis price competitive with other lignosulfonates ▪ Lignosulfonates are used in a broad range of industries mitigating potential market risk ▪ BioDisperSis is a green alternative to mainstream wood-pulp-derived lignosulfonates ▪ Low water usage throughout process and water extracted from vinasse is returned to distilleries	**WEAKNESSES** ▪ Reliance on operating pilot plant and operating cost subsidies ▪ Have inherent risks with expansion ▪ High level of investment required to launch expansion plant ▪ Have only developed one product with vinasse – BioDisperSis – therefore, significant R&D is still required to open up new markets and process vinasses of different qualities ▪ Capacity of the plant has to be linked to the capacity of the alcohol distillery as transport of vinasse would not be cost effective
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Domestic and overseas expansion as significant supply of vinasse waste that is not being exploited ▪ Source raw material from a number of other vinasse producing industries, e.g. bread making ▪ Expand product line to open up new markets and industries ▪ Growing popularity for sustainable products globally	**THREATS** ▪ Supply of raw material is not secured ▪ Change in quality of raw material will alter the solution properties and slow process ▪ Patent not yet granted

Contributors

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Eco Biosis S.A.

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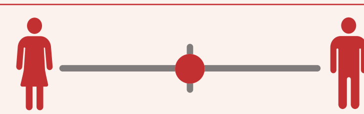
Case descriptions are based on primary and secondary data provided by case operators, insiders, or other stakeholders, and reflects our best knowledge at the time of the assessments (2015–2016). As business operations are dynamic, data can be subject to change.

BUSINESS MODEL 9

Bio-ethanol and chemical products from agro and agro-industrial waste

Solomie Gebrezgabher and Krishna C. Rao

A. Key characteristics

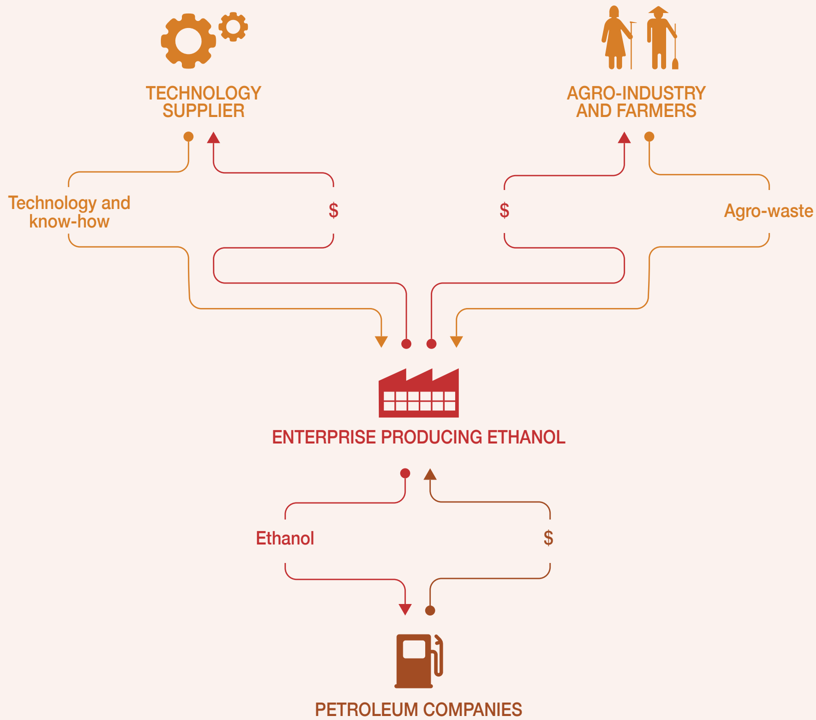
Model name	Bio-ethanol and chemical products from agro and agro-industrial waste
Waste stream	Organic waste – Agro-waste from farms and agro-processing factories and vinasse waste generated during ethanol production
Value-added waste product	Bio-ethanol (as additive to petrol/gasoline as transportation fuel) and chemical products (like lignosulfonate substitutes for various industries)
Geography	Regions with large agro-industries
Scale of production	Small to medium scale 20–30 tons of chemical product or ethanol per day from agro or agro-industrial waste
Supporting cases in this book	Carabobo, Venezuela; Veracruz state, Mexico
Objective of entity	Cost-recovery [ ]; For profit [X]; Social enterprise [ ]
Investment cost range	Approx. 150–400 USD/ton of chemical product or ethanol
Organization type	Private
Socio-economic impact	Employment generation (12–50 jobs), improved income of farmers, reduced water, land and air pollution from vinasse and agro-waste, reducing GHG emissions by substituting petrol used for transportation or non-eco-friendly product (like lignosulfonates)
Gender equity	No advantage to a specific gender 

B. Business value chain

This business model is owned and operated by either a standalone private entity or agro-industries such as rice mills, coffee, cassava and palm-oil-processing units. The business processes solid or liquid agro-waste or crop residues such as wheat stalk, rice husk, maize stalk, groundnut shells, coffee husks and cassava waste to produce ethanol or chemical products (Figure 114). Specific technology tailored to the quality of available waste needs to be developed for each case, depending on the type of waste. If ethanol is produced, this can be blended with gasoline and used in motor vehicles. This is becoming an increasingly cost-effective renewable solution to transport, as gasoline stations around the world start to provide blended fuel and motor vehicles no longer need any modifications to use this fuel.

The key stakeholders in the business value chain are the suppliers of agro-waste (farmers and agro-industries), technology suppliers and petroleum companies and consumers of ethanol. The process of

FIGURE 114. VALUE CHAIN FOR BIO-ETHANOL AND CHEMICAL PRODUCTS FROM AGRO AND AGRO-INDUSTRIAL WASTE



generating ethanol uses enzymes to break down cellulose in the agro-waste into fermentable sugars. For the business to be successful, it is important to develop enzymes that break down complex cellulose efficiently and economically. In addition, the business could require developing special strains of yeast or bacteria for improved fermentation processes for better yields of ethanol. These micro-organisms can be engineered to work more efficiently in specific temperatures and acidities, or can be engineered to have new scopes of enzymatic activities or combinations thereof. R&D of such technology is costly and can only be initiated with availability of sufficient R&D capacity, either in-house (for a large company) or with a R&D partner, and with the availability of sufficient funds throughout the technology development stages. The newly-developed materials and/or processes should also be patented to protect the technology to ensure return on investment. However, this represents another substantial cost over the course of life of the patent(s).

Overall, the model contributes to the reduction of environmental and health hazards associated with disposing of waste from agro-processing units, and thus creating a green image for the agro-processing units. The business is eligible for sale of carbon as ethanol is a biofuel and is generated from sustainable biomass source. Furthermore, the production of ethanol results in vinasse, a by-product of waste distillation which can be treated to recover clean water. Finally, there is also the potential to produce value-added animal feed, biogas and bio-fertilizers by further processing of remaining sludge.

C. Business model

The primary value proposition of the business model is production of environment-friendly ethanol from cellulose in agro-waste for blending with petrol/gasoline as transportation fuel. Figure 115 depicts the business model canvas for emerging technologies.

As an additional business line and in consideration of pursuing an emerging technology route, the business should consider developing a product from the vinasse waste generated during ethanol production. One of the business cases described (Eco Biosis) in the energy section of the catalog elaborates on the company's successful efforts to research and produce a low-cost substitute for lignosulfonates from the vinasse. These chemical additives are used extensively in several industries such as construction, agriculture, mining and cosmetics. Benefits in this manner double, as effluent is minimized and cleaned, while another revenue stream is added. Both the Eco Biosis material and the process are protected with patents.

It requires considerable investment in developing the technology and process. The business spends a substantial amount of money on product R&D and subsequent patenting. In order to develop the new product that meets customers' needs at a competitive price and to ensure sales, the business requires collaboration and consultation with different agencies for technical assistance, product development including partnership with an R&D institute, business development and legal assistance including patent protection measures. The business model may require technology validation for which the "launching customer" concept is an ideal strategy. For example, the business starts as a pilot plant in partnership with agro-processing units and gradually increases its scale of operation while at the same time securing off-take contracts with specific buyers. These projects require high-risk money with flexibility of adopting strategies to the business needs for technology and process development.

Once the technology and the process are streamlined for commercial production, it is important for the business to form partnerships with agro-processing units to secure reliable supply of inputs. Hence, this business is either located near or is incorporated into the agro-processing factories as production of ethanol depends, among other things, on the availability of the feedstock. The business receives the feedstock free of charge or pays a nominal value because it offsets the cost of disposal for the agro-processing factory. Incorporating the business into the agro-processing factory is a strategic decision for the agro-processing factory.

An alternative strategy is for the business to buy-in newly-developed technology from a specialized R&D organization that it partners with. This might take longer and have less security but it dramatically reduces the risks associated with the R&D stages. The business may enter a contract R&D arrangement or may invest in participating in a technology development consortium. Still alternatively, the business may adopt an R&D networking strategy in which it vigilantly monitors technology developments within the R&D arena and buys in at a time of interest. It should expect to invest considerable time liaising within the R&D network and the technology transfer channels, with smaller chances of a good match.

A further alternative is for the business to license in strategically-important technology developed and patented by another party. Benchmarks for upfront payments and royalties on sales vary widely and depend on the type of technology, technology maturity and market dynamics. In both two alternatives mentioned, it is important to avail the required critical understanding and capacity in intellectual property rights and legal affairs.

FIGURE 115. BUSINESS MODEL CANVAS – BIO-ETHANOL AND CHEMICAL PRODUCTS FROM AGRO AND AGRO-INDUSTRIAL WASTE

KEY PARTNERS

- Farmers and agro-processing units
- Research institutes
- Funders/investors

KEY ACTIVITIES

- R&D of products
- Production of ethanol/chemical product
- Marketing of product

KEY RESOURCES

- Land
- Capital
- Agreement with agro-processing units and farmers
- Agro-waste
- Technical and operational competencies
- Patent protected IP
- Patent expertise
- Green brand image

VALUE PROPOSITIONS

- Environment friendly ethanol from agro-waste for blending with petroleum
- Producing environment-friendly lignosulfonate substitute from alcohol distillation by-product waste and reduce environment pollution

CUSTOMER RELATIONSHIPS

- Direct interaction with user
- Industries/petroleum companies

CHANNELS

- Direct supply to petroleum companies under contract

CUSTOMER SEGMENTS

- Petroleum companies
- User industries

COST STRUCTURE

- Investment cost (land, building, machines)
- Operational cost (raw material cost, labor, utilities, maintenance)
- Marketing cost
- Depreciation
- R&D
- Patent filing, maintenance and patent attorney costs
- Equity and/or interest on loans

REVENUE STREAMS

- Sale of ethanol
- Sale of chemical products

SOCIAL & ENVIRONMENTAL COSTS

- Possible risk of pollution of water from vinasse

SOCIAL & ENVIRONMENTAL BENEFITS

- Creation of jobs
- Reduced water, land and air pollution through processing of agro-waste and vinasse
- Reduced GHG emissions by using ethanol from renewable source blended into petrol
- Clean water savings
- Environmental benefit from consuming substitutes of lignosulfonates made from wood pulp
- Carbon footprint reduction from the local purchase of lignosulfonates instead of importing them

D. Potential risks and mitigation

Market risks: This business model is offering a new product, which can substitute existing products with an established market. The business faces uncertainty in successfully deploying the new product from R&D and pilot stage to commercialization. Ethanol from agro-waste can be used as a substitute for ethanol from other sources such as sugarcane and corn. This business faces the challenges of developing a viable business and requires extensive marketing and awareness creation among its end users to secure off-take contracts.

Competition risks: The success of ethanol from agro-waste depends on how fast the technology is commercialized and how much it costs compared to established alternative products. The business can avoid competition from existing companies in the market by targeting those buyers which are not served by existing companies or enter a market through strategic positioning by offering the product that is environmentally-friendly and is lower-priced than established alternative products in the market. Ethanol from agro-waste is expected to be less expensive than the alternatives as inputs can be sourced at a low cost, and thus giving this business a competitive advantage over other ethanol producers.

Technology performance risks: Technology is new and was not tested at the assessment time on an industrial scale. Technology development and market introduction are a multi-year, multi-step process, often requiring financial injections at various stages. Capital costs are uncertain when constructing a pilot plant and a commercially-viable demonstration, as the technology is not proven. Hence, there is considerable risk from inability to reach investment coverage at each individual stage. Partnership with an R&D institute is required to move the technology from pilot to commercial scale, and in the process mitigate any risk associated with technology performance.

Political and regulatory risks: There is limited awareness on the technology or process among policy makers. Since the technology is new and not tested on an industrial scale, the business may face challenges from unfavourable business environment, encounter resistance from the government to obtain permits prior to initiating production and go through a lengthy process for obtaining approval for patent. Few governments in developing countries have implemented the policy of mandatory blending of petrol/gasoline with ethanol and such policies will significantly help this business model.

Social-equity-related risks: The model is considered to have no advantage to any specific gender. The benefits of the model are to agro-industries to help manage their waste and the employment opportunities created are for highly-skilled labor. The model could suffer from social-equity risks which can be mitigated from corporate social responsibility initiatives that provide benefits to the community around the plant.

Safety, environmental and health risks: There is possible risk of water pollution and environmental hazard if the production of ethanol from agro-waste does not remove pathogens and pollutants completely and is discharged into the open. Untreated vinasse waste discharged into the open is an environmental hazard and can harm the local ecosystem. However, there are technologies and good practices to prevent this (Table 33).

TABLE 33. POTENTIAL HEALTH AND ENVIRONMENTAL RISKS AND SUGGESTED MITIGATION MEASURES FOR BUSINESS MODEL 9

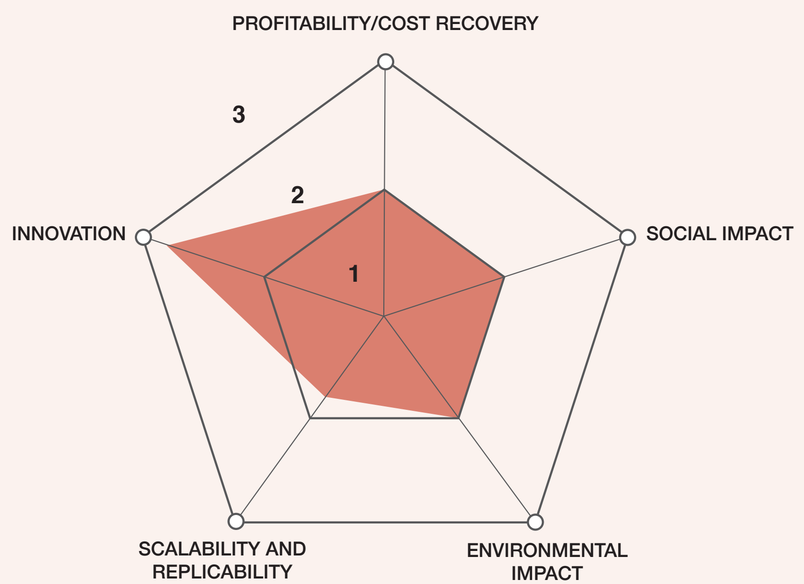
RISK GROUP	EXPOSURE					REMARKS
	DIRECT CONTACT	AIR	INSECTS	WATER/ SOIL	FOOD	
Worker						Risks to workers from direct contact with the waste can be mitigated using protective gear/equipment.
Farmer/User						
Community						
Consumer						
Mitigation measures						

Key: NOT APPLICABLE | LOW RISK | MEDIUM RISK | HIGH RISK

E. Business performance

This business model is rated as high in innovation but medium on profitability, social and environmental impact and low on scalability and replicability potential (Figure 116). The business is highly innovative in

FIGURE 116. RANKING RESULTS BIO-ETHANOL AND CHEMICAL PRODUCTS FROM AGRO AND AGRO-INDUSTRIAL WASTE BUSINESS MODEL



terms of its developing new and patented materials and/or processes. The business is also innovative in creating strategic partnerships with different players in the market, such as input suppliers, technology developers, business development and legal advisors. This business model can result in high returns from its innovative process and strategic partnership. However, the deployment of the new technology into the commercial market requires significant amount of capital, and thus affecting the profitability and future cash flows.