Resource Recovery and Reuse (RRR) Project

# Synthesis Report on Feasibility Assessment for the Implementation of RRR business models proposed for Kampala

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# Abbreviations

| | |
|---|---|
| AIW | Agro-Industrial Waste |
| AM | Animal Compost |
| BCR | Benefit to Cost Ratio |
| BM | Business Model |
| BMDT | Business Model Development Training |
| CEDAT | College of Engineering, Design, Art and Technology |
| CEWM | Centre of Excellence in Waste Management |
| CREEC | Centre for Research of Energy and Energy Conservation |
| DALY | Disability-adjusted life year |
| EIA | Environmental Impact Assessment |
| ERA | Electricity Regulatory Authority |
| ESCO | Energy Services Company |
| FAO | Food and Agriculture Organization |
| FS | Faecal Sludge |
| GHG | Green House Gas |
| HFO | Heavy Fuel Oils |
| HIA | Health Impact Assessment |
| HRA | Health Risk Assessment |
| IFPRI | International Food Policy Research Institute |
| IPP | Independent Power Producers |
| IRR | Internal Rate of Return |
| KCCA | Kampala Capital City Authority |
| kW | Kilowatt |
| MC | Market Concentration |
| MCA | Multi-criteria Assessment |
| MoH | Ministry of Health |
| MSW | Municipal Solid Waste |
| MW | Market Waste |
| MW | Megawatt |
| MWE | Ministries of Water and Environment |
| NEMA | National Environment Management Authority |
| NPV | Net Present Value |
| NWSC | National Water and Sewerage Corporation |
| P&L Statement | Profit and Loss Statement |
| PPA | Power Purchase Agreement |
| PPE | Personal Protective Equipment |
| PPP | Public-private Partnership |
| RoI | Rate of return on Investments |
| RRR | Resource Recovery and Reuse |
| SCP | structure–conduct–performance |

| | |
|---|---|
| SSP | Sanitation Safety Plan |
| SSWARS | Sustainable Sanitation and Water Renewal Systems |
| STEP | Specific Topic Entry Page |
| STH infections | Soil-transmitted Helminth Infections |
| UDHS | Uganda Demographic and Health Survey |
| UETCL | Uganda Electricity Transmission Company |
| UGX | Ugandan shillings |
| UMEME | Energy Distribution Network Company in Uganda |
| UNDP | United Nations Development Program |
| VAT | Value Added Tax |
| WfP | Water For People |
| WHO | World Health Organization |
| WTP | Willingness to Pay |
| WW | Wastewater |
| WWTP | Wastewater Treatment Plant |

# Executive Summary

This report presents the results from the feasibility studies for the implementation of RRR business models interlinked with an assessment of health and environmental risks and mitigation measures for proposed waste reuse (resource recovery and reuse - RRR) business models in Kampala, Uganda. The feasibility studies conducted in Kampala are a core of the research project and sought to explore across different settings the applicability, adaptability and comprehensiveness of the proposed business models in real-life settings; resulting in the strengthening of the methods and procedures, but also in view of scalability and viability. A key output of the feasibility studies are city-strategies for resource recovery and reuse and aim to provide recommendations for investment options and related health risk monitoring and mitigation measures.

A 7-component multi-criteria assessment (MCA) framework was adopted to ensure that the assessment of the viability, applicability, scaling-up potential of implementing different RRR business models at scale was conducted from a holistic view, taking into consideration both micro- and macro-environment factors. The constituent criteria were: a) Waste supply and availability, b) Market assessment (demand quantification and product market assessment), c) Technological aspects, d) Institutional and legal settings and public support, e) Financial viability assessment, f) Health and environmental risk assessment, g) Socio-economic impact assessment (valuation of economic benefits and assessment of additional externalities).

Eight (8) business models were selected for feasibility testing in Kampala, covering several waste streams (faecal sludge, municipal solid waste (MSW), wastewater, agro-industrial waste) and resulting end-products categorized into energy and nutrient recovery and wastewater use. The business models were selected based information from: a) a pre-feasibility study, b) feedback from stakeholder workshops and c) a no-go analysis based on information from baseline surveys. The selected business models had to have at least triple bottom line targets: high impact from a scalability and replicability perspective and catalyze innovation adoption. The feasibility of each model was then analyzed based on the MCA framework and for its overall potential feasibility based on a 4-level ranking system, i.e. whether it has:

**No feasibility** **Low feasibility** **Medium feasibility** **High feasibility**

The notion behind the ranking of the RRR business models is to provide different stakeholders, in particular, investors with an overview of the potential feasibility for implementation of the business models. Particularly, it provide insights on constraints, if any, possibly related to key resource factors, and the level of risk associated with their potential investments.The overall feasibility of the selected RRR business models is presented in table A below. It is noted that the nutrient business models have the highest feasibility for Kampala; with the energy business models generally having a low feasibility as do the wastewater business models.

The nutrient business models, with two key end-products of MSW-based compost and a co-compost of MSW and faecal sludge, have the *highest feasibility* potential for implementation in Kampala, with most of the assessment criteria ranked highly. From the waste availability and access perspective, although not source-separated, there is sufficient and easy access to MSW and adequate technology available for its efficient sorting and conversion to compost. The market assessment results suggest that there is a significant demand for MSW-based compost as surveyed potential consumers have significantly higher willingness-to-pay than the average market price for substitute products at 100 UGX (Ugandan shillings)/kg.The results suggest that high quality compost product if labelled with information on the source of the inputs, has 3rd party certification on been a safe product and is in a pelletized form, will command a market price of 234.84 UGX/kg - which is almost 2.5 times higher than the current market price. Although chemical fertilizers represent the largest share of the market, there is no large-scale government fertilizer program that provides subsidized chemical fertilizer to farmers nor an active private fertilizer sector that supplies fertilizer at competitive prices. Thus, this represents a great opportunity for waste-based organic fertilizer businesses to take advantage of the erratic chemical fertilizer prices and limited number of actors in the respective market.The financial assessment showed that the business model (BM15) to be highly viable and more so under increased scale. Whilst, the product is relatively unknown, the estimated demand for faecal sludge-based compost (models 17 and 19) was also noted to be significant, with average WTP value ranging between 713 and 1098 UGX/kg. Farmers are willing to pay more for fortified and certified compost, although they did not have a preference for pelletized compost.This business model is also characterized by high financial viability, which is mainly driven by product pricing and demand. From an institutional perspective, there are supportive national policies and legal framework for the production of high value fertilizers from municipal solid waste, faecal sludge and wastewater under controlled regulation; as is government support for private companies' entry into the sub-sector.Whilst the current production levels of organic fertilizers are unknown, it is clear that this sector is a burgeoning industry with some entry barriers but supportive and existing policies encouraging business development.

The energy business models, on the other hand, were all ranked as having a *low feasibility.* Generally, there is significant and growing demand for energy, particularly electricity, in Kampala and increasing opportunities for waste-to-energy entities to fill this gap based on the anticipated rapid rural electrification program; foreseeable increasing trend in electricity prices; structural and legal feasibility for private sector involvement; a lesser vertically integrated market; and supportive renewable energy policies among others.Key drivers for the low feasibility of the models are related to: a) limited availability and access to the waste input, particularly, agro-waste and b) related institutional regulations in the case of faecal sludge- where, for example, public entities such as the National Water and Sewerage Corporation (NWSC) have sole ownership/depository of faecal sludge from onsite sanitation public facilities. The use of other waste streams can however be considered to improve the feasibility of the briquette (BM1a) model. The calorific value of dried faecal sludge, for example, is comparable to other biomass fuels and can be used for the production of briquettes. This, however, will require establishing strategic partnerships with the municipality and private entities (e.g. public faecal sludge emptying and transportation service providers) to ensure consistent supply of the waste input and compliance with regulations.

The selected wastewater business models were also noted as having low (BM 9) and no feasibility (BM 10) potential. Limitations of market demand for treated wastewater were notable, particularly among potential users for industrial purposes. About 98 percent of the enterprises surveyed expressed that they were satisfied with the current quality of water supplied by NWSC and 96% noted facing no shortages with water supply. Only 7% of the respondents expressed interest in using treated wastewater, particularly for washing purposes, and noted willing to pay higher prices than the current fees at UGX 500/$m^3$. Farmers, on the other hand, showed a higher interest in wastewater reuse for their operations and a willingness-to-pay (WTP) of UGX 530/$m^3$ - although still lower than the current fees paid for water.

Additionally, even though urban agriculture is practiced widely, business oriented reclamation of wastewater in urban areas may be difficult due to the scattered nature of urban farmers. Large-scale farming activities are sometimes located far off from urban areas, and where wastewater infrastructure is not planned to be implemented, this would require the treated wastewater to be piped long distances. There is a potential for the establishment of a cooperation with the National Water and Sewerage Corporation (NWSC) as part of a public-private partnership agreement to consider a strategy for upgrading the wastewater treatment infrastructure and incorporating reuse. However, it is important to note that, considering the high investment costs associated with wastewater treatment infrastructure, the retro-fitting of existing plants may not only come at high cost but negate the potential economic benefits to be derived from reuse. The infeasibility of BM 10, on the other hand, is mainly driven by institutional regulations, which note the use of untreated wastewater for irrigation as impermissible under the city and national policies on wastewater and irrigation. Additionally, the limited market demand and associated negative health risk and impact will likely not support the promotion of untreated wastewater for irrigation in Kampala.

Table A: Overall feasibility ranking of the business models

| | | Level of feasibility of the business models | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Ranking criteria | Outputs | ENERGY | | | WASTEWATER | | NUTRIENT | | |
| | | **BM1a** | **BM2a** | **BM4** | **BM9** | **BM10** | **BM15** | **BM17** | **BM19** |
| 1 | Waste supply and availability | | | | | | | | |
| 2 | Market assessment | | | | | | | | |
| 1 | Institutional analysis | | | | | | | | |
| 3 | Technical assessment | | | | | | | | |
| 4 | Financial assessment | | | | | N/A | | | |
| 5 | Health risk assessment | | | | | | | | |
| | Health impact assessment | | | | | | | | |
| | Environmental risk and impact assessment | | | | | | | | |
| 6 | Socio-economic assessment | | | | | | | | |
| | **Overall ranking of BM** | | | | | | | | |

Legend:

- **BM 1a:** Dry Fuel Manufacturing: Agro-Waste to Briquettes
- **BM 2a:** Energy Service Companies at Scale: Agro-Waste to Energy (Electricity)
- **BM 4:** Onsite Energy Generation by Sanitation Service Providers (faecal sludge to electricity)
- **BM 9:** On Cost Savings and Recovery (wastewater use for irrigation, energy and nutrient recovery)
- **BM 10:** Incentivizing safe reuse of untreated wastewater
- **BM 15:** Large-Scale Composting for Revenue Generation (municipal solid waste to compost)
- **BM17:** High value Fertilizer Production for Profit (combination of municipal solid waste and faecal sludge to organic fertilizer)
- **BM 19**: Compost Production for Sanitation Service Delivery (faecal sludge-based compost and urine as a fertilizer).

# 1 Introduction

## 1.1 Overview of Research Project

The overall goal of the project is to implement globally and at large scale recovery and safe reuse models of resources generated from liquid and solid waste streams in order to promote food security, cost recovery in the sanitation sector, and livelihood opportunities, while safeguarding public health and the environment in poor urban and peri-urban areas in developing countries. This translates into two key objectives:

1. To increase the scale and viability of productive reuse of water, nutrients, organic matter and energy from domestic and agro-industrial waste streams through the analysis, promotion and implementation of economically viable business models;
2. To safeguard public health in the context of rapidly expanding use of wastewater, excreta and greywater in agriculture and aquaculture and protect vulnerable groups from specific health risks associated with this pattern of agricultural development.

This intervention thus had several increasingly interlinked components carried out over **two phases**: (1) a research dominated phase, and (2) an implementation dominated phase. While the research has an impact pathway based on two phases: (1) a research dominated phase and (2) an implementation dominated phase; the one described here centers on phase 1 and in particular on the 1st objective focusing on the analysis and feasibility testing of RRR business models.

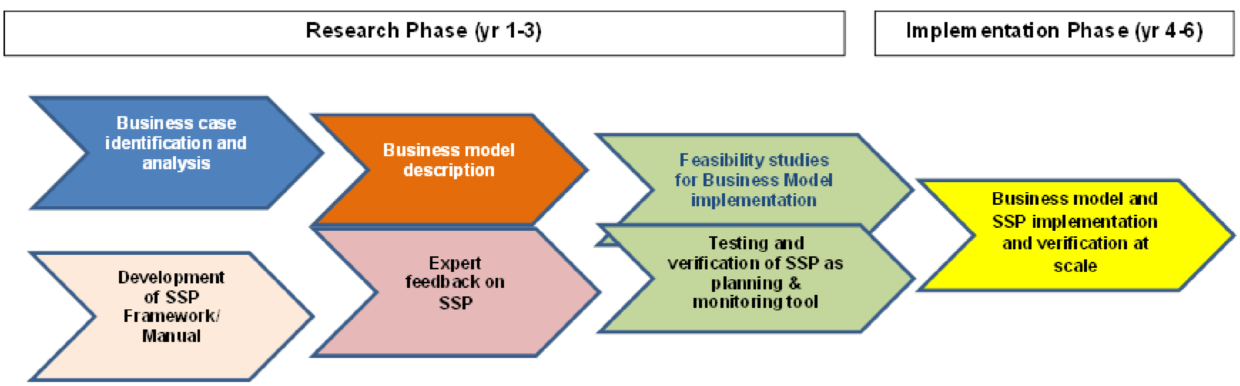


Figure 1: Research Framework for the Project

The 1st objective focused on the identification of existing or emerging reuse cases in Asia, Africa and Latin America to learn about their performance and analyze in depth the most promising and/or scalable cases. The in-depth assessment of both formal and informal RRR business cases sought to understand the factors that drive their success and potential sustainability, replicability and scalability barriers, particularities and opportunities. This was based on a 7-component multi-criteria analysis covering among others the financial, institutional, policy, health and technical aspects of RR&R to understand the performance of each respective business case in their given context. Performance indicators for benchmarking of success were identified through a comparative analysis, and business models emerging from the analysis was described for each waste resource. Subsequent to the development of the RRR business models, **multiple feasibility studies** which were a core of the intervention and involving all relevant local stakeholders were conducted to explore across different settings the applicability, adaptability and comprehensiveness of the proposed business models in real-life settings; resulting in the strengthening of the methods and procedures both are proposing, also in view of scalability and viability. A key output of the feasibility studies are city-strategies for RR&R which include recommendations for investment options and related health risk monitoring and mitigation measures aligned to the *Sanitation Safety Plan (*SSP).

## 1.2 Methodology for Feasibility Studies

Feasibility studies in the context of this project are defined as the assessment and analysis of the viability, applicability, scaling-up potential of implementing different RRR business models at scale. This requires the application of an approach that assesses the feasibility of RRR business models from a holistic view, taking into consideration both micro- and macro-environment factors. For this purpose, different qualitative and quantitative approaches and related methodologies were used. The adopted methodology here builds on a multi-criteria assessment (MCA) framework and identified performance indicators and applied an institutional, policy and market analyses, perception studies, and business scenario modeling. The list of criteria selected for the MCA framework is based on previous research and is as follows:

1. Waste supply and availability
2. Market assessment (demand quantification and product market assessment)
3. Technological aspects
4. Institutional and legal settings and public support
5. Financial assessment
6. Health and environmental risk assessment
7. Socio-economic impact assessment (valuation of economic benefits and assessment of additional externalities)

The list of criteria presented here is based on previous research. While it is impossible to identify a complete list of factors that will determine the feasibility of implementing an RRR business without knowing the specific context, the goal here was to present an extensive range of different criteria that would be of importance in different contexts and that are helpful in accurately assessing the feasibility potential of the business models. This list may be reduced or expanded for each specific business model and context. The application of the MCA framework for the feasibility assessment of the business models is detailed out in the related document for *Output 2 - Methodological Guidelines* on multi-criteria indicators determining promising business models and their targeted application in low-income countries and emerging economies.

The framework consists of a set of criteria, indicators, research questions, and detailed methodology under the overarching umbrella of a multi-criteria analysis (figure 2). Each criterion has its own set of indicators, with these indicators having a set of research questions and to address these research questions, a specific approach/ methodology applied. The selected indicators for each criterion allows for comparisons between business model options to assess their viability, scalability and sustainability. The indicators are criterion-specific although a few were cross-cutting and applied to all criteria, addressing, e.g. opportunities and constraints for going at scale. The indicators shed light on the financial flows, production factors, resources or capacities requirements, associated health and environmental risks and economic benefits from the implementation of the specific RRR business models. It in essence allows one to address questions of financial sustainability, scalability, development impact, related health risks and environmental impact of the RRR business. The selected criteria essentially allows us to identify any limitations associated with both the input and output markets and related impacts. For example, the *Waste Supply* criterion assesses the quantity of waste input available and accessible to a business. This is an important criterion as resource limitation is a key factor for business sustainability. Each criterion is explained and described in Annex 2. There are overarching research questions and sub-questions; of which the research questions were formulated to serve either:

i. The determination of the indicators
ii. Provide background information on the business model
iii. Assess the suitability of the indicator and functionality in and any given bio-physical or socio-economic setting (institutional capacity, infrastructure and technology)

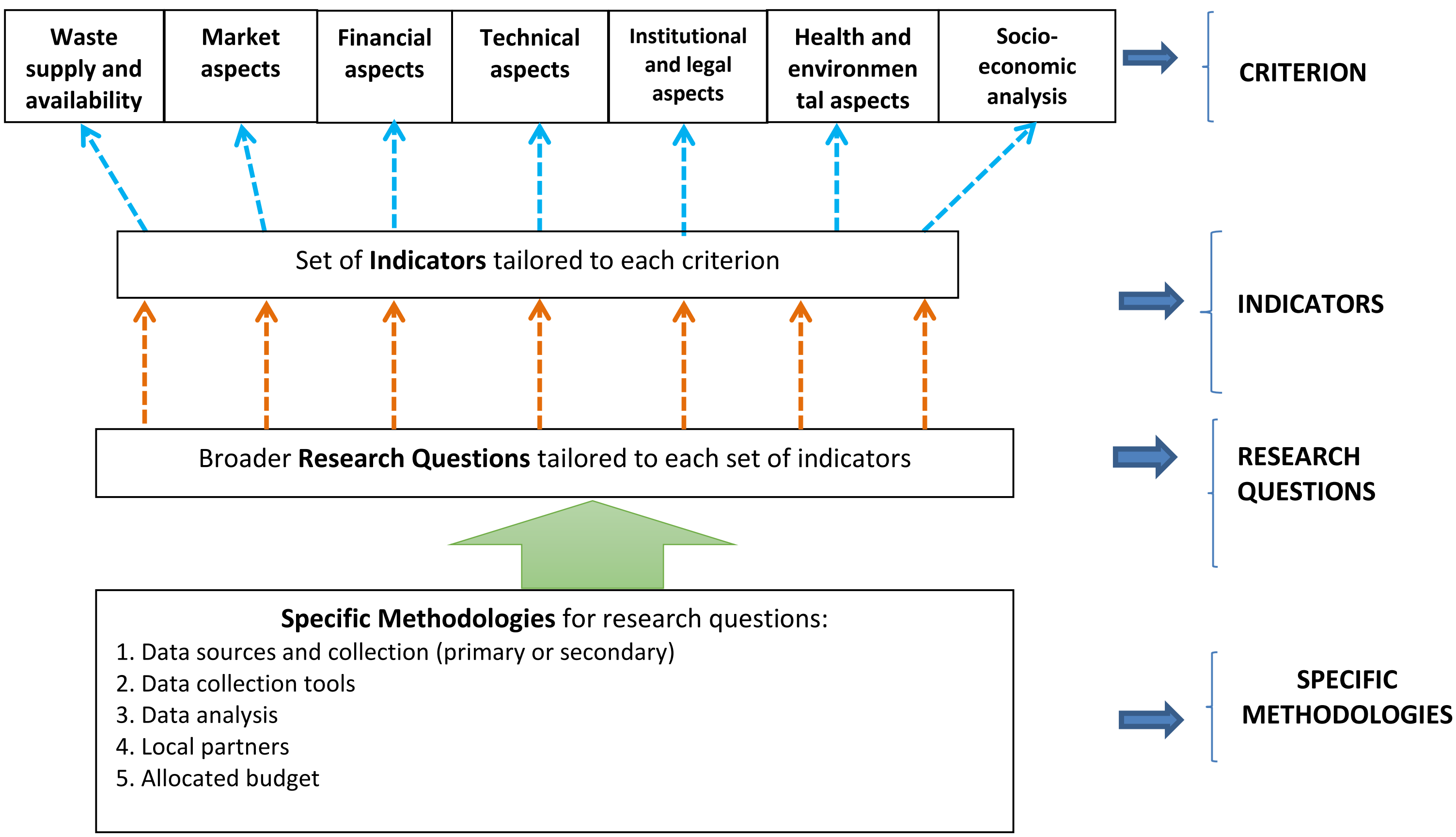


Figure 2: Framework for Feasibility Studies

Prior to the feasibility studies, baseline surveys were conducted to guide the selection of appropriate cities for testing the business models. Based on a screening and previous research work, the following cities were preliminarily shortlisted: Kampala, Uganda, Bangalore, Mysore and Hubli-Dharwad in India, Kumasi, Accra and Tamale in Ghana, Cagayan de Oro in Philippines, Hanoi in Vietnam, Lima in Peru, and Ouagadougou in Burkina Faso. Baseline surveys were conducted to serve as a pre-feasibility study of cities, to preliminarily assess the extent of reuse and the types of RRR business models with the highest potential for sustainability and impact. The baseline surveys were buttressed with pre-stakeholder workshop visits, which permitted the following:

- to consolidate the baseline survey reports provided by the consultants with complementary dimensions (if the former proved to have insufficient information)

- to meet key authorities on one-to-one basis to align the project with their needs;
- to visit existing treatment or reuse cases in the city and discuss with the respective operators the options for RRR;
- to pre-select the number and types of possible BMs that locally made sense;
- to have first contacts with potential partners for the different dimensions of the feasibility phase.

The final feasibility city selection criteria was based on: a) confirmed official interest, b) supporting policies, c) local partner capacity to carry out feasibility and health studies, d) urban and peri-urban farming sector in need of resources, and e) already ongoing reuse activities to test the SSP. The final selected cities were Kampala, Uganda; Lima, Peru; Bangalore, India; and Hanoi, Vietnam. This report focuses on the results from the feasibility studies conducted in Kampala, Uganda. It is important to note that the feasibility studies considered an urban - peri-urban system boundary and defined based on the specific context and city under consideration. Eight (8) business models selected for feasibility testing in Kampala are presented in table 1. The selection process of the business models was based on three components: a) a pre-feasibility study, b) feedback from stakeholder workshops and c) a no-go analysis based on information from the baseline survey.

Each business model was assessed based on the seven criteria listed in the MCA framework and subsequently evaluated for its overall potential feasibility based on a 4-level ranking system, i.e. whether it has:

**No feasibility** **Low feasibility** **Medium feasibility** **High feasibility**

The subsequent sections present the feasibility assessment results of the different models from the different criteria. Section 10 provides a synthesis of the overall feasibility assessment and ranking of all the selected business models.

Table 1: Selected RRR Business Models for Feasibility Testing in Kampala

| RRR Business Models | Brief Description |
| --- | --- |
| **ENERGY** | |
| **Model 1a:** Dry Fuel Manufacturing: Agro-Waste to Briquettes | The business entity processes crop residues like wheat stalk, rice husk, maize stalk, groundnut shells, coffee husks, saw dust etc. (any agro-based waste) and converts them into briquettes as fuel to be used in households, large institutions and small and medium energy intensive industries. |
| **Model 2a:** Energy Service Companies at Scale: Agro-Waste to Energy (Electricity) | The business processes crop residues like wheat stalk, rice husk, maize stalk, groundnut shells, coffee husks, saw dust etc. to generate electricity which is sold to households, businesses or local electricity authority. |
| **Model 4:** Onsite Energy Generation by Sanitation Service Providers | The business model is initiated by either enterprises providing a sanitation service such as public toilets or by residential institutions such as hostels, hospitals and prisons with a concentrated source of human waste (i.e. faecal sludge). The business concept is to process and treat human waste in a bio-digester to generate biogas to be used for lighting or cooking. |
| **WASTEWATER REUSE** | |
| **Model 9:** On Cost Savings and Recovery | The business concept is to treat wastewater for safe reuse in agriculture, forestry, golf courses, plantations, energy crops, and industrial applications such as cooling plant. The sludge from the treatment plant can be used as compost and soil ameliorant and energy generated can be used for internal purpose resulting in energy savings. |
| **Model 10:** Informal to Formal Trajectory in Wastewater Irrigation - Incentivizing safe reuse of untreated wastewater | Informal reuse of wastewater is commonly practiced by farmers in developing countries but it also entails significant health costs, often borne by the public and are of social nature. This social nature of these costs justifies public investments in incentives to promote safe reuse of wastewater and minimize risk along the entire value chain as such incentives could potentially turn this unsafe informal activity into a safe and formal one with shared rewards for all the stakeholders. |
| **NUTRIENTS** | |
| **Model 15:** Large-Scale Composting for Revenue Generation | The business concept is to better manage Municipal Solid Waste (MSW) and recover valuable nutrients from the waste that would otherwise be unmanaged and disposed on streets and landfills without reuse. Compost from MSW is sold to farmers, landscaping, and plantations and other entities. |
| **Model 17:** High value Fertilizer Production for Profit | Similar to Model 15 in concept but in addition to MSW, the business uses faecal sludge as an input from onsite sanitation systems which is rich in nutrients. There are opportunities for pelletization and blending of faecal sludge-based compost with rock-phosphate, urea/struvite or NPK which is an additional value proposition that can be explored under this business model, allowing the product to have nutrient levels specific for target crops and soils, and a product structure improvement (pellets) to improve its competitive advantage, marketability and field use. |
| **Model 19**: Compost Production for Sanitation Service Delivery | The business concept is to provide sanitation service provision and to manage and transform human excreta into safe fertilizer and soil conditioner. |

# 2 Key findings of Waste Supply and Availability Assessment

This section presents the key findings of the “Waste Supply and Availability” analysis that was conducted in Kampala, Uganda. The business models under consideration required analyzing the following waste streams:

1. Municipal Solid Waste (MSW)
2. Market Waste (MW)
3. Wastewater (WW)
4. Faecal Sludge (FS)
5. Agro-Industrial Waste (AIW)
6. Animal Compost (AM)

Table 2 provides a summary of the key findings for each business model under consideration. The waste streams and end-products are listed, including a ranking of feasibility for implementation (high/medium/low) and recommendations for adaptation to increase feasibility. Detailed analysis were conducted for each waste stream on:

- Quantities and characteristics of defined waste streams.
- Current and future solid waste and liquid waste management strategies of Kampala.
- Accessibility of defined waste streams, and the implications on the potential for implementation of waste-based business models.

The information was collected through review of secondary data, interviews, field observations and collection of primary data. Sources included:

- Existing reports from Kampala Capital City Authority (KCCA) and research institutes working in the field of waste management and sanitation,
- On-going PhD and MSc. research through interviews and review of students’ publications,
- Collection of raw data from public utilities,
- Conducting interviews with experts,
- Field data measurements for quantities of faecal sludge (Schoebitz, et al. 2015)

Detailed information, data analyses and data sources are available in the report on: *"Waste Supply and Availability: Kampala, Uganda. May (2014)”*.

Table 2: Rating of feasibility of business models from a 'Waste Supply and Availability' perspective

| Business Model | Waste stream | End-product | Feasibility rating | Recommendations |
|---|---|---|---|---|
| 1 (a, b) | • MSW<br>• AIW | • Briquettes | **Low (see recommendations)**<br>MSW in Kampala is not source-separated and therefore unsuitable for the production of briquettes, as inorganic impurities can create hazardous emissions. AIW is not sufficiently available and the competition for the waste is high as it is highly valuable for direct combustion to generate heat, and electricity through gasification. Kampala already has many businesses producing briquettes from AIW, which increases the market competition. | Considering the use of other waste streams for the production of briquettes can increase the feasibility. The calorific value of dried faecal sludge is comparable to other biomass fuels. Other possible adaptations include the production of pellets instead of briquettes, which are often preferred by industries. Targeting industries rather than households as a possible market for the end-product would decrease the social stigma that is created with using briquettes/pellets made of faecal sludge as a fuel. Targeting the recently commissioned Lubigi Wastewater and Faecal Sludge Treatment plant could be a possibility as there are currently no strategies in place for the accumulated dried faecal and wastewater sludge. |
| 2 (a, b) | • MSW<br>• AIW | • Biogas -> Electricity | **Low (see recommendations**)<br>Same reasons as for business model 1 (a, b) | The feasibility can be increased by considering the use of faecal sludge for anaerobic digestion. Co-digestion of faecal sludge with other waste streams such as the organic fraction of solid waste and market waste as well as animal compost has high potential. However, this requires arrangements with the municipality and private as well as public faecal sludge emptying and transportation service providers, as regulations prescribe to discharge faecal sludge at the official discharge locations in Lubigi and Bugolobi. |
| 4 | • Faeces<br>• Urine<br>• FS | • Biogas -> Cooking fuel | **Low (see recommendations)**<br>Upgrading of existing systems appears unlikely due to the needed acquisition of land in densely populated areas where sanitation services are lacking. The biogas yield from faecal sludge alone is comparatively low. | The Kampala Capital City Authority (KCCA) is currently increasing the implementation of public toilets in Kampala. Adapting the business model and starting communications with the authority to implement anaerobic digestion technologies into planned public toilet facilities can increase the feasibility of this business model. However, sanitation service based business models often only create revenues through the applied user fee and not through utilization of end-products. |
| 9 | • WW<br>• WW sludge | • Electricity<br>• Soil conditioner<br>• Water (for reclamation) | **Low (see recommendations)**<br>Considering the high investment costs for WW infrastructure this model ranks low in feasibility for Kampala. | The existing Kampala Sanitation Master Plan (2004) and Kampala Sanitation Plan (2008) outline the strategy for upgrading the WW infrastructure in Kampala towards 2030. The feasibility of the business model can be increased through cooperation of the implementing business with the National Water and Sewerage Corporation (NWSC) as part of a PPP agreement. This partnership can lead to the implementation of resource, recovery solutions at WW treatment plants in Kampala. |

| | | | | |
|---|---|---|---|---|
| 10 | • WW | • Water (for reclamation)<br>• Water for groundwater recharge | **Low**<br>Even though urban agriculture is practiced widely, business oriented reclamation of wastewater in urban areas is not manageable due to the scattered organization of urban farmers. Large-scale farming activities are located far away from urban areas, where wastewater infrastructure is not planned to be implemented, which would require the treated wastewater to be piped long distances. | No recommendations for adaptations to increase the feasibility. |
| 15 | • MSW<br>• FS | • Compost | **Medium**<br>Collected MSW in Kampala is not source separated, and even though characterized by a high organic fraction, the remaining inorganic fraction is considered to be problematic. Mechanical sorting would highly increase the complexity of a composting facility without necessarily significantly improving the input quality and respectively the final compost product. Considering these facts, the final end-product from composting activities of mixed or mechanically sorted MSW would tend to be of low quality, potentially not fulfilling local regulations for compost quality. Using FS for co-composting not only complicates the business model in terms of health concerns but also complicates the logistics of the business model in the case of Kampala. FS is delivered to the recently commissioned Lubigi Faecal Sludge and Wastewater Treatment Plant, where currently no plans for end-use of the dewatered and dried faecal sludge exist. The dewatered and dried sludge will be transported to Kiteezi landfill for discharge. | The use of market waste instead of mixed MSW can increase the feasibility of the business model. A co-composting facility could be implemented at the Kiteezi landfill, as the location also receives the dewatered and dried faecal sludge. If trucks that solely deliver market waste to the Kiteezi landfill can be identified and diverted from discharging into the landfill, then, co-composting with faecal sludge might be feasible. Another feasible option is to arrange a special PPP agreement with KCCA, which focuses on the collection and management of MW from selected markets and also transports dried faecal sludge form Lubigi to the site of co-composting. Implementing a source-separation campaign at the household level is desirable for the future of solid waste management in Kampala, but unlikely to take effect fast enough for a co-composting business to make use of it in the coming years. |
| 17 | • MSW<br>• FS | • Fertilizer (NPK added) | **Medium**<br>For the same reasons as for business model 15. Fortifying the compost with nutrients does not affect the feasibility from a waste supply perspective other than a slight increase in production complexity, the need for good supply chains, and the need for regular analysis to ensure a high quality fertilizer. | The same recommendations as for business model 15 to increase the feasibility of this business model. |
| 19 | • Urine<br>• Faeces | • Stored urine, Soil conditioner | **Medium**<br>Sanitation services based on urine diverting dry toilets have not shown to be successful in Kampala. 73 public toilets have been identified as ecosan toilets in Kampala with no data availability on reuse of urine or faeces. | In recent years, many businesses providing sanitation services in Kampala have started. One example is Water for People who not only provide sanitation infrastructure but also gain a significant market share in regular and safe manual emptying of pit latrines and septic tanks. Supporting the existing entities to further expand their business would increase the feasibility of this business model. The user acceptability of urine diverting dry toilets remains low and other sanitation should be considered for implementation. |

# 3 Key findings of Market Assessment

## 3.1 Introduction

A key component of the feasibility studies is the market assessment of the RRR business models as functioning markets, an enabling institutional environment and positive economic and financial conditions are essential for sustainable business activity in any sector including the waste reuse sector. The set-up of any RRR business and the commercialization of a new product in a new market requires an accurate or close to accurate estimation of the relative market size for the new product. The successful development of any subsector market depends among other factors particularly on market demand. Specifically, the question of whether a demand actually exists and the price end-users are willing to pay for this new product needs to be explored. “Demand, even among those with limited resources, is not automatic.” (Phillip et al., 2003; page 194). For this reason, the market assessment set out to evaluate the current and potential market for the recovered resource and the effect of different factors (e.g. socio-cultural aspects and perceptions, price of substitute products, etc.) on market demand. Information on market segments, potential clients of the RRR product, their actual and potential number and resource absorption capacity and their willingness-to-pay (WTP) were assessed.

Additionally, the adoption of effective marketing and pricing strategies to ensure business sustainability require entrepreneurs to comprehensively understand the dynamics inherent in the relevant sub-sectors. This translates into the need for evaluating the structure (i.e. competition, differentiation of substitute products, barriers to market entry, among others) of the product market they operate in, i.e. how the behavior and performance of other businesses influence their decision making. Another important facet to the market assessment is demand forecasting – i.e. market outlook. Market forecasting is a crucial element for business owners in assessing future capacity requirements, evaluating their decisions in the implementation of new business strategies and pricing decisions. Businesses need to adopt different strategies ranging from establishing key partnerships and price markups to maintain a competitive advantage and ensure sustainability. An assessment of the above listed aspects provides entrepreneurs with a solid market information base crucial for business start-up and sustainability. In that regard, the specific objectives of the market assessment were:

1. To assess the market value of the RRR products under consideration –
    a. To assess consumers’ willingness-to-pay (WTP) and differences in WTP estimates across different consumer segments and related factors influencing consumer demand;
    b. To estimate the potential market size for the RRR product;
2. To assess the extent and characteristics of the market structure;
3. To evaluate the market outlook of the RRR products and to what extent the RRR products would be viable over time in the market.

As noted earlier, a total of 8 RRR business models were selected for the feasibility studies in Kampala. For the purposes of the market assessment, an end-use typology of the business models was employed as although the underlying concept of the business models were different, a number of the end-products were the same across different business models. Thus for some business models, the related customer segments and relevant actors along the value chain considered would be the same. In that regard, for the selected business models, the following 5 value-added products were considered: 1) briquettes, 2) electricity, 3) treated wastewater, 4) MSW-based compost and 5) faecal sludge-based compost. Untreated wastewater is not considered a marketable commodity as it is considered to increase human health risk and environmental pollution and thus potential users' valuation was not assessed.

Table 3: List of RRR business models and related products

| Business Model | Value-added product | Recovered resource |
|---|---|---|
| Model 1a: Dry fuel manufacturing: agro-waste to briquettes | Briquettes | Energy |
| Model 2a: Energy service companies (agro-waste to energy (electricity) | Electricity | |
| Model 4: Onsite energy generation by sanitation service providers | | |
| Model 9: On cost savings and recovery (treated wastewater for irrigation) | Treated wastewater | Wastewater |
| Model 10: Informal to formal trajectory in wastewater irrigation | Untreated to partially treated wastewater | |
| Model 15: Large-scale composting for revenue generation (MSW to compost) | MSW-based compost | Nutrients |
| Model 17: High value fertilizer production for profit (faecal sludge to compost) | Faecal sludge-based compost | |
| Model 19: Compost production for sanitation service delivery (faecal sludge to compost) | | |

## 3.2 Methodology

### *3.2.1 Overview of Methodology*

The successful development of any RRR business depends on the effective workings of different facets of the respective value chain including: (a) market linkages between related subsector markets; (b) business dynamics between relevant economic actors and (c) consumers' responsiveness to newly developed and available products. When introducing a new product into the market or simply entering a new industry, businesses are particularly interested in three factors: current and future consumer demand, competition and production costs. Though cost estimations are simple and straightforward, the assessment of consumer demand (as measured by willingness-to-pay (WTP)) and competition are comparatively more complicated and not a straight forward calculation as historical data of consumer purchase patterns are guidelines at best (Lusk and Hudson, 2004). Specific methods were developed and used for the evaluation of the consumers' WTP, the assessment of market structure and outlook. The choice of methods for evaluating the different research questions were dependent on the context, the related RRR product, access to data and analytical tools to be employed. The subsequent sections will outline in detail the data collection tools and estimation approaches. The WTP and market outlook analysis viewed the business models from an end-product perspective, whilst the market structure viewing was conducted from a sector perspective; i.e. (a) alternative fuel market, b) electricity market, c) water market and d) fertilizer market).

#### *3.2.1.1 Willingness-to-pay and Market size estimation*

Stated and revealed preference methodologies have gained immense popularity in eliciting consumers' valuation of new products (Lusk and Hudson, 2004; Kimenju and Groote, 2008).The choice between the use of stated or revealed preference methods is dependent on the RRR product under consideration. Stated preference methods such as contingent valuation methods are typically used for assessing consumer WTP of products with an inexistent market price (Adamowicz and Deshazo, 2006; Freeman, 2004). An example would be that of faecal sludge-based organic fertilizer which is a new product in the fertilizer market. Alternatively, revealed preference methods such as hedonic pricing can be used to obtain the price of a good via real market purchasing mechanisms. These methods are grounded in economic theory of welfare analysis and can also be used for the valuation of goods and services without market prices or shadow prices. Contingent valuation approaches has been successfully applied in the estimation of the demand for compost in Ghana (Danso et al., 2006); Tanzania (Valerian et al., 2011), and Ethiopia (Hagos et al., 2012). For the purpose of this study, contingent valuation methods were applied for the WTP assessment of the energy business models (i.e. briquettes, electricity) and choice modeling for the nutrient and wastewater business models. Based on the WTP measures, the potential market size of the RRR products was estimated.

#### *3.2.1.2 Market structure assessment*

This assessment was based on the notion that businesses require information on the extent and characteristics of the market structure for decision-making on strategies that ensure firm performance. To achieve this, a structure–conduct–performance (SCP) evaluation model was applied along the different stages of the product supply chain. The SCP approach provides insights into how markets function in the real world as opposed to in theory (Holtzman 2002; Wanzala et al. 2009). The SCP approach is based on the underlying rationale from economic theory of competitive markets, which suggests that competitive markets produce efficient prices and quantities. If a monopolist or oligopolist dominates a market, the lack of competition will yield higher prices and lower quantities traded. If the market structure is monopolistic or oligopolistic, then prevailing prices may be higher than what they would be in a competitive market. The SCP approach assesses the structure of the market (number of actors involved), their conduct (what products/services they perform), and how those two things lead to the performance of the market—in terms of prices, quantities traded, and costs of performing various functions. Based on this analysis, insights of market performance and possible strategies that businesses can adopt (measured in terms of price and accessibility) can be drawn. To set the stage for assessing the market structure, the supply chain for competitive products was evaluated. This served to identify the constraints and distortions affecting the functioning of the markets of competitive products been considered and propose suitable mitigation measures to address these distortions. The supply chain analysis utilized data from the market size, key players in the supply chain, regulatory framework and subsidy programs. The SCP framework was applied as follows:

1. The **structure of the market** was assessed from four aspects: market concentration (MC), product differentiation (as measured by businesses' awareness of differentiated products), market integration (e.g. extension of credit between businesses) and conditions for entry in sector (threshold capital requirements, sources of funding). An MC ratio based on market share was calculated and monthly turnover data for relevant businesses was used to measure market share.
2. The **market conduct** was evaluated based on the behaviour (whether players are price-taking or price-making agents: pricing and promotion) and activities of existing competing businesses. If data was available, their performance was assessed as reflected in the variation of their cost elements. A structural pyramid of players, functions and the **performance** of the product markets was developed to highlight the different dynamics.
3. An overview of factors affecting the functioning of different markets was evaluated to capture supply-side constraints (e.g. business environment, taxes, tariffs) and demand-side factors (access to financing, production risk, purchasing power).

#### 3.2.1.3 Market outlook assessment

The evaluation of the market outlook, i.e. market forecasting will aid new and existing RRR businesses in planning for the future. Because investment toward an uncertain future is very difficult and risky, market forecasting tools have been developed to alleviate the risk and to obtain more accurate or reliable information. This assessment is a projection of demand levels in the future, based on current or past evolutions. A Bass model is usually used to describe consumers' behavior in relation to their loyalty towards a product. Most frequently, this model is used in marketing for dynamic forecasts of the market demand against the background of intense rivalry between products or brands. Since most of the RRR products are new in the market, it was difficult to obtain time series data to develop a standard demand equation for the market trend analysis. Thus, to forecast the revenue or profit of a new product, the initial income from existing businesses if available was used. For a given RRR product, a Bass model was applied to analyze the market demand over time. In addition, this approach was used to estimate the growth in demand of an RRR-business product with other competing products.

### 3.2.2 Study Area and Data

The primary survey covered the five districts of Kampala as shown in Figure 3 below. For the WTP and market size assessment, primary data on price offers from market experiments, participants' demographics and socio-economic factors were collected from different groups of respondents depending on the RRR product. Additionally, data on price of substitute products, macro-economic factors, etc. were collected from secondary sources. WTP measures were derived directly from the purchase price and additional econometric analysis. For the market structure, both primary and mostly secondary data were collected and used for the supply chain analysis, although this was dependent on the RRR product. For example, supply chain analyses have been conducted on the fertilizer market in many agricultural dependent countries. If applicable to the city, these served as key sources for secondary data. Data on the number and size of key players, the characteristics of these players (e.g. economies of scale, access to financing, marketing and distribution costs, and level of integration and nature of contractual agreements) was collected from primary sources. For the market outlook, data on market demand and market share were obtained from the WTP and market structure assessment components. Additional secondary data on alternative products, prices and quantity of sales of existing competing products in the market (e.g. quantity of fertilizer sold per year, time series data of fertilizer, etc.) was collected from relevant institutions (e.g. marketing boards and departments). Revenues and cost data were collected from existing business as well as alternative input and output products markets. The sampling strategy for the different research aspects and models are outlined in table 4 below.

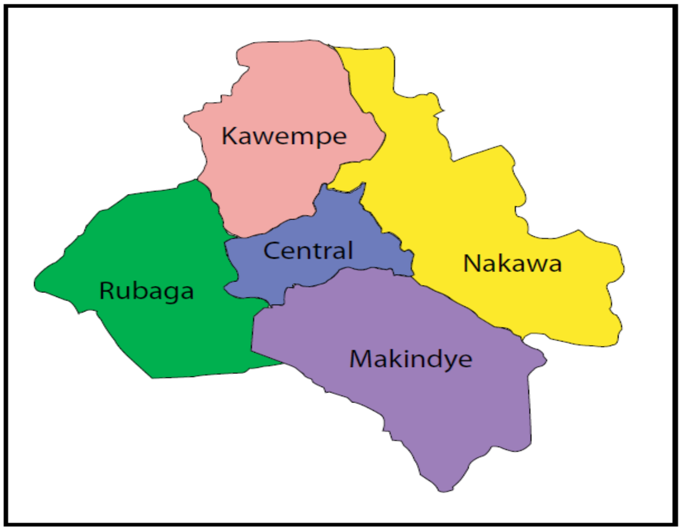


Figure 3: Map of Kampala City, Uganda showing administrative divisions of the city

*(Source: Kampala, the Capital City of Uganda, 2005)*

Table 4: Sampling Strategy for Market Assessment

| **Sub-research components** | **Business Models** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **BM 1a [Briquette]** | | **Model 2a & 4 [Electricity]** | | **Model 9 & 10 [Wastewater]** | | **Model 15 [Compost]** | | **Model 17 & 19 [Faecal sludge-based fertilizer]** | | |
| **WTP and Market size** | H = 527 | B = 32 | H =300 | B = 81 | F = 201 | B = 95 | H = 84 | F = 254 | H = 96 | F = 179 | L = 50 |
| **Market structure** | *Alternative fuels sector* D = 40; P = 25 W = 25 | | *Electricity market* G =2 TD = 2 | | *Water sector* | | *Fertilizer market* I = 10 D =10 | | | | |
| **Market Outlook** | Time series $2^{o}$ data; $1^{o}$ data from WTP assessment | | | | | | | | | | |

**Legend:**

H = Households
B = Businesses
F = Farmers
L = Landscape designers, floriculturists, golf clubs

D = Distributors
P = Producers & Processors
W = Wholesalers & Retailers

G = Generation
TD = Transmission & Distribution
I = Importers

## 3.3 Results of the Market Assessment

### Model 1: Dry fuel manufacturing: Agro-waste to briquette

The results indicate that there is a growing and substantial market demand for briquette in Kampala. Overall, the results suggest that most of respondents are aware of the benefits and costs of briquettes and are willing to pay over and above the current market price of 1000 UGX (Ugandan shillings)/kg. The WTP estimates for businesses and households are 1.5 – 2 and 2 – 3 times higher than the current market price of competitive products, respectively. The potential market demand for briquette for is significant and estimated at 55,400 tons/year and 240,000 tons/year for households and businesses, respectively (taking the demand from surrounding districts into consideration). Subsequent scenario analyses to assess the impact of trade-offs associated with different government policies on consumers' WTP for briquettes indicated that households, in particular, were willing to pay a price 3 times higher than the current price of substitute products with the institution of an enforceable law which prohibits the use of non-renewable energy sources with a fine equivalent to the current market price. A similar effect on WTP estimates was observed for businesses although the marginal price increase was lower than that of the households. Entrepreneurs can consider a segmented pricing strategy for its different customer groups.

Table 5: Mean Willingness-to-Pay of Briquettes with and without cheap talk method

| **Scenario** | **Households** | | **Businesses** | |
|---|---|---|---|---|
| | Without cheap talk | With cheap talk | Without cheap talk | With cheap talk |
| No change in current legal environment | 1913.2 (6558.34) | 1660.38 (4431.59) | 866.67 (296.34) | 826.67 (283.98) |
| Government institutes a law that prohibits the use of non-renewable energy sources but you are unsure if it is enforceable yet | 1839.2[a] (5787.45) | 2517.02[a] (6656.48) | 1083.33[b] (512.66) | 1226.67[b] (635.14) |
| An enforceable law instituted by the government that prohibits the use of non-renewable energy sources with a fine when caught of an unknown amount *(could be lower or higher than* market price of fuel) | 2755.1 (8466.45) | 2716.73 (7110.73) | 1350.00[c] (543.77) | 1483.33[c] (662.85) |
| An enforceable law instituted by the government that prohibits the use of non-renewable energy sources with a fine equivalent to the current market price of the prohibited fuel when caught | 2678.6 (7784.09) | 2806.92 (6886.65) | 1516.67[d] (885.55) | 1633.33[d] (937.10) |

[a, b, c, d] Differences in estimates are statistically significant.
Standard deviations are in parentheses.

Whilst the current production level of briquettes is unknown, it is clear that it is a nascent industry with minimal entry barriers, and supportive and existing policies encouraging business development. There are several factors that will catalyze the development of the briquette industry: a) instituted government policies on renewable energy [favorable policies to improve charcoal trade standardization; certification will restrict illegal timber trade; plans to increase the National Forestry Authority levies on charcoal burners with the support of UNDP] and b) better efficiency on energy value that will increase market demand. Specific marketing strategies are however required as there are no established retail distribution networks as yet (only super markets and institutions); and there is a level of difficulty in linking up with the existing charcoal retail network. While there are currently limited financial incentives (e.g. VAT exemption; higher upfront production cost than for charcoal and firewood production), there are special lending schemes for briquette businesses.In terms of the market outlook of the product, the penetration of RRR briquettes products will be facilitated by the prevailing market conditions. A lower market price than the prevailing price of charcoal will increase consumers' adoption rate. Strong awareness programs coupled with promotional approaches will be important to eventually increase market demand due to the strong positioning of the charcoal market and further shorten the growth stage which currently is estimated between 5 – 8 years.

### Model 2a: Energy service companies at scale: agro-waste to energy and Model 4: Onsite energy generation by sanitation service providers

The potential market for waste-generated electricity was assessed as measured by households and businesses' WTP estimates. The results of the study indicate that businesses have a WTP (ranging between 319.07 – 355.94UGX/ kwh) lower than that of the current unit prices charged by the Uganda Electricity Transmission Company (UETCL) at a rate of 450UGX/kwh. Similarly, the WTP estimates for households are significantly lower than the current tariff set by UETCL. Generally, there is a significant and growing demand for electricity in Kampala and opportunities for waste-to-energy entities to fill this gap based on the anticipated rapid rural electrification program; foreseeable increasing trend in electricity prices; structural and legal feasibility for private sector involvement (structural unbundling of the Ugandan power sector, vertically integrated monopoly and privatization of the generation and distribution); a lesser vertically integrated market; and supportive renewable energy policies among others. The WTP estimates however suggest that although there are incentives to catalyze investment, there is limited demand, which is predictive of the potential pricing strategy to be implemented. The increasing number of independent power producers (IPP) in the energy sector in recent years is also indicative of the structural feasibility of the Ugandan electricity sector. Electricity producers are however currently price takers and restricted to the price ceiling set by the state-owned transmission entity – UETCL (limited negotiation ability – monopolistic market). Thus, in actuality, the level of market concentration, price setting behavior and potential net profit margins (business performance) will determine the sustainability of a waste-to-energy business, which for the first two factors are significant limiting drivers. The opportunity for waste-generated electricity can only materialize when offered prices in the power purchase agreement (PPA) can substantially cover production costs. Additional limiting factors to business development and sustainability in the sector are: a) continued interest and large hydro-power potential; b) significant interest in small hydro-power projects and c) waste-to-energy projects currently viewed as high-risk ventures by financial investors. While producer prices can be increased, additional market failures inherent in the energy sector can only be rectified with the institution of sound policies.

Table 6: Mean Willingness-to-Pay for Waste-generated electricity with and without cheap talk method

| Scenario | Households (UGX/kwh) | | Businesses (UGX/kwh) | |
|---|---|---|---|---|
| | Without cheap talk | With cheap talk | Without cheap talk | With cheap talk |
| Current state of affairs is unchanged | 270.74 | 291.97 | 349.34 | 319.07 |
| A policy allows the national electricity company (UMEME) to raise the price of the grid-power by 10% annually | 280.78 | 297.25 | 400.06 | 347.36 |
| Power shortages occur as much as twice compared to the current situation due to increasing number of electricity users | 282.26 | 295.57 | 419.40 | 355.92 |
| An environmental law instituted by the government that raises cost of treating wastes by other methods and applies a heavy fine for illegal waste dumping | 282.08 | 292.97 | 420.06 | 349.34 |

Statistical significance of differences in estimates yet to be assessed.

### Model 9: On cost savings and recovery and Model 10: Informal to formal trajectory in wastewater irrigation

Models 9 and 10 were assessed based on one product (i.e. treated wastewater) as we assume that incentives are instituted to catalyze the adoption of safety measures under model 10. Additionally, untreated wastewater is not considered a formally marketable commodity given the associated human health risks. A choice experiment was implemented with two key customer segments were assessed: a) businesses/industries and b) farmers. A common set of attributes and corresponding levels were used to formulate 9 choice sets as shown in Table 7below.

Table 7: Description of attributes and levels used in choice experiment

| Attribute | Number of Levels | Description |
|---|---|---|
| Price | 3 | Low(UGX 500/m$^3$);Medium(UGX 900m$^3$); High(UGX 1900m$^3$) |
| Entity providing certification | 3 | None, National Water &Sewerage Corporation (NWSC), Ministry of health (MOH) |
| Delivery mechanism | 2 | Trucks, NWSC connection |
| Payment method | 2 | Credit (quarterly payment), Cash on delivery/monthly |

About 98 percent of the enterprises surveyed expressed that they were satisfied with the current quality of water supplied by the National Water and Sewerage Corporation (NWSC) and 96% noted facing no shortages with water supply. Only 7% of the respondents expressed interest in using treated wastewater, particularly for washing purposes, and also noted willing to pay higher prices than the current fees at UGX 500/m$^3$. The results however indicated that this subset of enterprises did not have a strong preference for certification (i.e. had no valuation for 3rd certification that the wastewater delivered was treated to an acceptable level). However, it is quite clear that enterprises have a strong preference for connections provided by NWSC and that quarterly payments seemed more suitable.

Farmers , on the other hand, showed a higher interest in wastewater reuse for their operations. About 74% of the surveyed farmers were willing to pay for reliable supply of treated wastewater services at the farm. This is supported by the sourced that the farmers obtain water from - about 37% were dependent on groundwater, 13% on rain-fed irrigation, 26% received water through pipes and 10% from the canals. The remaining percentage relied on springs and swamps for irrigation water. The total payment elicited by the farmers for treated wastewater supplied by NWSC is UGX 530/m$^3$. It is also noted that the farmers would prefer supply from NWSC and interestingly are willing to pay more for certification. While 70% of the respondents preferred operation, maintenance and delivery by NWSC, 12% preferred KCCA and 10% opted for farmers' organizations. The results also indicate that farmers are willing to pay higher if the treated wastewater is delivered through canals and payments are made on a quarterly basis.

The total number of agricultural households in the urban and the peri-urban areas of Kampala was estimated at about 44,962 households (Makita, 2009). Assuming a conservative adoption rate of 70% by farmers, the total number of farms demanding treated wastewater would approximately be 31,473 farming households and total agricultural land at 31,473 hectares. Gross irrigation water requirement in Uganda is about 8000 m$^3$/ha in a year (FAO, 1997). Hence the total water requirement in the urban and per-urban area of Kampala can be estimated to be about 250 million m$^3$ in a year. This demand estimate clearly exceeds the total wastewater generated. It is important to note however that the estimated demand may be limited by costs related to delivery especially for farmers located far off from the wastewater treatment plants.

### Model 15: Large-scale composting for revenue generation (compost)

### Model 17: High value fertilizer production for profit and Model 19: Compost production for sanitation service Delivery (faecal sludge-based fertilizer)

The market assessment for MSW-based compost, in addition to estimating consumers' WTP and demand for the product, evaluated their specific WTP for attributes of the compost product. This represents pertinent market information on the types of pricing strategies new businesses should implement. The results indicate that there is a significant demand for compost as measured by the consumers' WTP, which is significantly higher than the average market price for substitute products at 100 UGX/kg. The results indicated that the farmers were willing to pay more to know the source of the input materials used to produce the compost (i.e. MSW, faecal sludge and/or animal waste). The marginal WTP analysis shows that farmers are willing to pay 58.78 UGX/kg more to know the sources of materials used to produce compost, 45.97 UGX/kg for pelletized compost and 30.09UGX/kg for certified compost. This suggests that high quality compost product if labelled with information on source of the inputs, has 3rd party certification and is pelletized will command a market price of 234.84 UGX/kg - which is almost 2.5 times higher than the current market price. Likewise the demand for faecal sludge-based compost (models 17 and 19) was significant with average WTP values ranging between 713 and 1098 UGX/kg. The marginal WTP analysis shows that farmers are willing to pay 161 UGX/kg more for fortified compost and 580 UGX/kg more for certified compost. However, 97UGX/kg will be needed to compensate farmers to use pelletized compost.

The potential market for MSW-compost is noted to be substantial with the demand estimated at 0.78 million tons/year, with an adoption rate of 49% and application rate of 12.5 tons/ha/year. The potential market for Fortifer was estimated at 0.026 million tons/year, assuming an adoption of 38% and application rate of 0.5 tons/ha/year. It is important to note that notable surrounding agricultural districts were considered in the market size estimation, i.e. Luwelo, Mpigi, Mukono and Wakiso in addition to Kampala. The total cultivated area under the 5 districts considered is 130,000 ha (Source: Uganda Census of Agriculture, 2008/09 Volume 4). Additionally, chemical fertilizer application rates were used as a basis for the calculation of the application rates for MSW-compost and Fortifer (IFPRI, 2012). The average chemical fertilizer applications were estimated at 107.5kg/ha and Fortifer at 5 times this estimate as Fortifer is considered a close competitive substitute product. MSW-based compost, on the other hand, is considered to be a complementary product to chemical fertilizer.

Whilst the current production level of compost is unknown, it is clear that it is a burgeoning industry with some entry barriers but supportive and existing policies encouraging business development. The organic fertilizer market is less commercialized and the related market structure and business dynamics are very informal. Given data limitations, the inorganic fertilizer market, which is more formal, commercialized and well-researched during past decades was used as the basis to the extent possible for the market structure and outlook assessment. A market condition that would potentially impact the development of compost businesses is the market power held by chemical fertilizer producers. The fertilizer market in Uganda is highly concentrated – the top four fertilizer importers (except the commercial farms) accounted for about 92% with the largest importer taking 56% of the fertilizer market. This suggests a very high concentration - which is characteristic of a strong oligopolistic market. The chemical fertilizer market has however never expanded to a significant level due to an ineffective fertilizer policy. Though liberalization of Uganda's fertilizer market had its own legacy to increase market competition via inducing the participation of private sector, high cost of entry and participation in fertilizer trade make the fertilizer market imperfectly competitive. Barriers to entry indicate an important determinant of market concentration of the fertilizer markets. Although chemical fertilizers represent the largest share of the market, a limited established distribution network represents an opportunity that organic fertilizer producers can capture. Additionally, there is neither a large-scale government fertilizer program that provides subsidized fertilizer to farmers nor an active private fertilizer sector that supplies fertilizer at competitive prices. Thus, this represents a great opportunity for waste-based organic fertilizer businesses who can take advantage of erratic chemical fertilizer prices and the limited number of actors in the respective market. On the other hand, the product mix available of chemical fertilizer products is rather extensive, reflecting the grade (nutrient)-specific requirements of the commercial crop growers (estates and horticultural crop farms). This suggests that new organic fertilizer businesses will need at the start-up a highly unique and differentiated product, and innovative marketing strategies to mitigate the effects of the currently limited marketing and distribution channels available in the fertilizer market.

The overall feasibility of the business models was then evaluated based on the different aspects (market demand, market structure and market outlook). It was noted in table 8 that models 1a, 17, 19 have a high feasibility and model 15 - medium feasibility from a markets' perspective. On the other hand, waste-to-energy models, in particular agro-waste and faecal sludge to electricity have a low feasibility potential from a market perspective.

Table 8: Summary of the feasibility of the selected RRR business models from a market perspective

| Business model | WTP and Market Demand | Market Structure | Market Outlook | Cumulative feasibility score | Value-added product/recovered resource |
|---|---|---|---|---|---|
| Model 1a – Dry fuel manufacturing: agro-waste to briquettes | WTP > Current market price of substitute product | 1. Easy market entry<br>2. Low-to-medium level of concentration<br>3. Limited to no product differentiation<br>4. Price setter<br>5. Potential net profit margins | 6 – 7 years to reach growth stage in business life cycle | High feasibility | Briquettes |
| Model 2a – Energy service companies at scale: agro-waste to energy (electricity) | WTP < Current market price | 1. Difficult market entry<br>2. High level of concentration (oligopolistic market)<br>3. No product differentiation<br>4. Price taker<br>5. Potential negative profit margins (without subsidies) | Limited data to evaluate business life cycle | Low feasibility | Electricity |
| Model 4 – Onsite energy by sanitation service providers | WTP < Current market price | 1. Difficult market entry<br>2. High level of concentration (oligopolistic market)<br>3. No product differentiation<br>4. Price taker<br>5. Potential negative profit margins (without subsidies) | Limited data to evaluate business life cycle | | |
| Model 9 – On cost savings and recovery (wastewater reuse) | WTP < Current market price | With an inexistent formal wastewater market, the assessment of its structure would be limited to a base reference of the freshwater market, which in this case would result in a flawed assessment. | Not applicable | Low feasibility | Wastewater |
| Model 10 – Informal to formal trajectory in wastewater irrigation | WTP < Current market price | Same as for Model 9. | Not applicable | Low feasibility | |
| Model 15 – Large-scale composting for revenue generation (MSW to compost) | WTP > Current market price of competitive/ substitute products | 1. Medium level of difficulty for market entry<br>2. Limited level of concentration<br>3. Limited to no product differentiation<br>4. Oligopolistic fertilizer market but potential price setter<br>5. Potential net profit margins –positive | 6 – 7 years to reach growth stage in business life cycle | Medium feasibility | Compost |
| Model 17 – High value fertilizer production for profit | WTP > Current market price of competitive/ substitute products | 1. Easy entry<br>2. Limited level of concentration<br>3. Limited to no product differentiation<br>4. Oligopolistic fertilizer market but potential price setter<br>5. Potential net profit margins –positive | 6 – 7 years to reach growth stage in business life cycle | High feasibility | Faecal sludge-based organic fertilizer |
| Model 19 – Compost production for sanitation service delivery | | | | | |

# 4 Key findings of the Institutional and Legal Analysis

Municipal authorities in developing countries are facing mounting problems in dealing with the growing volumes of liquid and solid waste in the form of municipal solid waste (MSW), agro-industrial waste (AIW), wastewater and faecal sludge. Solid and liquid waste is often disposed off without the expectation of compensation for its inherent value. However, it is increasingly being recognized that some or all of the value of refuse could be recovered as energy, nutrients and cleaned water for several uses. Despite these benefits, recycling activities have not become a major way of managing solid and liquid waste disposal in Uganda. There is a lack of clear evidence of stakeholder involvement and institutional support and challenges related to waste resource recovery and reuse (RRR) in Kampala. This section presents the results from the institutional and investment analysis related to waste reuse in Kampala; covering four major waste streams generated in the city: MSW, AIW, wastewater and faecal sludge. The institutional feasibility assessment is presented in table 9 for the selected business models.

There are a number of institutions that regulate solid and liquid waste management in Uganda and most often applicable to Kampala. Some of these are general and cut across the waste streams at the central and local government levels. The lead central government agencies are the Ministries of Water and Environment (MWE) and the National Environment Management Authority (NEMA). Other key central government agencies with some policy and regulatory mandate are the Ministry of Health (MoH), the Ministry of Education and Sports (MoES), the Ministry of Local Government, the Ministry of Trade and the Ministry of Justice and Constitutional Affairs. The key pieces of legislation directly related to the establishment, resourcing for, and the functioning of RRR enterprises and related activities around Kampala City are the National Constitution (1995); the National Environment Act, Cap. 153; the Water Act (1997); the KCCA Statute (2010) and the Local Government Act (1997). There is little variation in terms of content between legislation for MSW, AIW, wastewater and faecal sludge in the country with respect to generation, collection and recovery. At the local and community levels, KCCA is responsible for the implementation of most of the waste management regulations. KCCA is charged with the collection, transport and disposal of all solid waste; cleaning of the streets; the collection and disposal of dead animals; cleaning of the alleys; roadside drain and choke clearing; and maintaining a clean environment in the city (KCCA Act, 2010). End-user regulators are sector-specific. However, the process of recovery and generation of recovered resources is to a large extent still regulated under the general liquid and solid waste management regulations.

There are several primary stakeholders involved in MSW reuse related activities in Kampala. Most of them are small-scale and informal. The main energy resource recovered from MSW in and around Kampala are briquettes. There are several products recovered from agro-waste. On an industrial scale, coffee husks are used as energy alternatives. Animal droppings are also used as compost, while animal bones and horns are used as ingredients in the production of animal feeds and sometimes body ornaments. One of the resources that are recovered from AIW and MSW are compost and bio-fertilizer, although it is intermittent and generally on a very low scale, taking place on-site on a few urban farms, where direct composting is taking place. Other resources recovered from AIW and MSW in the country are green electricity and furnace fuel from outside Kampala. Specifically, the main law about the generation and use of electricity is the Electricity Act (1999). The main recovery activity from wastewater currently taking place in Kampala is wastewater sludge composting. This is still recent and carried out on a limited and pilot scale by the National Water and Sewerage Corporation (NWSC) around Kampala. The use of wastewater sludge as a building material component, fuel component and animal feed component is almost absent. The main reasons noted were concerns related to cultural perceptions of wastewater sludge use, as a building component, fuel component and animal feeds component, and the abundance of conventional raw materials, which obviate the need for an alternative. There are, however, legal framework gaps in the regulatory framework concerning wastewater and fecal sludge management and recovery. The Government of Uganda has put in place policy and legal instruments for the discharge of human waste but there are no express provisions for the use of wastewater and faecal sludge.

Funding opportunities for waste reuse enterprises were identified at three levels, depending on the degree of formality and organization of the enterprises involved. Some are public-level funding windows, while the others are private (formal and informal). Public sector financing is very low and limited to collection and compliance efforts. A potential source can be private-sector involvement, in the form of public-private partnerships (PPPs). Most RRR enterprises in Kampala are informal and emerging and are, therefore, more likely to hinge on or be associated by proxy to informal lending windows or sources close to where they stay or from within and among waste RRR enterprise entrepreneurs themselves.

The institutional feasibility assessment was based on a number of assumptions about the institutional framework and the fundamental question was if the current institutional framework supports the specific RRR business model in terms of establishment, operation, survival and sustainability. The details of the basis for the feasibility analysis are presented in the full *Institutional Analysis* report. A simple rating scale of 0 to 3was used, with 1 indicating very low feasibility or the toughest institutional measures for implementation and 3 indicating high institutional feasibility or the easiest and most supportive institutional environment, while 0 indicates no institutional measures in place. An overall rating score of less than 10 implies low feasibility, an overall score of between 10-20 indicates medium level of success (institutional feasibility), while an overall score of above 20 indicates a high level of success (institutional feasibility).A summary of the results of the institutional feasibility assessment for the business models considered for Kampala is presented in Table 9 below. The results indicate that on-site recovery and energy generation from fecal sludge is currently not supported under city laws. The use of untreated wastewater for irrigation is similarly not permissible under the city and national policies on wastewater and irrigation.

Table 9: Feasibility Assessment of Business Model from an Institutional Perspective

| Business models | Content | Structure | Culture | Overall | Overall institutional feasibility and comments |
|---|---|---|---|---|---|
| Model 1: Dry Fuel Manufacturing: (a)Agro-industrial Waste to Briquettes for Use at Household Level or Industries | Medium | Medium | Low to Medium | Medium | The manufacture and use of briquettes in Uganda is gaining momentum owing to the ease of using the technology involved and the growing interest associated with its advantages (clean, smokeless, long burning hours, more heat energy etc.). The national policies and legal framework support the production of briquettes and investment in this sub-sector. The level of development is still fairly low and nearly all enterprises involved in briquette production are informal. |
| Model 2: Energy Service Companies at Scale: (a) Agro-Waste to Energy (Electricity) | High | Medium to High | Medium to High | High | The generation of electricity is regulated under the Electricity Act (1999). This Act provides for the following: the establishment of the Electricity Regulatory Authority (ERA); its functions, powers and administration; the generation, transmission, distribution, sale and use of electricity; the licensing and control of activities in the electricity sector; among other regulatory mandates. ERA is fairly well established. By implication, the NEMA is also involved in the screening process for potential investors in this business model. The Electricity Act created one company in Uganda – the Uganda Electricity Transmission Company – which buys and sells all the electricity generated in Uganda for commercial purposes. There is already a guaranteed market and distribution network for electricity generated in the country. The national demand for electricity is not yet met from the current sources. Once a license is acquired from the Uganda Electricity Regulatory Authority and a Power Purchase Agreement from Uganda Electricity Transmission Company, financing can be accessed from several sources in and outside the country. This model has a fairly high feasibility for success. |
| Model 4: Onsite Energy Generation by Sanitation Service Providers | No city and national polices that directly support onsite generation at public facilities in the city. Mandate restricted to NWSC only. | Low<br><br>Regulation limited to safe disposal (further sludge management including energy generation) is possible under the NWSC act and mandate held by NWSC | Low | Low | The mandate of the public and private cesspool emptiers for onsite sanitation facilities around the city does not include handling the fecal sludge in any way other than depositing it at the NWSC treatment sites. The mandate currently is limited to NWSC due to its monopoly as the sole depository of fecal sludge from onsite sanitation public facilities. Therefore, this business models has a very low level of success from an institutional feasibility perspective. |
| Model 9: On Cost Savings and Recovery - Wastewater for Irrigation, Energy and Nutrient Recovery | Medium | Medium | Low | Medium | This business model has fairly medium level of success if supported and restricted to NWSC given the limited legal and policy mandates that centralize wastewater disposal and recovery to NWSC. |
| Model 10: Informal to Formal Trajectory in Wastewater Irrigation | No city and national polices to support business model | No city and national polices to support business model | Low | Low | The use of untreated wastewater for irrigation is not permissible under the city and national policies on wastewater and irrigation. The National Irrigation Master Plan (2010-2035) does not emphasize irrigation using untreated wastewater. This is |

| | | | | | |
|---|---|---|---|---|---|
| The model involves promoting use of untreated waste water for irrigation. | | | | | likely due to the abundance of alternative sources of water for production in the country around the city and the country. |
| Model 15: Centralized Large-scale Compost Production for Revenue Generation | Medium | Medium | Low to Medium | Medium | The potential for the use of compost as a fertilizer is quite high. Recovery processes are guided and regulated by NEMA. However, the nutrient content of the compost generated must be quantified and the hygiene quality of the compost determined in order to properly assess the quality of the resource recovered. There is increasing public and donor support to promote agriculture using compost and non-compost fertilizers. There is also the Uganda Carbon Bureau that promotes carbon trading for emissions reduction; however, few people are aware about its operations in the country. This model has a fairly medium level of feasibility for success if the target are large scale farmers outside Kampala. |
| Model 17: High value Fertilizer Production for Profit from Fecal Sludge | Medium | Medium | Low | Medium | National policies and legal framework support the production of high value fertilizers from faecal sludge and wastewater under controlled regulation. There is government support for private companies' entry into the sub-sector. NWSC is also mandated to enter into private and public partnerships for the production of high value fertilizers from faecal sludge. Funding is a challenge. There are government departments to implement policy/legal provisions, especially at the collection and disposal levels. There are likely to be capacity and logistical challenges. There are negative value orientations about the use of organic fertilizers recovered from fecal sludge. |
| Model 19: of Compost Production for sanitation service | No city and national polices that directly support compost generation at public sanitation facilities in the city. Mandate restricted to NWSC only. | Low<br>Regulation limited to safe disposal (further sludge management including compost generation) is possible under the NWSC act and mandate held by NWSC | Low | Low | The mandate of the public and private cesspool emptiers for onsite sanitation facilities around the city does not include handling the faecal sludge in any way other than depositing it at the NWSC treatment sites. The mandate currently is limited to NWSC due to its monopoly as sole depository of faecal sludge from onsite sanitation public facilities. Therefore, this business models has a low level of success from an institutional feasibility perspective. |

# 5 Key findings of Technical Analysis

This section summarizes the key findings of the component on technology assessment. The business models do not prescribe a specific technology option or scale, but rather define a process (e.g. anaerobic digestion) and targeted end-product (e.g. biogas). Based on this limited level of technical detail, the technology assessment provides:

- A flow diagram, which shows the inputs (e.g. municipal solid waste), outputs (e.g. soil conditioner) and processes (e.g. composting) for each business model
- An overview of treatment options (e.g. windrow composting) for each of the processes in the flow diagram
- An overview of mitigation measures (e.g. temperature control) for each output that has a potential environmental hazard (e.g. pathogens)
- Technology Score Cards that rank technology options based on requirements such as and, electricity, and operation and maintenance
- A context specific evaluation, based on local characteristics, and summarizes the potential of the business model from a technical perspective.

The technical feasibility of the business models cannot be judged in detail, as information on facility scale, specific location in the city and market demand is not available. Therefore, all business models are ranked "medium feasibility". Required treatment infrastructure can only be clearly defined after the market demand of end-products and the corresponding specific goal of treatment is determined. This would also include detailed laboratory analysis of the waste to be treated, so that treatment technologies can be selected and designed accordingly. This was not available within the scope of this report, given the size and complex waste management infrastructure of the feasibility study cities. Feasibility of a treatment technology depends strongly on the enabling environment (i.e. institutional, legal and political concerns), supporting such an implementation. The technology assessment therefore cannot be regarded as a stand-alone component, but is highly dependent on other components of the feasibility analysis. The "Technology Assessment" report is a guidance document for the decision making process, as the implementing business can use the technology and process descriptions, proposed mitigation measures, technology score cards and context specific information to identify the constraints certain technologies have. **Error! Reference source not found.**10 provides a summary of all business models, including the input waste stream, the anticipated end-product, technologies under consideration, and conversion processes.

Detailed information is available in the following report: "*Resource, Recovery and Reuse Project. From Research to Implementation. Technology Assessment: Bangalore, India; Hanoi, Vietnam; Kampala/Uganda; Lima, Peru. February (2015)*".

Table 10: Summary of business models under consideration for Kampala

| Business Model | Waste stream | End-product | Technologies | Process |
|---|---|---|---|---|
| 1 (a,b) | • MSW<br>• AIW | • Briquettes | • Carbonized - low pressure<br>• Raw - mechanized high pressure,<br>• Carbonized - mechanized | • Briquetting |
| 2 (a,b) | • MSW<br>• AIW<br>• AM | • Gasification -> Electricity<br>• Biogas -> Electricity | • Gasification technologies<br>• Single stage<br>• Multi-stage<br>• Batch<br>• Biogas conversion technologies | • Gasification<br>• Anaerobic digestion<br>• Biogas to electricity conversion |
| 4 | • Feces<br>• Urine<br>• FS | • Biogas -> Cooking fuel | • Single stage<br>• Multi-stage<br>• Batch | • Anaerobic digestion |
| 9 | • WW<br>• WW sludge | • Electricity<br>• Soil conditioner<br>• Water (for reclamation) | • Conventional wastewater treatment technologies<br>• Biogas conversion technologies | • Conventional WW treatment<br>• Biogas to electricity conversion |
| 10 | • WW | • Water (for reclamation)<br>• Water for groundwater recharge | • Slow rate infiltration<br>• Rapid infiltration<br>• Overland flow<br>• Wetland application | • Land treatment |
| 15 | • MSW<br>• FS | • Soil Conditioner | • Solid/liquid separation<br>• Drying beds<br>• Co-composting | • Co-composting (MSW + FS) |
| 17 | • MSW<br>• FS | • Fertilizer (NPK added) | • Solid/liquid separation<br>• Drying beds<br>• Co-composting | • Co-composting (MSW + FS) |
| 19 | • Urine<br>• Feces | • Stored urine<br>• Soil conditioner | • UDDTs<br>• Co-composting | • Urine application<br>• Co-composting |

# 6 Key findings of the Financial Analysis

## 6.1 Introduction

The section presents the financial feasibility assessment of the selected RRR business models. The financial analysis of the RRR business models considered all the business models described in Table 1 except for Model 10, which is a social model driven by policies for the region based on socio-economic benefits. Due to the informal nature and practice of the business model, it does not have a clear ownership structure, operator, and in the process no direct revenue attributable to a specific entity and thus limits the ability to conduct a financial assessment of the business model.

## 6.2 Methodology

The methodology used for the financial assessment was based on a pre-defined step-by-step process with the objective to mirror the business model and respective financials relevant to local context and to assist investors, donors, governments and entrepreneurs as a decision making tool. The following steps were undertaken for the financial analysis of the RRR business models:

- **Step 1:** Identification of business cases in Kampala similar to the generic RRR business models.
- **Step 2:** Development of scenarios wherever necessary to mirror the business model to local context based on the local business cases identified. Development of scenarios for different scale based on business cases across developing countries in Asia, Africa and Latin America and from literature review.
- **Step 3:** Description of the technology for the RRR business models based on the technical assessment report and as observed from the business cases in the region.
- **Step 4:** Identification of key input data points based on scenarios developed, type of technology used and scale of the business.
- **Step 5:** A mix of primary and secondary data was also used for this analysis. Data from the waste supply, market demand, technical aspects and health assessments of the RRR business models fed into the financial analysis. The analysis took into consideration investment and production cost data of similar business models in the selected city. Where the business models under study were not currently existing in the selected city, the analysis was based on secondary data. Data on economic indicators such as interest rates, inflation, tax, escalation, annual write off, insurance and debt-equity ratios were obtained from published data reports by Bank of Uganda and industrial benchmarks for the region.
- **Step 6:** The profitability and financial viability of an RRR business model was analyzed based on the Profit and Loss Statement (P&L), Operational Breakeven, net present value (NPV), internal rate of return (IRR) and Payback period valuation criteria. For the financial risk assessment of the business models, a Monte Carlo risk analysis method was used. Microsoft Excel was used for the financial analysis and an Excel add-in, @Risk, used to execute the Monte Carlo simulations.

The Monte Carlo risk analysis involved the following steps:

- *Selection of valuation criteria*: The NPV, IRR or depending on the business model under analysis, other criteria were used as the valuation criteria.
- *Identification of sources of uncertainty and key stochastic variables*. Possible sources of uncertainty considered were technical development, change in government policy, inflation, variation in input and output prices, competitors' actions and other various factors. After the sources of uncertainty were identified stochastic variables (investment cost, yield, price of inputs, price of output, etc.) which could potentially significantly affect the economic performance of the RRR business model and were subject to uncertainty were identified.
- *Definition of the probability distributions of stochastic variables*: Probability distributions for all risky variables were defined and parameterized.
- *Running of the simulation model*: Determination of the NPV and IRR for each year using sampled values from the probability distributions for project life. This process was repeated a large number of times (larger than 1000) to obtain a frequency distribution for NPV and IRR.
- *Determination of the probability distribution of the simulation output (NPV& IRR):* The simulation model generated empirical estimates of probability distributions for NPV and IRR, so that investors can evaluate the probability of success for an RRR-business model.

*Data limitations:* In any research, data access and availability is critical. The fact that the RRR sector is not yet well developed in Uganda, suggests data availability and research on financial viability are limited. Additionally, significant challenges were encountered in obtaining data relevant to Kampala context. As much as possible, input data were collected from business cases identified in Kampala, however when data was not available or not provided by the businesses, data collected from similar business cases operating in Asia, Africa and Latin America was verified and used; and also supplemented with data from literature and actualized for Kampala. Data was also validated from the data collected by other components of the feasibility study – market, waste supply and availability, technical, and institutional assessment. It is important to note that despite undertaking these measures, data for the wastewater business model is considered to be fairly weak.

## 6.3 Financial Synopsis of the RRR Business Models

The following section presents the key financial highlights of the RRR business models assessed. For detailed assessment, please refer to the full *Financial Analysis* report. The financials for the RRR business models are classified according to Energy, Wastewater and Nutrient models.

### 6.3.1 Energy Business Models

Table 11 presents the key highlights of the energy business models. Model 1 – Dry fuel manufacturing and Model 4 - onsite energy generation by sanitation service providers have positive NPV and IRR greater than 12% which is the discount rate in Kampala. However both the scenarios under Model 2: Energy Service Company have negative NPVs and IRR below discount rate.

Table 11: Energy Business Models

| | Model 1a: Dry Fuel Manufacturing - Agro-Waste to Briquettes | Model 2a: Energy Service Companies at Scale - Agro-Waste to Energy (Electricity) | | Model 4: Onsite Energy Generation by Sanitation Service Providers |
|---|---|---|---|---|
| **Scale** | 2,000 tons of briquette per year | 120kW generation for 750 households | 8 MW generation and 250 tons per day crop residue | 800 users per day and 54m$^3$ of biogas produced per day |
| **Investment required (in USD)** | 292,742 | 462,340 | 6.5 million | 56,000 and additional investment of 4K once every 7 years |
| **Operations Cost (in USD/year)*†** | 350K to 638K | 47K to 67K | 1.6 million to 2.5 million | 10K to 16K |
| **Revenue (in USD/year)*** | 412K to 790K | 105K to 150K | 3.07 million to 3.5 million | 27K to 29K |
| **NPV @ discount rate 12%**** | $189,718 | ($140,932) | ($229,654) | $30,573 |
| **IRR**** | 21% | 1.22% | 11% | 22% |

* Range is based on first year to life cycle term costs and revenue
† Operations cost does not include depreciation, interest and tax
** Calculated for life cycle term
K = 1,000

### 6.3.2 Wastewater Reuse Business Models

Table 12 provides key highlights of wastewater reuse business models. The scale was based on the input wastewater quantity in Kampala, which was from the waste supply and availability data based on sewer network in Kampala. As noted earlier, Model 10 was not considered for financial analysis. In the financial analysis of model 9, the assessment assumed investment of reuse infrastructure in an existing treatment plant. The financial assessment takes into consideration additional investment required to incorporate recovery of energy, nutrient and treated wastewater for irrigation and related operation cost and revenue for the treatment plant. All three recovery options show positive NPV and IRR greater than discount rate.

Table 12: Wastewater Reuse Business Models

| | Model 9: On Cost Savings and Recovery | | | Model 10: Informal to Formal Trajectory in Wastewater Irrigation - Incentivizing safe reuse of untreated wastewater |
|---|---|---|---|---|
| **Scale** | 40,000 m$^3$ for irrigation | 282 tons of sludge per day | 282 kW generation | Financial analysis was not done for this business model. |
| **Investment required (in USD)** | 15 million | 170K | 494K | |
| **Operations Cost (in USD/year)*†** | 397K to 588K | 20K to 26K | 148K to 207K | |
| **Revenue (in USD/year)*** | 594K | 42K to 63K | 202K to 305K of savings | |
| **NPV @ discount rate 12%**** | $521,308 | $94,750 | ($172,779) | |
| **IRR**** | 38% | 20% | 4% | |

* Range is based on first year to life cycle term costs and revenue
† Operations cost does not include depreciation, interest and tax
** Calculated for life cycle term
K = 1,000

### 6.3.3 Nutrient Business Models

Table 13 provides key highlights of the nutrient business models. As seen from the table below, for Model 15 - large scale composting plants as the scale increases the NPV and IRR also increases. For all three scenarios, NPV is positive and IRR is equal to above discount rate. In the case of high value fertilizer production and compost production for sanitation service delivery, they both have positive NPVs and IRR greater than discount rate.

Table 13: Nutrient Business Models

| | **Model 15: Large-Scale Composting for Revenue Generation** | | | **Model 17: High value Fertilizer Production for Profit** | **Model 19: Compost Production for Sanitation Service Delivery** |
|---|---|---|---|---|---|
| **Scale** | 70 tons of MSW per day | 200 tons of MSW per day | 600 tons of MSW per day | 1,000 tons of compost per year | 1,000 users per day, 5 public toilets and 113 tons of compost per year |
| **Investment required (in USD)** | 473,500 | 1.3 million | 3 million | 375,000 | 75K and additional investment of 17K once every 7 years |
| **Operations Cost (in USD/year)*†** | 73K to 112K | 170K to 270K | 387K to 720K | 56K to 87K | 43K to 65K |
| **Revenue (in USD/year)*** | 149K to 280K | 348K to 851K | 0.94 million to 2.3 million | 131K to 238K | 65K to 99K |
| **NPV @ discount rate 12%**** | $17,086 | $280,629 | $2,408,703 | $114,434 | $33,709 |
| **IRR**** | 12% | 15% | 23% | 17% | 19% |

* Range is based on first year to life cycle term costs and revenue
† Operations cost does not include depreciation, interest and tax
** Calculated for life cycle term
K = 1,000

## 6.4 Summary assessment of financial feasibility of RRR Business Models

Table 14 provides a summary overview of the feasibility of RRR business models for Kampala. As mentioned earlier in the methodology, a Monte Carlo risk analysis was done for the financial models for variable parameters with a high level of uncertainty. A stochastic simulation model was run for a large number of iterations to generate empirical estimates of probability distributions for NPV and IRR, to guide investors, donors and entrepreneurs to evaluate the probability of success for an RRR business model. This simulation results evaluated several aspects: a) a probability of NPV < 0, mean NPV and IRR, pessimistic and optimistic NPV and IRR values. The mean NPV and IRR is the net average of the lowest and highest NPV and IRR value for various iterations. The results from the simulation exercise formed the basis for the selection of key indicators to assess the feasibility of the RRR business model. The indicators used to assess the feasibility of the RRR business models were based on: P (NPV<0), *Mean NPV* been positive or negative and a *Mean IRR* greater than or less than the discount rate in Kampala (12%). The methodology used to define the feasibility is as described in Table 14 below.

Table 14: Feasibility ranking methodology

| P (NPV < 0) | Mean NPV | Mean IRR | Feasibility |
|---|---|---|---|
| 0 < P (NPV) < 30% | + | Greater than discount rate | High |
| 30% < P (NPV) < 50% | + | Greater than discount rate | Medium to High |
| 0 < P (NPV) < 30% | + | Less than discount rate | Medium |
| 50% and above | + | Greater than discount rate | |
| 0 < P (NPV) < 30% | - | Greater than discount rate | Low to Medium |
| 30% < P (NPV) < 50% | + | Less than discount rate | |
| 30% < P (NPV) < 50% | - | Greater than discount rate | Low |
| 50% and above | + | Less than discount rate | |
| 0 < P (NPV) < 30% | - | Less than discount rate | Not Feasible |
| 30% < P (NPV) < 50% | - | Less than discount rate | |
| 50% and above | - | Greater than discount rate | |
| 50% and above | - | Less than discount rate | |

Using the methodology defined in Table 14, the RRR business models were assessed for their viability to Kampala context. Model 2 – Energy Service Company (120kW and 8MW) and Model 15 – large scale composting for revenue generation (70 tons) as seen in Table 15 indicates that these models are not feasible while the remaining models show either medium or high feasibility. The models with high feasibility are Model4 – Onsite energy generation by sanitation service providers, Model 15 – large scale composting for revenue generation @ 600 tons per day of waste processed and Model 17 – high value fertilizer production. Each of these models are also public-private partnership (PPP) based models where it is assumed that land is provided by the municipality. In terms of sole private sector management, the only feasible business model is Model 1 – dry fuel manufacturing. Model 9 – On cost savings and recovery (sludge recovery and electricity generation) when all three components are combined in a treatment plant is of medium to high feasibility.

Table 15: RRR Business Models Feasibility

| RRR Business Models | P (NPV< 0) | Mean NPV | Mean IRR | Feasibility |
|---|---|---|---|---|
| **ENERGY** | | | | |
| **Model 1:** Dry Fuel Manufacturing - Agro-industrial Waste to Briquettes | 39.3% | $143,980 | 22.58% | Medium to High |
| **Model 2:** Energy Service Companies at Scale - Agro-Waste to Energy (Electricity) – *120 kW Social Business Model* | 93% | ($120,376) | 1.94% | Not Feasible |
| **Model 2:** Energy Service Companies at Scale - Agro-Waste to Energy (Electricity) – *8MW Profit Maximization Model* | 62% | ($248,965) | 11.45% | Not Feasible |

| | | | | |
|---|---|---|---|---|
| **Model 4:** Onsite Energy Generation by Sanitation Service Providers | 1.5% | $27,146 | 21% | High |
| **WASTEWATER REUSE** | | | | |
| **Model 9:** On Cost Savings and Recovery – Irrigation reuse | 35.3% | $280,989 | 43.31% | Medium to High |
| **Model 9:** On Cost Savings and Recovery – sludge recovery as soil conditioner | 11% | $140,716 | 23.36% | High |
| **Model 9:** On Cost Savings and Recovery – electricity for onsite use | 60.4% | ($171,746) | 16.305% | Not Feasible |
| **Model 9:** On Cost Savings and Recovery – combined energy, water and nutrient recovery | 35.5% | $197,817 | 27.66% | Medium to High |
| **Model 10:** Informal to Formal Trajectory in Wastewater Irrigation - Incentivizing safe reuse of untreated wastewater | *Financial Feasibility not undertaken* | | | |
| **NUTRIENTS** | | | | |
| **Model 15:** Large-Scale Composting for Revenue Generation - 70 tons | 88.9% | ($130,586) | 8.38% | Not Feasible |
| **Model 15:** Large-Scale Composting for Revenue Generation - 200 tons | 46.4% | $46,480 | 12.68% | Medium to High |
| **Model 15:** Large-Scale Composting for Revenue Generation - 600 tons | 1.2% | $1,465,442 | 19.12% | High |
| **Model 17:**High value Fertilizer Production for Profit | 7% | $44,793 | 13.79% | High |
| **Model 19**: Compost Production for Sanitation Service Delivery | 48.5% | $30,117 | 19.21% | Medium to High |

While the Table 15 attempts to give a snapshot of the RRR business models viable for the Kampala context, it however needs to be noted that all the business models under different conditions other than that in Kampala may show a medium to high feasibility. For example, Model 2 – Energy Service Company, becomes increasingly viable when the debt component is reduced. It warrants to be noted that, in Kampala, the debt rates were taken at 22% (as per the Bank of Uganda), which is very high and the interest burden significantly hampers the viability of the business. It is recommended that if the cost-benefit analysis shows a greater social good from the investment, subsidizing interest payments or providing access to low interest credit can make all of these business models highly viable. Other than interest rates, product price and percentage of sale of product plays a significant role in the viability.

Below is a brief overview of the key aspects that will influence the feasibility of each of the business models in Kampala:

*Model 1 – Dry fuel Manufacturing:* Eastern Africa has seen a surge in the business of briquette production. These businesses have performed consistently for a number of years resulting in a relatively stable market environment for the business model. Despite such stability, it is observed that the price of inputs (agro-waste) highly fluctuate and pose a significant threat to the business along with quality of briquette which determines the price of briquette in the market.

*Model 2 – Energy Service Companies:* This business model is observed at a very small scale in Uganda where the businesses are using corn cobs as key agro-waste input. Uganda lags considerably on electrification and these small-scale electricity generation models are used to electrify households in peri-urban and rural areas. However the small-scale model is significantly dependent upon capital subsidies. The financial assessments show that neither smaller nor larger-scale plants are feasible. The larger scale plants are observed to be very sensitive to price of electricity for feed-in-tariffs, which are currently on the lower side in Uganda. Both larger and smaller-scale show increasing viability when the equity portion of the investment is increased.

*Model 4 – Onsite energy generation by sanitation service providers:* The primary revenue of the business is from toilet user fees and revenue from reuse is significantly lower. The business model viability is highly dependent upon the location of the public toilet, typically such as bus stands and market areas where one could have significant customers using the toilets. The business can never depend on its feasibility from sale of biogas.

*Model 9 – On Cost savings and recovery:* Financial analysis of this model is focused on the reuse component and does not take into consideration the setting up of a new wastewater treatment plant. Three scenarios were developed based on the type of resource recovered (energy, water and nutrient). The key assumption in the case of water and nutrient recovery is the sale of treated wastewater for irrigation (or industry) or sale of sludge as soil conditioner. We acknowledge that these assumptions of sale is the riskiest aspect of this business model as farmers rarely pay for freshwater in developing countries and to assume that they would pay for treated water is questionable. In the event of drought or water scarcity, there is a possibility of increased willingness to pay for treated wastewater. Alternatively, the treatment plant could target sale of treated water to industries. The feasibility of supplying treated wastewater also depends on the length of the canal or pipeline and pumping costs to deliver the water to its customer segment. Similar is the case for sale of sludge as soil conditioner where farmers are willing to pay for sludge from treatment plant. In the case of electricity generated, financial assessment shows that it is not feasible, however we note that electricity prices in Uganda are comparably fairly low and the cost of generating electricity at the existing price makes the investment unviable. In the future if the electricity price were to increase by even USD 0.5 per unit, it would make the investment viable. A treatment plant incorporating all these reuse investments yields a positive NPV.

*Model 15 – Large scale composting for revenue generation:* As observed above, the financial assessment was conducted for three different scenarios and it was observed that as the scale of waste processed increases, the feasibility of the compost production plant improves. Similar to Model 2, the debt to equity ratio plays a significant role for positive NPV. Critical assumption in the business model is the significant quantity of compost sold year on year (from 50% to 80%). In our study we have observed that in developing countries, most compost plants from municipal solid waste face some challenges with the sale of compost and they undertake compost production to reduce the overall quantity of waste sent to landfill. In addition, the compost price in Kampala is significantly higher in comparison to other African countries. The price of compost is one the most sensitive parameters that drives viability of the business.

*Model 17 – High value fertilizer production for profit:* Under this business model, one of the products is co-compost (mix of fecal sludge and solid waste). The product is relatively unknown and due to the nature of raw material used (faecal sludge), it has significant risk on acceptability of the product by consumers. The business model also shows high viability because of higher pricing of the product and quantity of product sold, as discussed for Model 15. In our stochastic simulations, we observed that the percentage of sales from year 3 onwards was the most sensitive variable.

*Model 19 – Compost Production for Sanitation service delivery:* Similar to Model 4, the business model viability is dependent on the number of toilet users. Revenue generated from toilet user fees (85% of total revenue) drives the business viability and revenue from sale of compost (6% of total revenue) in comparison is significantly lower.

# 7 Key findings of the Health Risk and Impact Assessment

## 7.1 Introduction and methodology

For the 4 targeted feasibility cities of the RRR project, the health components around the selected business models (BM) employed two methodologies, with two different foci: Health Risk Assessment (HRA) and the Health Impact Assessment (HIA). The HRA aimed at identifying health risks associated with the input resources (e.g. faecal sludge, waste water) of proposed BMs and defining what control measures are needed for safeguarding occupational health and producing outputs (e.g. treated waste water, soil conditioner) that are compliant with national and international quality requirements. The HIA aimed at identifying potential health impacts (positive or negative) at community level under the scenario that the proposed BMs are implemented at scale in Kampala area. The magnitude of potential impacts was determined by means of a semi-quantitative impact assessment. The feasibility studies in Kampala were oriented towards eight BMs that were selected due to their potential in the given context. These BMs are:

- Model 1a: Dry fuel manufacturing: agro-waste to briquettes
- Model 2a: Energy service companies at scale: agro-waste to energy (electricity)
- Model 4: Onsite energy generation by sanitation service providers
- Model 9: On cost savings and recovery
- Model 10: Informal to formal trajectory in wastewater irrigation: incentivizing safe reuse of untreated wastewater
- Model 15: Large-scale composting for revenue generation
- Model 17: High value fertilizer production for profit
- Model 19: Compost production for sanitation service Delivery

## 7.2 Evidence-base of the HRIA

A broad evidence-base was assembled for the health risk and impact assessment (HRIA). At a large scale (i.e. city level) this entailed the collection of secondary data on the epidemiological profile, environmental exposures and the health system of Kampala. This included statistics of health facilities from urban, peri-urban and rural areas in and around Kampala city, as well as data from the peer-reviewed and grey literature. The literature review had a focus on (i) soil-, water- and waste-related diseases; (ii) respiratory tract diseases; and (iii) vector-borne diseases, since these disease groups are closely associated with unsafe disposal of waste and waste recovery. At a small scale, primary data was collected at the level of existing RRR activities by means of participatory data collection methods and direct observations. A total of 8 existing RRR cases were investigated in Kampala area:

- Case 1: Tiribogo gasification plant
- Case 2: Wastewater treatment at Bugolobi sewerage treatment and disposal works
- Case 3: Faecal sludge management by the Pit Emptier Association of Uganda (PEAU) and Kampala Capital City Authority (KCCA)
- Case 4: Kampala Jellistone briquette making factory
- Case 5: Katikolo compost plant

- Case 6: Municipal solid waste (MSW) to Kitezi sanitary landfill
- Case 7: Agali-Awamu organic banana peelings market
- Case 8: Eco-San latrines at St. James Biina primary school

The cases were studied considering the given context and by following a similar methodology in all 4 feasibility study cities. An additional important component of the case studies were an assessment of the use and acceptability of personal protective (PPE) among the workforce. In addition to the standardized methodology of the health component around these 8 existing RRR cases, the city of Kampala benefited from particular complementary in-depth studies through one PhD study and one MSc. study which focused on environmental and health risks related to the reuse of wastewater and faecal sludge for agriculture. The two in-depth studies were carried out in the context of the Nakivubo channel and wetland. With the aim to generate evidence on the exposure risk along the wastewater and faecal sludge chains in Kampala, a cross-sectional survey was implemented, targeting different exposure groups: wastewater treatment plant worker (n=114); faecal sludge worker (n=117); farmer (n=314); community members living in proximity to wastewater drainage channels (n=257); and community members as a control group without any direct contact to wastewater (n=354). In total, 1’156 individuals participated in the study, which comprised a questionnaire survey and the collection of stool samples to determine the prevalence and the intensity of parasitic infections. The second study had the goal to fill important data gaps in the knowledge on the environmental pollution of the Nakivubo channel and wetland. A total of 268 water, sediment, soil and plant samples were collected at strategic points and analyzed for physiochemical parameters, bacteria, helminth eggs and heavy metals.

## 7.3 Summary of findings of the literature review and in-depth studies

According to health statistics from rural, peri-urban and urban areas of Kampala, malaria and acute respiratory infections were the leading causes of consultations in 2011 and 2012, independent of the environment. These were followed by skin diseases, intestinal worm infections, urogenital infections, gastrointestinal disorders, pneumonia, eye diseases, urogenital infections and sexually transmitted infections as major causes of morbidity. According to the 2011 Uganda Demographic and Health Survey (UDHS), two in three households use non-improved toilet facilities (73% in rural areas and 28% in urban areas), while one in ten households in Uganda, mainly in rural areas, does not have a toilet facility. Approximately 20% of all households are connected to the water supply grid, which is concentrated to high-income areas. However, there are an estimated 70% of the population using piped water for domestic needs in combination with the use of alternative sources. Against this background, it is not surprising that all major STH species are endemic and of public health importance in Uganda. In our own in-depth study at the Nakivubo channel and wetland, the most common STH infections were hookworm and *T. trichiura* with prevalences of 27.8% and 26.1% in local farmers, respectively. Prevalence of *Giardia lamblia* was found to be considerably lower (below 2% in all population groups sampled). *Entamoeba coli* was found to be the most common type of intestinal protozoa in farmers (prevalence: 38.4%) and the general community (prevalence: 36.2%). Eye problems and skin problems were reported by approximately 30% of all population groups investigated.

Acute respiratory diseases are a major public health concern in Kampala (second leading cause of consultations at health facilities). This clearly shows that a lot of transmission is taking place, with poor personal hygiene and poor sanitation system as two important determinants. Also the burden of chronic respiratory diseases and cardiovascular diseases is high, accounting for 2% and 9% of total mortality (all ages, both sexes), respectively, in Uganda. Various vector-borne diseases are endemic and of major public health relevance (e.g. malaria, dengue, yellow fever, Rift Valley fever, lymphatic filariasis). Clearly, malaria is the most important vector-borne disease. It is the leading cause of morbidity and mortality, accounting for approximately 8–13 million episodes per year in Uganda. In urban areas, however, generally less than 5% of people are infected with malaria. Kampala district does not belong to the districts affected by lymphatic filariasis. Trachoma, another vector-borne disease (flies), is the leading infectious cause of blindness with an estimated eight million Ugandans being at risk of suffering from Trachoma. For Kampala, little recent data is available on environmental determinants such as water and soil quality. In our own in-depth study, high levels of faecal coliform bacteria, *E. coli*, *Salmonella* spp., and hookworm eggs were found in water and soil samples within the Nakivubo wetland. Concentrations showed temporal variability and values were always above the national standards for the discharge of effluents into the environment and WHO guidelines for the safe use of wastewater in agriculture. In terms of industrial pollution, high levels of copper, iron, and cadmium were found in water, and high levels of zinc, iron, cadmium and lead were found in soil. Plants also showed heavy metal concentrations above existing safety levels.

## 7.4 Key findings of the HRA

All of the identified occupational health risk – such as exposure to pathogens, skin cuts or inhalation of toxic gases – can be managed by providing appropriate PPE, health and safety education to workers and appropriate design of the operation and technical elements. Biological hazards mostly derive from human and/or animal wastes that serve as inputs *per se* for the proposed BM (e.g. animal compost or human faeces) or are a component thereof (e.g. human waste in wastewater). For meeting pathogen reduction rates as proposed by the World Health Organization's 'Guidelines for the Safe Use of Wastewater, Excreta and Greywater' and other standards, a series of treatment options are at disposal. The HRA provides guidance on which treatment options are required for what reuse option. When it comes to the implementation of the BM, the challenge will be to respect indicated retention times and temperatures for achieving the required pathogen reduction rates. Since the proposed retention times may also have financial implications, it is important that these are taken up by the financial analysis. Also vector-related diseases are an important concern in Kampala area and therefore vector-control measures are indicated for many processes of the BMs.

Chemical hazards primarily concern wastewater fed BMs. The environmental sampling in the Nakivubo channel and wetland found high variation in heavy metal concentration, often exceeding national and international thresholds. Besides the soil and water samples, also Cd, Pb and Cr concentrations in yam and sugarcane exceeded WHO threshold values. This clearly indicates that irrigation with wastewater is of concern in Kampala from a health and environmental perspective, though high local variation might apply. This needs to be taken into account for the planning of any wastewater fed BM, i.e. environmental sampling is indicated for identifying suitable locations. Where threshold values of toxic chemicals exceed national and WHO guideline values, physiochemical treatment for removing toxic chemicals such as heavy metals are required. Also co-composting with wastewater sludge is only an option if the sludge is compliant with heavy metal thresholds. In addition, for both irrigation with treated wastewater and the use of sludge-based soil conditioner, chemical parameters of receiving soils need to be taken into account.

In terms of physical hazards, sharp objects deriving from contaminated inputs (e.g. faecal sludge or MSW) ending-up in soil conditioner are a risk that has been identified for a number of BM. This will require careful pre-processing of inputs and sieving of end-products. Moreover, users need to be sensitized about the potential presence of sharp objects in the soil conditioner and advised to wear boots and gloves when applying the product. Also emissions such as noise and volatile compounds are of concern at workplace and community level. While PPE allows for controlling these hazards at workplace level, a buffer zone between operation and community infrastructure needs to be respected so that ambient air quality and noise exposure standards are not exceeded. Of note, the actual distance of the buffer zone is depending on the level of emissions. Finally, for businesses involving burning processes and power plants, fire/explosion and electric shock are risks of high priority that need to be managed appropriately.

Overall, the health risks associated with most of the proposed BM can be mitigated with a reasonable set of control measures. Concerns about heavy metals and other chemical contaminants remain for all the wastewater-fed BM. Model 10 – untreated wastewater for irrigation and groundwater recharge – is not recommended in the setting of Kampala. Model 15 and 17, both of which use municipal solid waste (MSW) as an input, are only an option if no medical waste from health facilities is mixed with common MSW. Although, at the kick-off workshop in Kampala in March 2013 it was reported that there is a separate collection system for medical waste, this needs further investigation.

## 7.5 Key findings of the HIA

The objective of the HIA was to assess potential health impacts at community level of proposed BMs for Kampala under the assumption that the control measures proposed by the HRA are deployed. This included consideration of both potential health benefits (e.g. business is resulting in reduced exposure to pathogens as it entails treatment of wastewater) and adverse health impacts (e.g. exposure to toxic gases by using briquettes as cooking fuels). Since the HIA aimed at making a prediction of potential health impacts of a given BM under the assumption that it was implemented at scale, a scenario was defined for each BM as an initial step. The scenario was then translated into the impact level, the number of people affected and the likelihood/frequency of the impact to occur. By means of a semi-quantitative impact assessment, the magnitude of the potential impacts was calculated.

A summary of the nature and magnitude of anticipated health impacts for each of the proposed BM is presented in Table 16. Most of the proposed BMs have the potential for resulting in a minor to moderate positive health impacts. Under the given scenarios, Model 4 (onsite energy generation in enterprises providing sanitation services) and Model 9 (treated wastewater for irrigation/fertilizer/energy: cost recovery) have the greatest potential for having a positive impact since they will result in a reduction in exposure to pathogens at community level. Model 1a – Dry fuel manufacturing: agro-waste to briquettes – bears the risk to result in a moderate negative impact by replacing more clean cooking fuels such as gas and electricity with briquettes. As already highlighted under the HRA, from a health perspective it is not recommended to promote the reuse of untreated wastewater for irrigation purposes in Kampala (Model 10).

Table 16: Summary table of anticipated health impacts and their respective magnitude

| Business model | Scale of the BM: applied scenario | Anticipated health impact | Magnitude (score) |
|---|---|---|---|
| Model 1a – Dry fuel manufacturing: agro-waste to briquettes | One percent of the population in Kampala will use briquettes from the BM as cooking fuel | Impact 1: increase in chronic respiratory disease and cancer | **Moderate negative impact (-300)** |
| Model 2a – Energy service companies at scale: agro-waste to energy (electricity) | 50 villages in rural and peri-urban areas of Kampala will implement the BM | Impact 1: changes in health status due to access to electricity | **Insignificant (0)** |
| | | Impact 2: reduction in respiratory, diarrhoeal and intestinal diseases | **Moderate positive impact (75)** |
| Model 4 – Onsite energy generation by sanitation service providers | 30 villages in rural and peri-urban areas of Kampala will implement the BM | Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases | **Moderate positive impact (472.5)** |
| | | Impact 2: access to electricity | **Insignificant (0)** |
| Model 9 – On cost savings and recovery | Wastewater treatment plant similar to BSTDW with 500 farmers and 10'000 community members being exposed to the treated wastewater | Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases | **Moderate positive impact (535)** |
| | | Impact 2: reduction in exposure to toxic chemicals (e.g. heavy metals) | **Moderate positive impact (25)** |
| | | Impact 3: access to electricity | **Insignificant (0)** |
| Model 10 – Informal to formal trajectory in wastewater irrigation: incentivizing safe reuse of untreated wastewater | Unknown | Impact 1: increase in exposure to pathogens and chemicals such as heavy metals | **Not recommended** |
| Model 15 – Large-scale composting for revenue generation | Two centralised co-composting plants are installed in Kampala, serving 2'000 households each | Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases | **Minor positive impact (2.5)** |
| | | Impact 2: indirect health benefits due to reduced MSW loads on landfills | **Moderate positive impact (75)** |
| Model 17 – High value fertilizer production for profit | Two centralised co-composting plants are installed in Kampala, serving 2'000 households each | Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases | **Minor positive impact (2.5)** |
| | | Impact 2: indirect health benefits due to reduced MSW loads on landfills | **Moderate positive impact (75)** |
| Model 19 – Compost production for sanitation service Delivery | 30 villages in rural and peri-urban areas of Kampala will implement the BM | Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases | **Moderate positive impact (472.5)** |

# 8 Key findings of the Environmental Assessment

For the Environmental Impact Assessment (EIA), business model flow diagrams are used as a tool to visualize both impact assessments. The EIA takes into consideration the “Technology Assessment”, which comprises an extensive literature review on technologies for resource recovery also identifying potential environmental hazards and measures of mitigation. Within the scope of this assessment, the environmental impact of the business models are not assessed in detail, as information on facility scale and specific location in the city was not available. Rather, with the level of technical detail currently available, the EIA shows potential environmental hazards, which should be recognized and mitigated during implementation. More detailed analysis of specific environmental impacts can follow at a later stage if treatment infrastructure has been clearly defined based of an analysis of market demand for end-products and the respective determination of treatment goals. Such an evaluation would have to include detailed laboratory analyses of the waste streams to be utilized, so that treatment technologies can be selected and designed in detail. Currently, and based on the EIA as a stand-alone component, the feasibility of business models cannot be ranked, which is the reason for all business models resulting in “medium feasibility”. Ultimately, the implementing business has to mitigate the identified potential environmental hazards, which will results in little, or no environmental impact. Table 17 provides a summary for all business models, the respective waste streams, end-products technologies, processes and potential environmental hazards, including proposed mitigation measures.

Detailed information is available in the report on: Output 7 – Health and environmental risk and impact assessments of waste reuse business models: Kampala/Uganda.

Table 17: Summary of business models under consideration for Kampala

| Business Model | Waste stream | End-product | Technologies | Process | Potential Environmental Hazards | Mitigation measures |
|---|---|---|---|---|---|---|
| 1 (a,b) | • MSW<br>• AIW | • Briquettes | • Carbonized - low pressure<br>• Raw - mechanized high pressure,<br>• Carbonized - mechanized | • Briquetting | • Hazardous air emissions<br>• Accumulated inorganic waste<br>• Process water | • Air emission control technologies (e.g. activated carbon, scrubbers)<br>• Proximate and ultimate analyses<br>• Post-treatment of process water |
| 2 (a,b) | • MSW<br>• AIW<br>• AM | • Gasification -> Electricity<br>• Biogas -> Electricity | • Gasification technologies<br>• Single stage<br>• Multi-stage<br>• Batch<br>• Biogas conversion technologies | • Gasification<br>• Anaerobic digestion<br>• Biogas to electricity conversion | • Hazardous air emissions<br>• Residuals (tar, char, oil)<br>• Solid residue (digestate)<br>• Liquid effluent | • Air emission control technologies<br>• Collection/Storage/Disposal at appropriate location<br>• Solid/liquid residue post-treatment |
| 4 | • Feces<br>• Urine<br>• FS | • Biogas -> Cooking fuel | • Single stage<br>• Multi-stage<br>• Batch | • Anaerobic digestion | • Air emissions<br>• Solid residue (digestate)<br>• Liquid effluent | • Maintenance of anaerobic digester<br>• Solid/liquid residue post-treatment |
| 9 | • WW<br>• WW sludge | • Electricity<br>• Soil conditioner<br>• Water (for reclamation) | • Conventional wastewater treatment technologies<br>• Biogas conversion technologies | • Conventional WW treatment<br>• Biogas to electricity conversion | • Heavy metals in effluent and/or WW sludge<br>• Solid residue (sludge from WW treatment)<br>• Air emissions | • Upstream monitoring of heavy metal concentration<br>• Monitoring of effluent and solids<br>• Solid residue (sludge from WW treatment) post-treatment<br>• Maintenance of anaerobic digester |
| 10 | • WW | • Water (for reclamation)<br>• Water for groundwater recharge | • Slow rate infiltration<br>• Rapid infiltration<br>• Overland flow<br>• Wetland application | • Land treatment | • Groundwater contamination (heavy metals/pathogens)<br>• Contamination of irrigated crops with heavy metals and/or pathogens | • Upstream monitoring of heavy metal concentration<br>• Monitoring of effluent and solids<br>• Crop selection<br>• 2006 WHO guidelines |
| 15 | • MSW<br>• FS | • Soil Conditioner | • Solid/liquid separation<br>• Drying beds<br>• Co-composting | • Co-composting (MSW + FS) | • Accumulated inorganic waste<br>• Leachate from composting<br>• Insufficient pathogen inactivation<br>• Liquid effluent (from FS treatment) | • Storage/transport/disposal (sanitary landfill)<br>• Moisture control<br>• Leachate treatment<br>• Temperature control (compost heap)<br>• Post-treatment of liquid effluent |

| | | | | | | |
|---|---|---|---|---|---|---|
| 17 | • MSW<br>• FS | • Fertilizer (NPK added) | • Solid/liquid separation<br>• Drying beds<br>• Co-composting | • Co-composting (MSW + FS) | • Accumulated inorganic waste<br>• Leachate from composting<br>• Insufficient pathogen inactivation<br>• Liquid effluent (from FS treatment) | • Storage/transport/disposal (sanitary landfill)<br>• Moisture control<br>• Leachate treatment<br>• Temperature control (compost heap)<br>• Post-treatment of liquid effluent |
| 19 | • Urine<br>• Feces | • Stored urine<br>• Soil conditioner | • UDDTs<br>• Co-composting | • Urine application<br>• Co-composting | • Ammonia intoxication<br>• Ammonia oxidization<br>• Insufficient pathogen inactivation<br>• Leachate from co-composting | • Urine dilution with water<br>• Moisture control<br>• Leachate treatment<br>• Temperature control (compost heap) |

# 9 Key findings of the Socio-Economic Assessment

## 9.1 Introduction

The section presents the socioeconomic assessment of the selected RRR business models. The socioeconomic assessment acts as a decision making tool for determining the feasibility of the business model from a socio-economic perspective. It incorporates all the costs and benefits of the potential impacts accruing from the economic, social, health and environmental considerations. Therefore this primarily involves the derivation of the monetary values of the direct and indirect, positive and negative effects from the implementation of the business model. A comprehensive socioeconomic assessment determines whether all the benefits of a particular business model outweigh its costs and thus supports in making decision.

## 9.2 Methodology

The first important footstep towards a socioeconomic assessment is the definition of the system boundary. This is an integration of two aspects –

- Determination of the baseline condition which becomes the benchmark for comparison of the alternative (i.e. establishment of the business model); and
- Identification of the input resources (from different waste streams) for the business models at the city level based on the availability. These constraints govern the scales of operation of the business, potential impacts and beneficiaries. Regarding the scale of operation of the businesses, the socioeconomic assessment utilized the scales of the financial models developed previously. However, it was up-scaled based on the waste resources available at the city context.

After having demarcated the system boundary the socioeconomic assessment conducted the following guided steps to evaluate the benefits and the costs:

- **Step 1:** Identification of socioeconomic impacts of similar business cases in Kampala
- **Step 2:** Scoping of the potential impacts (social, environmental and health) based on the system boundary. This step leads to the defining of the parameters to be used in the socioeconomic assessment.
- **Step 3:** Description of the technology for the RRR business models based on the technical assessment report and as observed from the business cases in the region.
- **Step 4:** Identification of key input data points based on scenarios developed, type of technology used. The financial models served as the base data source for the economic data as well as some of the social data. Investments and production costs were obtained from the financial models. Data on economic indicators such as wage rates, interest rates, inflation, tax, escalation, annual write off, insurance, depreciation and debt-equity ratios were obtained from published data reports by Bank of Uganda and industrial benchmarks for the region. The environmental and health data were collected from secondary sources based on the scale of the operation and assumption made under the system boundary which delineates the level of stakeholders for a particular model. For environmental data, emission rates, carbon equivalents, cost of pollution

(and abatement costs) were collected from the secondary sources and likewise for the health related parameters after having scoped the potential impact and the targeted population that can be impacted, DALYs were used to measure the impact in value terms. The economic values of the DALYs were obtained from secondary data sources for Uganda. In this step the parameters are also categorized as deterministic and stochastic based on literature survey and expert opinions.

- **Step 5:** The socioeconomic viability of an RRR business model was analysed based on the NPV of the benefits and costs, Benefit to Cost Ratio (BCR) and the Rate of return on Investments (RoI). For each of the economic, social, health and environmental aspects, the benefits and costs were measured (in monetary terms) separately, and the cumulative figure was used to assess the NPV, BCR and RoI. Subsequently, a Monte Carlo risk analysis method was performed for the NPV calculations using an Excel add-in, @Risk.

  The Monte Carlo risk analysis involved the following steps:

  - *Selection of valuation criteria*: The NPV of each of the business model was selected to study the stochastic variations under conditions of uncertainty of the parameters.
  - *Identification of sources of uncertainty and key stochastic variables*. Similar sources of uncertainty as considered in the financial models were also assumed in the socioeconomic assessment. However, in addition to technical development, changes in government policy, inflation, variation in input and output prices, competitors' actions and other various factors, other health and environmental parameters (like economic value of DALY and abatement costs) were also treated as stochastic parameters.
  - *Definition of the probability distributions of stochastic variables*: Probability distributions for all risky variables were defined and parameterized.
  - *Running of the simulation model*: Determination of the NPV for each year and the criteria (social, economic, health and environment) using sampled values from the probability distributions for project life. This process was repeated a large number of times (larger than 5000) to obtain a frequency distribution for NPV.
  - *Determination of the probability distribution of the simulation output (NPV):* The simulation model generated empirical estimates of probability distributions for NPV which was further used for the feasibility study.

*Data limitations:* As noted in the synopsis of the financial assessment, the RRR sector is nascent in Uganda, thus data access and availability are limited. This was even more critical for the socio economic assessment which relied heavily on secondary databases and the financial models. The financial models developed for the business cases served as the data source for the economic data used in the socioeconomic assessment. The data for the environmental and health costs and benefits were obtained from secondary sources and the literature survey contextualized for Uganda. However, in certain cases where data was unavailable, data from certain reports showing global figures or assessments were utilized and actualized for the context of Kampala. Since the financial model is the base for the economic model, it needs to be mentioned here that economic data not available for the businesses were mined from the different business sources operating in Asia, Africa and Latin America and were verified before their use. However, as explained before in the financial assessment, data sources for wastewater is weak and this may have influenced the socioeconomic assessment as well.

## 9.3 Overall approach of the socioeconomic assessment: Defining the system boundary of the models

The following matrix defines the system boundary of the socioeconomic models used in the assessment for the RRR business models. In all of these cases, the scale of the business model is so adjusted such that the entire waste can be utilized by the particular business. The socioeconomic assessment of the business models is performed taking into consideration two contrasting situations where the baseline condition refers to the present situation in Kampala and the alternative scenario proposes the introduction of the business. The scale of operation for each of the businesses is based on two aspects –

- The availability of different waste streams in the perspective of Kampala as derived from other reference literature, reports and documents; and
- The scale of operation is based on the scale assumed in the financial analysis. This is primarily assumed to keep a parity in the analysis performed since one of the important component of the socioeconomic assessment includes the financial analysis of the operation. However, to achieve the entire consumption of the waste streams for the respective businesses, a linear extrapolation of the scale of the business model assumed in financial analysis is utilized.

The following table (18) indicates the baseline and alternative scenarios and also describes the scale of operation for the different business models in Kampala.

Table 18: Baseline and Alternative Scenarios used for the Socioeconomic Assessment for the different Business Models

| Business Models | Base case | Alternative | Remarks |
|---|---|---|---|
| Centralized large-scale compost production for carbon emission reduction (MSW to compost) | The municipal waste that is being collected is open-dumped and landfilled. In Kampala, The total waste generated per day is 2357 tons (70,710 tons per month); of which 40% of the total generated amount of MSW is actually collected and transported to Kiteezi landfill. The rest is therefore assumed to be open-dumped. | 4 Compost plants of 600 tons is assume which would handle all the MSW generated. | In the financial analysis compost plants of 600 tons has been assessed. The data from these models will be incorporated in the Socio-economic Assessment (SEA) |
| High Quality branded/certified organic fertilizer from faecal sludge and MSW | Fecal sludge is dumped or being partially treated in the Bugolobi WWTP | The scale of operation for the fortifier is 8 plants which generates 1000 tons of fortifier yearly. This can accommodate 16 tons of fecal sludge per day since each of the plant will handle around 2 tons of dewatered fecal sludge per day. | 93.6% of the population have onsite sanitation services. According to Diener S et. al (2014) fecal sludge currently discharged (legally) is 16 tons per day. |
| Sustainable Sanitation Service Delivery via compost production from faecal sludge | There is presently no generation of compost from fecal sludge generated in the public toilets. | In the financial model we have assumed 600-1000 users per public toilet. The alternative scenario is based on 2 assumptions –<br>• Central division is the core economic zone and since population density is also high (235-391 persons/ha.) public toilets will be concentrated in this division | 2.7% of the population depend on open defecation |

| Business Models | Base case | Alternative | Remarks |
|---|---|---|---|
| | | • Number of public toilets will be only based on the persons using public toilets presently<br>The above two assumptions lead us to the fact that 3190 persons (2.5% of 127600 – population in Central division) needs to be catered and hence number of public toilets required is 4-5 | |
| Untreated wastewater for irrigation and groundwater recharge | Untreated wastewater of volume 50,000 $m^3$ /d moving into water bodies | Utilization of Waste Stabilization Ponds for partial treatment of 64000 $m^3$ / d of wastewater which is subsequently used for agriculture and indirectly recharges depleted aquifers | The estimated quantity of treated WW in Kampala in 2013 was approximately 64,000 $m^3$/d, of which 14,000 $m^3$/d is being treated at Bugolobi (12000 $m^3$), Naalya (1000 $m^3$) and Ntinda (12000 $m^3$) |
| Treated wastewater for irrigation/electricity/fertilizer – cost recovery | Effluent generated from treated wastewater of volume 14,000 $m^3$ /d moving into water bodies | Financial analysis shows a WWTP of 40,000 $m^3$/day from which electricity is generated, water is treated for irrigation and the digested sludge is converted to compost. However, the total wastewater generated is 64,000$m^3$/day. The alternative scenario would have to consider another WWTP which can treat a similar volume of wastewater. | Additional investments for electricity generation, water treatment and compost recovery is to be considered. |
| Dry-fuel manufacturing (Agro-waste to briquettes) | 1000mt of organic waste accumulates daily and only about30% of this is removed and dumped into Landfill in Kitezi (Sabitti, 2011). | The alternative scenario would consist of 10 large scale plants as had been considered in the financial analysis (consumption on 2222 tons of agro-waste per year). This would imply that about 10% of the agro-waste is being reused for energy. | In the financial analysis the briquette plant considered consumes 7.5 tons of waste per day and the case study supporting this model is one of the biggest plant operating in Kampala (KAMPALA JELLLITONE SUPPLIERS LTD). |
| Independent power producer/private power developer (Agro-waste to electricity) | 1000mt of organic waste accumulates daily and only about 30% of this is removed and dumped into Landfill in Kitezi (Sabitti, 2011) | Financial analysis considers 8 MW plant utilizing 250 tons/ day. This implies that 4 plants have to be considered in SEA which takes up all of the organic waste generated. Thus the benefit needs to incorporate that 30% of the agro-waste which is not moving into the landfill, increases the landfill life. | |
| Onsite Energy generation in enterprises providing sanitation service | There is presently no generation of compost from fecal sludge generated in the public toilets. | In the financial model we have assumed 600-1000 users per public toilet. The alternative scenario is based on 2 assumptions – | 2.5% of the population have access to public toilets |

| Business Models | Base case | Alternative | Remarks |
|---|---|---|---|
| | | • Central division is the core economic zone and since population density is also high (235-391 persons/ha.) public toilets will be concentrated in this division<br>• Number of public toilets will be only based on the persons using public toilets presently<br>The above two assumptions lead us to the fact that 3190 persons (2.5% of 127600 – population in Central division) needs to be catered and hence number of public toilets required is 4-5 | |

## 9.4 Synopsis of the socioeconomic assessment of the RRR business models

The following section presents key highlights of the RRR business models in terms of the Net Present Value (NPVs) of the different components assessed under this study and for detailed assessment please refer to respective RRR business models presented in subsequent sections. The respective business models were evaluated based on the monetization of the costs and benefits pertaining to the financial/economic, environmental and social consequences of the potential impacts from the business model. The financials for the RRR business models are classified according to Energy, Wastewater and Nutrient models.

### *9.4.1 Energy Business Models*

Table 19 provides key highlights of Energy business models. To iterate, the table indicates the NPV of the three components of each of the energy business model. It can be seen from the table, that the energy models have a Benefit-Cost ratio (BCR) greater than 1. However, the changes in integrating the environmental and social components has contrasting impacts for different models. It can be observed that the ESCO model has a higher return in terms of environmental and social benefits over the other two models although there are possibilities of losses based on the financial assessment of the model.

Table 19: Energy Business Models

| | **Model 1: Dry Fuel Manufacturing - Agro-industrial Waste to Briquettes** | **Model 2: Energy Service Companies at Scale - Agro-Waste to Energy (Electricity)** | **Model 4: Onsite Energy Generation by Sanitation Service Providers** |
|---|---|---|---|
| **Scale of operation** | 10 plants, each having a production capacity of 2000 tons per year | 4 plants each with a production capacity of 8 MW | 5 public toilet facilities has been assumed to cater to the entire population of Kampala Central Division |
| **NPV** Financial (in USD)** | 2,846,811 | (919,589) | 185,249 |

| | | | |
|---|---|---|---|
| **NPV** Financial & Environmental (in USD)** | 3,980,813 | 461,607 | 189,307 |
| **NPV** Financial, Environmental & Social (in USD)** | 16,044,166 | 108,883,864 | 302,248 |
| **B:C Ratio** | 5.62 | 5.11 | 2.63 |
| **ROI** | 87% | 48% | 29% |

** Calculated for life cycle term using Discount Rate of 12%
K = 1,000

### 9.4.2 Wastewater Reuse Business Models

In the context of Kampala, two different scenarios are considered – (i) Treated wastewater for irrigation, fertilizer and energy, and (ii) Wastewater for irrigation and ground water recharge. Table 20 provides key highlights of wastewater reuse business models. The scale was based on the input wastewater quantity in Kampala which was from the waste supply and availability data based on sewer network in Kampala. Both of these models exhibits higher environmental and societal benefits in terms of reduction of pollution and health benefits. Using WSPs has a lower cost which is also being reflected in the NPV of the financial benefits from the introduction of wastewater for recharge and utilization in agriculture.

Table 20: Wastewater Reuse Business Models

| | **Model 9: Treated wastewater for irrigation/fertilizer/energy – cost recovery** | **Model 10: Untreated wastewater for irrigation and groundwater recharge** |
|---|---|---|
| **Scale of operation** | The capacity of the wastewater treatment plant is considered to be 40,000 $m^3$ | An estimated 64,000 $m^3$ of wastewater generated in Kampala is diverted for irrigation and groundwater recharge |
| **NPV** Financial (in USD)** | 9,669 | 141,133,195 |
| **NPV** Financial & Environmental (in USD)** | 42,999,611 | 292,596,480 |
| **NPV** Financial, Environmental & Social (in USD)** | 56,913,752 | 360,596,480 |
| **B:C Ratio** | 49.88 | 59.59 |
| **ROI** | 740% | 606% |

** Calculated for life cycle term using discount rate of 12%
K = 1,000

### 9.4.3 Nutrient Business Models

The nutrient business models have been compared in the following table (**Error! Reference source not found.**). This table provides key highlights of Nutrient business models in terms of the NPVs for the financial, environmental and societal net benefits. It can be seen from the table that High value Fertilizer production and compost derived from Sanitation Service Delivery have higher increase in societal benefits compared to the compost production from MSW. This is primarily due to the fact that sanitation infrastructure either in terms of better service delivery or treatment of faecal sludge have pertinent health benefits as well as positive environmental impacts for the society.

Table 21: Nutrient Business Models

| | Model 15: Large-Scale Composting for Revenue Generation | Model 17: High value Fertilizer Production for Profit | Model 19: Compost Production for Sanitation Service Delivery |
|---|---|---|---|
| **Scale of operation** | 4 plants each with a handling capacity of 600 tons of MSW is assumed. Total compost production capacity in each plant is 96 tons per day | 13 plants are assumed to consume the entire faecal sludge produced and each with a production capacity of 1000 tons in a year | 5 public toilet facilities has been assumed to cater to the entire population of Kampala Central Division. This considers 2.7% of population practicing open defecation. |
| **NPV** Financial (in USD)** | 17,540,347 | 1,170,913 | 55,339 |
| **NPV** Financial & Environmental (in USD)** | 24,554,559 | 3,982,575 | 65,955 |
| **NPV** Financial, Environmental & Social (in USD)** | 69,132,856 | 65,878,167 | 942,030 |
| **B:C Ratio** | 5.42 | 15.36 | 69.38 |
| **ROI** | 167% | 224% | 682% |

** Calculated for life cycle term using Discount Rate of 12%
K = 1,000

## 9.5 Summary Assessment of Socio-Economic Feasibility of RRR Business Models

Table 23 provides a summary overview of the feasibility of RRR business models for Kampala based on the socioeconomic assessment. Three main criteria were used to assess the feasibility of the business model - (i) Benefit-Cost Ratio (BCR), (ii) Rate of Investment; and (iii) Probability distribution of the Net Present Value (NPV). The BCR was derived as a ratio of economic, social, health and environmental benefits to the costs in monetary terms. Any project or business with a BCR greater than 1 is termed to be generating more societal benefits compared to the costs for implementing the project and therefore the BCR was used as the governing criterion for the feasibility assessment. The Rate of Investment (RoI) was determined based on all the benefits that accumulated from the business with respect to the initial investments made for the business. Along with these criteria, the probability distribution of the NPV based on the uncertainty of different parameters used in the model was used.

As mentioned earlier in the methodology, a Monte Carlo risk analysis was performed on the Net Present Value (NPV) derived from the costs and benefits from the different parameters of the socioeconomic models. These parameters which were considered as stochastic in the model were defined by a suitable probability distribution to represent uncertainty in the values used for the models. For the Monte Carlo analysis, a large number of iterations were performed to obtain empirical estimates of the NPV and also derive a probability distribution of the NPV. The probability distribution obtained for the NPV was used as one of the criterion for assessing the feasibility of the business model. The mean value obtained from the probability distribution of the NPV was taken as a benchmark for determining the feasibility. The probability distribution thus generated was utilized to find out the probability of the NPV value below the benchmark (mean). The methodology used to define the feasibility is as described in Table 22 below.

Table 22: Feasibility ranking methodology

| **P (NPV < $NPV_{mean}$)** | **B:C Ratio** | **Rate of Investment (RoI)** | **Feasibility** |
|---|---|---|---|
| 0 < P (NPV< $NPV_{mean}$) < 30% | > 1 | > 100% | **High** |
| 30% < P (NPV < $NPV_{mean}$) < 50% | > 1 | > 100% | **Medium** |
| 50% and above | > 1 | > 100% | |
| 0 < P (NPV < $NPV_{mean}$) < 30% | < 1 | > 100% | **Low** |
| 30% < P (NPV < $NPV_{mean}$) < 50% | < 1 | > 100% | |
| 50% and above | < 1 | > 100% | |
| 0 < P (NPV < $NPV_{mean}$) < 30% | > 1 | < 100% | |
| 30% < P (NPV < $NPV_{mean}$) < 50% | > 1 | < 100% | |
| 50% and above | > 1 | < 100% | |
| 0 < P (NPV < $NPV_{mean}$) < 30% | < 1 | < 100% | **Not Feasible** |
| 30% < P (NPV < $NPV_{mean}$) < 50% | < 1 | < 100% | |
| 50% and above | < 1 | < 100% | |

Using the methodology defined in Table 22, the RRR business models were assessed for their viability in the context of the Kampala city. Based on the criteria of assessment, it is found that the energy models have a lower feasibility compared to that of the wastewater and the nutrient models. All the energy models have a BCR greater than 1 however, the ROI is lower than 100% indicating that the business model would not be able to reap benefits larger than the investments. Along with these observations, it was also estimated that a probability of NVP lower than the mean value will be more than 50% or close to it. In comparison to these scenarios, although the models for wastewater and nutrients had probability values close to 50%, the other criteria of BCR to be greater than 1 and RoI of more than 100% make the business models to be feasible at a medium range. It has been mentioned previously that economic costs and benefits utilize the database from the financial analysis. The financial models were scaled up linearly to meet the waste resources from different waste streams produced in Kampala. Therefore, it becomes imperative to check the convergent validity of the financial and socioeconomic model in which further we assess the social, environmental and health aspects. The results of the socioeconomic assessment for the wastewater and nutrient models conforms to that of the financial analysis while that of the energy models (except the Energy Service Companies) differ in the results.

Table 23: RRR Business Models Feasibility

| **RRR Business Models** | **P (NPV<$NPV_{mean}$)** | **B:C Ratio** | **Rate of Investment (ROI)** | **Feasibility** |
|---|---|---|---|---|
| **ENERGY** | | | | |
| **Model 1:** Dry Fuel Manufacturing - Agro-industrial Waste to Briquettes | 52.2% | 5.26 | 87% | Low |

| | | | | |
|---|---|---|---|---|
| **Model 2:** Energy Service Companies at Scale - Agro-Waste to Energy (Electricity) – *8MW Profit Maximization Model* | 53.4% | 5.11 | 48% | Low |
| **Model 4:** Onsite Energy Generation by Sanitation Service Providers | 48.9% | 2.63 | 29% | Low |
| **WASTEWATER REUSE** | | | | |
| **Model 9:** On Cost Savings and Recovery – combined energy, water and nutrient recovery | 50.7% | 49.88 | 740% | Medium |
| **Model 10:** Informal to Formal Trajectory in Wastewater Irrigation - Incentivizing safe reuse of untreated wastewater | 52.7% | 59.59 | 606% | Medium |
| **NUTRIENTS** | | | | |
| **Model 15:** Large-Scale Composting for Revenue Generation - 600 tons | 49.8% | 5.42 | 167% | Medium |
| **Model 17:**High value Fertilizer Production for Profit | 52.1% | 15.36 | 224% | Medium |
| **Model 19**: Compost Production for Sanitation Service Delivery | 53% | 69.38 | 682% | Medium |

Below is brief on key aspects that determine the feasibility of each of the business models in Kampala:

*Model 1 – Dry fuel Manufacturing:* The business model is economically and financially viable. There is a significant increase in the economic feasibility of the business due to social and environmental benefits associated with the business. However, price of the inputs highly fluctuate which pose a significant threat to the business. In addition, health impacts can only be mitigated if there is use of efficient cook stoves among the households, the switching costs of which poses a threat to the business from societal benefits since emissions which lead to indoor air pollution cannot be abated.

*Model 2 – Energy Service Companies:* This business model has a lot of potential when we consider electricity generation which Uganda considerably lacks. The total potential for all agro-waste being utilized for electricity generation in Kampala is about 32 MW. Associated with this there is net GHG emissions saved per kwh of electricity generated is 2.724 kg CO2eq. The highest savings in GHG emissions are mainly from avoided burning of agro-waste while the highest emissions from the business model is from the gasifier. In the present situation most of the agro-waste goes to landfills and open dumpsites. However, as the financial analysis indicates that larger scale plants are very sensitive to price of electricity for feed-in-tariffs which are currently on the lower side in Uganda, this model faces a stiff challenge financially. The next challenge for the business model is the accessibility of the agro-waste as mentioned previously.

*Model 4 – Onsite energy generation by sanitation service providers:* This business model although promising in economic and financial terms, the contribution to the overall societal benefits are restricted mainly to health restrictions. The health benefits derived are mainly in cost savings for end users from avoided expenditures on health expenditures, saving in time spent accessing a place of convenience and savings in time spent cooking. In terms of financial stability also the business model is totally driven by the fact that it depends on the number of users and can never depend on the feasibility from the sale of the biogas which also restricts the net emission savings/earnings.

*Model 9 – On Cost savings and recovery:* The primary assumption of the business model is its focus on the reuse component and does not take into consideration the setting up of a new wastewater treatment plant. It is being assumed that the wastewater treatment plant exists and additional investments are made to retrieve water for irrigation, sludge for compost and electricity for use in the plant. This model is price sensitive in terms of the feed-in-tariff, however there are cost savings in terms of electricity generated and used within the plant. Economically, the business model is viable based on the sale of treated wastewater to farmers and compost. Consideration of the health and environmental aspects shows that there is substantial amount of reduction in surface and groundwater which has indirect costs associated inter-temporally. In addition there is also a potential of earning benefits due to reduced GHG emissions and savings incurred in using compost as a soil ameliorant which reduced the fiscal burden. Use of compost reduces the dependence on inorganic fertilizers in the long run and Uganda which is a fertilizer-importing country can benefit from reducing their fertilizer consumption and subsequently their foreign exchanges.

*Model 9 – On Cost savings and recovery:* The feasibility of the business model is governed by the fact that there is lower initial investments compared and practically no operation costs, while the benefits like irrigation and groundwater recharge are more favorable. The socioeconomic feasibility shows that health issues among farmers which might arise due to use of wastewater is overweighed by the benefits incurred. However, application of the business model should be subjected to research on health effects both on consumers and farmers consuming food irrigated by wastewater and producing food irrigated by wastewater respectively.

*Model 15 – Large scale composting for revenue generation:* The financial analysis shows that large sized compost plants of 600 tons/day is highly feasible. The socioeconomic assessment considered the 4 plants of same scale for absorbing the city's total waste. Economically, the compost plants are feasible because the compost price in Kampala is significantly higher in comparison to other African countries. The price of compost is one the most sensitive parameters that drives viability of the business. Additionally in the socioeconomic assessment when other aspects of health environment are considered, this model is feasible due to its potential for reduction in GHG emissions, positive health benefits and also savings in foreign exchanges. However, it has to be noted that there needs a lot of behavioral change communication among the farmers so that they understand the utility and adopt to such practices of using compost along with inorganic fertilizers.

*Model 17 – High value fertilizer production for profit:* This product is relatively unknown and due to the nature of raw material used (faecal sludge), there is inherent risks of acceptability among farmers. The economic viability of the business model closely follows that of the compost obtained from municipal solid wastes. In similar lines as explained in the previous model, there are opportunities of reduction of GHG emissions, foreign exchange savings. In addition, the products are priced higher and can be fortified with inorganic fertilizers which are close substitutes to fertilizers and utilizing the faecal sludge reduces the risks from water pollution. However, the primary challenges of the business being the adaptability among farmers which needs a lot of trainings and communications.

*Model 19 – Compost Production for Sanitation service delivery:* This is a similar model to that of Model 4. Both of these models are economically viable. The economic viability depends primarily on the number of users. However, when we consider composing as an option over electricity generation, the price of compost provides an extra leverage. Additional benefits as per health, societal and environmental is considered is similar.

# 10 Synthesis of Feasibility Studies

This section presents the overall synthesis and ranking of the potential feasibility of the selected business models for Kampala. The notion behind the ranking of the RRR business models is to provide different stakeholders, in particular, investors with an overview of the potential feasibility for implementation of the business models. In particular, it provides insights on the constraints, if any, possibly related to key resource factors such as land, investment, finance, etc., and the level of risk associated with their potential investments. It is important to note that this is an overview assessment and any actual implementation will require a detailed ex-ante assessment, particularly related to the environmental impact given information on site specificity. The key focus for the business models considered is that they have at least triple bottom line targets: high impact from a scalability and replicability perspective and catalyze innovation adoption. The different criteria/indicators selected to assess these targets are: a) profitability/cost recovery, b) social impact, c) environmental impact, d) scalability and replicability, and e) innovation.

## 10.1 Methodology for the Ranking of the Business Models

As noted in section 1, the feasibility assessment of the RRR business models was based on a multi-criteria framework and utilized performance indicators for the assessment of business viability. The MCA framework consisted of 7 comprehensive criteria to assess the enabling environment for the implementation of each RRR business model. The criteria were: waste supply and availability, institutional, market, technical, financial, health &environmental, and socio-economic assessment. It is to be noted that the results from the different components are embedded and used to develop and conduct the socio-economic assessment, in particular, the financial and health & environment assessment which form the basis for the socio-economic analyses. Each business model was assessed based on the seven criteria listed in the MCA framework and subsequently evaluated for its overall potential feasibility based on a 4-level ranking system, i.e. whether it has a potential of:

**No feasibility** **Low feasibility** **Medium feasibility** **High feasibility**

The methodology developed uses a step-wise screening hierarchy and screening criteria to assess how the feasibility of the different business models rank in comparison to each other based on the 4-level system outlined above.

- *Screening hierarchy:* The 7 criteria each have a different weightage and related effects on the level of viability of each RRR business model. The following is the hierarchy used for applying the screening criteria:
    - Waste Supply &Availability > Institutional > Market > Technical > Financial > Health &Environment> Socio-economic assessment

- *Assessing the 'No' and 'Low'* Feasibility ranks: As noted in the screening hierarchy, of the 7 criteria, the *'Waste Supply &Availability'* and *'Institutional'* assessment have the highest weightage and related impact for the potential feasibility of the implementation of any RRR business model. If there is not enough waste available or limited to no access to be processed into energy, water or nutrient resource product, the business cannot be operate and/or if the local laws and regulations restrict the reuse of a specific waste source, related specific RRR business model cannot be implemented without policy reforms. Thus based on these factors, the ranking assessment rules are as follows:

- If either results from the 'Waste Supply &Availability' OR 'Institutional' assessment indicate that a **business model (BM)** is **"Not feasible" (NF)**, irrespective of the results of the other criteria, the implementation of the RRR business model is considered **not feasible**. If not, then we subsequently check for **"Low feasibility" (LF).**
  - If either results from the Waste Supply & Availability OR Institutional analyses indicate that a business model has **LF**, then irrespective of the results of the other criteria, the implementation of the RRR business model is considered to have **low feasibility**. If not, then we subsequently move on to the next criterion in the hierarchy.

If both 'Waste Supply & Availability' and 'Institutional' results show that the business model has medium or high feasibility, we move to the next criterion in the hierarchy. The cycle continues till all the criteria in the hierarchy is covered. Subsequent rules followed for assessing 'no feasibility' or 'low feasibility 'have minimum conditions of the dominant criteria to have medium or high feasibility:

- If **Market** is **NF** irrespective of results of subsequent lower hierarchy criterion, then **BM = NF** else move to next criterion in hierarchy
- If **Technical** is **NF** irrespective of results of subsequent lower hierarchy criterion, then **BM = NF** else move to next criterion in hierarchy
- If **Financial** is **NF** irrespective of results of subsequent lower hierarchy criterion, then **BM = NF** else move to next criterion in hierarchy
  If **Health & Environment** is **NF**, then **BM = NF** else move to next criterion in hierarchy
- If **Socio-economic** is **NF, then** BM = **NF** else check to assess LF

- *Assessing LF from Market, Technical, Financial, Health & Environment* and *Socio-economic* components, the following rules were applied:
  - If **Market** is **LF** irrespective of results of subsequent lower hierarchy criterion, then **BM = LF** else move to next criterion in hierarchy
  - If **Technical** is **LF** irrespective of results of subsequent lower hierarchy criterion, then **BM = LF** else move to next criterion in hierarchy
  - If **Financial** is **LF** irrespective of results of subsequent lower hierarchy criterion, then **BM = LF** else move to next criterion in hierarchy
  - If **Health & Environment** is **LF**, move to assessment of medium of high feasibility

- *Assessing medium feasibility and high feasibility:* RRR business model will be assessed for medium or high feasibility, once the business model has gone through a cycle of 'no feasibility' and 'low feasibility' for all the criteria along the mentioned screening hierarchy and as per the rules described for assessing 'no feasibility' and low feasibility. To assess **Medium feasibility (MF)** and **High feasibility (HF)** of RRR business models, Waste Supply &Availability and Institutional criteria has to be of either medium or high feasibility and then following rules are applied:
  - If **Market** is **MF,** irrespective of whether **Technical**, **Financial** and **Socio-economic** is either **MF or HF**, then **BM = MF**
  - If **Market** is **HF**, **Technical** is **MF**, **Financial** is **MF**, **Socio-economic** is either **LF,MF or HF, BM = MF**
  - If **Market** is **HF**, **Technical** is **HF**, **Financial** is **MF**, **Socio-economic** is either **LF, MF or HF, BM = HF**
  - If **Market** is **HF**, **Technical** is **MF**, **Financial** is **HF**, **Socio-economic** is either **LF, MF or HF,**

**BM = HF**

- If **Market** is **HF**, **Technical** is **HF**, **Financial** is **HF**, **Socio-economic** is either **LF, MF or HF, BM = HF**

It is assumed that for the Health & Environmental assessment criterion, irrespective of its results as LF, MF and HF, it will not dictate the final RRR business model viability for implementation as risks and associated mitigation measures are incorporated/ captured in both the technical and financial feasibility; as is for the socio-economic assessment. The methodology rules described above is captured as a snapshot in Table 24 below.

Table 24: Methodology for the Ranking of the Feasibility of the Business Models

| Waste supply& availability | Institutional assessment | Market assessment | Technical assessment | Financial assessment | Health &Environmental assessment | Socio-Economic assessment | Feasibility Ranking |
|---|---|---|---|---|---|---|---|
| No feasibility | Irrespective of feasibility for these components | | | | | | |
| Irrespective | No feasibility | Irrespective of feasibility for these components | | | | | |
| No feasibility | No feasibility | Irrespective of feasibility for these components | | | | | |
| Medium and/or High feasibility | | No feasibility | Irrespective of feasibility for these components | | | | |
| Medium and/or High feasibility | | L, M, H | No feasibility | Irrespective of feasibility for these components | | | No feasibility |
| Medium and/or High feasibility | | L, M, H | L, M, H | No feasibility | Irrespective of feasibility for these components | | |
| Medium and/or High feasibility | | L, M, H | L, M, H | L, M, H | No feasibility | Irrespective of feasibility | |
| Medium and/or High feasibility | | L, M, H | L, M, H | L, M, H | L, M, H | No feasibility | |
| Low | Irrespective of the feasibility for these components | | | | | | |
| Irrespective | Low | Irrespective of the feasibility for these components | | | | | |
| Low | Low | Irrespective of the feasibility for these components | | | | | Low feasibility |
| Medium and/or High feasibility | | Low | Irrespective of the feasibility for these components | | | | |
| Medium and/or High feasibility | | L, M, H | Low | Irrespective of the feasibility for these components | | | |
| Medium and/or High feasibility | | L, M, H | L, M, H | Low | Irrespective | | |
| Medium and/or High feasibility | | L, M, H | L, M, H | L, M, H | Low | | |
| Medium and/or High feasibility | | Medium | Medium | Medium | L, M, H | L, M, H | |
| Medium and/or High feasibility | | Medium | Medium | High | L, M, H | L, M, H | Medium feasibility |
| Medium and/or High feasibility | | Medium | High | Medium | L, M, H | L, M, H | |
| Medium and/or High feasibility | | High | Medium | Medium | L, M, H | L, M, H | |
| Medium and/or High feasibility | | High | High | Medium | L, M, H | L, M, H | |
| Medium and/or High feasibility | | High | Medium | High | L, M, H | L, M, H | |
| Medium and/or High feasibility | | High | High | Medium | L, M, H | L, M, H | High feasibility |
| Medium and/or High feasibility | | Medium | High | High | L, M, H | L, M, H | |
| Medium and/or High feasibility | | High | High | High | L, M, H | L, M, H | |

## 10.2 Synthesis of feasibility ranking of business models

The overall feasibility of the selected business models are presented in table 25 below. It is noted that the nutrient business models have the highest feasibility for Kampala; with the energy business models generally having a low feasibility as are the wastewater business models. It is important to note however that some of the feasibility of some of the business models can be improved with some adaptation (e.g. use of strategic partnerships, consideration of alternative waste streams, institution of supportive policies).

**Model 1a - Agro-waste to briquettes:** This model has an overall low feasibility although there are currently several factors that will catalyze the development of the briquette industry: a) growing local and regional market demand, b) instituted government policies on renewable energy [favorable policies to improve charcoal trade standardization; certification will restrict illegal timber trade; plans to increase the National Forestry Authority levies on charcoal burners with the support of UNDP] and c) better efficiency on energy value that will increase market demand, and d) strong financial viability. The low feasibility ranking is mainly driven by limited availability and access to agro- waste (key resource and driver for business sustainability). As noted in the *Waste Supply* report, the use of other waste streams for the production of briquettes can possibly increase the feasibility of this model. The calorific value of dried faecal sludge is comparable to other biomass fuels. Additional value propositions that can be considered include the production of fuel pellets instead of briquettes, which are often preferred by industries. Targeting industries rather than households as a possible market for the end-product could potentially address the negative social stigma often associated with briquettes/pellets made of faecal sludge as a fuel. Strategic involvement of key players - such as targeting the recently commissioned Lubigi Wastewater and Faecal Sludge Treatment plant could be a possibility as there are currently no strategies in place for the use of the accumulated dried faecal and wastewater sludge.

**Model 2a - Energy Service Companies at Scale: Agro-Waste to Energy (Electricity):**
Uganda lags considerably on electrification and electricity generation models can be used to electrify households in peri-urban and rural areas. Similar to the briquette model however, this model has a low feasibility ranking which mainly driven by the limited availability of agro-waste. Agro-waste is not sufficiently available and the competition for the waste is high as it is highly valuable for direct combustion to generate heat, and electricity through gasification. As with the briquette model, there is potential to improve the model's feasibility by considering the use of faecal sludge for anaerobic digestion. Co-digestion of faecal sludge with other waste streams such as the organic fraction of solid waste and market waste as well as animal compost has high potential to address the resource input constraints. This, however, will require strategic partnerships with the municipality and private entities (e.g. public faecal sludge emptying and transportation service providers) to ensure consistent supply but also because regulations prescribe to discharge faecal sludge at the official discharge locations in Lubigi and Bugolobi.

Other key factors driving the feasibility level of the business model are: a) the market demand and b) financial viability.Generally, there is significant and growing demand for electricity in Kampala and opportunities for waste-to-energy entities to fill this gap based on the anticipated rapid rural electrification program; foreseeable increasing trend in electricity prices; structural and legal feasibility for private sector involvement; a lesser vertically integrated market; and supportive renewable energy policies among others. The WTP estimates however suggest that although there are incentives to catalyze investment, there is limited demand as measured by the WTP estimates, which is predictive of the potential pricing strategy to be implemented. The market assessment results suggest that businesses have a WTP (range between 319.07 – 355.94UGX/ kwh) lower than that of the current unit prices charged by the Uganda Electricity Transmission Company (UETCL) at a rate of 450UGX/kwh, as are for households.

From the financial viability perspective, this business model is observed at a very small-scale in Uganda where the businesses are using corn cobs as key agro-waste input. However the small-scale model are significantly dependent upon capital subsidies. The financial assessments show that neither smaller nor larger scale plants will be financially feasible. The larger scale plants are observed to be very sensitive to price of electricity for feed-in-tariffs which are currently on the lower side in Uganda. It however needs to be noted that this business models under different conditions other than that in Kampala may show a medium to high feasibility. This business model becomes increasingly viable when the debt component is reduced. It warrants to be noted that, in Kampala, the debt rates were taken at 22% (as per the Bank of Uganda) which is very high and the interest burden significantly hampers the viability of the business. It is recommended that if the cost-benefit analysis shows a greater social good from the investment, subsidizing interest payments or providing access to low interest credit can make all of these business models highly viable. Other than interest rates, product price and percentage of sale of product plays a significant role in the viability. Additionally, electricity producers are currently price takers and restricted to the price ceiling set by the state-owned transmission entity – UETCL (limited negotiation ability – monopolistic market). Thus, in actuality, the level of market concentration, price setting behavior and potential net profit margins (business performance) are foreseen to be key limiting factors to the sustainability of future waste-to-energy businesses.

Table 25: Overall feasibility ranking of the business models

| | | Level of feasibility of the business models | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Ranking criteria** | **Outputs** | **BM1a** | **BM2a** | **BM4** | **BM9** | **BM10** | **BM15** | **BM17** | **BM19** |
| 1 | Waste supply and availability | | | | | | | | |
| 2 | Market assessment | | | | | | | | |
| 1 | Institutional analysis | | | | | | | | |
| 3 | Technical assessment | | | | | | | | |
| 4 | Financial assessment | | | | | N/A | | | |
| 5 | Health risk assessment | | | | | | | | |
| | Health impact assessment | | | | | | | | |
| | Environmental risk and impact assessment | | | | | | | | |
| 6 | Socio-economic assessment | | | | | | | | |
| | **Overall ranking of BM** | | | | | | | | |

**Model 4 - Onsite Energy Generation by Sanitation Service Providers (faecal sludge to energy):** Although financially feasible and having significant positive health and environmental impact, the implementation of this model may be limited by several factors. The financial assessment of this model indicates that the primary revenue of the business will come from toilet user fees and revenues solely from reuse are significantly low. The business cannot survive from only the sale of biogas as the biogas yield from faecal sludge alone is noted to be comparatively low. The financial viability is highly dependent upon the location of the public toilet, and places such as bus stands and market areas where there could be significant customers demand of public toilets are necessary. Additionally, the setting-up of new systems will be required as the upgrading of existing systems appears unlikely due to the needed acquisition of land in densely populated areas where sanitation services are lacking. The Kampala Capital City Authority (KCCA) is currently increasing the implementation of public toilets in Kampala. Adapting the business model and starting communications with the authority to implement anaerobic digestion technologies into planned public toilet facilities can increase the feasibility of this business model.

**Model 9 - On Cost Savings and Recovery (Wastewater use for irrigation, nutrient recovery and electricity generation):** The concept underlying this business model is to treat wastewater for safe reuse in agriculture and industrial applications, convert the sludge from the treatment plant to compost and soil ameliorant for sale and generate energy for internal purposes resulting in energy savings or sale to the national grid. The premise is that these activities will generate revenue to curb maintenance costs of the wastewater treatment plant and ensure its sustainability. Whilst there is significant potential for improved health and environmental impact, there are a number of key factors related to the waste supply, current infrastructure and market demand that drive the low feasibility of this model for Kampala.

Limitations of market demand were notable, particularly among potential users for industrial purposes. About 98 percent of the enterprises surveyed expressed that they were satisfied with the current quality of water supplied by NWSC and 96% noted facing no shortages with water supply. Only 7% of the respondents expressed interest in using treated wastewater, particularly for washing purposes, and noted willing to pay higher prices than the current fees at UGX 500/$m^3$. Farmers, on the other hand, showed a higher interest in wastewater reuse for their operations and WTP of UGX 530/$m^3$ - although still lower than the current fees paid for water. Additionally, even though urban agriculture is practiced widely, business oriented reclamation of wastewater in urban areas may be difficult due to the scattered organization of urban farmers. Large-scale farming activities are sometimes located far off from urban areas, and where wastewater infrastructure is not planned to be implemented, this would require the treated wastewater to be piped long distances. Thus, it is also important to note that the estimated market demand will be determined and may be limited by the length of the canal or pipeline and related pumping costs to deliver the water to especially for farmers located far off from the wastewater treatment plants.

Additionally, considering the high investment costs associated with wastewater treatment infrastructure, the retro-fitting of existing plants may not only come at high cost but negate the potential economic benefits to be derived from reuse. The existing Kampala Sanitation Master Plan (2004) and Kampala Sanitation Plan (2008) outline the strategy for upgrading the wastewater treatment infrastructure in Kampala towards 2030. The feasibility of the business model may be improved through a cooperation of implementing the business with the National Water and Sewerage Corporation (NWSC) as part of a PPP agreement given the limited legal and policy mandates that centralize wastewater disposal and recovery to NWSC. This partnership can lead to the implementation of resource, recovery solutions at WW treatment plants in Kampala.

**Model 10** - **Informal to Formal Trajectory in Wastewater Irrigation - Incentivizing safe reuse of untreated wastewater:** The infeasibility of this model in Kampala is driven mainly by the institutional regulations which notes that the use of untreated wastewater for irrigation is not permissible under the city and national policies on wastewater and irrigation. Additionally, the National Irrigation Master Plan (2010-2035) does not emphasize irrigation using untreated wastewater, likely due to the abundance of alternative sources of water for production in the country around the city and the country. The latter is corroborated by the market assessment, which indicates farmers' WTP for treated wastewater to be significantly lower than the current water price. Additionally, as highlighted under the health risk and impact assessment, it is not recommended to promote the reuse of untreated wastewater for irrigation purposes in Kampala from a health perspective.

**Model 15 - Large scale composting for revenue generation:** The business concept is to better manage Municipal Solid Waste (MSW) and recover valuable nutrients from the waste that would otherwise be unmanaged and disposed without reuse. Compost from MSW is sold to farmers, landscaping, and plantations and other entities. From the waste supply perspective, although not source-separated, there is sufficient and easy access to MSW and adequate technology available for efficient sorting and production. The market assessment results suggest that there is a significant demand for compost as measured by the consumers' WTP, which is significantly higher than the average market price for substitute products at 100 UGX/kg. The results also indicate that farmers are willing to pay over and above the current market price at an amount equivalent a) to know the sources of materials used to produce compost(i.e. MSW, faecal sludge and/or animal waste), b) for pelletized compost and c) for certified compost. This suggests that high quality compost product if labelled with information on source of the inputs, has 3rd party certification and is pelletized will command a market price of 234.84 UGX/kg - which is almost 2.5 times higher than the current market price.Additionally, although chemical fertilizers represent the largest share of the market, a limited established distribution network represents an opportunity that organic fertilizer producers can capture. There is also neither a large-scale government fertilizer program that provides subsidized fertilizer to farmers nor an active private fertilizer sector that supplies fertilizer at competitive prices. Thus, this represents a great opportunity for waste-based organic fertilizer businesses who can take advantage of erratic chemical fertilizer prices and the limited number of actors in the respective market.The financial assessment showed that the model to be viable and more so under increased scale. It is important to note however that the decision of a business to operate at a certain scale will be determined by several factors: a) demand, b) price of the compost, c) economies of scale, among others. Whilst the current production levels of compost is unknown, it is clear that the compost sector is a burgeoning industry with some entry barriers but supportive and existing policies encouraging business development.

**Model 17 - High value fertilizer production for profit (faecal sludge-based compost)***:* This model is similar to model 15 in concept but in addition to MSW, the business entity uses fecal sludge as a waste input from onsite sanitation which is rich in nutrients. There are opportunities for pelletization and blending of faecal sludge-based compost with rock-phosphate, urea/struvite or NPK which is an additional value proposition that can be explored under this business model, allowing the product to have nutrient levels specific for target crops and soils, and a product structure improvement (pellets) to improve its competitive advantage, marketability and field use. This model has a medium feasibility for implementation and ranks positively high across the different assessment criteria.The demand for faecal sludge-based compost (models 17 and 19) was noted to be significant with average WTP value ranging between 713 and 1098 UGX/kg. Farmers are willing to pay more for fortified and certified faecal sludge-based compost, although they did not have a preference for pelletized compost.Whilst, the product is relatively unknown and there might be some risk associated with consumer acceptability, the potential market for Fortifer is noted to be substantial with the demand estimated was estimated at 0.026 million tons/year, assuming an adoption of 38% and application rate of 0.5 tons/ha/year[1]. The business model has a high viability which is mainly driven by the pricing of the product and quantity of product sold, as similarly discussed for Model 15.

[1]Surrounding notable agricultural districts in addition to Kampala were considered - Luwelo, Mpigi, Mukono, Wakiso - for the demand estimation.

From an institutional perspective, there are supportive national policies and legal framework for the production of high value fertilizers from faecal sludge and wastewater under controlled regulation; as is government support for private companies' entry into the sub-sector. NWSC is also mandated to enter into private and public partnerships for the production of high value fertilizers from faecal sludge. On the other hand, while the health risk and impact assessment show the significant potential positive impact from the implementation of this model, it is noted that both models 15 and 17, both of which use municipal solid waste (MSW) as an input, are only an option if no medical waste from health facilities is mixed with common MSW.

**Model 19– Compost Production for Sanitation service delivery:** The business concept for this model is to provide sanitation service provision and to manage and transform human excreta into safe fertilizer and soil conditioner. This model has a medium feasibility ranking as it ranks highly positive across the different assessment criteria. It is noted that the institutional regulations[2] - which has allow feasibility ranking here and should cause this model to be of 'low feasibility', there are many avenues for establishing strategic partnerships with NWSC to ensure the supply of faecal sludge from onsite sanitation systems to the production entities. This model is highly financial viable although it is important to note that similar to Model 4, its viability is largely dependent on the number of toilet users. The revenue generated from toilet user fees consists of 85% of total revenue, which is the essential driver of the business' viability as revenue from compost sales only constitute 6% of total revenue. There is significant demand for faecal sludge-based compost and treated urine use as a fertilizer. However for the latter, distribution costs are noted to be fairly high. Potential health and environmental benefits accruing from the implementation of this model will be significant from reduced human health risk, especially for households in the slums who now have increased access to affordable toilets and waste collection services and b) reduced environmental pollution from decreased open-dumping.

[2]The mandate of the public and private cesspool emptiers for onsite sanitation facilities around the city does not include handling the faecal sludge in any other way other than depositing it at the NWSC treatment sites. The mandate currently is limited to NWSC due to its monopoly as sole depository of faecal sludge from onsite sanitation public facilities.

# 11 Annex 1: Linking Research and Business Development

An online platform called Specific Topic Entry Page (STEP) for Business Development in Resource Recovery and Safe Reuse ("STEP RRR Business Development", http://www.sswm.info/category/step-rrr-business-development/rrr-business-development) was developed as part of the research project. It reflects, combines and makes available in a concise and comprehensible way scientific insights and up-to-date research results obtained from the feasibility studies and provides entrepreneurs the needed technical and business strategy tools to support the entrepreneurial process when conceiving, launching and growing a venture in the water, sanitation or resource management sector.

To help empower the private and public sector in Kampala, a 6-day Business Model Development Training (BMDT) focusing on the translation of RRR business ideas into promising business models for the safe resource recovery from liquid and solid waste, was held from 20th to 27th November 2014. The BMDT was completed by a total number of 9 enterprises, organizations and institutions:

- The Centre for Research of Energy and Energy Conservation (CREEC, http://creec.or.ug/) is a not-for-profit organization for research, training and consultancy, located at and working closely together with the College of Engineering, Design, Art and Technology (CEDAT) within Makerere University (MAK). The centre aims at application and adaptation of technologies to the specific Ugandan and local environment with an emphasis on systems with components that can be locally manufactured.
- The Centre of Excellence in Waste Management (CEWM) strives to develop sustainable agricultural production systems through ecological resource management and value addition.
- i-San Consulting (iSan, http://www.isanconsulting.com/) focuses on urban sanitation planning in developing countries.
- Kampala Capital City Authority (KCCA, http://www.kcca.go.ug/) is mandated to facilitate the delivery of quality services to the people in the city of Kampala.
- Kenlon Industries Ltd. (Kenlon, http://www.kenlonindustries.com/) is an agro processing company that amongst others produces charcoal powder from agro-industrial wastes as substitute to Heavy Fuel Oils (HFO) that are traditionally used in industries.
- Oribags Innovations (U) Ltd. (Oribags, http://oribags-innovations.com/) is a social and environmental enterprise that develops and commercializes technological solutions that provide practical solutions to peoples' needs.
- Sustainable Sanitation and Water Renewal Systems (SSWARS, http://www.sswarsuganda.org/) is a non-profit making, non-governmental organization that aims to develop, improve and sustain the status of the communities through use of sustainable and renewable systems with a prime objective of reducing risk of exposure to poor sanitation and water related diseases, and ultimately alleviate poverty amongst the communities.
- WaterAid - Uganda (http://www.wateraid.org/) supports local communities to build their own solutions, encouraging people to take ownership of projects to ensure they are in control of changes to their environment.
- Water For People - Uganda (WfP, http://www.waterforpeople.org/) introduced the sanitation as a business program to improve access to affordable pit emptying services to the urban poor using the gulper technology.

A total number of eight Business Models (BM) were worked on during the training (2 organizations worked on a common BM). The generic BMs originally analyzed, described and developed as part of the project *(Output 3 - Catalogue of RRR business models)* were used as resource base for the development of BMs tailored to the participants' entrepreneurial expectations:

- CREEC's BM revolved around producing and selling briquettes made from faecal sludge (FS) as cooking fuel. The BM draws from generic BM#1 "Dry Fuel Manufacturing".
- The BM designed by the Centre of Excellence in Waste Management is inspired by BM#2 "Energy Service Companies at Scale". However, instead of treating municipal solid waste (MSW), it assumed a cooperation of farmers, collectively using their waste to generate energy using anaerobic treatment.
- Water for People-Uganda prepared a blueprint for a BM to be used by small-scale pit emptying companies providing services in densely populated, low-income areas. Their business model was based on BM 4 - Onsite energy generation from sanitation service providers.
- WaterAid and iSan designed a BM that combines FS composting, producing a protein-rich organic feed (i.e. processed black soldier fly larvae) and biogas at scale. This BM cannot be associated to any particular generic BM, but features aspects from several other BMs such as BM#2 "Energy Service Companies at Scale" and BM#8 "Large-Scale Composting for Revenue Generation".
- Kenlon produces charcoal powder from agro-industrial wastes as alternative energy source in industries. The developed business model by Kenlon features aspects from BM#1 "Dry Fuel Manufacturing".
- With a focus on large-scale composting of market waste for the production of a well-balanced nutrient-rich agro fertilizer, KCCA's BM is inspired by e.g. BM#8 "Large-Scale Composting for Revenue Generation".
- Oribags intends to launch a new business wing by producing briquettes from agro-waste (based on BM#1 "Dry Fuel Manufacturing" - but based on agro-industrial waste).
- SSWARS designed a BM for a women association that manufactures balls and dolls from recycled plastic bags. These toys are used by children living in the same low-income area and bought by tourists in craft shops. There was no direct overlap to the business models developed as part of *Output 3*, however the underlying business concepts served well for the exercise.

# 12 Annex 2: MCA Framework

The MCA framework used consists of a 7-component criteria with each criterion having its own set of indicators and related questions. Detailed questions were employed to provide data/information for the evaluation of indicators. The list of criteria selected for the MCA framework is based on previous research and is as follows:

1. Waste supply and availability
2. Market assessment (demand quantification and product market assessment)
3. Technological aspects (waste transport, storage, valorization, process and product safety)
4. Institutional and legal settings and public support
5. Financial feasibility/viability assessment
6. Health and environmental risk assessment
7. Socio-economic impact assessment (valuation of economic benefits and assessment of additional externalities)

The MCA builds on the assessment of a set of criteria and indicators to a) analyze if existing local conditions support the model, and b) to run e.g. sensitivity analyses under various scenarios of demand, supply, technical options etc. Each of the criteria sought to assess the following:

**1. Waste supply and availability** (access): There is a perception that waste is abundant in urban cities and supply limitations are uncommon. However preliminary observations indicate that different governance systems dictate ownership rights of the city's waste, which has implications for accessibility, availability and how efficient the business's processes will be. This criterion is particularly important in explaining a firm's business model as access to inputs (a key resource) represents a major factor of production. Adequate access to waste or a lack thereof may signify an important source of constraint to business viability. Key questions that were sought to be answered include but not limited to: What are the types, quality and quantity of waste available? Who owns the waste currently? What is the periodicity of availability? Who are the actors along the sanitation service chain providing the resource? Which competing alternative destination is available? Is the supply legal? Is the supplied product safe? Are there supply limitations and so on?

**2. Market assessment (demand quantification and product market assessment)**

This criterion is particularly important in explaining a firm's business model as insufficient market demand may be the key driving force of business failure. The market assessment provides pertinent information on key elements of the business model: value proposition, key resources, cost structure, revenue model, customer relations and customer segments. The estimation of market demand implicitly provides insights on key customer segments that the business needs to target (number of current customers by segment; profitability by segments; growth potential by customer segments). Information on the structure of the output market will guide a business in adopting the most efficient pricing and marketing strategy to ensure it maintains its competitive advantage in the market. These in addition to the assessment of the outlook of the market, efficient marketing strategies will drive how a firm's business model is structured).

**3. Technological aspects (waste transport, storage, valorization, process and product safety)**

This criterion focuses on the actual technical approach/process applied for the output production. It focuses on the analysis of the technical options for its energy requirement, related costs, repair sensitivity, supply chain, level of expertise available/needed, etc. This criterion is particularly important in explaining a firm's business model as the technical process used represents a key resource for the business. The robustness of the technical process, its safety capabilities and conversion efficiency of waste to the marketable product represents the key strengths of the business model that the business can actually leverage. This criterion focuses on the actual technical approach/process applied for the output production. It focuses on the analysis of the technical options for its energy requirement, related costs, repair sensitivity, supply chain, level of expertise available/needed, etc.

**4. Institutional and Legal Settings and Public Support**

This criterion targets the legal, institutional and administrative context within which a business case operates, as well as the public perception. As noted in previous research, the success or failure of any business, particularly in developing countries depend largely on institutional factors. A thorough analysis of this criterion is particularly important as the lack of a supportive institutional and legal environment are cited as one of the major constraints to business start-up. Key questions addressed include: ownership of operations, acceptance by local community, the institutional set-up, linkages, dependencies, agreements and decision pathways.

**5. Financial feasibility/viability assessment**

This criterion assesses the financial viability of the business model. Given a myriad of factors including but not limited to demand, cost structure, macroeconomic factors, etc., is the business model financially viable? This assessment evaluates the investment and production costs, earnings, taxes, depreciation and amortization, funding sources among others and evaluates them to the business model's profitability and operating performance. Key questions addressed include: Is the business financially viable (break-even; profit-generating)? Can the product be produced cost-effectively with positive profits and under what conditions? Is the business financially viable and under what conditions? Is the firm operating at an optimal production capacity based on the choice of technical process, related costs, etc.?

**6. Health and Environmental risks and risk mitigation**

This criterion focuses on the assessment of the risks associated with production and consumption of the value-added product. Risks (i.e. occupational and consumer) and risk mitigation processes should be assessed across the waste chain (sanitation and solid waste service chain) at all strategic points, starting from the input market to the output market. Key questions addressed include: What are the foreseen health and environmental risks/ challenges associated with informal sector participation in providing services along the waste chain? What are the health risks associated with the handling and processing of the particular waste input used?

**7. Socio-economic impact assessment**

This criterion provides an assessment of the societal and environmental benefits and costs resulting from the RR&R activity. This criterion assesses the socio-economic impact of the business model based on the valuation of socio-economic, environmental and health benefits and costs associated with the model and any additional externalities.

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