2015

Resource Recovery and Reuse (RRR) Project

Socioeconomic Analysis of RRR Business Models, Kampala City Report

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Contents

List of Tables

List of Figures

Data used in the analysis is from 2013 and 2014.

Denomination: 1 USD = 1 USD (2014); 1 USD = 2,750 UGX

UGX: Ugandan Shillings

Introduction

The report 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 societal 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 the all the benefits of a particular business model outweigh its costs and thus supports in making decision. In this report the following business models had been assessed as shown in Table 1.

Table 1: Selected RRR Business Models for Kampala

RRR Business Models	**Brief Description**
ENERGY	
Model 1A: Dry Fuel Manufacturing - Agro-industrial Waste to Briquettes	The business processes crop residues like wheat stalk, rice husk, maize stalk, groundnut shells, coffee husks, saw dust etc. and convert 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 be sold to households, business or local electricity authority.
Model 4: Onsite Energy Generation by Sanitation Service Providers	The business model is initiated by either enterprises providing sanitation service such as public toilets or by residential institutions such as hostels, hospitals and prisons with concentrated source of human waste. 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 could 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) (*service*) and recover valuable nutrients (*products*) 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 so on.

Model 17: High value Fertilizer Production for Profit	Similar to Model 15 in concept but in addition to MSW, the business uses fecal sludge from onsite sanitation which is rich in nutrients as input. The business also develops enriched compost and pelletized compost which has higher nutrient content with improved and efficient delivery of nutrient to crops.
Model 19: Compost Production for Sanitation Service Delivery	The business concept is to provide sanitation services and to manage and transform human excreta into safe fertilizer and soil conditioner.

Methodology

The first important footstep towards a socioeconomic assessment is defining 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 analyzed 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 look into 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, change 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 stochastic.
- *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 had been mentioned previously in the synopsis of the financial assessment that since the RRR sector is nascent in Uganda, data access and availability were limited. This was even more critical for the socio economic assessment which relied heavily on the 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 not available, 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 produces a cascading effect in the socioeconomic assessment as well.

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 (Table 2) indicates the baseline and alternative scenarios and also describes the scale of operation for the different business models in Kampala.

Table 2: Baseline and Alternative Scenarios used for the Socioeconomic Assessment for the different Business Models

Business Models	Base case	Alternative	Remarks
Model 15: Large-Scale Composting for Revenue Generation	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)
Model 17: High value Fertilizer Production for Profit	Fecal sludge is dumped or being partially treated in the Buglobi 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.
Model 19: Compost Production for Sanitation Service Delivery	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 – • 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 • Number of public toilets will be only based on the persons using public toilets presently 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	2.7% of the population depend on open defecation
Model 10: Informal to Formal Trajectory in Wastewater Irrigation - Incentivizing safe reuse of untreated wastewater	Untreated wastewater of volume 50,000 m^3 /d moving into waterbodies	Utilization of Waste Stabilization Ponds for partial treatment of 64000 m^3 / d of wastewater which is subsequently used for agriculture	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

Business Models	Base case	Alternative	Remarks
		and indirectly recharges depleted aquifers	treated at Bugolobi (12000 m^3), Naalya (1000 m^3) and Ntinda (12000 m^3)
Model 9: On Cost Savings and Recovery	Effluent generated from treated wastewater of volume 14,000 m^3/d moving into waterbodies	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 64,000m^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.
Model 1A: Dry Fuel Manufacturing - Agro-industrial Waste to Briquettes	1000mt of organic waste accumulates daily and only about 30% 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 agrowaste 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).
Model 2A: Energy Service Companies at Scale - Agro-Waste to Energy (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.	
Model 4: Onsite Energy Generation by Sanitation Service Providers	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 – • 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 • Number of public toilets will be only based on the persons using public toilets presently 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	2.5% of the population have access to public toilets

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.

Energy Business Models

The following table (*Table 3*) 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 3 Energy Business Models

	Model 1A: Dry Fuel Manufacturing - Agro-industrial 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 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

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. The following table (Table 4) 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 4 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 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

Nutrient Business Models

The nutrient business models have been compared in the following table (Table 5). 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 5 Nutrient Business Model

	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

Summary assessment of financial feasibility of RRR Business Models

Table 6 provides a summary overview of the criteria used for 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 14 below.

Table 6: 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%	

$30\% < P (NPV < NPV_{mean}) < 50\%$	< 1	< 100%	**Not Feasible**
50% and above	< 1	< 100%	

Using the methodology defined in Table 6, the RRR business models were assessed for their viability in the context of the Kampala city (shown in Table 7). 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 the probability of NVP dipping down from the mean value is more than 50% or close to it. In comparison to these scenario, 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. At the same time the financial models had been 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 (excepting the Energy Service Companies) differ in the results.

Table 7: Synopsis of Socioeconomic Feasibility RRR Business Models

RRR Business Models	**$P (NPV < NPV_{mean})$**	**B:C Ratio**	**Rate of Investment (ROI)**	**Feasibility**
ENERGY				
Model 1A: Dry Fuel Manufacturing - Agro-industrial Waste to Briquettes	52.2%	5.26	87%	Low
Model 2A: 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 agrowaste 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 agrowaste finds its way to the 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 agrowaste as mentioned previously.

Model 4 – Onsite energy generation by sanitation service providers: This business model although is promising in economic and financial terms, the contribution to the overall societal benefits are restricted mainly to health. 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 it is focused 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 the 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 waste of the city. Economically compost plants are feasible because 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 is considered composting plants are 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.
In addition, the

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.

Socio-economic impact assessment of dry fuel manufacturing business (Agro-industrial Waste to Briquettes) in Kampala

Introduction

In Uganda, a large portion of households, institutions and commercial entities rely on traditional biomass as the primary source of energy for heating and cooking. Over 90% of the national energy demand is met from biomass sources, wood being the most common source (Ferguson, 2012). This continued over-dependence on wood fuel and other forms of biomass as the primary source of energy has adverse effects on forest resources and are associated with high levels of environmental pollution. According to FAO estimates, Uganda is losing 50,000 ha (0.8%) of its forestland per year through deforestation. The major cause of this continuing dependence on firewood is lack of affordable and reliable alternative sources of energy. Extensive and inefficient use of fuelwood and other biomasses contributes to increased rates of deforestation, environmental pollution and adverse impacts on public health. Thus there is a need for more efficient utilization of biomass energy sources through efficient biomass processing technologies.

The opportunity to utilize more efficiently agricultural residues, with a reduction in pollution levels, has in recent years aroused the interest of developing countries in dry fuel manufacturing technologies (Grover and Mirsha, 1996). Waste processing technologies such as briquetting have the potential to counteract many adverse health and environmental impacts associated with traditional biomass energy. To improve the waste management, to reduce the rate of deforestation and to increase access to modern energy technologies, recycling agricultural waste to manufacture briquettes is a simple and low cost technology. Briquettes are densified biomass fuels used for heating in different systems. They are affordable source of energy and can be used in cooking instead of the traditional charcoal and firewood. The main purpose of briquetting a raw material is to reduce the volume and thereby increase the energy density. This also improves the handling characteristics of the materials for transporting, storing and usage (Grover and Mishra, 1996).

The potential economic, environmental and social impacts of the dry fuel manufacturing business model need to be assessed to ensure its sustainable development. In this study, we evaluated the socio-economic impacts of dry fuel manufacturing business with annual capacity of 2,000 tons of briquettes in Kampala. The socio-economic analysis is conducted based on the valuation of financial, environmental and health benefits and costs associated with the business model.

Technological options for briquette business

Raw materials used for briquette production

Briquettes can be produced from various raw materials such as agricultural residues, organic municipal solid waste, sawdust from timber mills and other woody biomass. However, the quality of the briquette which is measured by its energy content, depends on the raw materials used. The selection of suitable input materials, in addition to availability, is based on the input's desirable characteristics such as low moisture content (10-15%), low ash content (4%) and uniform or granular flow characteristics of the raw material (Tripathi et al., 1998). The main sources of input for briquette production in Uganda include agricultural residues (such as maize cobs, rice husks, coffee husks, groundnut husks etc.), wood processing waste (such as sawdust) and organic municipal solid waste. Uganda, where the agriculture sector is an important component to the growth of the economy generates large quantities of agro waste as data provided by the government indicated that annual agricultural wastes available is 1.2 million tonnes and daily MSW generated in the city of Kampala is estimated to be 1,500 tonnes (Uganda Investment

Authority, 2010; Uganda Renewable Energy Policy, 2007). Table 8 shows the characteristics of agricultural residue and the available amount in Uganda.

Table 8: Agricultural residues available and their ash content in Uganda

Agricultural residue	Ash content[a] (%)	Annual production (,000 tons/year)
Bagasse	1.8	590
Rice husks	22.4	25-30
Rice straw	17	45-55
Sunflower hulls	1.9	17
Cotton seed hulls	4.6	50
Tobacco dust	19.1	2-4
Maize cobs	1.2	234
Coffee husks	4.3	160
Ground nut shells	6.0	63

Source: Uganda Renewable Energy Policy, MEMD, 2007; [a]Grover and Mishra, 1996

Technology description

The process of making briquettes depends on whether the briquettes are carbonized or non-carbonized (Figure 1). Carbonized briquettes are made from raw materials that have been carbonized through partial pyrolysis to produce char which is then compacted into a briquette. Carbonized briquettes are used as a replacement to charcoal for domestic and institutional cooking and heating. The traditional charcoal making techniques such as carbonization of raw materials using earth pit or steel kilns with conversion efficiencies of less than 10% are the dominant methods of carbonization in developing countries (Ferguson, 2012). However some improved processes have been developed for small scale char production, with improved efficiencies of up to 30% (Ferguson, 2012). Eco-Fuel Africa, a carbonized briquette making enterprise in Uganda, for example invented a low-cost kiln made out of old oil drums to carbonize its agricultural waste to produce charcoal powder. Non-carbonized briquettes on the other hand are made directly by solidifying/compacting the raw material. They are used by industrial and commercial processes such as brick manufacturing, lime production, fish smoking, tobacco curing, beer brewing, coffee and tea drying which rely on charcoal and firewood for cooking and heating purposes. They can also be used as a replacement fuel among rural populations where firewood is still dominant (Ferguson, 2012).

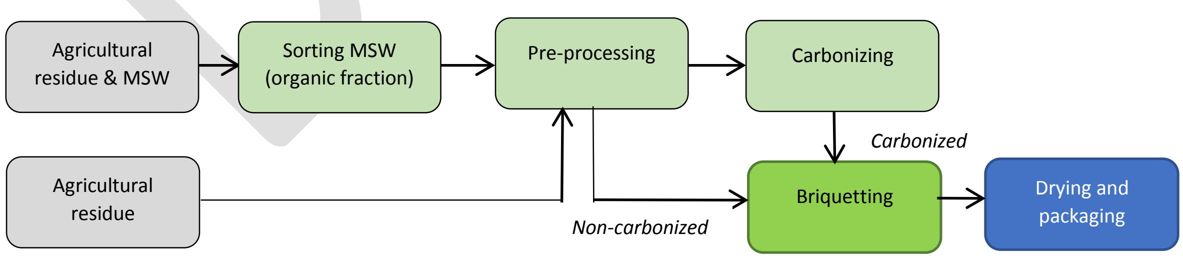

Figure 1: Process diagram of briquetting

Pre-processing

Depending on the characteristics of the raw material used and depending on the type of briquette to be produced, the raw materials need to go through a pre-processing stage before briquetting. This primarily involves shredding of raw materials, sieving, pulverizing and drying. This pre-processing step can be done manually by crushing and chopping or by using mechanized milling machines and can potentially be labour and energy intensive depending on the type of raw material used. For example, residues such as rice husks and sawdust require no drying, minimum chopping and crushing to break them down, and thus considerably reduce the energy and labour required to prepare the raw materials (Chaney, 2010). Thus careful consideration should be taken when selecting appropriate raw materials for briquetting to minimize cost of production.

Binding materials

Binding materials are needed in order to ensure that the final product remains in a compact form and has the required strength to be able to withstand handling, transportation and storage. Examples of briquette binders include starch (rice flour, cassava flour, sweet potato paste), natural resins, tar, molasses, algae and gum Arabic (EEP, 2013). Starch is the most commonly used in East Africa. When selecting a binder, careful consideration should be taken to ensure that it is non-toxic for laborers working in briquette making. Furthermore, the effect of the binder on briquette's combustion, emission occurring during burning and the residue after combustion need to be considered during selection of binding materials.

Briquetting/densification

Briquetting essentially involves two parts; the compaction under pressure of loose material to reduce its volume and to agglomerate the material so that the product remains in the compressed state (http://www.fao.org/docrep/t0275e/t0275e04.htm). There are different methods of briquetting which can be grouped into high pressure, medium pressure and low pressure compaction. For these methods, a wide range of technologies have been developed. These can be grouped into low pressure presses, piston presses, screw presses and roller presses (Maninder et al., 2012; FAO, 1990). Each of the technologies are described below.

- *Low pressure or manual presses* are simple low-capital cost options which require low skill levels and no electricity to operate and are used for producing both carbonized and non-carbonized briquettes. These are suitable in areas where there is no access to electricity. A number of manual technologies exist in low income countries that have been developed as low-cost options especially in the rural context. However, the briquettes produced through this process may not have the desired quality as they are known to crush easily especially when mishandled or exposed to water.

- *Piston presses* are large machines whereby a heavy piston forces biomass material through a tapered die, which compacts the biomass as a result of a reduction of the diameter, using high pressure. Depending on the operating method, piston extruders can produce between 200 and 750 kg of briquettes per hour (Ferguson, 2012). Briquettes are extruded as a continuous cylinder. These machines are used to produce non-carbonized briquettes.

- *Screw presses* extrude a briquette through a die and produce briquettes with a homogenous structure which are often cylindrical. They can be operated continuously, which is the main advantage compared to piston extruders. The main disadvantage is the wear of the screw, which needs relatively high investment costs compared to the costs of the extruder itself. A screw press typically has the capacity to produce150 kg of briquettes per hour (Ferguson, 2012).

- *Roller presses* are mainly used to produce carbonized briquettes and are also widely applied for the production of charcoal briquettes. Roller presses involve two rollers continuously rotating in the opposite direction, converging at point of compaction where the processed raw materials are transformed in to the shape of the desired briquette (EEP, 2013). As this technology does not provide enough pressure to compact the raw materials, water and binders such as cassava or wheat flour are added to hold the material together. A roller press has the capacity to produce 1,500 kg of briquettes per hour which is high compared to other briquetting technologies (Ferguson, 2012).

Overall approach to socioeconomic impact assessment

The socio-economic analysis of a project is concerned with its viability from a societal perspective and answers the questions of whether it is economically rational to proceed with the project (De Souza et al., 2011). In contrast to a financial analysis, socio-economic analysis provides a more comprehensive investigation on the effects of a proposed project, takes a broader perspective and determines the project's overall value to society. The analysis, therefore, includes benefits and costs that directly affect the business entity running the project and the effects of the project on households, governments and other businesses outside of the business. The analysis also includes the benefits and costs that cannot be readily measured using observable market prices and costs (De Souza et al., 2011). In this study, the financial viability of the business was assessed through a cost benefit analysis and for the environmental impacts, a life cycle emissions of agricultural-residue derived briquette fuel are evaluated. The scale of study considered is 10 plants of operational capacity of 2,000 tons per plant. This assumptions leads to the fact that 10 plants take up about 75 tons of agrowaste per day for producing briquettes. Therefore, the socioeconomic model linearly extrapolates the financial analysis of a single plant of capacity of 2,000 tons annually. This assumption was primarily based on the fact that in Kampala, the largest existing briquette plant has a production capacity of 2,000 tons annually.

The following sections will elaborate on the assumptions made, the scenarios modeled and the data sources used for assessing the environmental, social and financial impacts associated with dry fuel manufacturing business. The potential costs and benefits are evaluated at the plant level and extrapolated at the city level.

Environmental impact assessment

A life cycle emissions of agricultural residue derived briquette fuel were evaluated. The purpose of the environmental assessment was to identify the environmental impact of utilizing agricultural residue for the production of fuel briquettes and to compare the resulting environmental impact to that of the fuel used under baseline scenario i.e. firewood. The functional unit used for quantifying the environmental impacts is 1 kg of briquette used for cooking and heating. Environmental indicators selected in this study are CO_2, CH_4, N_2O for climate change, SO_2 and NO_x for acidification and eutrophication. Gaseous emissions were expressed in CO_2-eq using conversion factors of 1, 21, 310 for CO_2, CH_4 and N_2O respectively (IPCC, 2001). SO_2 and other particulate matter are associated with acute and chronic respiratory and heart diseases and given their potentially direct effect on human health, gaseous SO_2 are regulated as criteria air pollutants (Burtraw and Szambelan, 2009).

Total emissions under baseline represent emissions from burning of agricultural residue in open fields and from combustion of fuelwood in stoves. Total emissions under the briquette business scenario represent emissions from agricultural collection and transportation, emissions from briquetting, emissions from transport and combustion of briquettes in institutional stoves. These calculations of the total emissions were based on a number of studies (Hu et al., 2014; Ruiz et al., 2013; Okello et al., 2013; Sparrevik et al., 2012;; Young and Khennas, 2003; IPCC/OECD methodology).

Baseline and alternative scenarios

In conducting socio-economic analysis of any project, it is important to determine the baseline scenario which will be the benchmark to compare project alternatives. This study will assess the economic viability of briquette business model and a comparison of the costs and benefits of the business model vs. a business as usual scenario. Firewood is the most widely used energy source for institutional and commercial use in Kampala and therefore was taken as the reference system.

System boundary

The system boundary applied in this study contains, 1) agricultural residue collection and transportation, 2) residue briquetting, 3) briquette fuel distribution and 4) briquette fuel combustion in stoves. The environmental impacts at each stage or process are taken into account. For the briquettes produced, we assumed a replacement of fuelwood for use in institutions and commercial sectors for heating and cooking. For the agricultural residue used as input in the briquetting process, we assumed that under baseline, the residues are burnt in open field during land preparation for planting crops (Okello et al., 2013). Thus, emissions associated with this practice were accounted for when assessing the environmental impacts. Energy used and the environmental impacts associated with the main agricultural commodity were excluded from the scope of the study. Moreover, emissions associated with machine or equipment use in the briquette business are excluded from the scope of the study.

Agricultural residue under baseline

Under baseline scenario, agricultural residues are burnt in open field during land preparation for planting crops. The GHG and other particle emission effects from agricultural residue burning are estimated based on Sparrevik et al., 2012 (Table 9). The GHG and other emissions avoided as a result of using the agricultural residues are measured in terms of the avoided kg of CO_2 and other pollutants (SO_2, NO_x, CO) based on agricultural residues used to produce 1 kg of briquettes.

Table 9: Emission factors for open burning of agricultural residue under baseline

Emissions	Emission factor (kg emission /kg of dry residue burned)
CH_4	0.0012
N_2O	0.00007
SO_2	0.002
NO_x	0.0031
CO	0.0347

Source: Sparrevik et al., 2012

Agricultural residue transportation and briquetting

The agricultural residues used in the briquette making are sourced from farmers which are spread over a large geographical area. It is assumed that during processing, input loss of 8-12% occurs. Assuming a 10% input loss during processing, for a 2,000 ton briquette production, 2,222 ton (2,000/0.9) of input is required. The CO_2 emissions produced at the collection stage and subsequent transportation to the briquette plant are included in the assessment. In general, the level of emissions under the briquette business scenario is expected to be low compared to the amount of CO_2 emissions avoided by using the agricultural residues and thus avoiding open field burning (Ruiz et al., 2013). The GHG emissions are measured in terms of the kg of CO_2 emitted as a result of collection and transportation, in supplying 1 kg of briquettes. It was assumed that collection of agricultural residues is done within an average distance of

40 km from the processing plant using a truck of 16 ton capacity (Okello et al., 2013). Use of trucks results in CO_2 emissions from use of fossil fuel. The CO_2 emissions per liter of diesel fuel ranges between 2.6 to 3 kg/liter of diesel fuel (Ruiz et al., 2013). In this study, CO_2 emissions of 3 kg/liter of diesel fuel was used. The CO_2 emissions are calculated based on a mean distance of 40 km and diesel consumption of 0.45 liter/km (Table 10).

At the plant, the agricultural residues are sieved, pulverized using a hammer mill and dried to a moisture content of 13% using a flash drier. The agricultural residues are then blended to get a homogeneous mixture of different materials and fed into a briquetting machine to be compacted. According to Hu et al. (2014), energy use during pre-processing is 3 kwh/ton for drying, 18 kwh/ton for chopping and 13 kwh/ton of briquette. The environmental impacts associated with the energy used during production of briquettes should be taken into account. In this study it is assumed that the source of energy for preprocessing is from hydropower generation stations (which is CO_2 neutral) as Uganda relies on electricity generated from hydropower generation. In contrast, other studies such as Hu et al. (2014) have accounted the environmental impacts associated with electricity used for briquetting as the electricity is supplied by a coal fired power plant. In Kampala, there are frequent power cuts and business entities have back-up generators which run on diesel fuel. Emissions related to diesel used for generator during power cuts is not accounted in this study due to lack of sufficient information on the frequency of power cuts and use of diesel fuels for generators.

Table 10: CO_2 emissions from transportation of agro-residue to briquette plant

Item	Unit	Value	Source
Average return trip distance -agro-waste to briquette plant	km	40	Okello, 2014
Average return trip distance briquette plant to final users	km	20	Assumed
Capacity of truck agro-waste (per load)	ton	16	Okello, 2014
Diesel consumption	lt/km	0.45	Ruiz et al., 2013
CO_2 emission per liter of diesel	kg CO_2/lt	3	Ruiz et al., 2013

Briquette transportation and combustion

The same truck with a capacity of 16 ton is assumed to be used to transport the briquettes to end users within an average distance of 20 km. The briquettes are substitute for fuelwood and can be used for cooking without stove modifications. It is estimated that the energy content in 1 Kg of briquette is 16.8 MJ and 13.8 MJ in 1 kg of fuelwood (IPCC/OECD methodology; Hu et al., 2014). This implies that 0.82 kg of briquette can replace 1 kg of fuelwood. Other studies have assumed that 1 kg of fuelwood can be replaced by 0.7 kg of briquettes (Young and Khennas, 2003). Thus, the use of 1 Kg of briquette would conserve 1.22 Kg of fuelwood. The combustion efficiency of and the resulting emissions from briquettes greatly depend on the combustion equipment used (Roy and Corscadden, 2012). The institutional wood stoves used in most East African countries have an efficiency of 45% when wood is used and 50% when wood is replaced by briquettes (Young and Khennas, 2003). This nominal increase in efficiency of 5% is due to the fact that briquettes have uniform shape and can fit to stove allowing cooking in enclosed stove and thus increasing efficiency (Young and Khennas, 2003). The emissions associated with combustion of fuelwood under baseline and briquettes under the briquette business scenario are presented in Table 11.

Table 11: Emission factors from combustion of firewood and briquette

Emissions	Fuelwood use	Briquette use

	(Kg emission/kg of fuelwood)	(Kg emission/kg of briquette)
CO_2 emission	1.513	0.7604
CH_4 emission	4.14E-03	2.98E-03
N_2O emission	5.52E-05	9.68E-06
SO_2 emission	-	-
NO_X	1.38E-03	4.84E-06
CO	6.9E-02	1.48E-02

Source: IPCC/OECD methodology; Okello, 2014

Environmental impact results

This section presents the GHG and other criteria emissions under baseline and alternative scenario at the city level. The total emissions under baseline scenario are the total of emissions associated with fuelwood use and burning of agro-residues in open field. These emissions are the emissions avoided as a result of utilizing agricultural residue for the production of fuel briquettes thereby replacing fuelwood. The emissions from the briquette business are the total of emissions associated with agro-residue transportation, briquette transportation and combustion in stoves. Total emission savings is the total avoided emissions net of the emissions from the briquette business.

Emissions under baseline scenario

The emissions avoided per kg of briquette produced is shown in Table 12. These are emissions under the baseline scenario. The highest contribution to GHG emission savings is from avoided burning of firewood. Reduced use of firewood also implies that environmental degradation through deforestation is minimized. The overall savings in GHG emissions from avoided use of firewood and agro-residue burning is 2.021 kg CO_2eq/kg of briquette. Considering the other criteria emissions, the highest contribution to reduction of acidification and eutrophication expressed respectively, in kg of SO_2 and NOx is from avoided burning of agro-residues. Given the assumption made in this study, savings of 0.0022 kg of SO_2, 0.0051 kg of NO_x and 0.1225 kg of CO are avoided per kg of briquette.

Table 12: Emission savings from avoided firewood use and agro-residue burning per 1 kg of briquette

Savings from	GHG emissions	Other criteria emissions		
	CO_2	SO_2	NO_x	CO
Firewood conservation	1.969	0	0.0017	0.0840
Burning agro-residue	0.052	0.0022	0.0034	0.0386
Total savings	**2.021**	**0.0022**	**0.0051**	**0.1226**

Emissions under briquette scenario

Processing of agro-residues to produce briquettes results in GHG and other criteria emissions. These emissions are from transporting of agro-residue to the plant, briquetting of agro-residue, transporting and combustion of briquettes. The environmental emissions from the production and combustion of 1 kg of briquette fuel are shown in Table 13. The highest contribution to GHG emissions and other criteria emissions is from combustion of briquettes showing total GHG emission of 0.8312 kg CO_2eq, 4.84E-06 kg of NO_x and 1.48E-02 kg of CO per kg of briquettes.

Table 13: Environmental emissions from the production and use of 1 kg of briquette

Emissions from	GHG emissions	Other criteria emissions

	CO_2	SO_2	NO_x	CO
Agro-residue transportation	0.0038	-	-	-
Briquette transportation	0.0017	-	-	-
Briquette combustion	0.8260	-	4.84E-06	1.48E-02
Total emissions	**0.8314**	**-**	**4.84E-06**	**1.48E-02**

Net emissions

The overall GHG emissions from the production and use of 20,000 tons (considering 10 plants) of agro-residue briquette fuel is shown in Figure 2. GHG emissions from firewood combustion and burning of agro-waste are negative representing GHG emission savings from use of briquette. The savings are mainly from avoided fuelwood use. Under the briquette business scenario, the highest GHG impact is from briquette combustion. Other processes such as transport and electricity use during production of briquette did not contribute significantly to the total environmental impacts of the briquette business. Although, the briquette business results in environmental impacts, the impacts are far less than the baseline scenario. The GHG emission savings are more than the emissions from the briquette business thus resulting in net GHG emission savings of 23.79 tons CO2eq per annum.

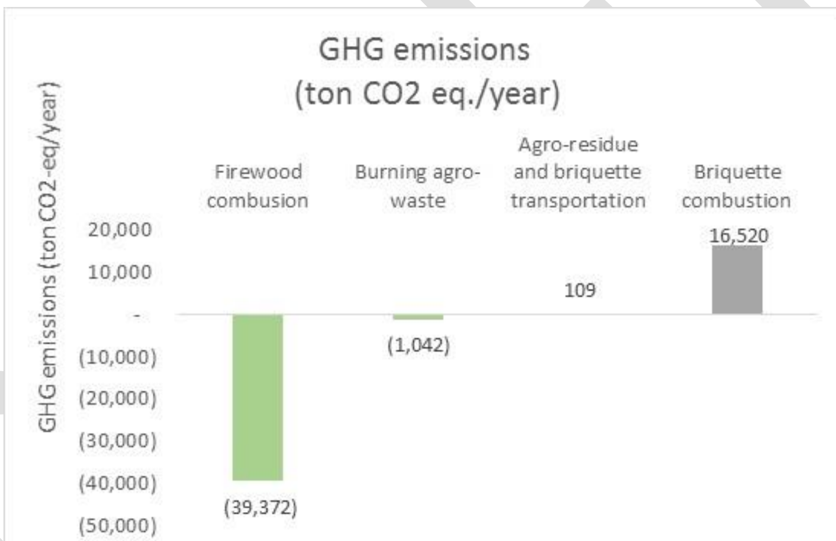

Figure 2: GHG emissions and savings from briquettes plants at city level (ton CO2eq/year)

Figure 3: Other emission savings from briquette plants at city level (ton/year) shows other criteria emissions, SO_2, NO_x and CO under baseline and briquette business scenario (2000 tons of briquettes). The untreated or burning of agro-residue under the baseline scenario contributes the highest SO_2 and NO_x emissions which respectively cause acidification and eutrophication. In the briquette scenario the agro-residue is processed to briquette resulting in a small eutrophication impact. The highest CO emissions is from firewood use. The combustion of briquette also contributes to CO emissions but less impact than the baseline scenario thus resulting in net emission savings. The net emission savings from 20,000 tons of briquette are respectively 44 tons of SO_2, 103 tons of NO_x and 2122 tons per annum.

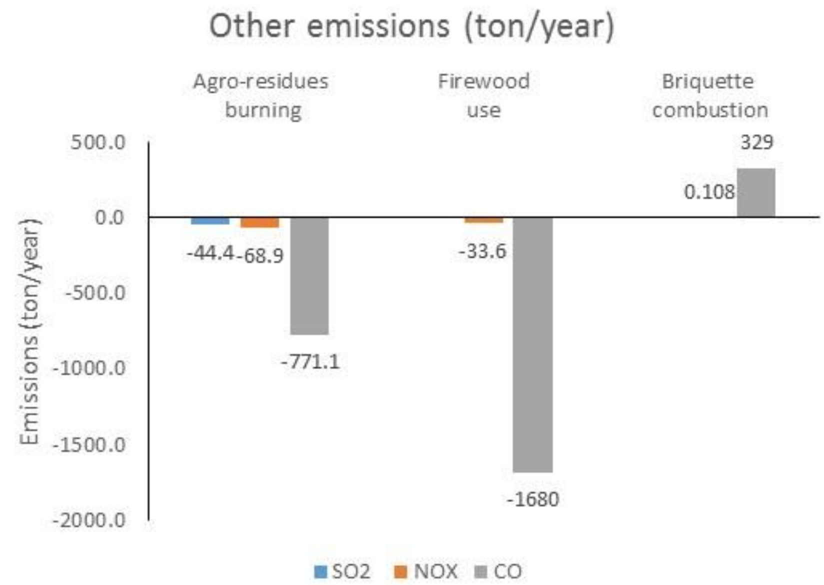

Figure 3: Other emission savings from briquette plants at city level (ton/year)

Value of Carbon credits and other emissions

Carbon credits are traded on either the regulatory CDM market or on the voluntary carbon market depending on their eligibility. The Certified Emission Reduction (CER) is the credit generated under CDM while the Voluntary Emission Reduction (VER) is generated under the voluntary carbon market. Since the VER is suited for small scale projects and are typically sold in volumes that appeal to clients seeking small reductions to offset their footprints, in this study the VER unit is considered. The VER unit is equivalent to a reduction of 1 ton of CO_2 equivalent emissions (Reuster 2010). Based on the World Bank (2014), carbon credit prices in the EU ETS range about USD 5-9 ((€4-7) in 2014 while prices were USD 18 ((€13) in 2011. In this study it is assumed that carbon credits are worth on average USD 7 per ton of CO_2 equivalent (Table 14). However value of the other emission savings that have acidification potential (NO_x and SO_2) were not included in the analysis[1].

Table 14: Annual value of GHG emission reduction from briquette business (2,000 tons)

Item	Amount
Total GHG emission savings (ton CO_2eq)	4,041
Total GHG emissions from briquette business (ton CO2 eq)	1,662
Net emission savings (ton CO_2eq/year)	2,379
Price of VER (USD/ton CO_2eq)	7
Total value of Carbon credit (USD/year)	**16,653**

The above table provides the economic value of GHG emission reductions at the plant level which can be utilized to calculate the benefits for the city. Therefore, the net benefits for the city operating with 10 briquette plants amounts to USD 166,530 annually.

[1] The economic value of acidification potential in the context of Kampala was hard to obtain and hence could not be included in the socio-economic analysis. It is being assumed that the DALYs utilized for the potential air pollution captures the economic value to certain extent in terms of potential health benefits accruing to the society.

Social impacts

Additional income from agricultural residue waste

As a predominantly agricultural country, Uganda generates large quantities of agricultural residues. The major agricultural residues include maize cobs, groundnut shells and coffee and rice husks. Data provided by the government indicated that annual agricultural wastes available is 1.2 million tonnes (Uganda Renewable Energy Policy, MEMD, 2007). While these agricultural residues are important sources of energy, currently they are burned in open field wasting valuable energy resources and also leading to serious environmental pollution. In areas where there are large agricultural residues, briquetting fuel plants can be established using local agricultural residue as input to their system. This will benefit farmers and local residents. Farmers will benefit from sales of agricultural residues and thus earning additional income. The cost of the agricultural residues for the briquette plant, based on existing plant in Kampala, is 129 USD/ton of which 3-14 USD/ton is paid directly to farmers indicating that a 2,000 ton briquette plant has the potential to provide annual additional income of USD 6,666-31,108 to farmers. Thus, on average (USD 8.5), the briquette plants for the city as a whole contributes to providing additional income to the farmer of 9.44 USD/ton of briquette produced, resulting in total annual additional income of 188,889 USD from 20,000 tons of briquettes.

In addition to providing additional income to farmers, briquette plant contributes to creating of employment for the local community. However, the briquette business is likely to also impact the livelihood of charcoal or fuelwood traders. The briquette business has 50 full time workers earning a total annual salary of USD 39,600 where the total monthly salary of the employees at a representative briquette plant is USD 33,000 annually. Thus for the city as a whole, there is an opportunity for 500 additional employment which leads to circulation of USD 396,000 annually in the economy. Business opportunities aligned with briquettes business is cook stoves which are more efficient in controlling emissions and releasing particulate matter. It has been assumed that about 50% households adapt to cook stoves. Such business opportunities can induce an additional USD 641,026 annually within the economy.

Savings for end-users

Replacing fuelwood with briquette fuels for cooking has the potential to contribute to reducing the costs incurred by end users for cooking fuel. In this study end users are institutional and commercial users. Table 8 shows the potential savings for end users from using briquettes. The energy content in 1 Kg of briquette is 16.8 MJ while the energy content in 1 kg of fuelwood is 13.8 MJ (IPCC/OECD methodology; Hu et al., 2014). Thus, less briquette by weight is required for the same amount of heat as compared to fuelwood. In addition to the calorific value of the energy sources, the replacement value of briquettes to fuelwood depends on the efficiency of cook stoves used in institutions. Based on calorific value only, the use of 1 Kg of briquette would conserve 1.22 Kg of fuelwood. Assuming efficiency of stoves of 45% and 50% respectively when fuelwood and briquettes are used for cooking, the actual price per MJ of useful energy is 0.039 USD in fuelwood equivalent and 0.034 USD in briquette equivalent. At the current price of fuelwood (0.24 USD/kg), using briquettes priced at 0.282 USD/kg has the potential cost saving of 13% as compared to fuelwood used in institutional stoves. Total annual cost savings for end users from producing 20,000 tons of briquettes is estimated to be USD 767,478. The following table (Table 15) provides the figures for a representative plant operating in the city.

Table 15: Savings to end users from using briquettes

Item	Fuelwood	Briquette
Fuelwood replaced by briquettes (ton) (A)	2,435	2,000

Heating value (MJ/kg) (B)	13.8	16.8
Price (USD/ton) (C)	0.24	0.282
Efficiency of stoves (%) (D)	45%	50%
Actual price per useful energy (USD/MJ) *(E= C/(B*D)*	**0.039**	**0.034**
Total energy value of fuelwood replaced (1000 MJ) *(F=A*B*D)*	**15,121**	
Savings from briquette use (%) *(G= [E (Fuelwood)-E(Briquette)]/E(Fuelwood)*	**13%**	
Total savings from shifting to briquettes (USD/year) (E*F*G)	**76,664**	

Health impacts

Use of fuelwood and other biomass in stoves with low-efficiency and inadequate venting leads to indoor air pollution exposing people working in kitchens to a major public health hazard (Schirnding et al., 2002). Biomass smoke contains a large number of pollutants that pose substantial risks to human health. Harmful pollutants include particulate matter, CO, NO_2 and SO_2 emissions. Exposure to biomass smoke increases the risk of diseases such as chronic bronchitis, chronic obstructive pulmonary diseases and lung cancer (Lim et al., 2013; Norma, 2011; Schirnding et al., 2002).

Briquettes are direct replacement to fuelwood used in institutions which have a combustion efficiency of 45%. The fact that complete combustion of biomass is not achieved in the institutional cook stoves results in production of toxic gases such CO and other toxic emissions. The combustion of briquettes in existing institutional stoves will also result in emissions of toxic gases. However, briquettes have advantages over fuelwood as they have low moisture content compared to fuelwood and thus less smoke and toxic emissions are produced during briquette combustion. This will lower gaseous emissions in the kitchen and exposure of people working in kitchens to health hazards.

In addition to health impacts associated with combustion of briquette, health impacts on workers' exposure to emission pollutants during briquette manufacturing should also be taken in to consideration. For example, communication with existing briquette plant in Kampala have revealed that the dust from most of the agricultural residue is hazardous when inhaled by the workers. Thus there is a need to provide workers with protective gears[2]. At the same time households substituting briquettes for firewood for cooking need to also substitute cook stoves designed for briquettes to reduce indoor air pollution. However, this requires awareness about utilizing cook stoves and hence it is assumed that would be 50% adaptation rate once this is introduced along with the briquettes and households are informed about the reduction in particulate matter when burning briquettes in the specialized cook stoves.

According to GVEP (2012), a household of 5 members usually consume 3 Kgs. of briquette for cooking purposes. Therefore it can be estimated that 128,205 households can be served when 20,000 tons of briquette is being produced. As mentioned earlier that since the adaptation rate for cook stoves is 50%, about 320,513 persons would be able to avert indoor air pollution. DALYs for indoor air pollution was used to estimate the health benefits derived from used of cook stoves. The benefits derived from the DALYs amounts to USD 2,211,538 annually. However, these households need to invest on the cook stoves to avoid health impacts. Based on the fact that the price of cook stoves in Uganda is USD 5, the net annual benefit for the households is calculated to be about USD 1.5 million. The opportunities and benefits from a cook business is separately considered in the social impact of the study.

[2] The costs associated with the protective gears are considered in the financial analysis and is estimated to be about USD 2500 annually. As the component is being present in the financial analysis it is not used for calculating net health benefits to avoid double accounting.

Financial analysis

In this section, the financial analysis of one typical briquette business is presented which is used for calculating the benefit cost ratio for the city as a whole considering 10 briquette plants. The financial viability is analyzed based on Return on Investment (ROI), Net Present Value (NPV) and Internal Rate of Return (IRR) valuation criteria. The costs of the briquette business primarily include capital investment and operating costs which include input cost, labour cost, O & M costs, utilities, marketing and packaging costs. The useful life of the briquette plant is assumed to be 15 years. Total investment cost is USD 292,742. The production capacity of the plant is 2,000 tons/year and 2,222 tons of agricultural residue will be purchased at a price of 129 USD/ton as feedstock. The selling price of briquettes is 282 USD/ton. It is assumed that in the first year, 75% of the total briquette production is sold, the second year, 85% and in the third year and the rest of the period, 95%.The total number of full time workers is 50 and total monthly labor cost is 3,300 USD. Other costs include marketing and distribution (12 USD/ton), packaging cost (4 USD/ton) and utilities (42 USD/ton). Operating and maintenance costs are assumed to be 5% for machine and equipment and 2% for building. A discount rate of 12% is assumed. Selling price of briquette and other input costs are subjected to an escalation of 3%. A straight line method of depreciation is used for depreciable capital costs assuming a useful life of 15 years with a salvage value of 10% of total depreciable cost. Current tax for similar businesses in Uganda is 24% comprising of 18% VAT and 6% withholding tax (*Refer to financial analysis document for details*).

The financial analysis of a briquette business is presented in Table 16: Financial results of briquette business (USD). Results show that the business model resulted in a positive net profit. In the first year where it is assumed that 75% of production is sold, net profit is USD 20,175 while for second year where 85% of production is assumed to be sold, it is USD 30,183 and for the rest of the period mean net profit increases as proportion of sales to production increases to 95%. The ROI in the first year is 7% and increases to 10% in the second year and to more than 25% for the rest of the period. The payback period is four years. Assuming a discount rate of 12% and useful life of 15 years, the business model resulted in a mean NPV of USD 284,681 and IRR of 25% indicating that the business model is financially viable.

Table 16: Financial results of briquette business (USD)

	Year							
	0	1	2	3	4	5	6	7	…
Capital cost	**292,742**								
Revenue:									
Briquette sales		564,000	580,920	598,347	616,298	634,787	653,830	673,445	…
Costs:									
Input cost		215,000	250,977	280,503	288,918	297,586	306,514	315,709	…
Labor cost		39,600	40,788	42,012	43,272	44,570	45,907	47,284	…
Marketing		18,000	21,012	23,484	24,189	24,914	25,662	26,431	…
Packaging		6,000	7,004	7,828	8,063	8,305	8,554	8,810	…
Utilities		63,000	73,542	82,194	84,660	87,200	89,816	92,510	…
O&M cost		9,025	9,295	9,574	9,861	10,157	10,462	10,776	…
Annual write-off		8,460	9,876	11,369	11,710	12,061	12,423	12,795	…
Depreciation		15,870	15,870	15,870	15,870	15,870	15,870	15,870	…
Total cost		**374,954**	**428,363**	**472,833**	**486,542**	**500,662**	**515,206**	**530,186**	**…**
Interest payment		21,500	25,705	-	-	-	-	-	…
Profit before tax		**26,546**	**39,714**	**95,597**	**98,941**	**102,385**	**105,933**	**109,587**	…

Income tax		6,371	9,531	22,943	23,746	24,572	25,424	26,301	
Net profit		20,175	30,183	72,654	75,195	77,813	80,509	83,286	…
Cash flow	**(292,742)**	**36,074**	**46,052**	**88,523**	**91,065**	**93,682**	**96,379**	**99,156**	**…**
ROI		**7%**	**10%**	**25%**	**26%**	**27%**	**28%**	**28%**	**…**
NPV		**284,681**							
IRR		**25%**							

The above mentioned financial analysis is being used for the estimating the financial viability at the city level. The benefit-cost ratio calculated for the businesses across the city is calculated to be 2.09 which makes it financially viable.

Socio-economic results

The consolidated socio-economic results at the scale of operation for Kampala as a whole is presented in Table 17. The analysis looked at the potential impact of dry fuel manufacturing at three levels where the levels range from including the direct benefits and costs that affect the business entity to including indirect benefits and costs to other sectors. The annual social and environmental benefits and costs from the business were discounted at a rate of 12% to obtain the present value of social and environmental impacts.

The briquette business results in cost benefit ratio (CBR) of 2.09, NPV of USD 2,846,811 and ROI of 30% when only direct benefits from the briquette production are taken into account. The NPV increases by 34% when environmental benefits are taken into account and to more than 400% when the environmental and social impacts are taken into account. The ROI taking all externalities into account is 87% showing a more than 100% increase compared to when only direct benefits are considered. The major contribution to the economic feasibility of the business is from the social benefits. The total value of the social benefits of the business is USD 9.8 million with major benefits coming from the savings in energy costs to end users accounting for 57% of the total value of social benefits. Thus from a socio-economic perspective, the dry fuel manufacturing business model is highly attractive.

Table 17: Net socio-economic results of dry fuel manufacturing business

Socio-economic result (USD/year)	Financial value	Financial and environmental value	Social, environmental and financial value
Financial result:			
NPV	2,846,811	2,846,811	2,846,811
Environmental benefit:			
Value of net GHG emission saving		1,134,001	1,134,001
Social benefit:			
Savings in energy costs for end users			522,7190
Additional income to farmers			128,6497
Value of employment			269,7102
Sell of cook stoves			641,026
Benefit:Cost ratio (BCR)	**2.09**	**2.48**	**5.62**
NPV	**2,846,811**	**3,980,813**	**16,044,166**
ROI (average)	**30%**	**35%**	**87%**

Sensitivity analysis

Sensitivity analysis was performed to determine which variables have important effect on the socio-economic impacts of the business model. The most influencing factor in the socio-economic performance of the business model is the price of fuelwood which influenced the savings in energy costs for end users. The price of fuelwood is assumed to be 0.24 USD/kg. A ±20% change in the price of fuelwood results in NPV values ranging from USD 0.572 to 2.164 million USD. ROI and BCR showed respectively variations ranging from 49% to 128% and 3.09 to 8.53 due to a ±20%variation in price of fuelwood. Thus a ±20% variation in price of fuelwood results in ±58% change in NPV, ±46% in ROI and ±47% in BCR values. The other variable which has effect on the socio-economic performance is the discount factor. The discount rate assumed in this study is 12%. A ±25% variation in the discount factor resulted in NPV values ranging from USD 1.12 million to 1.695 million and BCR ranging from 4.95 to 6.94 while the ROI remains the same. A 25% increase in discount factor results in 18% and 15% decrease in NPV and BCR respectively while a 25% decrease in discount factor results in 24% and 19% increase in NPV and BCR respectively. Other factors such as the price of carbon credit and the price and price paid to farmers for agro-residues do not have a significant impact on the socio-economic performance of the business model. The following table (Table 18) shows the variables that are assumed to be stochastic in nature for deriving the probability distribution of the NPV of the net benefits derived from the integrated (financial, environmental and social) model.

Table 18: Variables used for the stochastic assessment of the model

Variable	Unit	Distribution specified	Source
Price of briquette	USD/Kg	*Triangular:* (0.25 , 0.282, 0.35)	Based on existing business
Discount rate	%	*Triangular*: (10%, 12%, 15%)	Assumed
Carbon Credit price	USD/t CO_2 eq.	*Triangular Distribution* (5,7,10)	Assumed
Economic value of a DALY	USD	*Triangular Distribution* (245, 300, 500)	The lower range corresponds to estimates for cancer and higher range to gross national per capital income.

To perform a stochastic analysis for different variables were assigned with different probability distribution and the NPV was calculated through iterations. The following figure (Figure 4) presents the probability distribution of the NPV, along with the probability of achieving a NPV above the calculated mean value. The probability associated with the NPV reaching below the mean is 52% and the lower and higher limits of 90% confidence interval for the distribution is USD 16.34 and 22.59 million respectively.

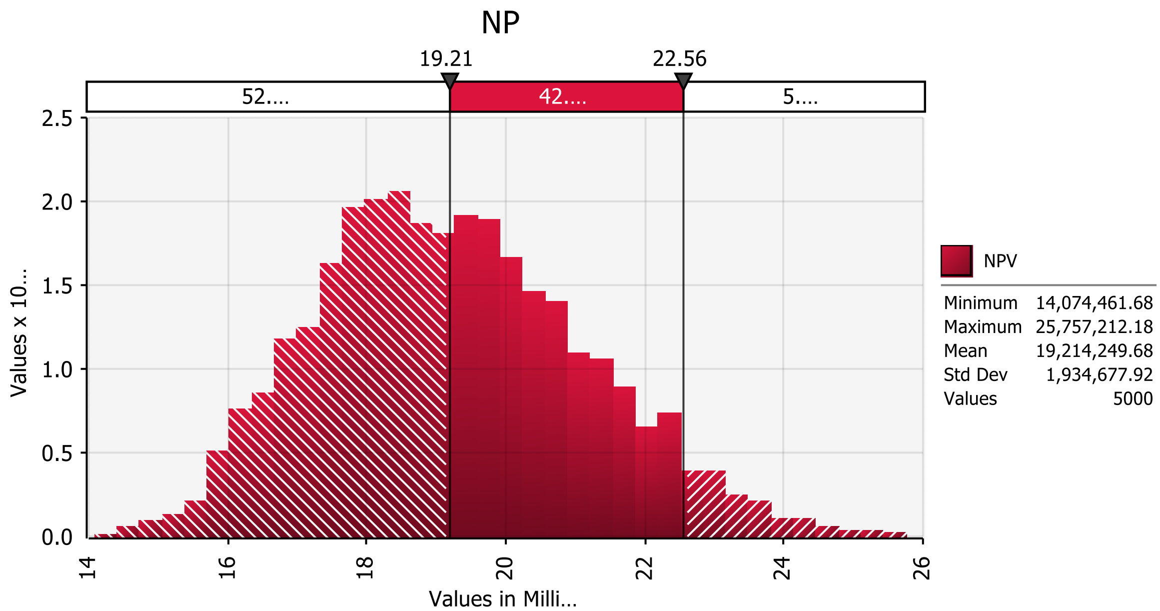

Figure 4: Probability distribution of the NPV of net benefits of briquette businesses in Kampala

Conclusion

This study assessed the socio-economic impact of a dry fuel manufacturing business model in Kampala, Uganda. The socio-economic analysis is conducted based on the valuation of financial, environmental and social benefits and costs associated with the business model. The following conclusions can be drawn from the study:

- The environmental impacts associated with the business model were estimated based on emissions avoided from fuelwood combustion and open burning of agricultural residues net of emissions from the briquette business which included agricultural residue transportation, briquetting, transportation and combustion of briquettes. The major contribution to GHG emission savings is from avoided use of fuelwood which accounted for 97% of the avoided emissions. For other criteria emissions, major savings are from avoided burning of agricultural residue in the open field. The combustion of briquettes in stoves contributes the highest GHG and other criteria emissions. Using efficient cook stoves for combustion of the briquettes and improving the combustion efficiency of the briquettes could reduce the life cycle emissions of the briquette fuels. Compared to the baseline scenario, the briquette business results in net GHG and other criteria emission savings.

- The dry fuel manufacturing business model, in addition to combating deforestation and climate change, generates additional income for farmers, creates jobs for local residents, and enables end users to save on energy costs as well as improving the cooking environment.

- Looking at the overall socio-economic impacts, the business model is both financially and economically feasible. There is a significant increase in the economic feasibility of the business due to social and environmental benefits associated with the business. The business model has a potential to result in social NPV of USD 16 million and ROI of 87%.

- The major contribution to the economic feasibility of the business is from the social benefits with major benefits coming from the savings in energy costs to end users. Thus from a socio-economic perspective, the dry fuel manufacturing business model is highly attractive

Socio-economic impact assessment of Onsite Energy Generation by Sanitation Service Providers in Kampala

Introduction

To address the sanitation and liquid and solid waste management challenges, during the past decade a number of business oriented solutions to sanitation have been implemented in various developing countries. In Kenya, the Athi Water Service Board (AWSB)[3] have developed and implemented projects that are aimed at improving access to safe water and sanitation for the informal settlements by building toilet facilities with biogas systems. Such facilities are also referred to as B*io-centres* (AFD and AWSB, 2010). These bio-centers provide, not only toilet services but also cooking services to different users by using the biogas generated from bio-digesters fed with faecal sludge from the toilet facilities. A number of biogas systems have also been constructed in institutions such as schools, hospitals, prisons and other institutions in Rwanda, Nepal and Philippines. The institutional biogas systems, in addition to improving waste management, are primarily applied to save on fuelwood energy used for cooking. This business model can be implemented in institutions with large number of residents (schools, prisons, hospitals) or as a separate business enterprise i.e. toilet complex with biogas system. In this report, we focus on the later. The objective of this study is to assess the potential socio-economic impacts of onsite energy generation system serving a target population of 3,190 people in central zone of Kampala, Uganda. The socio-economic analysis is conducted based on the valuation of financial, environmental, social and health benefits and costs associated with the business model.

Description of technology

The business model has sanitation facilities and a bio-digester. The technology applied by the business to convert human waste into biogas is anaerobic digestion. Biogas is "a gas mixture comprising around 60% methane and 40% carbon dioxide that is formed when organic materials are broken down by microbiological activity in the absence of air" (Bates, 2007). The biogas can be used for cooking, lighting or heating. The bio-digester is fed with the faecal sludge (FS) from the sanitation facilities equipped with flush toilets (Figure 1).

Various types of organic waste can be used to produce biogas. Table 19 presents biogas yields of different types of organic waste (mainly dung). The hydraulic retention time (HRT) ranges from 15 to 25 days depending on the climatic conditions. Average HRT is 20 days at an ambient average temperature of 25 °C. The biodigester unit, in addition to biogas, produces a digested slurry that can be used as liquid fertilizer. Figure 5 shows the schematic diagram of the onsite energy generation of the business model.

[3] Athi Water Service Board is one of the eight Water Boards under the Ministry of Environment, Water and Natural Resources created to bring about efficiency, economy and sustainability in the provision of water and sewerage services in Kenya.

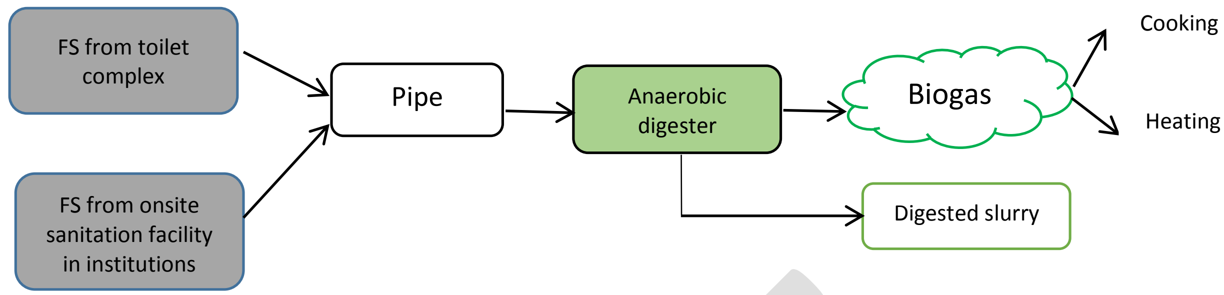

Figure 5: Schematic of onsite energy generation business model

Table 19: Gas yield potential of dung

Input	Biogas yield (m^3/kg)
Human waste	0.02-0.028
Cattle dung	0.023-0.04
Pig manure	0.04-0.059
Poultry manure	0.065-0.116

Source: Updated Guidebook on Biogas Development sited by Buxton and Reed, 2010

There are different types of biogas systems in use in developing countries. The two basic designs are fixed dome type and floating drum which are commonly found in Asian countries such as China, India and Vietnam. A fixed dome digester consists of an underground brick masonry compartment (fermentation chamber) with a dome on top for gas storage. The digester and the gas holder are integrated parts of the brick masonry structure and the gas pipe is fitted on the crown of the masonry dome (Singh and Sooch, 2004). The floating drum model consists of a cylindrical shaped digester and floating gas-holder or drum (Singh and Sooch, 2004). This drum can move up and down depending on the amount of gas in the digester. If biogas is produced, the drum is pushed up and when the gas is used up, the drum sinks providing useful visual indicator of how much gas is available (Buxton and Reed, 2010).

Overall approach to socioeconomic analysis

In this study, the economic analysis of onsite energy generation in enterprises providing sanitation services is conducted based on the valuation of socio-economic, environmental and health benefits and costs associated with the business model. It is assumed that public toilet complexes will be concentrated in areas where there is high population density such as the central division of the city of Kampala. The central division is the core economic zone with a population density of 235-391 persons/ha. Total population in the central division is 127,600 and 2.5% of the population (i.e. 3,190) is assumed to be targeted to be catered by public toilets. Assuming that 600-1000 users are served per day per public toilet, the number of public toilets required to serve the target population of 3,190 is 4-5 public toilets. The public toilet in addition to toilets, is equipped with a biogas digester and has a meeting room which can be rented out. Our analysis is based on a 54 m3 biogas production unit sited at four different locations.

The economic analysis of a project is concerned with its viability from a societal perspective and answers the questions of whether it is economically rational to proceed with the project (De Souza et al., 2011). In contrast to a financial analysis, economic analysis provides a more comprehensive investigation on the effects of a proposed project, takes a broader perspective and determines the project's overall value to society (Raucher et al., 2006). The analysis, therefore, includes benefits and costs that directly affect the business entity running the project and the effects of the project on households, governments and businesses outside of the agency.

Environmental impact assessment

The environmental impact assessment of a public toilet complex with a biogas plant capacity of 54 m3 per plant is carried out to identify the impact on the environment of using human excreta to produce biogas for institutional heating or cooking and also to compare these impacts with those created through the existing mode of disposal of human excreta. The public toilet with a biogas plant has the potential to mitigate the GHG and other emissions through the i) avoided emissions from open defecation, ii) replacing fuelwood for cooking in commercial entities. Environmental impacts considered in this study include GHG and other criteria emissions (Table 20).

Table 20: Environmental impact categories

Environmental impact categories	Assessment criteria	unit
Climate change	Carbon dioxide CO_2 Methane CH_4 N2O emission	Kg CO_2-equivalent
Other	Sulfur dioxide (SO_2) Nitrogen Oxides (NO_x) Carbon mono-oxide	Kg SO_2 Kg NO_x Kg CO

Climate change impacts (GHG) emissions are expressed in a common unit of kg CO_2-equivalent using conversion factors of 1, 21, 310 for CO_2, CH_4 and N_2O respectively (IPCC, 2001). The GHG emissions balance is estimated based on emissions under baseline scenario i.e. emissions from open defecation and the use of firewood for cooking by institutions. The climate change mitigation benefits of the conversion of human excreta into usable energy which traps and uses the methane released during the decomposition of human excreta is based on a number of studies (Zhang and Wang, 2014; Winrock International India 2008; Pathak et at., 2008).

Baseline scenario

The situation under baseline scenario is that a large number of people in densely populated commercial centers find it difficult to access a decent place of convenience and therefore resort to the practice of open defecation in the nearby bush in and around city centers. Open defecation has environmental and health implications.

The main source of fuel for cooking for commercial and institutional proposes such as schools and prisons and chop bars is fuelwood. The GHG and other particle emission effects from the use of fuelwood are estimated based on IPCC default factors. The GHG and other emissions avoided as a result of using human excreta to produce biogas and the resultant avoided use of fuelwood for cooking by institutions are measured in terms of the avoided kg of CO_2 and other pollutants (SO_2, NO_X, CO).

System boundary

The system boundary for this study starts with the use of public toilet facility and ends with the biogas combustion in commercial and institutional kitchens. The environmental impact at each stage is accounted for by calculating the GHG and other criteria emissions. The energy used and the environmental impacts associated with use of equipment in the construction of the toilet facility and biogas plant are not included in this study.

Source of energy for end users under baseline

Under baseline it is assumed that institutions derive energy for their cooking activities from fuelwood. The environmental emissions associated with the use of fuelwood as fuel during cooking are shown in Table 21.

Table 21: Emission factors from combustion of firewood

Emissions	Kg emission/kg of fuelwood
CO_2 emission	1.513
CH_4 emission	4.14E-03
N_2O emission	5.52E-05
SO2 emission	0.7E-02
NO_X emission	1.38E-03
CO emission	6.9E-02

Source: IPCC/OECD methodology; Okello, 2014

Human excreta under baseline

The practice of open defecation which some city dwellers resort to in the quest for a place of convenience results in human excreta being left in the open environment indiscriminately and the decomposition of which emits methane into the atmosphere. The GHG and other emission effects from open defecation were estimated based on the findings of the study conducted by Winrock International India, 2008 (Table 22).

Table 22: Methane emission from human excreta

Source	unit	value
Open defecation	Kg/person/day	0.00108
Pit latrine	Kg/person/day	0.00046

Source: Winrock International India, 2008

Biogas production

The main feedstock for the biogas production process is human waste from the public toilet facility. Biogas production is assumed to be 0.04 m3/person/day (Bond and Templeton, 2011). Assuming 800 users per day per public toilet and assuming operational efficiency of 80%, a total of 7,552 m^3 of biogas per public toilet is produced annually. Thus four public toilet complexes with 800 users produces 30,114 m3 of biogas per annum. The biogas is channeled directly to commercial users for cooking and heating. The GHG emissions from the biogas plant include emissions from methane leakage, emissions from biogas production and combustion (Table 5). Based on IPCC, 2001, leakage of CH4 from the biogas plant ranges from 5 to 15%. In this study a methane leakage of 10% is assumed. Following Zhang and Wang, (2014) this study assumes GHG emissions of a 4.52 x 10^{-3} kg CO_2-eq per MJ and 1.17 kg CO_2-eq per m3 of biogas during production and combustion of biogas respectively. This values are shown in Table 23.

Table 23: GHG emissions from the biogas plant

	Unit	Value	Source
Methane leakage (%)	%	10	Pathak et al., 2009
Density of methane	Kg/m^3	0.71	Pathak et al., 2009
Emissions from 1 MJ of biogas	Kg CO_2-eq/MJ	4.52E-03	Zhang and Wang, 2014
Biogas combustion	Kg CO_2-eq/m^3	1.17	Zhang and Wang, 2014

Environmental impact results

This section presents the GHG and other criteria emissions under baseline and alternative scenario. The emissions under baseline are the emissions avoided as a result of employing biogas as the energy source for cooking in institutions thereby replacing the use of fuelwood. The emissions from the business are the total of emissions associated with emission during biogas production and combustion process. Total emission savings is the total avoided emissions net of the emissions from the biogas plant.

Emissions under baseline scenario

Under the baseline scenario, the total emissions are those attributed to emission from open defecation, emissions from the use of fuelwood by institutions. A sum of all these emission levels gives total avoided emissions due to biogas use. The business model also results in environmental emissions which are generated from the processing of the feedstock into biogas. Total GHG emissions savings is the difference between total avoided emissions and total emissions from the biogas production process.

Table 24 shows the emissions avoided as a result of biogas production using human excreta as feedstock. GHG emissions avoided per unit of biogas produced is 3.93 kg CO_2-equivalent/m3. Avoided emissions from firewood usage gives the most significant sources of saving in GHG emissions accounting for 83% of the total savings. Savings in other emissions are majorly from avoided use of fuelwood.

Table 24: Emission savings per m3 of biogas generated by onsite energy model

Savings from	GHG emissions	Other criteria emissions		
	CO_2	SO_2	NO_x	CO
Open defecation	0.71			
Use of fuelwood	3.22	0.0139	0.0027	0.137
Total savings	**3.93**	**0.0139**	**0.0027**	**0.137**

Emissions under Biogas model

The main composition of biogas is methane (CH_4) and Carbon-dioxide (CO_2) and the leakage of these gases from the digester and valves provides a potent emissions source for these GHGs during the biogas production process itself. GHG emissions are triggered from the use or combustion of biogas during cooking. Table 25below shows GHG emissions from the biogas business model in CO_2-equivalent. The GHG emissions per m3 of biogas is 1.347 kg CO2-eq with the highest contribution to GHG emissions originating from combustion of biogas (1.17 kg CO_2-eq).

Table 25: GHG emissions per m3 of biogas generated (kg CO2-eq/m^3)

Emissions from	GHG emissions
	CO_2
Methane leakage	0.053
Biogas production	0.124
Biogas combustion	1.170
Total emissions	**1.347**

Net emissions

The biogas plants produce a total of 30,114 m^3 of biogas per annum. This amount of biogas substitutes 59,878 kg of fuelwood, the GHG emission of which is 96,826 kg CO_2-eq (Figure 6). Moreover, the toilet complex will serve the population which previously resorted to open defecation, the methane emissions of which is 21,343 kg CO_2-eq. Thus total emission saving from avoided fuelwood use and open defecation is 118 ton CO_2-eq. However, the biogas plant leaks methane of 1,604 kg CO_2-eq and results in GHG emissions of 38,968 kg of CO_2-eq during production and combustion of biogas which contribute to global warming. The net GHG emissions savings is 77.60 ton CO_2-eq/year.

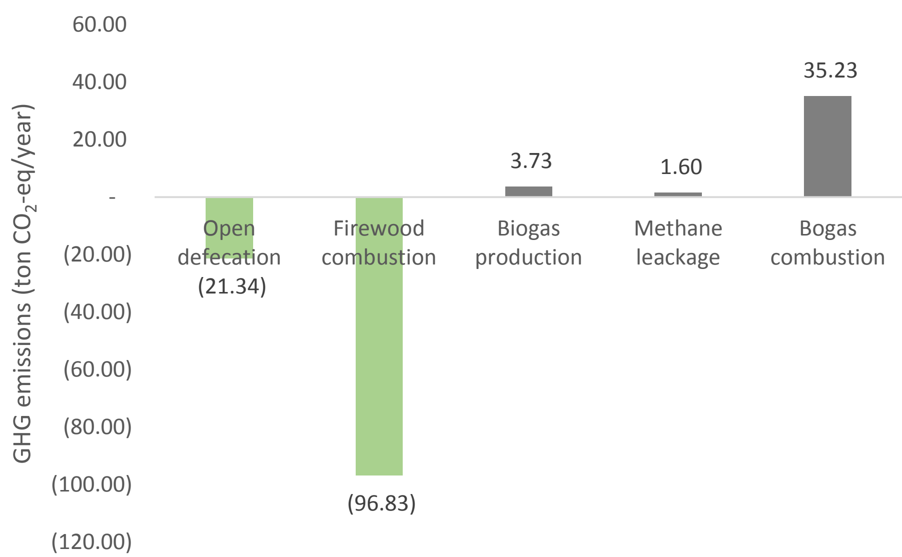

Figure 6: GHG emissions and savings from 4 public toilet complexes with biogas plant

Value of Carbon credits and other emissions

In this study it is assumed that carbon credits will be traded in Voluntary Emission Reduction (VER) units as VER is suited for small scale projects and are sold in volumes that are targeted to clients seeking small reductions to offset their footprints. The VER unit is equivalent to a reduction of 1 ton of CO_2 equivalent emissions ((Reuster 2010). Based on the World Bank (2014), carbon credit prices in the EU ETS range about USD 5-9 ((€4-7) in 2014 while prices were USD 18 ((€13) in 2011. In this study it is assumed that carbon credits are worth on average USD 7 per ton of CO_2 equivalent (Table 26). The total annual value of carbon credit is USD 543. However value of the other emission savings that have acidification potential (NO_x) were not included in the analysis.

Table 26: Annual value of GHG emission reduction from ESCO model (120 KW)

Item	Amount
Total GHG emission savings (ton CO_2eq)	118.17
Total GHG emissions from biogas business (ton CO2 eq)	40.57
Net emission savings (ton CO_2eq/year)	77.60
Price of VER (USD/ton CO_2eq)	7
Total value of Carbon credit (USD/year)	**543**

Social impacts

Savings in energy cost for end-users

Using biogas instead of fuelwood has the potential to result in savings for end users. Table 26 shows the potential savings for end users from using biogas. The energy content in 1 m3 of biogas is 27.44 MJ while the energy content in 1 kg of fuelwood is 13.8 MJ (IPCC/OECD methodology; Hu et al., 2014). In order to estimate the total value of fuelwood savings, the total amount of fuelwood replaced by biogas is calculated using the heating value per unit of fuelwood and biogas. The net annual biogas production from the toilet facility after accounting for methane leakage is 30,114 m3 which has a potential to replace 59,878 kg of fuelwood. The biogas assumed to be piped to adjacent institutions (e.g. cafes, restaurants). Each biogas plant is assumed to serve one institutional kitchen which have cooking stoves with a large size (45 kg) gas cylinder. The biogas is sold to institutions at the prevailing price of 2.13 USD/m3 of LPG. The LPG equivalent of biogas is assumed to be 0.43 kg (Singh and Sooch, 2004). Thus the price of biogas is 0.92 USD/m3. Assuming efficiency of stoves of 45% and 100% respectively when fuelwood and biogas are used for cooking, the actual price per MJ of useful energy is 0.039 USD in fuelwood equivalent and 0.033 USD in biogas equivalent. At the current price of fuelwood (0.24 USD/kg), using biogas has the potential cost saving of 14% as compared to fuelwood used in institutional stoves. Total annual cost savings for end users from utilizing 30,114 m3 of biogas is estimated to be USD 1,959. However, shifting to biogas has cost implications for the end users as there is a need for a one time investment in biogas cooking stoves. The total incremental cost of shifting to biogas is estimated based on the cost of institutional stoves with large size gas cylinder in Uganda. The total incremental cost for end users is estimated to be USD 7,461 (Table 27). The switch to biogas from firewood use also save time spent preparing food. Savings in cooking time using biogas compared to biomass fuels average about 1.82 hours per day in Uganda (Habermehl, 2008). This makes available a significant of extra time to be used for other productive activities.

Table 27: Incremental costs and benefits from shifting to biogas for end users

	Fuelwood	Biogas
Cost savings from shifting to biogas:		
Fuelwood replaced by biogas (Kg) (A)	59,878	
Heating value (MJ/unit) (B)	13.8	27.44
Unit price (USD/unit) (C)	0.24	0.92
Efficiency of stoves (%) (D)	45%	100%
Actual price per useful energy (USD/MJ) (E=C/(B*D)	0.039	0.033

Savings from shifting to biogas (%)	14%	
Total energy value of wood replaced (MJ)		
Cost savings from shifting to biogas (USD/year)	**1,959**	
Incremental cost of shifting to biogas (for 4 institutions):		
Investment in institutional cooking stoves		6,933
Investment in 45 kg cylinders		528
Total one time investment on cooking stoves		**7,461**

Health expenditure savings

Using biomass instead of fuelwood or other biomasses has the potential to improve indoor air quality and thus contributes to preventing a number of health conditions. Exposure to indoor air pollution from the combustion of fuelwood is a major cause of respiratory diseases, mostly among young children and their mothers (Bruce et al., 2006; Smith et al., 2004). Various studies have pointed to the health impacts associated with exposure to indoor air pollution due to use of solid fuels (Renwick et al., 2007). Avoiding these health related expenditures by using clean cooking fuels such as biogas presents savings to end users. Also found in the literature is a number of studies that have consistently demonstrated that the risk of contracting diarrhea is reduced significantly by 32%-45% through sanitation interventions such as the adequate disposal of human excreta (Cairncross et al., 2010; Renwick et al., 2007; Fewtrell et al., 2005). Improvement in water and sanitation facilities has the major advantage of cost savings related to health care mainly due to the reduced number of treatments of diarrhea (Hutton and Haller, 2004).

Time savings from access to toilet service

Having access to toilet services results in saving in time spent in accessing a place of convenience away from home or public place or work such as associated with open defecation (Renwick et al., 2007). Based on a study by Renwick et al. (2007) and Hutton and Haller (2004), it is estimated that 75% will quit open defecation and 30 minutes will be saved per person per day due to the provision of public place of convenience compared to the baseline situation of open defecation. In order to value the time gained, an hourly rate of 0.22 USD which is equivalent to unskilled rural labor wage rate in Uganda can be used to estimate the economic value of time gained (Renwick et al., 2007). Based on these assumptions, the public toilet complexes with a potential to serve a total of 3,190 persons per day have the potential to result in time savings of 470,525 hours per year which is valued at USD 103,516.

Financial analysis

The financial viability of the business is analyzed based on the Return on Investment (ROI), Net Present Value (NPV) and Internal Rate of Return (IRR) valuation criteria. The financial results presented in this section are for 4 plants which will serve a target population of 3,190. Each plant has a capacity of serving 800 people per day and has a biogas plant capacity of 54 m3. Total investment cost per plant is USD 56,000 and includes the toilet facility, biogas digester, a space for rental, labour and materials for construction. Biogas digesters have a useful life of 20 years (Singh and Sooch, 2004). However, the toilet stances are assumed to have a useful life of 7 years after which they have to be replaced. The toilet facility is assumed to have 8 toilet stances, each costing about USD 417 (NETWAS-U, 2011). Investment on toilet facility is done on the 7 and 14th year to replace toilet stances (Renwick et al., 2007; IRC, 1999). Land required per facility is 100 m2. Each plant is run by a community based organizations (CBOs). Campaigns and training on how to run the facility including training on biogas technology is provided to the members of the community at the beginning of the project year. Total cost for training is USD 10,000 per plant (based on Umande trust TOSHA 1 bio-centre business case in Kenya). Land is to be granted by the municipality while the investment cost including training is to be funded by developmental agencies and operational costs are to be covered by the community which run the facility.

Revenue streams for the toilet facilities include fees from toilet use, revenue from biogas use and revenue from rental space. Additional revenue could be generated from selling the slurry from the digester, however, in this analysis this is not considered. Toilet fee per use in Uganda ranges from USD 0.09 to USD 0.15 with an average of 0.10 USD/use. Daily biogas production depends on daily fecal sludge fed to the digester which also depends on the number of toilet users. To determine revenue from biogas, the LPG equivalent of biogas produced is calculated and the prevailing price for LPG in Uganda is used. LPG equivalent of biogas is 0.43 kg (Singh and Sooch, 2004) and current LPG price is 2.13 USD/kg in Uganda. Moreover, a 20% biogas loss due to leakage or other factors is assumed *(Refer to financial analysis document for details).*

Table 28 presents the financial results of 4 public toilet complexes with an onsite energy generation serving a total of 3,190 people. Results show that the target onsite energy generation businesses have the potential to operate under profit and result in a NPV of USD 185,249 and IRR of 25%.

Table 28: Financial results of onsite energy generation business model (USD)

	Year								
	0	1	2	3	4	5	6	7	…
Capital cost	**223,300**							**13,302**	
Total revenue		112,681	113,238	113,812	114,403	115,012	115,639	116,285	…
Operational costs:									
Campaign/training	40,000								…
Operational costs		52,547	54,124	55,747	57,420	59,142	60,917	62,744	…
Operating profit		60,133	59,114	58,064	56,983	55,869	54,722	53,541	…
Cash flow	**(263,300)**	71,298	70,279	69,229	68,148	67,034	65,887	51,404	**…**
ROI		**27%**	**26%**	**26%**	**26%**	**25%**	**25%**	**24%**	**…**
NPV		**185,249**							
IRR		**25%**							

Socio-economic results

The potential socio-economic impact of the onsite energy generation model serving 3,190 end users is presented in Table xxx. The socio-economic impact includes not only cost and benefits that directly affect the business entity but also cost and benefits that impact parties outside the entities i.e. externalities. The consolidated socio-economic results are presented in Table 29. The analysis looked at the potential impact of onsite energy generation model at three levels where the levels range from including the direct benefits and costs that affect the business entity to including indirect benefits and costs to other sectors. The annual social and environmental benefits and costs from the business were discounted at a rate of 12% to obtain the present value of social and environmental impacts. The business model is financially and economically feasible showing positive NPV and BCR of greater than 1. Moving from the financial results to including the environmental impacts, the incremental benefit from the GHG emission savings (benefit from carbon credit) is minor showing an increase in NPV of only 2% (USD 189,307). In contrast, the NPV of the target onsite energy generation businesses after including the social impacts is USD 302,248 and the ROI is 29% indicating that the NPV and the ROI increase by 63% and 34% respectively when the social benefits associated with savings for end users and value of employment are accounted for. The social benefits associated with time savings for end users was not accounted for in determining the NPV and ROI. The public toilet complexes with a potential to serve a total of 3,190 persons per day have the potential to result in time savings of 470,525 hours per year which is valued at USD 103,516, assuming a 0.22 USD/hour wage rate for unskilled labour in Uganda.

Table 29: Socio-economic results of onsite energy generation model

Socio-economic result (USD/year)	Financial value	Financial and environmental value	Social, environmental and financial value
Financial result:			
NPV	185,249	185,249	185,249
Environmental benefit:			
Value of net GHG emission saving		4,057	4,057
Social benefit:			
Savings in energy costs for end users			7,174
Value of employment			105,767
Benefit:Cost ratio (BCR)	**1.79**	**2.13**	**2.63**
NPV	**185,249**	**189,307**	**302,248**
ROI (average)	**22%**	**22%**	**29%**

Sensitivity analysis

The importance of variables in influencing the NPV, BCR and ROI were analyzed through a sensitivity analysis. The price fuelwood, price of LPG and discount factor were varied by ±25% while keeping other variables constant to assess the resulting effect on the overall economic feasibility of the business model. A ±25% variation in discount factor resulted in a ±40% variation in NPV. Prices of fuelwood and LPG were varied to assess the resulting effect on social impacts of the business and consequently on the overall economic feasibility of the business. A 25% increase in price of fuelwood resulted in 9% increase in NPV and 4% increase in BCR while a 25% increase in price of LPG resulted in an 8% decrease in NPV and 4% decrease in BCR. Thus an increase in the price of fuelwood is associated with higher savings for end users and positive net social impact. The following table (Table 30) indicates the stochastic variable used for the simulation of the NPV.

Table 30: Variables selected for the stochastic analysis of the socio-economic model

Variable	Unit	Distribution specified	Source
Number of users	#	*Triangular:* (600, 800, 1000)	Assumed
User fees	USD/user	*Triangular Distribution:* (0.09, 0,10, 0,14)	Assumed
Biogas production	m^3/person/day	*Triangular:* (0.35, 0,4, 0.5)	Bond and Templeton, 2011
Discount rate	%	*Triangular*: (10%, 12%, 15%)	Assumed
Carbon Credit price	USD/t CO_2 eq.	*Triangular Distribution* (5,7,10)	Assumed

Economic value of a DALY	USD	*Triangular Distribution (245, 300, 500)*	The lower range corresponds to estimates for cancer and higher range to gross national per capital income.

To perform a stochastic analysis different variables were assigned with different probability distribution and the NPV was calculated through iterations. The following figure (Figure 7) presents the probability distribution of the NPV, along with the probability of achieving a NPV above the calculated mean value. The probability associated with the NPV reaching below the mean is 49% and the lower and higher limits of 90% confidence interval for the distribution is USD 1.79 and 1.96 million respectively.

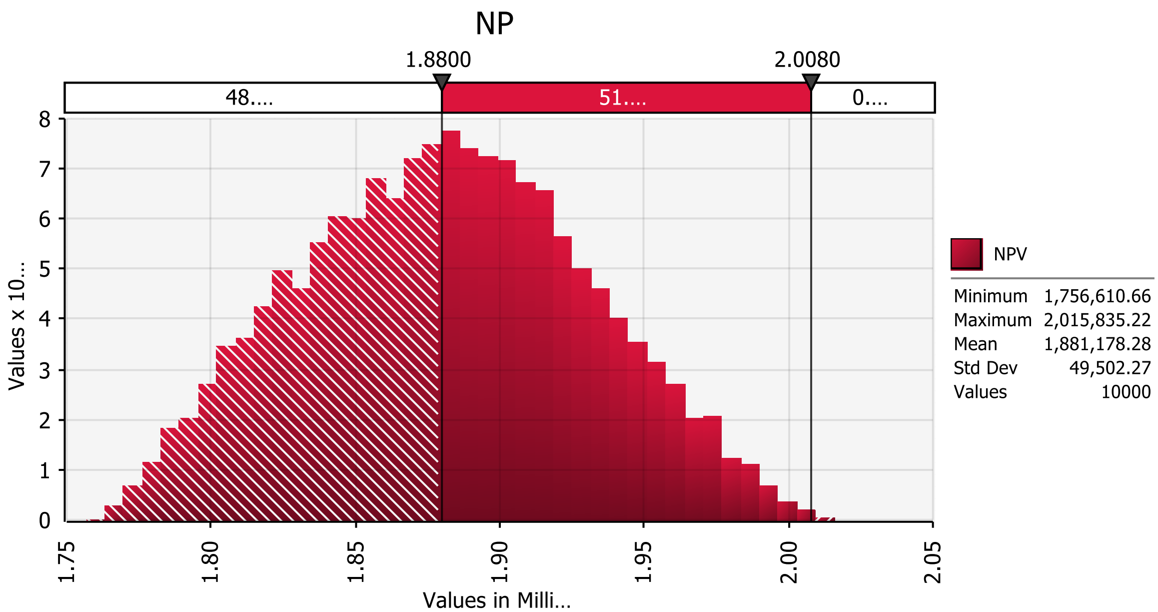

Figure 7: Probability Distribution of the NPV of the net benefits accruing from the biogas plants

Conclusion

This study assessed the socio-economic impact of onsite energy generation business model in Kampala, Uganda. The socio-economic analysis is conducted based on the valuation of financial, environmental and social benefits and costs associated with the business model.

- The environmental impacts associated with the business model were estimated based on emissions avoided from fuelwood combustion and open defecation net of emissions from the business model. Emissions from the business model accounted in this study include emissions associated with methane leakage, biogas production and combustion. The major contribution to GHG emission savings and other criteria emission is from avoided use of fuelwood which accounted for 81% of the avoided GHG emissions. The combustion of biogas in stoves contributes the highest GHG. Compared to the baseline scenario, the business model results in net GHG and other criteria emission savings.
- Although there is a need for additional investment in cooking stoves for end users when shifting to biogas, the estimated value of net savings in energy costs is higher than the one time investment in cooking stoves.
- The business model has a positive social impact to end users thorough the delivery of improved sanitation services which result 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.

- Looking at the overall socio-economic impacts, the business model is both financially and economically feasible. There is a significant increase in the economic feasibility of the business due to social and environmental benefits associated with the business. The business model has a potential to result in social NPV of USD 0.329 million and ROI of 31%.

Socio-economic impact assessment of Energy Service Companies at Scale - Agro-Waste to Energy (Electricity) business model in Kampala

Introduction

The access to modern form of energy is a challenge to most countries in Sub-Saharan Africa, where the majority of people still depend on raw biomass source for their energy needs. This prevailing situation stifles developmental efforts and encourages the prevalence of poverty. It is generally accepted fact that the access to reliable and affordable energy is imperative for the economic and social development of a country. The economic prosperity and quality of life of a country are closely linked to the level of its per capita energy consumption (Singh and Sooch, 2004). The provision of reliable, secure and affordable energy services is a key factor in providing basic human needs that improve the quality of life and that ensure sustainable development (Amigun et al., 2010). Consequently, initiatives to improve the availability of and reliable access to energy for the poorest communities around the globe has been central to developmental efforts. In such instances the use of small scale sustainable energy sources such as biomass gasification is often preferred over the extension of existing national grid infrastructure, which in most developing countries is already struggling to cope with existing demand (Hazelton et al., 2013).

The majority of the population in Uganda are rural dwellers with 84% of the population living in rural communities, however, connection to the nation's electrification grid is centered around the major cities leaving only 1% of the national electrification grid available to rural dwellers (Buchholz and Volk, 2012). Most Ugandans rely on traditional biomass for energy and about 90% of the total energy needs of Ugandans are supplied by fuelwood (Bingh, 2004). It is well accepted that this fuelwood consumption is not sustainable and is also an inefficient source of energy with its associated adverse social, health and environmental consequences.

Low levels of development emanating from inadequate access to energy is therefore a major issue in Uganda where the majority of people depend on biomass use for their energy sources. In order to reduce the over dependence on the already overstretched energy infrastructure, Uganda's decentralized energy sources are being encouraged including the use of local biomass resources in energy generation which forms the focus of the country's renewable energy policy. It is a generally held view that small scale, decentralized, wood-based bio power systems could be more efficient in meeting the energy needs of rural households as well as enable the achievement of their development objective where rural Uganda is no exception. This therefore makes such systems a potentially viable alternative off-grid electricity and energy solution to rural Ugandans.

This study sets out to conduct a socioeconomic impact assessment of a small scale energy service company in Uganda that uses the process of biomass gasification to process residue from agricultural production (mainly corncobs) to generate electricity, which is then sold to surrounding communities through a mini grid. The socio-economic analysis is conducted based on the valuation of financial, environmental and health benefits and costs associated with the business model.

Technology description

Biomass gasification enable the conversion of biomass waste including agricultural residues into producer gas, which can then be burned in simple or combined-cycle gas turbines to produce energy or electricity (IRENA, 2012). Two types of biomass conversion technologies can be identified generally i.e. Gasification and Combustion.

Gasification is undertaken using gasifiers which can be either fixed bed or fluidized bed. The resulting gas is a mixture of carbon monoxide, water, CO_2, char, tar and hydrogen and can be used in combustion engines to produce energy (IRENA, 2012). In most cases the particular form of the gasifier adopted depends on the capacity of the installation, the quality of the available feedstock, the quality of gas required and environmental pollution standards (Tennigkeit et al., 2006).

Fluidized bed gasifiers

For small to mediums sized capacity installations, the fluidized bed gasifiers are not deemed suitable due to large amount of waste water that is discharged and the associated environmental challenges coupled with its complicated operation and maintenance systems. These gasifiers can however accommodate different range of feedstock.

Fixed bed gasifiers

These gasifiers are characterized by high electric efficiency even on a small scale and have the potential of using the waste heat from the system. There are two main types of fixed bed gasifiers, the Up-draught and the Down-draught gasifiers.

- *Up-draught gasifiers* present the simplest technical solution and show high efficiencies but they produce high amounts of tar and hence are not well suited for production of electricity.
- *Down-draught gasifiers* have a lower gasification efficiency but produce gas with a low tar content which is suitable for engines. As a *downside* they have more strict requirements on the feedstock resulting in more demanding logistics. This gasifier has been widely used for rural electrification in India and Thailand using agricultural residues as feedstock.

Technology and processes

The electricity generation system consists of a gasifier, filters and a gas engine connected to a generator. The gasifier is a down-draft type, where the feedstock is loaded from the top into the hopper through to the combustion chamber. Air is drawn through the top, and partial combustion occurs under a restricted supply of oxygen to give producer gas, which comprises of hydrogen, carbon monoxide and methane. The residual char drops to the bottom of the chamber and is subsequently removed. The gas that is generated is water cooled and cleaned through a series of filters made of char and finally a cloth filter to eliminate particulate matter. The gas is then burned in an engine that is connected to a generator which generates electricity.

Tar and ash are removed during shut downs and at regular schedules from the cooling and cleaning units of the gasifier system as they adversely affect the performance of the engine. In producer gas mode of operation an appropriate provision is made for initiating combustion which can completely eliminate dependence on diesel especially in remote locations, where transportation of diesel itself may be a difficult task (Nouni et al., 2007). The electricity generated is then distributed to various households and other commercial consumers through a locally established grid (Figure 8).

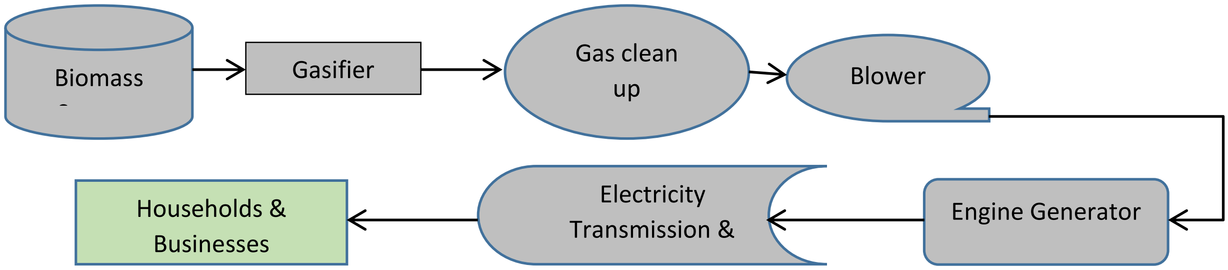

Figure 8: Process diagram of gasification

Biomass feedstock in Uganda

The main energy source in Uganda is biomass contributing over 90% of the energy requirements of the country meanwhile, Uganda has a gross energy potential from biomass residues equivalent to 70% of the gross biomass energy requirements (MEMD, 2008). Agricultural production is a predominant economic activity in Uganda, generating large amounts of crop residues every year (Table 31). The most common method of disposal of these crop and other biomass residues in cultivated fields is by burning during land preparation for the next planting season. Residues from agricultural processing facilities are also challenging to dispose-off due to costs incurred in their disposal. Even though these residues can be used in the production of energy presenting a more environmentally friendly way of their disposal, their use as an energy source is very limited in Uganda (Okello et al., 2013).

Table 31: Crop residues in Uganda

Crop produced	Annual production (kg)	Type of residue	Quantity of residue (kg)
Maize	2363	Stalk	4726
Maize		Cobs	638
Millet	264	Straw	369
Sorghum	373	Stalk	523
Rice	189	Straw	85
Beans	929	Trash	1300
Groundnuts	245	Trash and shells	514
Banana	4297	Stalk and peels	8594
Cassava	2894	Stems and peels	1158
Sweet potato	1818	Vines and peels	727
Pigeon peas	11	Stems	15
Soybean	23	Trash	62
Sesame	98	Trash	196
Sugar	197	Bagase	49
Sugar		Tops	63
Coffee	212	Husks	212
Cotton	23	Stalks	49

Source: Okello et al., (2013)

Overall approach to socioeconomic analysis

In this study the economic analysis of agro- waste to electricity – ESCO business model is conducted based on the valuation of socio-economic, environmental and health benefits and costs associated with the business model. Our analysis is based on an 8 MW generation capacity plant. The economic analysis of a project is concerned with its viability from a societal perspective and answers the questions of whether it is economically rational to proceed with the project (De Souza et al., 2011). In contrast to a financial analysis, economic analysis provides a more comprehensive investigation on the effects of a proposed project, takes a broader perspective and determines the project's overall value to society (Raucher et al., 2006). The analysis, therefore, includes benefits and costs that directly affect the business entity running the project and the effects of the project on households, businesses and industries, and governments. The analysis also includes the benefits and costs that cannot be readily measured using observable market prices and costs (De Souza et al., 2011).

Environmental impact assessment

The environmental impact assessment of an 8 MW capacity biomass gasification plant is carried out to identify the impact on the environment of using agricultural residues in biomass gasification based electricity generation systems to produce electricity and also compare these impacts with those created through the existing mode of disposal of these agricultural residues. The impacts considered under this study include climate change and acidification as shown in the following table (Table 32).

Table 32: Environmental impact categories

Environmental impact categories	Assessment criteria	unit
Climate change	Carbon dioxide CO_2 Methane CH_4 Nitrous Oxide N_2O	Kg CO_2-equivalent
Acidification	Sulphur dioxide SO_2 Nitrogen Oxide NO_x	Kg SO_2 Kg NO_x

Climate change impacts (GHG) emissions are expressed in a common unit of CO_2-equivalent. For each emission, the characterization factor with global warming potential (GWP) employed is given as: Carbon dioxide 1 CO_2-equivalent, methane (CH_4) 21 CO_2-equivalent and Nitrous Oxide (N_2O) 310 CO_2-equivalent (IPCC, 2001). The emissions with acidification potential are given the following characterization factors: Sulphur dioxide (SO_2) 1 SO_2-equivalent and Nitrous Oxides (NO_x) 0.7 SO_2-equivalent (Kimming et al., 2011). The GHG emissions balance is estimated based on the baseline scenario i.e. the open burning of agricultural residue on farms and the use of fossil fuel based electricity generator by non-households or commercial and institutional users for their electricity needs. The climate change mitigation benefits of the agricultural residue gasification system is assessed based on the findings of a number of life cycle assessment studies (Shafie et al., 2014; Ruiz et al., 2013; Zanchi et al., 2013).

Baseline scenario

The situation under baseline scenario is that agricultural residues mainly corncobs are burnt in the open field after processing of the harvest by removing the seed from the cobs. Households derive energy for their lighting needs from kerosene. Electricity supply for commercial centers and other public centers are derived from fossil fuel (diesel generators). The GHG and other particle emission effects from agricultural residue burning are estimated based on Shafie et al. 2014. Emissions from fossil fuels (diesel and kerosene) are calculated based on Sparrevik et al., 2012. The GHG and other emissions avoided as a result of using the agricultural residues and the generation and use of electricity are measured in terms of the avoided kg of CO_2 and other pollutants (SO_2 and NO_x).

System boundary

The system boundary for this study starts with agricultural residue collection and transportation and ends with the electricity generation process. The total agro-waste generation in Kampala and the peri-urban areas are estimated to be 1000 tons per day (Sabiiti, 2011). The financial analysis looked into the viability of an 8MW electricity generating plant which consumed 250 tons of agrowaste per day. Given this condition, it has been assumed that 4 such plants need to operate in Kampala and the peri-urban areas. The environmental impact at each stage is accounted for by calculating the GHG and other criteria emissions. However, there are two constraints of the socioeconomic model. First, although the emissions from agrowaste was calculated in the baseline condition, the economic value averted from acidification was partly assessed by the health benefits achieved by generation of the electricity from the agrowaste. The primary reason for the partial assessment was due to paucity of data on economic value of acidification averted in the context of Kampala. Secondly, energy used and the environmental impacts associated with the main agricultural crop production and equipment employed in the gasification process were not included within the scope of this study.

Source of energy for end users under baseline

Under baseline it was assumed that households derive energy for their lighting needs from kerosene. Electricity supply for commercial centers and other public centers are derived from fossil fuel (diesel generators). In Uganda, about 84% of the electricity comes from hydropower and the rest from coal based power plants. The environmental emissions associated with the use of kerosene lamps by households, diesel generators and coal based thermal power plants are shown in Table 33.

Table 33: GHG emissions associated with kerosene use and diesel generators under baseline

Source of emissions	Unit	Value
Kerosene:		
CO_2 emissions	Kg CO_2/lit	2.520
CH_4 emissions	Kg CH_4/lit	0.00035
N_2O emissions	Kg N_2O/lit	0.000021
Diesel generators:		
GHG emissions (CO_2 & CH_4)	Kg CO_2-eq/kwh	1.227
Coal based electricity		
GHG emissions (CO_2 & CH_4)	Kg CO_2-eq/kwh	0.9

Source: Zanchi et al., 2012; World Resource Institute http://www.ghgprotocol.org/calculation-tools/all-tools
http://www.epa.gov/ttnchie1/conference/ei20/session5/mmittal.pdf;
http://publications.jrc.ec.europa.eu/repository/bitstream/JRC21207/EUR%2019754%20EN.pdf

Agricultural residue under baseline

Agricultural residues are burnt in open field after processing of the harvest by removing the seed from the cobs. The GHG and other emission effects from open burning were estimated based on Shafie et al., 2014 and Sparrevik et al., 2012 (Table 34).

Table 34: Emission factors for open burning of agricultural residue under baseline

Emissions	Emission factor (kg emission /kg of dry residue burned)
CO_2	1.522[a]
CH_4	0.0012[b]
N_2O	0.00007 [b]
SO_2	0.002 [b]
NO_x	0.0031 [b]
CO	0.0347 [b]

Source: [a]Shafie et al., 2014; Sparrevik et al., 2012

Agricultural residue transportation and gasification

The agricultural residue to be used in the biomass gasification process is corncobs sourced from maize farmers spread across the communities. For an 8MW capacity plant a total of 250 tons of biomass is required per day. The GHG emissions are calculated in terms of CO_2-equivalent of all emissions as a result of agro- residue collection and transportation to the gasifier per kwh of electricity generated. Emissions associated with transportation of agro-residue are calculated assuming a maximum distance of 30 km radius from the gasifier to the various collection points using a truck of 25 tons load capacity. The effective load carried on each trip is 15 ton (Ruiz et al., 2013). The use of truck results in CO_2 emissions from use of fossil fuels (Ruiz et al. 2013). Following Ruiz et al., (2013) this study assumes CO_2 emissions of 3 kg/liter of diesel used on the average distance of 30 km and mean diesel consumption of 0.45 liters/km. Table 35 shows the parameters and assumptions made in the residue transportation model for a plant capacity of 8 MW. The total GHG emissions from transportation of the agro-waste utilizing the parameters mentioned above was calculated to be 175.5 tons of CO_2 eq. for each plant annually. Similarly, the GHG emissions from the gasifier was estimated to be 18,614.45 tons of CO_2 eq. for each plant annually. Therefore, the total emissions from each of the plant from transportation and gasification is around 18790 tons of CO_2 eq. annually.

Table 35: CO_2 emissions from gasification plant (transportation of agro-waste and gasification)

Transportation parameter	unit	value	reference
Average distance of travel by agro-waste to gasifier	km	30	Ruiz et al., (2013)
Capacity of truck for transporting agro-waste	Kg	25,000	Ruiz et al., (2013)
Max biomass weight in truck based on truck volume	kg	15,000	Ruiz et al., (2013)
Diesel consumption rate of truck	liters/km	0.45	Ruiz et al., (2013)
Number of trips per annum	#	4333	Calculated
CO2 emissions per liter of diesel	Kg CO_2/lt	3	Ruiz et al., 2013
CO2 emissions- Gasification	Kg CO_2eq/kwh	0.612	Zanchi et al.,2013

Environmental impact results

This section presents the GHG and other criteria emissions under baseline and alternative scenario. The emissions under baseline are the emissions avoided as a result of utilizing agricultural residue for electricity generation thereby replacing kerosene used by households and diesel generators by non-household users. The emissions from the business are the total of emissions associated with agro-residue transportation and emission during gasification process. Total emission savings is the total avoided emissions net of the emissions from the gasification plant.

Emissions under baseline scenario

This section presents the GHG and other emissions under baseline and under the ESCO social enterprise model. Under the baseline scenario the total emissions are those attributed to emission from open burning of agro residue, emissions from the use of kerosene lamps for lighting by households and emissions from the use of diesel generators. A sum of all these emission levels gives total avoided emissions due to electricity use from the ESCO model. The business model also results in environmental emissions which are generated from the transportation of feedstock and the gasification process itself. Total GHG emissions savings is the difference between total avoided emissions and total emissions from the gasification process.

Table 36 shows the emissions avoided as a result of electricity from the gasification of agro-residue. Net GHG emissions avoided per unit of electricity generated is 3.6 kg CO_2-equivalent/KWh. Avoided emissions from diesel generators are the most significant sources of saving in GHG emissions accounting for 78% of the total savings followed by open agro-residue burning 16%. Savings from kerosene use and thermal power used by the industries accounted for 3% each of the total savings in GHG emissions. Considering other emissions, all emission savings originate from avoided burning of agro-residue in the open field and coal based thermal power plants.

Table 36: Emission savings per kwh of electricity generated by ESCO model

Savings from	GHG emissions	Other criteria emissions		
	CO_2	SO_2	NO_x	CO
Open burning of agro-residue	0.675	0.0009	0.0014	0.0154
Diesel generators	3.316	-	-	-
Kerosene use	0.115	-	-	-
Thermal power	0.136	0.007	0.004	-
Total savings	**4.241**	**0.0079**	**0.0054**	**0.0347**

Emissions under ESCO model

The gasification of agricultural residue to generate electricity is not without emission of GHGs. These emissions are from transportation of agro-residue to the gasification plant and emissions from the gasifier. Table 37 shows GHG emissions from the business model in CO_2-equivalent. The highest contribution to GHG emissions is from the gasification process. The GHG emissions per unit of electricity generated is 0.642 kg CO_2-equivalent for all the four plants together annually.

Table 37: GHG emissions per kwh of electricity generated under ESCO model (kg CO2-eq/kwh)

Emissions from	GHG emissions
	CO_2
Agro-residue transportation	0.006
Gasification process	0.6536
Total emissions	**0.642**

Net emissions

The process of gasification produces the lower GHG emissions in terms of CO_2–equivalent per KWh of electricity compared to the emissions under the baseline. Considering the scope and system boundary for this study, the net GHG emissions savings is 3.6 kg CO_2-equivalent/KWh. This indicates that the total emissions savings far outweigh the emissions generated. The overall net GHG emissions from an 8 MW capacity biomass gasification plant is shown in Figure 9. GHG emissions associated with burning of agro-waste, use of diesel generator and kerosene lamps for lighting for households are negative representing GHG emission savings from use of electricity generated from gasification of agro-waste. 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. The GHG emissions from the gasification are far less than the emissions avoided under the baseline and thus resulting in net GHG emission savings of 1,139 ton CO_2eq per annum.

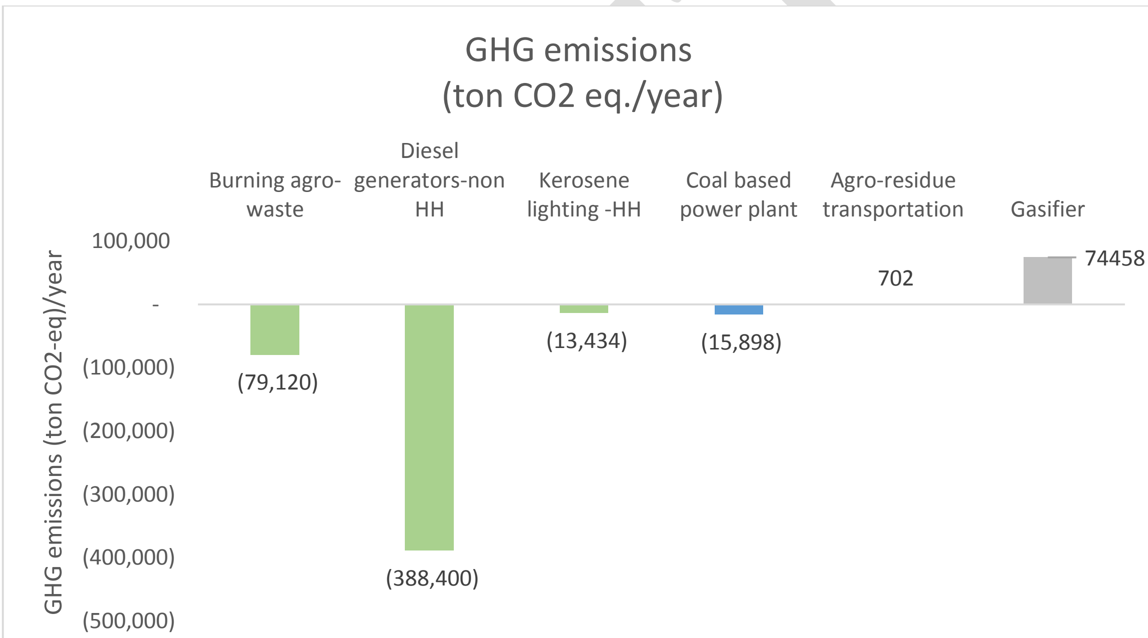

Figure 9: GHG emissions and savings from an 8 MW capacity gasification (ton CO_2eq/year)

Value of Carbon credits and other emissions

In this study it is assumed that carbon credits will be traded in Carbon Emission Reduction (CER) units as CER is suited for large scale projects and are sold in volumes that are targeted to clients seeking small reductions to offset their footprints. The CER unit is equivalent to a reduction of 1 ton of CO_2 equivalent emissions (Reuster 2010). Based on the World Bank (2014), carbon credit prices in 2013 is about USD 0.51 (€ 0.37) (Table 38).

Table 38: Annual value of GHG emission reduction from ESCO model (120 KW)

Item	Amount
Total GHG emission savings (ton CO_2eq)	496,851.491
Total GHG emissions from business (ton CO2 eq)	75,159.743
Net emission savings (ton CO_2eq/year)	421,691.747
Price of VER (USD/ton CO_2eq)	0.51

Total value of Carbon credit (USD/year)	215,063

The total annual value of carbon credit is USD 215,063. However value of the other emission savings that have acidification potential (NOx and SO2) were not included in the analysis.

Social impacts

Savings for end-users

Using electricity from the gasifier in place of other sources of lighting such as candles and kerosene lamps can contribute expenditure savings for end users. In this study three categories of end users were considered i.e. households, commercial users and industries. The gasifier has a capacity of 8 MW which is equivalent to a total of 117,145,600 KWh electricity generated at the 4 plants. Assuming energy efficiency of 88% and 12% captive power, the net available electricity is assumed to be consumed by the household, commercial and the industrial sector based on the present demand for electricity. The present demand in Uganda is respectively 24.4%, 11.16% and 64.6% for the household, commercial and the industries respectively. According to (Buchholz and Da Silva, 2010), the annual consumption of electricity by any household is about 360 kWh, which implies that if 24% of the generated electricity is transmitted, it would serve 78,878 more households which are not electrified presently. Similarly, 2,615 commercial establishment, 409 medium scale industries and 91 large scale industries can be provided with electricity. To calculate the number of commercial establishments which can be electrified it has been assumed that each establishment consumes 5000 kWh of electricity annually. However, to calculate the industries, the data from UMEME has been considered which provides an idea about the average electricity consumption among the medium and large scale industries in 2013 (i.e. 46,000 kWh and 62,600 kWh for medium and large scale industries respectively).

Table 39: General information on alternative energy use

	Unit	Value	Reference
Household average weekly consumption:			
Candles	#/week	6	GIZ (2011)
Kerosene	liter/week	1.3	GIZ (2011)
Unit price of candles	USD/candle	0.100	GIZ (2011)
Weekly expenditure on kerosene	USD/week/HH	1.04	GIZ (2011)
Unit cost of electricity-diesel generators	USD/KWh	0.25	Buchholz and Voltz (2007)
Unit price of diesel	USD/liter	1.21	http://www.globalpetrolprices.com/Uganda/diesel_prices/
Unit price of coal	USD/ton	70	http://siteresources.worldbank.org/INTPROSPECTS/Resources/334934-1111002388669/829392-1420582283771/Pnk_0415.pdf
currency conversion	USH/USD	2654	https://www.bou.or.ug/bou/collateral/exchange_rates.html (Accessed, 29-09-2014)

The above table (Table 39) provides the price information and the assumptions made in the estimation of expenditure saving for the avoided use of kerosene and candles by households and the expenditure savings by commercial centers by switching from diesel generators to electricity from the gasifier. It also elaborates the equivalent amount of coal saved which might be used to generate electricity for the industries presently and can be replaced by electricity from agrowaste. Replacing kerosene lamps, diesel generators and coal based electricity with electricity (derived from agrowaste) for lighting and other purposes has the potential to reduce the expenditures incurred by households, commercial and industrial end users. Table 40 shows the potential savings for end users from using electricity generated from gasification of agro-residues. The use of electricity from the gasifier for lighting instead of using kerosene lamps and candles will generate total expenditure savings of USD 476,033 per annum i.e. households save 0.017 USD/KWh of electricity used which accounts to about 6.04 USD/household/year. Likewise the net savings calculated for the commercial enterprises and industries taken together is 0.17 USD/kWh. This includes the net expenditure saved from use of diesel for the generators by the commercial establishments and expenses on diesel used for the gasifier along with the savings on coal for industrial electricity. It is observed that although electricity from the gasifier comes at a cost, the expenditure savings that will be attained offsets the costs.

Table 40: Savings in energy costs for end users from using electricity from ESCO (USD/year)

Item	Value
Savings in energy costs for households:	
Kerosene expenditure avoided	4,250,086
Candle expenditure avoided	2,473,087
Total savings for households	6,723,173
Expenditure on electricity by households	6,247,141
Net expenditure savings by households	**476,033**
Net savings per unit of electricity used(USD/kwh)	**0.017**
Savings in energy costs for Non-households:	
Diesel expenditure avoided	3,286,362
Expenditure on electricity due to operation of gasifier	878,592
Coal Expenditure avoided	445,153
Net savings in energy expenditure	**2,834,924**
Net savings per unit of electricity (USD/kwh)	**0.17**
Net savings (household and non-household)	**3,310,956**

Additional income to farmers and job creation

The gasification plant contributes to improving the local economy through job creation and providing of additional income to farmers. Corncobs are considered as agricultural waste and are currently burned in open field. However in order to have a sustainable supply of feedstock for the gasification plant, it requires the setting up of linkages and if possible purchase deals with both small and large scale farmers. This provides extra revenue stream to local farmers who will sell corncobs for extra income. The value of additional income to farmers from the gasification plant is USD 3,900,000 per annum. The gasification plant on average contributes to providing additional income to the farmer of 0.033 USD/kwh of electricity generated. The gasification plant contributes to job creation for the local community. The single plant of 8 MW employs about 11 workers earning a total annual salary of USD 22,000 and hence the total employment generated is 44 with an annual income generation of USD 88,000. In addition to providing additional income and job creation, the plant is likely to have indirect impacts to local economy as new businesses might thrive due to availability of electricity generated by the gasification plant. However, other indirect impacts to the local economy are not accounted for in this study.

Health impacts

The most commonly documented health impacts of kerosene are poisoning, fires and explosions. However Kerosene when lighted emits substantial amounts of fine particulate (PM), Carbon monoxide (CO), Nitric Oxides (NO_x) and Sulphur dioxides (SO_2) that are linked to the cause impairing lung function and increase in infectious illness (including tuberculosis), asthma, and cancer risks (Lam et al., 2012; World Bank, 2008). Thus the replacement of kerosene lamps and candles with electric light will improve indoor air quality and the health conditions of its user. A liter of kerosene when burnt emits PM 51 micrograms per hour, which is above the World Health Organization's 24 hour mean standard of 50 micrograms per cubic meter. This increases the risk of respiratory sickness from exposure to these pollutants. The health benefit from the replacement of kerosene lamps and that derived from reduction in open burning of agro-waste is quantified using DALYs for indoor air pollution and outdoor air pollution. The DALY for outdoor air pollution per 1000 capita is 0.1 whereas for indoor air pollution is 23 as estimated by WHO for Uganda. The economic value of each value in case of Uganda ranges between USD 244 (derived from a study which considers cancer as the fatal disease) to USD 500 (Gross National per capita Income for Uganda). Total health expenditure savings from averting sicknesses and mortality is estimated to be USD 2,771,080 per year.

Financial Analysis

This section presents the financial feasibility analysis and results of business model generating 8 MW from agrowaste. The financial viability is analyzed based on Return on Investment (ROI), Net Present Value (NPV) and Internal Rate of Return (IRR) valuation criteria. The capital cost for the gasifier plant per installed capacity is 2,087 US$ per kW installed (Buchholz and Volk 2007; IFAD, 2010; Buchholz and Da Silva, 2010). Total investment cost for each of the plant is USD 6,530,735. The project life of the plant is assumed to be 15 years. The financial assessment of the 4 plants operating in the city shows positive net profit, however there is a negative NPV from the business along with an IRR of 11% which is below the discount rate. The rate of investment (ROI) is 8% implying that revenues are not high enough to recover all costs of the business (Table 41). This is also observed that the benefit-cost ratio is less than 1 (0.909) indicating that financially the model is not viable.

Table 41: Financial results of ESCO model (USD)

	Years											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Total investment cost:	26,122,940											
Total revenues		12,292,020	12,292,020	12,292,020	12,292,020	12,292,020	13,521,222	13,521,222	13,521,222	13,521,222	13,521,222	....
Total production and other costs		6,571,840	6,761,430	6,956,707	7,157,843	7,365,013	7,578,398	7,798,185	8,024,565	8,257,736	8,497,903	....
Depreciation		1,741,200	1,741,200	1,741,200	1,741,200	1,741,200	1,741,200	1,741,200	1,741,200	1,741,200	1,741,200	....
Interest Payments		2,873,523	2,169,523	1,289,523	321,523	-	-	-	-	-	-	-
Profit before tax		1,105,457	1,619,867	2,304,589	3,071,453	3,185,807	4,201,624	3,981,837	3,755,457	3,522,286	3,282,119	....
Income tax		331,637	485,960	691,377	921,436	955,742	1,260,487	1,194,551	1,126,637	1,056,686	984,636	....
Net profit		773,820	1,133,907	1,613,213	2,150,017	2,230,065	2,941,137	2,787,286	2,628,820	2,465,600	2,297,483	....
Cash flow	(26,122,940)	2,515,020	2,875,107	3,354,413	3,891,217	3,971,265	4,682,337	4,528,486	4,370,020	4,206,800	4,038,683	....
Discount rate	12%											
Discounted cash flow		2,245,553	2,292,018	2,387,605	2,472,939	2,253,402	2,372,218	2,048,457	1,764,978	1,517,014	1,300,348	....
NPV	(919,859)											
IRR	11%											
ROI (Financial)		3%	4%	6%	8%	9%	11%	11%	10%	9%	9%	....
ROI (Financial average)	8%											

Socioeconomic results

The socioeconomic analysis of ESCO business model is performed by putting monetary value on all quantifiable cost and benefits in order to calculate the NPV, benefit cost ratio (BCR) and ROI for the business model. The consolidated socio-economic results are presented in Table 42. The analysis looked at the potential impact of ESCO model at three levels where the levels range from including the direct benefits and costs that affect the business entity to including indirect benefits and costs to other sectors. The annual social and environmental benefits and costs from the business were discounted at a rate of 12% to obtain the present value of social and environmental impacts.

The ESCO model, when only the direct benefits are accounted for results in negative NPV and BCR of less than 1 implying that the business model is not financially feasible. The business model performs better when the financial and environmental costs and benefits are taken into account. However, the net positive incremental benefits from the environmental impacts are not high enough to make the business model feasible as the NPV is still negative and the BCR is less than 1. The business model becomes economically feasible when all externalities are included in the analysis. The NPV when all externalities are considered is USD 108,883,864 and the BCR is 5.11. Thus, major contribution to the economic feasibility of the business is from the social benefits. The total value of the social benefits of the business is USD 108 million with major benefits coming from the additional income to farmers and jobs created for the local community which accounted for 86% of the total value of social benefits. Thus the ESCO business model is economically feasible but not financially feasible.

Table 42: Net socio-economic results of ESCO model

Socio-economic result (USD/year)	Financial value	Financial and environmental value	Social, environmental and financial value
Financial result:			
NPV	(919,589)	(919,589)	(919,589)
Environmental benefit:			
Value of net GHG emission saving		1,381,466	1,381,466
Social benefit:			
Savings in energy costs for end users			21,268,086
Additional income to farmers and employment			51,427,029
Health Benefits			35,727,142
Benefit:Cost ratio (BCR)	**0.91**	**0.96**	**5.11**
NPV	**(919,589)**	**461,607**	**108,883,864**
ROI (average)	**8%**	**12%**	**48%**

Sensitivity analysis

Sensitivity analysis was performed to identify variables which have important effects on the socio-economic impacts of the business model. The discount factor, carbon credit price, capital cost of the gasifier and economic value of a DALY were varied to assess the resulting effect on the overall socioeconomic feasibility of the business model. The following table (Table 43) elaborates the assumptions made on the stochastic variables.

Table 43: Variables selected for the stochastic model

Variable	Unit	Distribution specified	Source
Capital cost of the gasifier	USD/KW	*Triangular:* (2010, 2087,2890) for the smaller plant	Buchholz and Volk, 2007; IFAD, 2010
Discount rate	%	*Triangular*: (10%, 12%, 15%)	Assumed
Carbon Credit price	USD/t CO_2 eq.	Uniform distribution	Assumed
Economic value of a DALY	USD	*Triangular Distribution* (245, 300, 500)	The lower range corresponds to estimates for cancer and higher range to gross national per capital income.

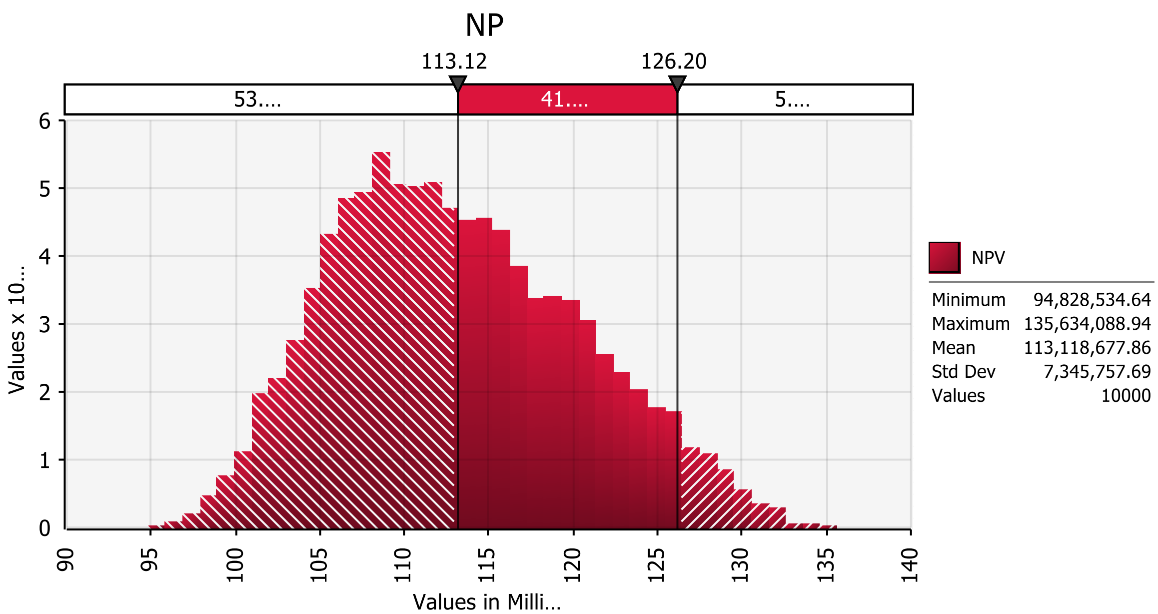

Figure 10: Probability Distribution of NPV

The above Figure (Figure 10) shows the probability distribution obtained for the NPV based on the stochastic variables described above. The probability distribution obtained shows that the mean NPV of the net societal benefits (benefits over and above costs) for such business operating at a scale which takes up all the agrowaste of the city is USD 113.12 million. The 90% confidence interval indicates values between USD 94,828 and USD 135.6 million. The above figure also shows that the probability that the net benefits will fall below the mean NPV is 53.4% which projects a higher variability of the NPV.

Conclusion

This study assessed the socio-economic impact of energy service company (ESCO) business model in Kampala, Uganda. The socio-economic analysis is conducted based on the valuation of financial, environmental and health benefits and costs associated with the business model. The following conclusions can be drawn from the study:

- From the socioeconomic perspective, findings from the study indicate that the use of agricultural residue as a feedstock in a small scale biomass gasification to electricity business model is viable in Uganda and has the potential of impacting positively the health, environmental and social life of the rural dwellers. The business model resulted in a BCR of 5.11 and ROI of 48% indicating that (although not all environmental and social impacts have been factored in the analysis) the business provides positive environmental and social impacts that offsets it costs.

- Net GHG emissions saved per kWh of electricity generated is 3.6 kg CO_2eq. The highest savings in GHG emissions would be mainly from substituting diesel generators for the commercial establishments while the highest emissions from the business model is from the gasifier.

- Major contribution to the economic feasibility of the business is from the social benefits. The total value of the social benefits of the business is USD 108 million with major benefits coming from the additional income to farmers and jobs created for the local community which accounted for 47% of the total value of social benefits. This was followed by savings in health expenditures (32%) and the savings on energy costs by the end users (19%).

Socio-economic impact assessment of cost savings and recovery of treated wastewater for irrigation, compost and energy in Kampala

Introduction

The developing countries are facing a steep challenge of wastewater management and policy makers are constantly exploring cost effective measures to mitigate the impacts. Wastewater treatment interventions can generate significant benefits for public health, and the economic sectors such as fisheries, tourism and property markets. In developing countries with growing population and need for industrialization to cater to the economic growth the need for such interventions become more demanding. This is particularly true for individuals living below the poverty line who need provisions of safe water supply, sanitation and wastewater services. Several studies indicate that benefit-to-cost ratios for basic water and sanitation services are as high as 7 to 1 for developing countries. Thus benefits derived from such interventions are substantial in the long run for the economy.

The situation in Uganda is not different from any developing country. Policy makers are engaging relevant stakeholders to explore effective and efficient options for wastewater management. Uganda's urban population currently stands at 20% and is growing, due to rural urban migration. This trend has led to an increase in the production of wastewater from households and the growing manufacturing industry. Wastewater in Uganda is mainly generated from domestic and municipal waste. It is estimated that about 7.62 million m^3 of wastewater is generated in Uganda every year, the major portion (50%) of which is generated in Kampala. In addition to this on average only about 2% of the people in 22 towns have access to sewerage systems. The dominant wastewater treatment facility existing is restricted to primary treatment and is discharged into wetlands.

One of the emerging key interventions towards wastewater management is diversion of the treated wastewater towards peri-urban agriculture and using the sludge retrieved as compost/manure for agriculture. In Uganda despite a remarkable economic growth being registered in the recent years, one key set back remains the persistent food shortages and critical nutritional deficiencies often experienced in many parts of the country. This situation is partly attributed to occasional poor harvests attributed to erratic rain seasons, which have a very significant impact on the largely rain-fed subsistence farming being practiced by over 80% of the population (UN-WATER, 2006). Given the context of Kampala this report investigates the socio-economic impacts of treating waste water for reuse in terms of treated wastewater for irrigation, conversion of biogas to electricity, and use of sludge as soil conditioner. This business model addresses cost recovery through three different mechanisms – (i) water sales and (ii) compost or manure sales to farming and additionally a cost saving mechanism (iii) using the treatment process to capture the biogas generated by anaerobic digestion and converting to electricity that is subsequently used to power the plant. These business interventions are pertinent for Uganda given the context of lower sanitation facilities and also related scarcity of water for agriculture in the peri-urban areas.

The potential economic, environmental, and social impacts of treatment plant needs to be assessed to ensure its sustainable development. In this study, it is assumed that the Wastewater Treatment Plant (WWTP) already exists and additional investments are being made to install recovery of electricity and sludge and diverting the water to the peri-urban agricultural farm lands. The socio-economic impacts of treating wastewater for cost recovery is evaluated with daily flow of 40,000 m^3. The socio-economic analysis is conducted based on the valuation of economic, social and health benefits and costs associated with the business model.

Technology description

In this assessment, three different technologies are being considered. Overall, wastewater is transported to the treatment plant by gravity through a conveyor pipeline. The wastewater then undergoes through secondary treatment in an activated sludge process. Sludge from the primary settling tanks and aerated tanks are covered in dissolved air flotation units. These two sludges are then pumped into anaerobic disgesters. Biogas is produced, but converted to electricty to be used on site. Also, compost is produced from the sludge. Biogas produced can be used for cooking, lighting or powering the plant. The treated wastewater and sludge are used for farming. Canal is constructed to distribute the water to the farmers. It is assumed that farmers are in the vicinity of the treatment plant. For treated sludge for farming, it is assumed that facluative ponds or the treatment plant already exisits and we only care about the additional costs of dewatering and obtaining the biosolids. Anaerobic digestion is commonly used in treatment plant for treating the sludge and to produce biogas. It stabilizes the organic matter in the sludge, reduces pathogens and odors, and reduces the total sludge quantity (EPA, 2006). The composition of biogas depends on the quality of the treatment plant, temperature and the flow of the wastewater or sludge. Typically, methane (CH_4) constitutes about 60% while 40% belongs to carbon dioxide (CO_2) (Rasi et al. 2007). Also, the efficiency of the process will be influenced by the temperature; as higher temperatures are more suitable for bacterial growth and the retention time, which is the time the process is allowed to take place. The hydraulic retention time (HRT) ranges from 15 to 25 days depending on the climatic conditions. Average HRT is 20 days at an ambient average temperature of 25 °C (Metcalf and Eddy, 2003; Degrémont, 2005). Various types of organic waste can be used to produce biogas. There are different types of biogas systems in use in developing countries. The technology employed is based on a biological activated sludge process with sludge anaerobic digestion, and includes equipment such as biogas combined heat and power engines (CHP), gas flare, standby diesel generators, biogas boilers, heat exchangers, and aeration turbo blowers for biological tanks aeration and mixing. However, only the facilities that use anaerobic digestion as part of their biosolids treatment process will be considered as the cost of building an anaerobic digester is unknown. These facilities already have an anaerobic digester onsite and are producing biogas. Capital costs and the potential electricity generation capacity will be estimated using data from existing wastewater case studies and existing literature.

Technology and processes

The electricity generation system consists of an anaerobic heated sludge digester, biogas holding tank and a gas engine connected to a generator. The compost/manure system consists of mechanical sludge thickening tanks, sludge storage tanks, mechanical sludge dewatering and drying beds. The treated water is diverted through canals or nearby waterbodies for aiding irrigation outside the urban areas.

Overall approach to socioeconomic analysis

As explained above the main focus of the study was to carry out a socioeconomic analysis of cost recovery from a wastewater treatment plant in Kampala. The motivation behind the socioeconomic analysis was to evaluate the net societal benefits (including the environmental and health costs and benefits) over and above the net economic benefits (which have been evaluated in the financial analysis). The economic analysis of a project is concerned with its viability from a societal perspective and answers the questions of whether it is economically rational to proceed with the project (De Souza et al., 2011). In contrast to a financial analysis, economic analysis provides a more comprehensive investigation on the effects of a proposed project, takes a broader perspective and determines the project's overall value to society (Raucher et al., 2006). The analysis, therefore, includes benefits and costs that directly affect the business entity running the project and the effects of the project on households, businesses and industries, and governments. The analysis also includes the benefits and costs that cannot be readily measured using observable market prices and costs (De Souza et al., 2011).

The estimated quantity of treated wastewater in Kampala in 2013 was approximately 64,000 m^3/day of which 14,000 m^3/day is being treated - at Bulobi (12,000 m^3/day), Nalaya (1,000 m^3/day), and Ntinda (1,000 m^3/day). Thus 50,000 m^3/day flows to the nearby waterbodies, streams and even to Lake Victoria polluting these water sources. For the financial analysis, a treatment plant of capacity 40,000 m^3/day is being considered, the socioeconomics analysis similarly considers the same capacity of the wastewater treated. Therefore, the environmental, health and social costs and benefits considered for the society is restricted to the wastewater treated and not for the entire 50,000 m^3/day generated.

Environmental impact assessment

Reduced pollution of the surface and groundwater sources

The environmental impact assessment of the cost recovery from wastewater treatment was carried out for the baseline scenario where the entire wastewater flows to the water courses. The primary environmental impact of the wastewater is the surface water pollution of the nearby water courses as well as chances of groundwater getting contaminated. In the present study the costs of surface water pollution and ground water contamination is estimated indirectly using the shadow prices for undesirable outputs of wastewater treatment. The following table (Table 44) shows the environmental value of the damage avoided (surface and groundwater contamination) based on the figures provided by Hernandez-Shancho et.al. 2010.

Table 44: Shadow prices of the undesirable outputs with reference to discharges

Destination	Reference price of water €/m^3	Shadow prices for undesirable outputs (€/kg)				
		N	P	SS	BOD	COD
River	0.7	16.353	30.944	0.005	0.033	0.098
Sea	0.1	4.612	7.533	0.001	0.005	0.010
Wetlands	0.9	65.209	103.424	0.010	0.117	0.122
Reuse	1.5	26.182	79.268	0.010	0.058	0.140

Source: Hernandez-Shancho et.al. 2010

The table illustrates the reference price of water treated from different sources and also the prices of the undesirable outputs which have a potential environmental damage when wastewater is drained off to different destinations. To calculate the environmental costs averted due to wastewater treatment, the average shadow prices of the pollutants for river and wetland had been utilized since the baseline scenario considers the nearby water courses as the primary destination of the untreated wastewater. At the same time the table indicates the values to be mentioned at 2010 euros, hence for the final valuation these values had been inflation adjusted to the present value.

The situation under baseline scenario is that about 14,000 m^3 of water is being treated while the rest of the untreated water is drained off towards the nearby waterbodies, streams. The wastewater effluent values provided by National Water and Sewerage Corporation (NWSC, 2013) was being utilized to calculate the amount of undesired outputs from the untreated wastewater (40,000 m^3/day). The following table provides the calculations for the estimations of the pollutants in the wastewater based on the operational days of the WWTP (297 days).

Table 45: Estimation of the environmental impact due to discharge of wastewater in Kampala

Parameter	Average discharge (mg/L)	Discharge standard (mg/L)	Amount of pollutant reduction required to meet standard (Kg/year)	Economic value (USD/kg)**	Economic value (USD/year)
BOD effluent	102	50	616,770	0.1094	67,552
COD effluent	223	100	1,461,240	0.1604	234,354
NH_3 effluent	19	10	106,920	59.45	6,357,324
SS	100	100	-	0.0109	-
PO_4 effluent	7	10	-	97.95	-
Total economic value for averting pollution (USD/year)					**6,659,230**

** The values expressed in the previous tables are averaged for river and wetlands, and actualized for obtaining the USD values for 2015. For these calculations the conversion factor of 1 euro at 2010 is considered to be 1.35 USD (yearly average) and the cumulative inflation of USED from 2010 to 2015 is taken to be 8.3%

The results shows that discharge of 40,000 m^3 of wastewater per day have environmental costs amounting to USD 22.14 million per year (Table 45). The treatment of the wastewater in the alternate scenario for generating of electricity, irrigation water and compost leads to net environmental benefits associated with the removal of the different pollutants as estimated above.

Reduced GHG emissions

The alternate situation of the socioeconomic model which considers the generation of electricity from treatment of wastewater is in contrast with the baseline situation where although wastewater treatment exists, there is no energy generation. One of the revenue stream from business model is from electricity generated which is fed to the grid as well as savings in terms of Wastewater Plant utilizing some of the electricity generated. The following table (Table 46) shows the amount of electricity generated, utilized in the plant and the availability for the grid. According to Gude (2015), about 2.24 kWh of electricity is produced per meter cube of wastewater treated while 0.7 kWh (Gude, 2015; Stillwell et. al., 2010) is consumed for treating the wastewater. Based on these assumptions and that the number of operational days as 297, it is estimated that about 3.85 MW of electricity can be fed to the grid.

Table 46: Electricity produced from wastewater treatment

Electricity produced per m^3	2.24
Wastewater treated (m^3)	40,000
Operating days	297
Electricity produced (kWh)	26611200
Electricity consumed (kWh/m^3)	0.7
Electricity consumed kWh	8316000
Electricity available for grid (kWh)	**18295200**

In the socio-economic model, it is being assumed that the end-users are of three categories – (i) households, (ii) commercial establishments and (iii) industries – medium and small scale. In the baseline situation, these end-users depend on different energy sources. For example, the households derive energy for their lighting needs from kerosene. Electricity supply for commercial centers and other public centers are derived from fossil fuel (diesel generators), while the industries depend primarily on hydropower and to certain extent on coal based power plants. This is assumed for the industries since in Uganda, about 84% of the electricity comes from hydropower and the rest from coal based power plants.

The environmental emissions associated with the use of kerosene lamps by households, diesel generators and coal based thermal power plants are shown in Table 47.

Table 47: GHG emissions associated with kerosene use and diesel generators

Source of emissions	Unit	Value
Kerosene:		
CO_2 emissions	Kg CO_2/lit	2.520
CH_4 emissions	Kg CH_4/lit	0.00035
N_2O emissions	Kg N_2O/lit	0.000021
Diesel generators:		
GHG emissions (CO_2 & CH_4)	Kg CO_2-eq/kwh	1.227
Coal based electricity		
GHG emissions (CO_2 & CH_4)	Kg CO_2-eq/kwh	0.9

Source: Zanchi et al., 2012; World Resource Institute http://www.ghgprotocol.org/calculation-tools/all-tools http://www.epa.gov/ttnchie1/conference/ei20/session5/mmittal.pdf; http://publications.jrc.ec.europa.eu/repository/bitstream/JRC21207/EUR%2019754%20EN.pdf

Emissions under baseline scenario

To determine the amount of emissions made in the baseline scenario, it is imperative to estimate the number of beneficiaries (households, commercial establishments and industries) served with new electricity connections utilizing the 3.85 MW electricity generated. These beneficiaries in the alternate scenario are the end-users in the baseline scenario. In the present situation the demand for electricity across different users in Uganda is respectively 24.4%, 11.16% and 64.6% for the household, commercial and the industries respectively (https://energypedia.info/wiki/Uganda_Energy_Situation). According to (Buchholz and Da Silva, 2010), the annual consumption of electricity by any household is about 360 kWh, which implies that if 24% of the generated electricity is transmitted, it would serve 12,319 more households which are not electrified presently. Similarly, 136 commercial establishment, 64 medium scale industries and 14 large scale industries can be provided with electricity. To calculate the number of commercial establishments which can be electrified it has been assumed that each establishment consumes 5000 kWh of electricity annually. However, to calculate the industries, the data from UMEME has been considered which provides an idea about the average electricity consumption among the medium and large scale industries in 2013 (i.e. 46,000 kWh and 62,600 kWh for medium and large scale industries respectively).

Table 48: Total monetary value of Carbon Emissions Reductions (CERs)

GHG emissions from diesel generators by non HHs	kg CO2-eq	60,658,307
GHG emissions from kerosene for lighting by HHs	kg CO2-eq	2,098,007
GHG emissions from coal thermal power by industries	kg CO2-eq	2,482,920
GHG emissions	**kg CO2-eq**	**65,239,234**
Net emissions savings in alternative scenario	**kg CO2-eq**	**65,239,234**
Price of Credit	USD/ton CO2-eq	0.51
Total annual value of Carbon credit	**USD/year**	**33,272**

The above table (Table 48) presents the emissions in the baseline scenario. Under the baseline scenario the total emissions are those attributed to emission from open burning of agro residue, emissions from the use of kerosene lamps for lighting by households and emissions from the use of diesel generators. A sum of all these emission levels gives total avoided emissions due to electricity use from the wastewater treatment model. This is entirely averted in the alternate scenario. In this study it is assumed that carbon credits will be traded in Carbon Emission Reduction (CER) units as CER is suited for large scale projects and are sold in volumes that are targeted to clients seeking small reductions to offset their footprints. The CER unit is equivalent to a reduction of 1 ton of CO_2 equivalent emissions (Reuster 2010). Based on the World Bank (2014), carbon credit prices in 2013 is about USD 0.51 (€ 0.37)

The subsequent table (Table 49) shows the emissions avoided as a result of electricity from the gasification of agro-residue. Net GHG emissions avoided per unit of electricity generated is 3.56 kg CO_2-equivalent/KWh. Avoided emissions from diesel generators are the most significant sources of saving in GHG emissions accounting for 92% of the total savings followed by open savings from kerosene use and thermal power used by the industries accounted for 4% each of the total savings in GHG emissions.

Table 49: Emission savings per kWh of electricity generated from the wastewater treatment plant

Savings from	GHG emissions	Other criteria emissions		
	CO_2	SO_2	NO_x	CO
Diesel generators	3.316	-	-	-
Kerosene use	0.115	-	-	-
Thermal power	0.136	0.007	0.004	-
Total savings	**4.241**	**0.0079**	**0.0054**	**0.0347**

The total annual value of carbon credit is USD 33,272. However, the major limitation of the estimation is that value of the other emission savings that have acidification potential (NOx and SO2) were not included in the analysis. Although the emissions from thermal power plants was calculated in the baseline condition, the economic value averted from acidification was partly assessed by the health benefits achieved by generation of the electricity from the agrowaste. The primary reason for the partial assessment was due to paucity of data on economic value of acidification averted in the context of Kampala. However, it needs to be mentioned that introduction of such business model with established WWTP leads to an annual saving of 26,000 SO_2, 40,300 NO_x , and 451,000 carbon monoxide annually.

Social impacts

Savings for end-users

Using electricity generated from the combined cogeneration of heat and power in place of other sources of lighting such as candles, kerosene lamps, diesel generators and coal based thermal power can contribute expenditure savings for end users. In this study three categories of end users were considered i.e. households, commercial users and industries. The generator used for the power generation has a capacity of 4.4 MW which is equivalent to a total of 18,295,200 KWh electricity. Assuming energy efficiency of 88% and 12% captive power, the net available electricity is assumed to be consumed by the household, commercial and the industrial sector based on the present demand for electricity. The present demand in Uganda is respectively 24.4%, 11.16% and 64.6% for the household, commercial and the industries respectively. According to (Buchholz and Da Silva, 2010), the annual consumption of electricity by any household is about 360 kWh, which implies that if 24% of the generated electricity is transmitted, it would serve 12,319 more households which are not electrified presently. Similarly, 136 commercial establishment, 64 medium scale industries and 14 large scale industries can be provided with electricity. To calculate the number of commercial establishments which can be electrified it has been assumed that each establishment consumes 5000 kWh of electricity annually. However, to calculate the industries, the data from UMEME has been considered which provides an idea about the average electricity consumption among the medium and large scale industries in 2013 (i.e. 46,000 kWh and 62,600 kWh for medium and large scale industries respectively).

Table 50: General information on alternative energy use

	Unit	Value	Reference
Household average weekly consumption:			
Candles	#/week	6	GIZ (2011)
Kerosene	liter/week	1.3	GIZ (2011)
Unit price of candles	USD/candle	0.100	GIZ (2011)
Weekly expenditure on kerosene	USD/week/HH	1.04	GIZ (2011)
Unit cost of electricity-diesel generators	USD/KWh	0.25	Buchholz and Voltz (2007)
Unit price of diesel	USD/liter	1.21	http://www.globalpetrolprices.com/Uganda/diesel_prices/
Unit price of coal	USD/ton	70	http://siteresources.worldbank.org/INTPROSPECTS/Resources/334934-1111002388669/829392-1420582283771/Pnk_0415.pdf
currency conversion	USH/USD	2654	https://www.bou.or.ug/bou/collateral/exchange_rates.html (Accessed, 29-09-2014)

The above table (Table 50) provides the price information and the assumptions made in the estimation of expenditure saving for the avoided use of kerosene and candles by households and the expenditure savings by commercial centers by switching from diesel generators to electricity from the generator. It also elaborates the equivalent amount of coal saved which might be used to generate electricity for the industries presently and can be replaced by electricity from agrowaste. Replacing kerosene lamps, diesel generators and coal based electricity with electricity (derived from agrowaste) for lighting and other purposes has the potential to reduce the expenditures incurred by households, commercial and industrial end users. Table 51 shows the potential savings for end users from using electricity generated from gasification of agro-residues. The use of electricity from the generator for lighting instead of using kerosene lamps and candles will generate total expenditure savings of USD 74,334 per annum i.e. households save 0.21 USD/KWh of electricity used which accounts to about 75.52 USD/household/year. Likewise the net savings calculated for the commercial enterprises and industries taken together is 0.11 USD/kWh. This includes the net expenditure saved from use of diesel for the generators by the commercial establishments and expenses on diesel used for the generator along with the savings on coal for industrial electricity. It is observed that although electricity from the generator comes at a cost, the expenditure savings that will be attained offsets the costs.

Table 51: Savings in energy costs for end users from using electricity generated from wastewater treatment (USD/year)

Item	Value
Savings in energy costs for households:	
Kerosene expenditure avoided	663,757

Candle expenditure avoided	386,234
Total savings for households	1,049,991
Expenditure on electricity by households	119,738
Net expenditure savings by households	**930,252**
Net savings per unit of electricity used(USD/kwh)	**0.21**
Savings in energy costs for Non-households:	
Diesel expenditure avoided	510,436
Coal Expenditure avoided	69,522
Expenditure on electricity due to operation of generator	106,184
Net savings in energy expenditure	**473,774**
Net savings per unit of electricity (USD/kwh)	**0.11**
Net savings (household and non-household)	**1,404,026**

Additional income through job creation

The co-generation plant contributes to improving the local economy through job creation and hence providing additional income to workers. The financial analysis shows that the plant employs about 11 workers earning a total annual salary of USD 22,000 which is the additional income generated per year. In addition to providing additional income and job creation, the plant is likely to have indirect impacts to local economy as new businesses might thrive due to availability of electricity generated by the gasification plant. However, other indirect impacts to the local economy are not accounted for in this study.

Increase in income in agricultural households

With increase in area under cultivation, it is expected that income of the households engaged in agriculture would rise. Uganda Strategy Support Program (USSP, 2009) indicates that the net earnings per hectare cultivating maize ranges from USD 3-15 per season. In the present study a value of USD 10 per hectare is being assumed and the ranges are being utilized for the sensitivity analysis. This implies that the total agricultural net income due to availability of water and assuming cultivation of maize is USD 33,371.4 per season and around USD 66,742.8 annually.

Health impacts

The primary health impacts in the current situation due to partial wastewater treatment and discharge in the nearby waterbodies is diarrheal diseases make up over four per cent of the global disease burden (UNEP, 2010). It is also assumed for the present study that the entire population of Kampala central division affected by the direct discharge of wastewater. Water Sanitation Programme (WSP, 2012) estimated that Uganda losses about USD 5.5 per capita due to poor sanitation of which about 1 USD is lost due to inconvenience in finding proper infrastructure for sanitation. In contrast WHO (2009) provides an estimate of 33 DALYs per 1000 population in terms of burden of diseases from environmental pollution (particularly water, health and hygiene) for Uganda. Using this estimate the per capita loss due to diarrheal diseases is USD 9.5. The present study considers both of these values as ranges. The lower value is used for the deterministic model while the higher range is used for the sensitivity analysis in the stochastic model. Thus the estimated savings from treating wastewater and avoiding diarrheal diseases is USD 358,293 per annum in the deterministic model.

Financial Analysis

The financial analysis is based on three different additional costs for an existing wastewater treatment plant. In this context, there is an NPV and IRR for (a) wastewater reuse for irrigation, (b) biogas converted to electricity for onsite consumption, and (c) sludge production as soil conditioner. Finally, the combined NPV and IRR for these three values are being estimated. It is assumed that the plant will obtain a combined heat and power technology (CHP). The total cost of this technology is estimated to be $493,931 (break-up is shown in Table 52). It is assumed that wastewater is treated and supplied to farmers. For simplicity, it is further assumed that the distance between farmers and the plant is 15km. It is important to stress that the total costs used in this analysis is subject to the location of the farmers. The unit cost of canal construction is estimated as $2.5 per m^3. The total treated water from the plant for reuse is assumed to be 40,000m^3/day. In this assessment, total construction cost of the canal is derived as $15,000,000. This cost includes materials, lining and installation costs. It is assumed that the wastewater plant is operating already and our concern in this assessment is to estimate the additional cost of manure production or removal from the plant for farmers or other premium customers. Thus, we only considered investment cost of primary and secondary sludge treatment without the costs of facultative ponds or any exiting treatment technology. It is estimated that the additional cost of the sludge removal will be $170,000. This cost includes construction, materials, and installation costs. The cost of sludge removal for farmers or other premium customers are not included. It is important to stress that all these assessments are based on an existing wastewater treatment plant in a Kampala. It is also assumed that this plant has an operating capacity of 40,000m^3/day.

Table 52: Capital cost of reuse components in Wastewater treatment plant

Investment type	Costs (in USD)
Cost of combined heat and power	493,931
Cost of treated water supply (canal)	15,000,000
Cost of sludge removal/production	170,000

Typically, wastewater treatment plant consumes between 0.5-2kWh per m^3 of energy (Gude, 2015). It is assumed that about 0.7kWh per m^3 of electricity will be consumed for this additional technology. The corresponding cost of electricity generation is 0.04$ per kWh (ERG (2011)). The operation and maintenance cost for the additional items is 5% of the capital costs and an escalation of 3% (based on current inflation rate in Uganda). This is applied annually to inflate the price of labor, electricity and the operation and maintenance costs used to estimate the net income over the life span of the investment. It is assumed that the project has a life span of 15 years. Also, it is assumed that farmers are in the vicinity of the treatment plant. The construction of the canal will require additional 3 people. The associated labor cost is $7 per day. Now, the water must be treated to avoid any health implications for the farmers. This will cost about 0.01$ per m3 (FAO, 1997). Finally, it will cost $0.23 per m3 to pump the water to the canals. This cost also includes the electricity cost of pumping. The operation and maintenance cost for the additional items is 5% with an escalation of 3%. It is assumed that project has a life span of 15 years. It is assumed that there will be 2 people to ensure the day-to-day operation of the sludge production. The corresponding cost is $7 per day. The largest cost is the additional labor necessary to remove the sludge to the appropriate area for the farmers. The associated labor cost is $6 per day. There is also a minor costs associated with sampling and monitoring. This cost also includes the electricity cost of pumping. The operation and maintenance cost for the additional items is 3% with an escalation of 3%. Typically, with 60% methane, it is possible to obtain 35m3 per day of biogas from wastewater. The electricity generation associated with this biogas is 2.24kWh per m3. Alternatively, one MGD (3970m^3/day) yields 26kW of electricity. Assume the capacity of the facility is 40,000m3 per day; it is possible to obtain 274kW of electricity. The price of electricity valued at the plant site is from 0.011 to 0.083$ per kWh. A value of 0.03$ per kWh is used in this analysis. It is assumed that the total quantity of wastewater treated and reuse is about 40,000m3 per day. This quantity of water will be transported through the canals to the farmers. Based on extensive literature review, it costs $0.05 per m^3 to supply water to the farmers ((Khouri (1992); Abu-Madi (2004)). Typically, about 2-10% of the wastewater flow is retained as sludge. In this assessment, we use 2% to obtain the sludge produced from this plant. This value is then converted to 282.52 tons per day. The corresponding price is between $5-10 per ton. But $0.5 per ton is used in this analysis. It is assumed that the plant will operate for 297 days per year.

The financial estimates and an assumption of 12% discount rate the NPV of additional investment for recovery of energy, nutrient and treated wastewater irrigation is calculated to be USD (172,779), USD 94,750 and USD 521,203 and the IRR is 4%, 20% and 38% respectively. The combined model shows a positive NPV of $9,668 with an IRR of 12%. This result suggests that additional costs could be beneficial to the plant (Table 53).

Table 53: Financial results of Electricity generation model along with irrigation and sludge (USD)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Revenue															
Treated water	594,000	594,000	594,000	594,000	594,000	594,000	594,000	594,000	594,000	594,000	594,000	594,000	594,000	594,000	594,000
Avoided electricity savings	391,194	402,929	415,017	427,468	440,292	453,501	467,106	481,119	495,552	510,419	525,732	541,504	557,749	574,481	591,716
Revenue from sludge	**1,027,147**	**1,040,142**	**1,053,526**	**1,067,312**	**1,081,511**	**1,096,136**	**1,111,200**	**1,126,717**	**1,142,698**	**1,159,159**	**1,176,114**	**1,193,577**	**1,211,564**	**1,230,091**	**1,249,174**
Total revenue	**838,070**	**845,392**	**852,934**	**860,702**	**868,703**	**876,944**	**885,433**	**894,176**	**903,181**	**912,456**	**922,010**	**931,850**	**941,986**	**952,426**	**963,178**
Expense															
Treated water for irrigation	397,637	408,816	420,331	432,191	444,406	456,988	469,948	483,297	497,045	511,207	525,793	540,817	556,291	572,230	588,647
Electricity recovery	386,327	396,929	407,849	419,096	430,681	442,614	454,904	467,564	480,603	494,033	507,866	522,114	536,790	551,906	567,475
Sludge recovery	19,878	20,219	20,571	20,933	21,306	21,690	22,086	22,494	22,913	23,346	23,791	24,250	24,722	25,209	25,710
Total Expense	**803,842**	**825,964**	**848,750**	**872,220**	**896,394**	**921,292**	**946,938**	**973,354**	**1,000,561**	**1,028,585**	**1,057,450**	**1,087,181**	**1,117,803**	**1,149,345**	**1,181,832**
Net profit	**223,306**	**214,178**	**204,776**	**195,092**	**185,118**	**174,844**	**164,262**	**153,363**	**142,137**	**130,574**	**118,664**	**106,396**	**93,761**	**80,747**	**67,342**
NPV	**9,669**														
IRR	**12%**														
ROI	**14%**														
BCR	**0.98**														

Socioeconomic results

The socioeconomic analysis of the business model is performed by putting monetary value on all quantifiable cost and benefits in order to calculate the NPV, benefit cost ratio (BCR) and ROI for the business model. The consolidated socio-economic results are presented in Table 54. The analysis looked at the potential impact of model at three levels – (i) financial, (ii) financial and environmental and (iii) financial, environmental and social where the levels range from including the direct benefits and costs that affect the business entity to including indirect benefits and costs to other sectors. The annual social and environmental benefits and costs from the business were discounted at a rate of 12% to obtain the present value of social and environmental impacts.

The business model, when only the direct benefits are accounted for results in positive NPV and BCR of less than 1 implying that the business model is financially feasible however with risks of lower returns on investments. The business model performs better when the financial and environmental costs and benefits are taken into account. The net positive incremental benefits from the environmental impacts are very high enough to make the business model feasible as the NPV is positive and the BCR is substantially high 37.92. This implies that per dollar invested gives a return of USD 38. The business model becomes economically more feasible when all externalities are included in the analysis. The NPV when all externalities are considered is USD 56,923,752 and the BCR is 49.38. Thus, major contribution to the economic feasibility of the business is from the environmental benefits. The total value of the social benefits (NPV over a period of 15 years) of the business is USD 14 million with major benefits coming from the additional income from jobs created for the local community, health benefits and savings in expenses for alternate forms of energy. It has been estimated that benefits from proper sanitation and water facilities ranges from USD 3- 34 (UNEP, 2010). The socio-economic model estimated that with treatment of water and recovery of electricity, water and sludge for compost increases the benefits accrued by USD 15 per annum.

Table 54: Net socio-economic results of Electricity generation model from wastewater treatment

Socio-economic result (USD/year)	Financial value	Financial and environmental value	Social, environmental and financial value
Financial result:			
NPV	9,669	9,669	9,669
Environmental benefit:			
Value of net GHG emission saving		42,989,611	42,989,611
Social benefit:			
Savings in energy costs for end users			9,081,831
Additional income due to generation of new employment			605,772
Health Benefits			4,619,421
Benefit:Cost ratio (BCR)	**0.98**	**37.92**	**49.88**
NPV	**9,669**	**461,607**	**56,923,752**
ROI (average)	**14%**	**588%**	**740%**

Sensitivity analysis

Sensitivity analysis was performed to identify variables which have important effects on the socio-economic impacts of the business model. The discount factor, carbon credit price, and economic value of a per capita losses due to diarrheal diseases were varied to assess the resulting effect on the overall socioeconomic feasibility of the business model. The following table (Table 55) elaborates the assumptions made on the stochastic variables.

Table 55: Selected variables for the stochastic analysis of the socioeconomic model

Variable	Unit	Distribution specified	Source
Discount rate	%	*Triangular*: (10%, 12%, 15%)	Assumed
Carbon Credit price	USD/t CO_2 eq.	Uniform distribution (0.51-1.5)	Assumed
Economic value of per capita loss due to diseases	USD	*Uniform Distribution* (4.49 – 9.5)	The lower range corresponds to estimates for cancer and higher range to gross national per capital income.

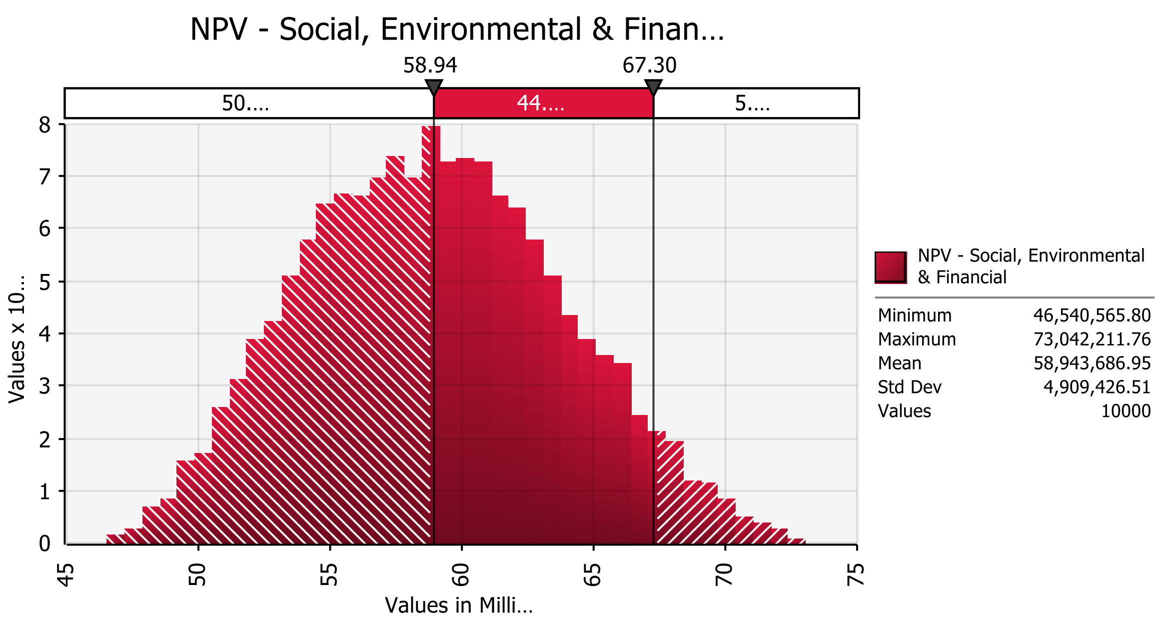

Figure 11: Probability Distribution of NPV (net benefits) derived from electricity generation and water for irrigation derived from wastewater treatment

The above Figure (Figure 11) shows the probability distribution obtained for the NPV based on the stochastic variables described above. The probability distribution obtained shows that the mean NPV of the net societal benefits (benefits over and above costs) for such business operating at a scale which takes up all the agrowaste of the city is USD 58.94 million. The 90% confidence interval indicates values between USD 46 and USD 73 million. The above figure also shows that the probability that the net benefits will fall below the mean NPV is 50.7% which projects a higher variability of the NPV. The probability distribution estimated also showed that the probability of achieving the NPV estimated through the deterministic model is around 30%.

Conclusion

The efficient implementation of policies to prevent the degradation and depletion of water resources requires determining their value in social and economic terms and incorporating this information into the decision-making process. A process of wastewater treatment has many associated environmental benefits. However, these benefits are often not calculated because they are not set by the market, due to inadequate property rights, the presence of externalities, and the lack of perfect information. Nevertheless, the valuation of these benefits is necessary to justify a suitable investment policy and a limited number of studies exist on the subject of the economic valuation of environmental benefits. In this paper, we propose a methodology based on the estimation of shadow prices for the pollutants removed in a treatment process. This value represents the environmental benefit (avoided cost) associated with undischarged pollution. This is a pioneering approach to the economic valuation of wastewater treatment. The comparison of these benefits with the internal costs of the treatment process will provide a useful indicator for the feasibility of wastewater treatment projects. This study assessed the socio-economic impact of cost savings from wastewater treatment in Kampala, Uganda. The model includes the generation of electricity, water for irrigation and digester sludge for compost. The socio-economic analysis is conducted based on the valuation of financial, environmental and health benefits and costs associated with the business model. The following conclusions can be drawn from the study:

- From the socioeconomic perspective, findings from the study indicate that the most pertinent benefits accrues from treatment of water reducing the environmental burdens. The benefits from wastewater treatment offsets the marginal financial benefits and the net returns amount to USD 37 from per dollar invested. The business model resulted in a BCR of 59.88 and ROI of 740% indicating that (although not all environmental and social impacts have been factored in the analysis) the business provides positive environmental and social impacts that offsets it costs.
- Net GHG emissions saved per kWh of electricity generated is 1.4 kg CO_2eq. The highest savings in GHG emissions would be mainly from substituting diesel generators for the commercial establishments while the highest emissions from the business model is from the gasifier.

Socio-economic impact of Informal to Formal Trajectory in Wastewater Irrigation - Incentivizing safe reuse of untreated wastewater in Kampala

Introduction

Wastewater management is a major challenge in many developing countries and policy makers are constantly exploring cost effective measures to mitigate both the direct and indirect negative impact. This is important for individuals who are living below the poverty line. The social costs of poor wastewater management is high, thus innovative approaches which aimed at reducing health risks and improving the environmental conditions are imminently needed. Kampala is not different from any developing country. Policy makers are engaging relevant stakeholders to explore effective and efficient options for wastewater management.

This report seeks to investigate the viability of a wastewater stabilization pond in Kampala. We considered two additional reuse investments. These are (a) reuse of treated wastewater for irrigation, (b) ground water recharge.

Given the context of Kampala this report investigates the socio-economic impacts of wastewater stabilization pond for reuse in terms of treated wastewater for irrigation, and ground water recharge.

The potential economic, environmental, Social and health impacts of wastewater stabilization pond need to be assessed to ensure its sustainable development. In this study, we evaluated the socio-economic impacts of wastewater stabilization pond with storage capacity of 2,000,000 m^3. The socio-economic analysis is conducted based on the valuation of economic, Social, environmental and health benefits and costs associated with the business model.

Technological description of treating wastewater

In this assessment, we considered wastewater is transported to the stabilisation pond by gravity through a conveyor pipeline. The wastewater is kept in the stabilisation pond and the ground water recharge happens in the natural way.

Overall approach to socio-economic impact assessment

The socio-economic analysis of a project is concerned with its viability from a societal perspective and answers the questions of whether it is economically rational to proceed with the project (De Souza et al., 2011). In contrast to a financial analysis, socio-economic analysis provides a more comprehensive investigation on the effects of a proposed project takes a broader perspective and determines the project's overall value to society. The analysis, therefore, includes benefits and costs that directly affect the business entity running the project and the effects of the project on households, governments and other businesses outside of the business.

The socioeconomic model consists of two alternative scenarios - First, the present situation is evaluated and in contrast the scenario where wastewater is diverted for agriculture and groundwater recharge is compared. The wastewater in Kampala mainly comes through from four different sources – household, commercial establishment, industries and institutions. It is estimated for 2013 based on Kampala Sanitation Plan, (KSP, 2008) that in Kampala the total wastewater generation is 64,294 m^3. The following table (Table 56) shows a cross-tabulation between the amount of wastewater generated from different regions of Kampala and the quantity of wastewater from different sources.

Table 56: Generation of wastewater in Kampala according to regions and categories

Origin	Household (m^3/day)	Institutional (m^3/day)	Commercial (m^3/day)	Industrial (m^3/day)	Total (m^3/day)
Central	3,141	664	8,246	1,877	13,928
Kawempe	7,235	1,344	0	400	8,979
Makindye	11,140	968	742	235	13,085
Nakawa	11,132	2,144	350	5,453	19,079
Rubaga	6,708	1,672	0	842	9,223
Total	**39,357**	**6,792**	**9,338**	**8,807**	**64,294**

Source: KSP, 2008

In the current scenario, about 12,000 m^3 is being partially treated in the Bugolobi Wastewater Treatment plant (WWTP) and in waste stabilization ponds (WSPs) in Naalya consists of two anaerobic, one facultative and one maturation pond and are able to treat 1000 m^3 of wastewater per day. Similarly, in Ntinda another WSP consist of one anaerobic, one facultative and one maturation pond, with the effluent going to a wetland and a treatment capacity of 1000 m^3/day. The effluent of the WWTP enters the Nakivubo Channel, which drains into Lake Victoria, causing health risks and eutrophication. The effluent from Naalaya is discharged to Naalya valley wetland, and there is no official end-use of treated wastewater. However, small-scale farmers have started to use the effluent for irrigation of agricultural crops.

The alternative scenario considers diversion of the entire wastewater to wastewater stabilization ponds (WSPs) with different capacities such that 64,000 m^3 of wastewater per day can be treated and can be subsequently used for agriculture. This mechanism also serves the purpose of recharging depleted aquifers which can be help in providing water. The costs and benefits of the baseline and the alternative scenarios are evaluated to obtain the net benefits for each parameters included under the environmental, financial and social classification. The entire assessment for increase in agricultural production is estimated assuming maize cultivation which is the major crop of Uganda.

Environmental Impact

Environmental Costs in the Baseline Scenario averted in the alternative scenario

Water pollution

The baseline scenario assumes partial treatment of 14,000 m^3 of wastewater and direct discharge of wastewater. The effluent from the WWTP and WSPs are also discharged in the nearby streams which ultimately ends up polluting Lake Victoria. This also has potential for ground water contamination. A study by United Nations Environment Programme (UNEP, 2010) estimates the environmental values of the undesirable outputs like nitrogen, phosphorus, suspended solids, Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). The following table (Table 57) illustrates the estimation of the value of environmental pollution averted using the wastewater treatment. These avoided costs represent the economic value of the minimal environmental benefits obtained from the treatment process and reuse of water in agriculture.

Table 57: Estimation of the environmental value of pollution due to discharge of wastewater

Parameters	Environmental value of pollution (USD/m^3)	Total value of Environmental Pollution (USD/year)
N	0.6060	14,157,562
P	0.3087	7,211,232
SS	0.00252	58,867

BOD	0.0164	382,636
COD	0.0831	1,942,618
Total	**1.016**	**23,752,915**

Costs due to eutrophication averted

In the baseline condition, a large part of the water (40,000 m^3) is directly discharged into the nearby waterbodies while the remaining wastewater is partially treated. The discharge of wastewater is leading to eutrophication of Lake Victoria (EAWAG, 2014). At present, the average cost of treatment of water for drinking or public supplies amounts to US$ 10 per 1000 m^3. However, the cost decreases to US$ 2 per 1,000 m^3 for treatment of water of good quality. Therefore the costs of water treatment increase in eutrophic systems. There are also different indirect economic effects of eutrophication, such as the loss of days of work by intoxication or health failures due to exposure or drinking of water with algal toxins. Algal toxins from *Cyanophyta sp.* produce a permanent chronic toxicity, which impairs human health. The costs of eutrophication in the streams and waterbodies which can be averted by using waste stabilization pondsis estimated to be USD 233,600 per annum.

Economic Impact

Economic Costs & Benefits in alternative Scenario

Capital Investments

There are three major cost components – (i) establishment of wastewater stabilization pond, (ii) pumping cost associated to channelize water towards WSPs and (iii) use of treated water for different uses like irrigation, ground water recharge. The major costs (and one of the disadvantages) of WSPs is the requirement of land. WSPs consists of a series of *anaerobic ponds, facultative ponds* and *maturation pond (aerobic pond)*. These ponds vary in depth, size and the retention time. In the present study the total requirement of land is based on the following assumption that around 60 hectares of land is required for constructing the series of the stabilization ponds. The details of the expenditure on these three heads are given in the Table 58. It is assumed that the cost of purchasing 1 m^2 is USD 9.3. Therefore, the cost of buying land is USD 5.58 million. The cost of construction of wastewater stabilization pond of 10 hectares is USD 671 and hence the cost of construction is USD 4026. The pumping costs associated with the WSPs is considered to be USD 0.02 /m^3 (FAO, 1997), which implies that the total cost annually would be USD 467,200 for the project.

Table 58: Capital cost for WSPs

Capital cost		
Land	USD	5,580,000
Construction of stabilization pond	USD	4,026
Pumping costs	USD	467,200
Total Investment	**USD**	**6,051,226**

Operation & maintenance costs

Apart from capital expenditure for establishing the WSP, there are associated Operation and Maintenance costs (O&M) for the maintaining the stabilization ponds for irrigation and groundwater recharge particularly with respect to desludging. However, such costs are periodic in a year. The O&M costs including the labour costs amounts up to be USD 9,538 annually.

Economic Benefits

The primary economic benefit for wastewater diversion arises from groundwater recharge which can be tapped by the private entities for sale to the communities with lower water access. The National Water and Sewerage Corporation is responsible for water and sewerage services in Kampala and the peri-urban areas around the city limits. The water supply system consists of treatment, pumping, storage and distribution. In Kampala, NWSC has outsourced 3 outlets to private contractors in Kampala as filling point for tankers. At present 2 of them are in operation and there exists more than 30 water tankers trucks in Kampala (Pangera and Pangera, 2008). The cited study also indicates the prices of water vending in Kampala which ranges from 50,000 - 80,000 shillings (16.7 – 26.7 USD) for 8000 lts. This indicates a price of USD 2 -3.3 per m^3.

An indirect consequence of irrigated agriculture is aquifer recharge, and it occurs in permeable soils whether it is performed with fresh, reclaimed or reused wastewater (Foster et. al. 2004). Recharge has the advantage of increasing the availability of water locally. Rashed et. al. (1995), estimated that infiltration is equivalent to 50-70% of the water used for agriculture. The value of the groundwater that is recharged in the process of wastewater utilization for agriculture in Kampala is thus estimated to be USD 23.36 million assuming the water prices as had been mentioned above.

Social Impact assessment

Employment generation in the agricultural sector

The pertinent impact of utilizing wastewater for agriculture is to meet the scarcity of water for cultivation. The prominent effect in the agricultural sector is thus an increase in employment since more cultivable land can be made available for agriculture implying that both gross and net cropped would increase from the baseline scenario. It has mentioned previously, the study assumes that the water diverted towards agriculture would be used for the cultivation of maize. Maize require 500-800 mm. of water per hectare for a season (FAO[4]). This implies that an additional 3337.14 hectares of land can be irrigated for the wastewater with treatment through the WSPs. Subsistence farming of maize requires 2-3 labours per season (calculated based on IFPRI data sheet[5] and minimum wages in the agricultural sector[6]). Thus utilization of the wastewater entails an additional employment in the agricultural sector by about 6674 labours. Wage Indicator Survey for Uganda[7] (2012), shows that the hourly wage rate for agricultural labour is 0.18 USD which implies that the monthly wages for these workers are USD 45. Employing the above figures, the total value of employment generated as net benefit for the society utilizing the wastewater is estimated to be USD 3,604,114.

Increase in income in agricultural households

With increase in area under cultivation, it is expected that income of the households engaged in agriculture would rise. Uganda Strategy Support Program (USSP, 2009) indicates that the net earnings per hectare cultivating maize ranges from USD 3-15 per season. In the present study a value of USD 10 per hectare is being assumed and the ranges are being utilized for the sensitivity analysis. This implies that

[4] http://www.fao.org/nr/water/cropinfo_maize.html
[5] http://www.ifpri.org/sites/default/files/publications/usspbp04.pdf
[6] http://www.afristat.org/contenu/pdf/lmis/lmis_status_ug.pdf
[7] http://www.wageindicator.org/documents/publicationslist/publications-2012/AIAS_WI_countryreports_f2f_report_Uganda_final_20121211.pdf

the total agricultural net income due to availability of water and assuming cultivation of maize is USD 33,371.4 per season and around USD 66,742.8 annually.

Health Impact in Baseline & Alternative Scenario

Health costs in the Baseline scenario

The baseline scenario considers discharge of the wastewater into the streams and wetlands ultimately leading to sources of water. To evaluate the health costs in the baseline condition, it is assumed that diseases related to sanitation cost USD 4.5 per capita in Uganda. This figure had been estimated for Uganda by Water and Sanitation Programme (WSP, 2012), where the category of the costs included are – access time lost, income lost due to premature death, productivity losses whilst sick or accessing healthcare, and expenditure on health care. For the present study the costs pertaining to access time has not been considered primarily because it does not directly links to the expenditures made avert diseases or losses in terms of productivity. The level of primary treatment of the waste through WSPs lead to a reduction of the chances of diarrhea, related expenditure and productivity losses. The alternative scenario of wastewater reuse assumes that these health costs in the baseline line scenario accrues as benefits for the society as a whole. The alternative scenario however, considers the farmers and the workers who might be affected by use of wastewater in irrigating the farms. The total size of the population including the farmers and farm workers is estimated to be 9,708. Utilizing similar values (USD 4.5) it is calculated that the net health benefit that accrues to the society id USD 7,019,514 annually.

Socioeconomic Analysis

The socioeconomic analysis of diverting wastewater towards irrigation and groundwater recharge utilizing WSPs is evaluated by putting monetary value on all quantifiable cost and benefits in order to calculate the NPV, benefit cost ratio (BCR) and ROI for the business model. The consolidated socio-economic results are presented in Table 59. The analysis looked at the potential impact of ESCO model at three levels where the levels range from including the direct benefits and costs that affect the business entity to including indirect benefits and costs to other sectors. The annual social and environmental benefits and costs from the business were discounted at a rate of 12% to obtain the present value of social and environmental impacts.

The socioeconomic assessment shows that progressively the BCR improves over financial benefits due to inclusion of environmental benefits from reduced pollution and groundwater recharge as well as increased employment and increase in farm income. The marginal increase in benefits is more when environmental benefits are being added over the financial benefits rather than the social benefits. The socioeconomic assessment of the wastewater being diverted for agriculture and groundwater recharge yields a positive NPV of USD 360 million and a benefit-cost ratio of 60 when all externalities are being included. This implies that per dollar invested yields an additional income of USD 60. Thus the social model is economically feasible but not financially feasible.

Table 59: Net socio-economic results of wastewater to irrigation and groundwater recharge model

Socio-economic result (USD/year)	Financial value	Financial and environmental value	Social, environmental and financial value
Financial result:			
NPV	141,133,195	141,133,195	141,133,195
Environmental benefit:			

Water pollution & Eutrophication		151,193,640	151,193,640
Social benefit:			
Additional income to farmers and employment			23,138,428
Health Benefits			45,131,128
Benefit:Cost ratio (BCR)	**22.32**	**48.31**	**59.59**
NPV	**141,133,195**	**292,596,480**	**360,596,480**
ROI (average)	**243%**	**493%**	**606%**

Sensitivity analysis

Sensitivity analysis was performed to identify variables which have important effects on the socio-economic impacts of the business model. The discount factor, water required for maize cultivation, price of drinking water, employment generated, groundwater recharge and economic value of a DALY were varied to assess the resulting effect on the overall socioeconomic feasibility of the business model. The following table (Table 60) elaborates the assumptions made on the stochastic variables.

Table 60: Variable selected for the stochastic analysis of the socioeconomic model

Variable	Unit	Distribution specified	Source
Discount rate	%	*Triangular*: (10%, 12%, 15%)	Assumed
Water required for maize cultivation	mm	Triangular: (600 – 800)	FAO
Price of drinking water	USD	*Triangular Distribution:* (1.5, 2, 3)	Assumed
Employment generated per farm	#	*Uniform Distribution* (2 -3)	Ugandan Labour survey
Groundwater Recharge	%	*Uniform Distribution* (50% - 70%)	Rashed et.al. (1995)
Economic value of per capita loss due to diseases	USD	*Uniform Distribution* (4.49 – 9.5)	The lower range corresponds to estimates for cancer and higher range to gross national per capital income.

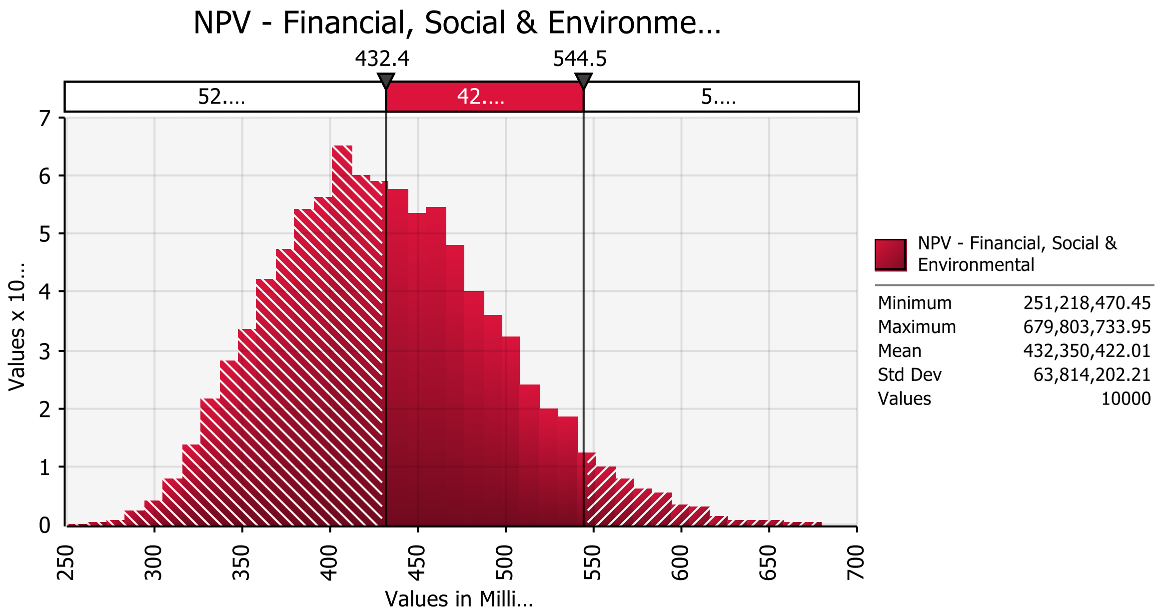

Figure 12: Probability Distribution of NPV from net benefits arising from wastewater to irrigation and groundwater recharge

The above Figure (Figure 12) shows the probability distribution obtained for the NPV based on the stochastic variables described above. The probability distribution obtained shows that the mean NPV of the net societal benefits (benefits over and above costs) for such business operating at a scale which takes up all the agrowaste of the city is USD 432 million. The minimum and maximum interval indicates values between USD 251 and USD 679 million. The above figure also shows that the probability that the net benefits will fall below the mean NPV is 53% which projects a higher variability of the NPV. In contrast if the NPV from the deterministic model is assumed to be the benchmark the probability of obtaining of a NPV less than that of USD 360 million is 13%.

Conclusion

This study assessed the socio-economic impact of wastewater stabilization pond model in Kampala, Uganda. The socio-economic analysis is conducted based on the valuation of financial, environmental and health benefits and costs associated with the business model. The following conclusions can be drawn from the study:

- Wastewater stabilization pond can reduce the surface water pollution and eutrophication of the lakes and water bodies in Kampala.
- Use of partially treated wastewater increases land under irrigations and subsequently increases employment in farm and farm income. However, there might be health burden to the farmers and workers in the farm, but these costs is offset by societal benefits as a whole. Use of WSP in partially treatment of water however have lower risks for farmers and workers utilizing wastewater.
- Wastewater stabilization pond increases the opportunity of groundwater recharge and hence open chances for water extraction for drinking purposes particularly when water is scarce in Kampala.

Socio-economic impact assessment of Large Scale for revenue generation in Kampala

Introduction

The increasing quantity of urban waste in urban towns of developing nations coupled with inadequate sanitation services is of a growing concern to the deteriorating urban environment (Oyoo, 2010). In Kampala 2333 tons of Municipal Solid waste is generated daily and out of this about 40 percent is collected and the remaining uncollected waste is normally burnt and/or dumped in unauthorised sites, causing health and environmental problems. However, the organic fraction of domestic waste can provide an opportunity to improve livelihoods and incomes through fertilizer and energy production (Komakech, 2014).

The potential economic, environmental, social and health impacts of composting plant needs to be assessed to ensure its sustainable development. In this study, we evaluated the socio-economic impacts of composting of MSW business with annual capacity of handling 36,000 tons of MSW in Kampala. The socio-economic analysis is conducted based on the valuation of financial, environmental and health benefits and costs associated with the business model.

Technological description for Large Scale Composting from MSW

There are two fundamental types of composting techniques – open or windrow composting and enclosed or in-vessel composting method (Dulac, 2001). Open composting processes are simpler, require less capital, and use less energy. This generally rely more on land and labour and less on machinery. In comparison enclosed or in-vessel composting is more technology driven and require complex equipment and also utilizing substantial amounts of energy. The aerobic process or the windrow composting is arguably the most suitable technology for developing countries like Uganda based on operation costs. While operating costs usually start at US $ 40 per ton, for the least expensive variant; more expensive systems can cost up to US $ 100 per ton, operational costs for windrow composting is comparatively lower around US $ 5 to US $ 20 per ton.

Windrow composting comprises of – (i) Pre-processing (segregation/sorting), (ii) Shredding, (iii) Piling of the waste, (iv) Turning of the windrows, (v) Maturing, (vi) Sieving, and (vii) Storage and Bagging. MSW comprises of different wastes from different sources and sorting is important since left over inorganic materials might contaminate the final product. The segregation and sorting can be done manually or using a conveyor belt. Manual sorting is labour intensive but can achieve a good result if done carefully while conveyor sorting is subject to maintenance and requires power supply to operate. Shredding primarily involves shredding of the raw materials (organic waste) and can be done manually by crushing or chopping or by using mechanized milling machine. However, this depends on the source of waste. Wastes generated from the horticulture and agriculture as well as the agro-industries requires shredding before they are composted. The shredded raw material is then loosely heaped (called windrow) to an appropriate height of about 2 meters. However, it should be noted that the size of the heap should be suitable to build up the heat and also retain it to achieve pathogen inactivation. Windrow composting involves aerobic decomposition and hence passive diffusion of oxygen into the centre of the heap is a prerequisite.

This aerobic degradation is exothermic in nature which generates heat within the pile. To ensure that aerobic degradation can continue a sufficient supply of oxygen must be ensured. Turning of the windrows also enhances oxygen supply. In the first weeks of the process it is recommended that the heap be turned

3 times weekly as temperatures such that higher temperatures are avoided as it will inhibit microbial activity. In such cases, turning can be an appropriate measure to cool the heap. After the first 2 weeks the turning frequency can be reduced to weekly turning and the pile can then be turned once every ten days. High temperatures and microbial activity during the thermophilic phase will lead to moisture losses. When moisture levels fall below 40 % additional water must be added to the heap with each turning. The moisture content should be maintained ideally between 40 and 60%.
It takes about 5-6 weeks from the day piling takes place for the temperature of the pile to fall below 50°C and the maturation phase to set in. The material is characterized by a soil like colour. Mesophilic microorganisms become active and further stabilize the immature compost within approximately 15 days. Turning is no longer necessary and only little watering is required if the piles are very dry. After a total of about 8 weeks the mature compost material is characterized by a dark brown colour, an earthy smell and a crumbly texture. The final mature compost can then be sieved to obtain the required particle size which depends on the customer requirements. Sieving can help remove still remaining inorganic particles in the compost. The coarse rejects form sieving can be added to the fresh incoming waste. Sieving can be performed using a flat frame sieve operated with manual labour or using mechanical rotating drum sieves. Depending on the marketing and sales strategy, the final compost product can be either stored or sold in bulk or else be packaged in bags of different volumes. The moisture content should be below 40% before bagging and the final product should be stored in a dry and sheltered location.

Overall approach to socio-economic impact assessment

The socio-economic analysis of a project is concerned with its viability from a societal perspective and answers the questions of whether it is economically rational to proceed with the project (De Souza et al., 2011). In contrast to a financial analysis, socio-economic analysis provides a more comprehensive investigation on the effects of a proposed project, takes a broader perspective and determines the project's overall value to society. The analysis, therefore, includes benefits and costs that directly affect the business entity running the project and the effects of the project on households, governments and other businesses outside of the business.

In the baseline scenario it is assumed that about 40% of the municipal solid waste is collected and landfilled at Kiteezi, 12 kilometres away from Kampala. A study by Kinobe et.al (2013), identified three types of storage sites within the city districts –

- Category 1: Legal temporary storage sites (demarcated by KCCA and collected),
- Category 2: Illegal temporary storage sites (not demarcated by KCCA but still collected)
- Category 3: Open dumpsites (Not collected. Often burned by a designated person)

The study identified a total of 227 storage sites, of which 133 belong to Category 2, 59 to Category 3 and 35 to Category 1. This study although identifies the category and the number of the temporary storage sites, but do not provide any idea about the waste that is being dumped/stored in these sites for further transfer to the landfill. Thus in these circumstances it is hard to distinguish the amount that is just open-dumped (in category 2) and not being collected and the amount which is open-dumped and burnt (category 3). Both of these activities have its onus on air and water pollution and hence quite pertinent to include it within the ambit of environmental impacts. More so since the number of category 2 & 3 storage sites are more in number.

For the present study a conservative assumption is being made in absence of the actual data. It is being assumed that the storage sites are homogeneous in terms of storage capacity. This assumption is used to make the calculations simplistic and would help in providing an idea about the waste that is being open-dumped without landfilled further or burned. The study by Kinobe et. al (2013) and NWSC data shows that about 850,500 tons of municipal solid waste is produced yearly of which 340,200 tons are collected and the rest are uncollected (510,200 tons). The daily generation of waste as reported in both these study is around 2363 tons. This waste is being stored temporarily in 227 storage sites (as mentioned above). Hence the average waste going to each of the storage site assuming a homogeneous storage capacity is around 10.4 tons daily. The following table (Table 61) shows the amount of waste collected in each of the three categories of the temporary storages.

Table 61: Estimation of MSW dumped in temporary waste sites in Kampala

Waste storage (tons)	Category 1	Category 2	Category 3
Daily	364	1384.49	614.17
Yearly	131,162	498,416	221,102

The above table shows that about 1385 tons of MSW daily is collected and stored at category 2 type temporary storage. All of this waste is not landfilled since the total waste that is landfilled is about 945 tons. It can be calculated that only about 42% of the waste (581 tons) from category 2 storage is landfilled along with the total waste from category 1. The rest of the waste (about 803 tons) is left open-dumped which is about 289,081 tons of waste yearly. Likewise about 221,102 tons of waste in category 3 storage is burned yearly.

Environmental Impact Assessment

The baseline scenario considers that the total Municipal Solid Waste generated in Kampala is 2347 tons daily. However, only about 37-40% (946 tons) is being collected and landfilled. Subsequently, in the alternative scenario it is being considered that the entire MSW generated in the city is used for 4 large scale compost plants each of size 600 tons. The environment impact assessment for the business models includes the following key issues –

- Avoided GHG emissions,
- Cost of leachate treatment that can be averted, and
- Increase in soil fertility since compost acts as a soil conditioner

Avoided GHG emissions

In the baseline scenario (business as usual), the waste generated in the city is usually open dumped or burned which had been explained in the system boundary previously. This leads to GHG emissions from landfilling and open-dumping as well as burning. In the situation where the entire waste is send to the landfill site, segregated and the organic fraction of the waste is used for composting and the recyclables sold back, the chances for GHG emissions are averted. The price for Carbon Emission Reductions (CERs) following the CDM mechanism is USD 0.51 (ton Co_2 equivalent). Utilising the above procedure and also considering the emissions from burning waste and open-dumping as 1.522 and 0.4 tons Co_2-eq/ton the annual savings in terms of GHG savings is calculated to be USD 230,596. Additionally, the project would also incur substantial GHG emissions in terms of transportation of the additional quantity of waste which is not being transported presently (additional 1498 tons).These costs had been calculated based on calculation of the number of trips required annually and the diesel consumption by a truck on average. The main assumption used while modelling the transport emissions are – (i) the fact that the carrying capacity of a truck is 15 tons, (ii) that it can transport waste 5 km per litre on an average, and (iii) GHG emissions from the automobile diesel is about 2.67 kg Co_2/lt. (World Resource Institute) The cost for such emissions is calculated to be USD 173,562 giving an annual net gain (emissions saved over incurred) of USD 57,033.

Cost of leachate treatment

The leachate potential form a MSW landfill primarily depends on the precipitation and thus is influenced by the climatic conditions such as rainfall and evaporation. In tropical conditions like that of Uganda, the average leachate produced per tons of MSW is considered to be 87.2 lts. Therefore, the total amount of leachate produced annually can be calculated to be 25,268 lts. Considering the treatment cost of leachate to be USD 10 per m^3 (Johannessen, 1999), the annual cost of leachate treatment can be estimated to be USD 252,678. In the alternate scenario, the entire amount of waste is bereft of the organic fraction and the recyclables which constitute the major fraction of the waste (more than 96%). The remaining inert material is considered to be landfill which also reduces the chances for production of leachate in the landfill even if the precipitation in Uganda is quite high (900-1000 mm. of rainfall annually.

Increase in soil fertility/amelioration

To provide a value for the increase in soil fertility the increase in yield due to application of the compost in the context of Uganda had been considered. In the present situation, the yield of maize is about 1.5 tons/ha (Okoboi, 2010). According to Amoding et.al. (2010), there is around 25-30% higher yield obtained by using compost from 5-10 tons per ha. Utilizing the farm gate prices for Uganda (around USD 212/ton – actualized price[8]), the net benefits have been calculated to be USD 590,218 annually assuming that the adaptation rate is 49% among the farmers.

The following table (Table 62) provide the net benefits obtained in terms of averting environmental costs for composting the organic fraction of the MSW and utilizing them for agricultural production enhancement –

Table 62: Estimation of the environmental benefits due to utilization of MSW for producing compost

Environmental Benefits	Valuation (USD/annually)
Avoided GHG emissions	57,033
Cost of leachate treatment averted	252,678
Soil amelioration	590,218
Total environmental benefits	**899,929**

Social Impact assessment

Employment

The total amount of MSW generated in Kampala is about 2363 tons daily (Kinobe et al., 2013). The study as well KCCA reports that 30 percent of solid waste generated is being collected i.e., about 945 tons. The entire waste is being sent to Kiteezi landfill site for being landfilled. In the baseline condition where a part of the waste is being landfilled, the number of labours engaged is 20. Based on an average wage rate of USD. 65 per month for labour in the unskilled category the annual wage income is USD 15,600.

The alternative situation considers that the whole of the MSW would be utilised for the compost business. This implies that 80% of the waste which comprises the organic fraction would be required for the compost and the rest landfilled (about 473 tons). In the alternative scenario thus the labour requirement would drop to half of the baseline scenario. However, for collecting the remaining MSW of 1,418 tons it is assumed that number of workers employed by municipality and private operators to collect solid waste are 50 and 50 respectively. At the same time each of the compost plant with a handling capacity of 600

[8] The price provided by FAO (2010) is USD 202 per ton (http://www.fao.org/3/a-at587e.pdf)

tons of waste requires 45 labours. Hence the net increase in the labour is 280. Therefore the net income to the society as a whole is USD 216,000 annually based on the wage rates existing in Uganda.

Foreign Exchange Saving

The other social benefits of composting are subsidies saved due to lower use of inorganic fertilizer and foreign exchange saved due to lower level of import of fertilizers. In Uganda no subsidies are being provided for inorganic fertilizers and this might be one of the primary reasons for lower use of the inorganic fertilizers in Uganda. While Uganda has one of the highest soil nutrient depletion rates in the world, it has one of the lowest rates of annual inorganic fertilizer application – only 1.8 kg per hectare (IFPRI, 2008). The substitutability between compost and inorganic fertilizer is assumed to be 10:1. This because of the fact that in comparison while nitrogen content in compost is 4% per ton, the nitrogen content in urea is 40%. This implies that given the annual production of compost of 129,757 tons, the total area under compost application can be calculated to be 7,208 ha. The average land holding in Uganda is reported to be 1.1 ha (UBOS, 2011), hence 6,553 farmers are the primary beneficiaries. However, the adaptation rate obtained from the market study indicates that only 49% of the farmers are ready to apply compost in their farm. Considering the average price per ton of inorganic fertilizer in Uganda is USD 893 (IFPRI, 2009), the annual foreign exchange savings can be calculated to be USD 5,973,653.

Saving of Landfill area & disposal cost

The other costs that can be saved from composting the MSW are cost of landfilling area and disposal cost of landfilling. The value of land in the baseline is USD 930,000 and in the alternative scenario we are composting only 14 percent of total MSW collected. Therefore, the land cost saved would be proportional which is equal to USD. 1,395,197. Similarly, the cost of disposal at the landfilled area also gets saved by 50% percent of the baseline scenario owning to the amount of the MSW to be landfilled being halved which is USD 70,390. Therefore, the net benefit for saving of the landfill life and the disposal cost per annum amount to USD 1,465,586.

Investment in trucks in baseline & alternative scenario

The density of MSW as reported by KCCA is 0.3 ton/m^3. Moreover, the capacity of a truck is 30 m^3 and each truck makes trip of 3 times a day. Hence, to collect 1418 tons of additional MSW daily municipality needs 32 additional trucks. These trucks are required for the uncollected waste which is presently open-dumped or burned in the baseline scenario. The cost of a truck is USD. 30,000. Therefore, the cost that needs to be incurred for buying trucks is USD 960,000. It has been assumed that operations and maintenance cost of trucks is 5 percent. Hence, annually the operation and maintenance cost incurred for truck is USD. 69,780. The investment costs as well as the operation and maintenance costs are deducted from the social benefits to obtain the net social benefits for the business model.

Transportation cost & landfilling cost

The difference between the waste collected in the baseline scenario and that of the alternate scenario is 1418 tons. The effective load carried in each trip is 15 ton (Ruiz et al., 2013) and it is also assumed that each truck can travel 5 kms per litre diesel used. The present cost of diesel in Uganda is USD 1.21 and assuming 360 days of operation, the total additional transportation cost amounts to USD 137,262 per annum. This provides an estimate of the additional transportation cost to be incurred by the municipality (here KCCA) for transporting the waste which is about USD 97 per ton annually.

Additional income to the farmers in terms of the higher yield

The primary assumption made in the study to calculate the amount of the additional income of the farmers utilising compost rests on the fact that farmers only grow maize. In Kampala although there are several other crops grown, it has been assumed in the study that all the farmers grow maize, to make the analysis simplistic. According to Amoding et.al. (2010), MSW compost leads to higher yield of maize by 29% per hectare when 5 tons of compost is applied per hectare. In the present situation, the yield of maize per hectare is 1.5 tons (Okoboi, 2010) and the farm-gate price of maize is around USD 212.23 (FAO, 2012; the price has been actualized to 2015 prices considering a consolidated inflation of 5%) per tonne. The cost of the MSW compost has been considered to be USD 45 per tonne and an acceptance rate of 49% is used from the market potential of compost. The net benefit obtained with use of compost based on the values explained previously is calculated to be USD 590,293.

Other externalities from the landfilling and composting

A study by CEEPA (2011) indicates that the residents close to the Kiteezi landfill are willing to pay a significant percentage of their monthly income to avoid living near to such facilities. The study indicates that land values are affected by the presence of a landfill. The study reports that residents complained that bad odour was the most common problem and due to the fact that the waste in the landfill was not properly covered with soil (as it should have been). Other problems associated with the landfill included flies (43%), scavenging birds (25%) and rats (19.8%). The willingness to pay for residents for staying away from the landfill were classified into three categories –

- first distance category where residents within 0-600 mts. of the landfill
- second distance category where residents within 600-1200 mts. of the landfill; and
- third distance category where residents within 1200-1800 mts. of the landfill

The following table (Table 63) illustrates the willingness to pay for different categories and also shows the calculations of the net externalities. The study conducted by CEEPA however, does not show the number of households living within the three distance categories as well as it does not establish at what distance the effect of the landfill vanish. For the present study it was assumed that after 2 kms the (the distance category three), externalities are lessened and that number of households residing within the three categories is homogeneous. In Kampala, the population density is 9429 persons/km^2. Assuming 4 persons in a household, the number of households in each category is calculated to be 2357.

Table 63: Total payments for externalities from a landfill and composting site in Kampala

Category	Number of households	Willingness to pay for averting externalities (USD/year)	Total payments (externalities from a landfill and composting site)
First – within 0 - 600 mts.	2357	22.17	52254.69
Second – within 600 – 1200 mts.	2357	15.53	36604.21
Third – within 1200 – 1800 mts.	2357	6.84	16121.88
Total payments			**104,980.78**

The net societal benefits derived from the large scale centralized composting business can be arrived at by utilizing all the above parameters of the savings and annual costs. The benefits accrue from employment generation, savings in foreign exchanges made from the reduced consumption of the inorganic fertilizers and savings incurred in terms of landfill life and disposal cost of the solid waste in the landfill site. In comparison the costs primarily depend on the investments made by the municipality for increasing the waste collection, the operational and maintenance costs of services and transportation of the solid waste for composting facilities and landfilling as well as the externalities to the residents to the landfill and composting site. The net benefit for the society has been calculated to be USD 6,780,233 annually.

In the social assessment, health aspects has not been considered. Health impacts from landfills or open MSW dumping is primarily associated with skin diseases (for workers) or vector borne diseases (to nearby households). However, direct one-to-one causal relationship is hard to obtain more so in terms of data. In the financial analysis, protective gear for the workers had been considered which values the health expenditure (for averting diseases). At the same time the valuation of the negative externalities take into account different menaces associated with residing near the landfill sites. These estimates as mentioned above provide a conservative approximations of health impacts with landfill and composting operations at a large scale.

Financial Analysis

This section presents the financial feasibility analysis and results of business model considering production of from large scale centralized compost plant. As explained previously, to utilize the whole waste of the city, 4 large scale plants of 600 tons each had been considered. The financial analysis incorporated in the socioeconomic analysis escalates linearly the economic and financial costs presented in the financial analysis of the 600 tons plant in the financial report. The financial viability of the 4 compost plants is analyzed simultaneously based on Return on Investment (ROI), Net Present Value (NPV) and Internal Rate of Return (IRR) valuation criteria. The capital cost for each of the compost plant considered is taken to be USD 5306 per ton. The capital costs includes the following entities –

- construction and building,
- machine and equipment,
- Environment Impact Assessment,
- Investments for CDM

The project life of the plant is assumed to be 15 years. The financial assessment of the 4 plants operating in the city shows positive net profit excepting for the first year. The IRR of the proposed business is 23% which is above the discount rate and the Rate of Investment (ROI) is 27% implying that revenues are high enough to recover all costs of the business. This is also observed that the benefit-cost ratio is more than 1 (1.37) indicating that financially the model is viable (Table 64).

Table 64: Financial results of Large Scale Centralized Compost Business Model (USD)

	Years											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Total investment cost:	12,735,600											
Total revenues		3,746,441	5,403,437	5,851,718	6,223,858	6,540,092	7,424,083	7,679,657	7,911,653	8,125,564	8,325,489	....
Total production and other costs		1,549,474	1,688,092	1,768,784	1,848,292	1,927,744	2,038,448	2,120,725	2,204,949	2,291,538	2,380,842	....
Depreciation		785,708	785,708	785,708	785,708	785,708	785,708	785,708	785,708	785,708	785,708	....
Interest Payments		1,818,062	1,598,062	1,026,062	278,062	-	-	-	-	-	-	-
Profit before tax		(406,802)	1,331,576	2,271,165	3,311,798	3,826,641	4,599,927	4,773,226	4,920,997	5,048,319	5,158,940	....
Income tax		-	319,578	545,080	794,831	918,394	1,103,983	1,145,574	1,181,039	1,211,597	1,238,146	....
Net profit		(406,802)	1,011,998	1,726,085	2,516,966	2,908,247	3,495,945	3,627,651	3,739,958	3,836,723	3,920,795	....
Cash flow	(12,735,600)	378,904	1,797,704	2,511,792	3,302,673	3,693,954	4,281.652	4,413,358	4,525,664	4,622,429	4,706,501	....
Discount rate	12%											
NPV	17,540,347											
IRR	23%											
ROI (Financial)		3%	14%	20%	26%	29%	34%	35%	36%	36%	37%	....
ROI (Financial average)	27%											

Socioeconomic Assessment of the business model

The socioeconomic analysis of large scale compost business model is performed by putting monetary value on all quantifiable cost and benefits in order to calculate the NPV, benefit cost ratio (BCR) and ROI for the business model. The previous sections have estimated the net benefits from the different impact assessments considering both the costs and benefits associated with the business at a city scale (the entire waste is consumed by the 4 large scale plants of 600 tons to produce compost). The consolidated socio-economic results are presented in Table 65. The analysis looked at the potential impact of compost business model at three levels where the levels range from including the direct benefits and costs that affect the business entity to including indirect benefits and costs to other sectors. The annual social and environmental benefits and costs from the business were discounted at a rate of 12% to obtain the present value of social and environmental impacts.

The large-scale compost model, has a positive NPV when only the direct economic/financial benefits are accounted and also has BCR of more than 1 implying that the business model is financially feasible. The business model additionally performs better when the financial and environmental costs and benefits are taken into account. The business model becomes further economically feasible when all externalities are included in the analysis. The NPV when all externalities are considered is USD 69,132,856 and the BCR is 5.42. Thus, major contribution to the economic feasibility of the business is from the social benefits - employment generation, savings in foreign exchanges made from the reduced consumption of the inorganic fertilizers and savings incurred in terms of landfill life and disposal cost of the solid waste in the landfill site. The total NPV value of the social benefits of the business is USD 44.5 million with major benefits coming from the. Thus the large scale compost business model is both socially and financially feasible.

Table 65: Net socio-economic results of Large-Scale Compost model

Socio-economic result (USD/year)	Financial value	Financial and environmental value	Social, environmental and financial value
Financial result:			
NPV	17,540,347	17,540,347	17,540,347
Environmental benefit:			
Value of net GHG emission saving		7,014,212	7,014,212
Social benefit:			44,578,297
Benefit:Cost ratio (BCR)	**1.37**	**1.93**	**5.42**
NPV	**17,540,347**	**24,554,559**	**69,132,856**
ROI (average)	**27%**	**37%**	**67%**

Sensitivity Analysis

Sensitivity analysis was performed to identify variables which have important effects on the socio-economic impacts of the business model. The discount factor, tipping fees per ton of waste, pricing of negative externalities by the residents, cost for leachate treatment, increase in yield due to application of compost, price of the inorganic fertilizers. The following table (Table 66) elaborates the assumptions made on the stochastic variables.

Table 66: Variables selected for the socioeconomic assessment of the stochastic model for Large Scale Compos

Variable	Unit	Distribution specified	Source
Discount rate	%	*Triangular*: (10%, 12%, 15%)	Assumed

Tipping fees	USD	*Triangular*: (2, 3, 5)	Assumed
Economic value negative externalities	USD	*Uniform Distribution*	All the WTPs for three distance categories were assumed to be uniformly distributed
Cost of leachate treatment	USD	*Triangular*: (10,12,15)	Johannessen 1999
Increase in yield of maize	%	*Triangular*: (25, 28, 30)	25-30% Amoding et.al. (2010)
Price of inorganic fertilizers	USD	*Triangular*: (800, 893,1000)	IFPRI, 2008

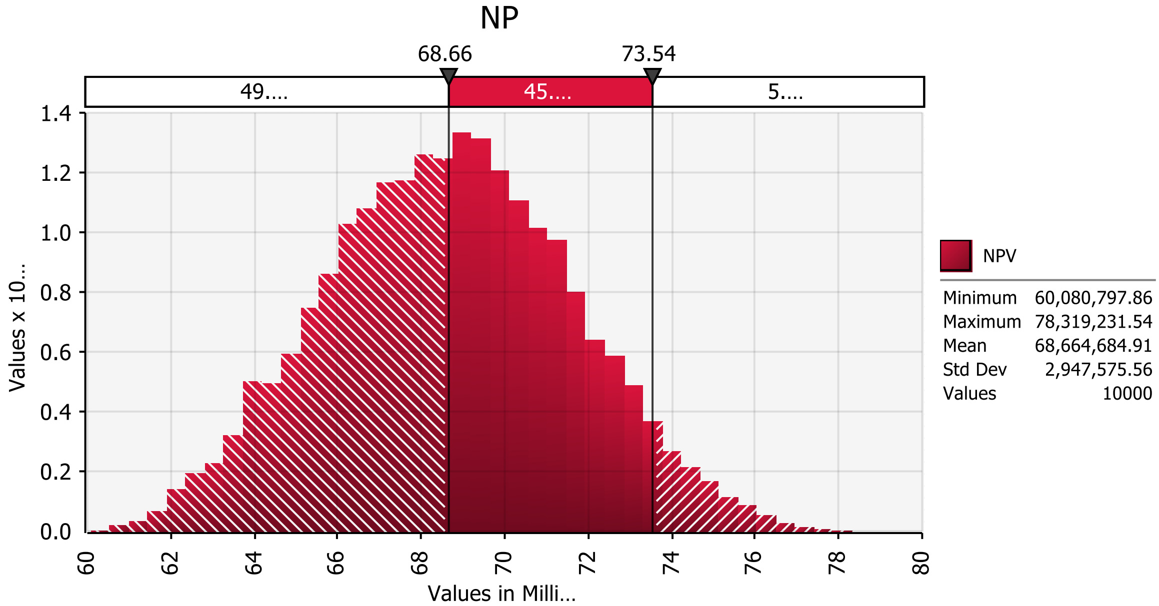

Figure 13: Probability Distribution of NPV (net benefits) derived from the large scale composting of MSW

The above Figure (Figure 13) shows the probability distribution obtained for the NPV based on the stochastic variables described above. The probability distribution obtained shows that the mean NPV of the net societal benefits (benefits over and above costs) for such business operating at a scale which takes up all the agrowaste of the city is USD 68.66 million. The above figure also shows that the probability that the net benefits will fall below the mean NPV is 49.8% which projects a medium variability of the NPV.

Conclusion

This study assessed the socio-economic impact of a composting business model in Kampala, Uganda. The socio-economic analysis is conducted based on the valuation of financial, environmental and health benefits and costs associated with the business model. The following conclusions can be drawn from the study:

- Composting plant can reduce the GHG gas emissions and leachate production and thus reduces the chances of air pollution, water pollution and soil pollution.
- Composting plant can produce sufficient revenue from collection of MSW and selling of compost.
- Use of compost may increase the soil productivity.
- Composting of MSW can reduce the health risks sufficiently as we increase the amount of composting.
- Composting can reduce the import of inorganic fertilizer and thus save foreign exchange.

- Composting plant can also raise the price of land in the adjacent area to landfill site or open dumping space.

Socio-economic impact assessment of High value Fertilizer Production for Profit in Kampala

Introduction

This business model focusses on processing urban waste that contains valuables such as nutrients and solid materials that can be recycled. The business can be set up either by a private or a public entity or even jointly as a public-private-partnership (PPP). Large scale recovery and reuse of nutrients from MSW as compost and night soil as super compost could generate revenue for the public entity from the waste that had would otherwise have to be disposed of at cost and make available partially subsidized compost to farmers for reuse as nutrients and soil conditioner. The entity benefits from cost savings, new revenue generation, and public satisfaction which is one of the primary motive of the public bodies. Public benefits from reduced indiscriminate disposal and improved environment through proper waste management practices and local jobs. Farmers benefit from availability of compost and higher agricultural productivity and incomes. Environment benefits from sustainable solid waste management practices and less waste disposal to landfills. Municipality could generate significant income from its several revenue streams – sale of regular compost and super compost to farmers and bulk sale for landscaping, and re-selling non-degradables to recycling firms at higher prices. This nevertheless requires capital investment in composting plant and ongoing costs for its operation and maintenance, which could potentially also come from central government subsidy and direct capital investments. The municipality has the in-built incentive to undertake those investments to help save costs and generate new revenue. The enabling environment for such investments is also ripe as municipality has the mandate to adopt sustainable waste management solutions, and almost unlimited supply of free waste feedstock and often does not require a permit from others for composting but must provide for monitoring of compost quality and quality assurance for safety of public health and environment and gain market penetration for compost. Most municipalities have access to such services for ensuring compliance with quality safeguards or can partner with a local university for quality analysis at cost. Sale of non-degradable such as plastics and metals to recycling firms can generate additional revenue, minimizing dependence on subsidies, and to may move the model from recovering costs to generating profits. Opportunities for making profits could entice private entities to partner with the public entity and bring win-win outcomes for the stakeholders.

Given the context of Kampala this report investigates the socio-economic impacts of producing compost using municipal solid waste and faecal sludge. The potential economic, environmental, Social and health impacts of composting plant needs to be assessed to ensure its sustainable development. In this study, we evaluated the socio-economic impacts of fortifier production using municipal solid waste and faecal sludge with annual production capacity of 600 tons of fortifiers annually. The socio-economic analysis is conducted based on the valuation of economic, Social, environmental and health benefits and costs associated with the business model.

Technological description of fortifier production using municipal solid waste and faecal sludge

The technological process of producing fortified compost includes two phases (Nikiema et. al., 2013). The first phase consists of – (i) drying, (ii) sorting, (ii) second sorting and shredding, (iii) co-composting and (iv) grinding. The second phase consists of – (i) enrichment, (ii) pelletizing, (iii) drying and (iv) packaging. Drying includes emptying of fecal sludge from public latrines and domestic septic tanks in the drying bed to get solid fecal sludge (main raw material). Usually 3 Drying beds of 240 m^2 each can produce 2tonnes of solid fecal sludge each in 2 weeks. While the fecal sludge is dried, the Municipal Solid Waste (MSW) is initially sorted and carried out off - site at the refuse dumps (markets) to remove plastics and other non-degradable materials. The second sorting of the MSW takes place onsite followed by shredding. Subsequently the organic market waste is added to the solid fecal sludge in the ratio 3:1 and co-composted using windrow composting (150 m^2 platform carries 3 tons of co-compost). This is followed by drying the matured compost and it takes about 60 days to produce a matured compost. The matured co-compost is further grinded into smaller particles using grinder.

The initial step towards second phase starts with enrichment of the co-compost. The finely grinded co-compost is mixed with starch (which acts as a binder), ammonium sulphate (to enrich it with nitrogen) and water. The composition of starch, ammonium sulphate and water are 3%, 7% and 26% respectively. The mixer from the enrichment stage are put into the pelletizer to form pellets. The pelletized compost are then sun dried on a platform which takes about 2-3 days. The dried pelletized composts are sieved, weighted and packaged in size according to suitability.

Overall approach to socio-economic impact assessment

The socio-economic analysis of a project is concerned with its viability from a societal perspective and answers the questions of whether it is economically rational to proceed with the project (De Souza et al., 2011). In contrast to a financial analysis, socio-economic analysis provides a more comprehensive investigation on the effects of a proposed project, takes a broader perspective and determines the project's overall value to society. The analysis, therefore, includes benefits and costs that directly affect the business entity running the project and the effects of the project on households, governments and other businesses outside of the business.

First, we have evaluated the current scenario in Kampala which is denoted as baseline scenario with the help of cost-benefits analysis. Total Municipal Solid Waste generated in Kampala is 1000 tons daily. It is assumed that 70 percent of solid waste generated is collected i.e., 700 tons are collected. Out of these 700 tons 30 percent of this MSW generated goes to landfill and 70 percent goes for open dumping. In Kampala city the amount of solid faecal sludge generated daily is about 16 tons which is equivalent to 192 m3 of watered faecal sludge. We assume that only 60 percent of the total faecal sludge generated in Kampala city is being collected. Moreover, we assume that 60 percent is collected by municipality and 40 percent is collected by private operators. All collected faecal sludge is open dumped indiscriminately.

Second, we have assumed that a composting plant produces 600 tons of fortifiers annually using municipal solid waste and faecal sludge will be established. Then the cost benefit analysis of this plant is being done and compared with the baseline scenario.

Third, we have increased the number of plants to such an extent so that all of the municipal solid waste and faecal sludge generated in Kampala can be handled. The cost-benefit analysis of this scenario is also being analyzed and compared with the baseline scenario.

In the following section describes the assumptions made, scenarios modelled and data sources used for assessing the Social, economic, environment and health impacts of the faecal sludge composting model.

Environmental Impact

Environmental Costs in the Baseline Scenario

Green House Gas Emissions

In the baseline condition, the amount of MSW that is collected and landfilled is around 37-40%. The rest of the uncollected waste assumed to be open-dumped or burned within the temporary storages. In contrast, the alternative scenario projects that for 13 plants to generate 1000 tons of high valued fertilizer, about 23,131 tons of MSW is required annually. This waste which can otherwise be utilized, stay in the open dumps or burned emitting greenhouse gases. The amount of GHG gas emissions from

MSW is calculated to be 0.1534 tons Co_2-equivalent/ton in the context of Kampala. This is derived from the first order decomposition equation as recommended by UNFCC. In this study it is assumed that carbon credits will be traded in Carbon Emission Reduction (CER) units as CER is suited for large scale projects and are sold in volumes that are targeted to clients seeking small reductions to offset their footprints. The CER unit is equivalent to a reduction of 1 ton of CO2 equivalent emissions (Reuster 2010). Based on the World Bank (2014), carbon credit prices in 2013 is about USD 0.51 (€ 0.37) per kgCo_2 - equivalent. Therefore, the amount of greenhouse gases which can be averted by co-composting MSW as well as fortifying is estimated to be USD 1,810 annually.

However, there are also emissions from the project which arises mainly from the additional transport of the collected MSW from the temporary storages to the fortifier plant site. This is in contrast with of FS collection and transport. In case of FS, the entire FS that is collected is send to the WWTP at Bugolobi, a part of which is partially treated or otherwise disposed off. The emissions from transportation of MSW is the environmental cost for the model. The following table (Table 67) shows the amount of GHG emissions due to transportation of the MSW.

Table 67: Economic value of the GHG emitted by transportation of the Faecal Sludge

Parameters	Values	References
Amount of MSW open-dumped	23,131 tons/annum	Calculated
Carrying Capacity of the trucks	15 tons	Ruiz et al., (2013)
Number of trips required	1542	Calculated
Amount of distance travelled in each trip	50	Assumed
Average distance travelled per litre of diesel	5 kms./lts	Assumed
Total Diesel consumption	15,421 lts.	Calculated
Co_2 emissions per litre of diesel	2.67 Kg Co_2/lts	Ruiz et al., (2013)
Amount of GHG emitted	**41,274 kg Co_2 – eq.**	
Economic value of GHG emitted	**21,049 USD/annum**	

Surface water pollution

In the baseline scenario open dumped MSW and faecal sludge have higher chances to run into surface water and discharge Nitrogen (N), Phosphorous (P), suspended solids (SS), biological (BOD) and the chemical demand (COD). The LVEMP study on pollutant loads (COWI 2002) indicates that due to urban wastewater and runoff pollutants loading in the Lake Victoria shows that total Nitrogen, Phosphorous, and BOD loading from Uganda into Lake Victoria are annually 767, 484, and 2145 tons respectively. The environmental value of pollutions for pollutants like N, P, SS, BOD and COD is provided by a study by UNEP (2010). The following table (Table 68) illustrates the calculation of the benefits derived by the introduction of fortifier business with reference to reduced surface water pollution. The environmental values express the damage the pollutant causes to the environment expressed in the monetary terms.

Table 68: Estimation of the economic value of the pollution load by discharging partially treated wastewater from WWTP

Pollutants	Environmental value of pollution (USD/m^3)[9]	Environmental value of pollution (USD/year)
N	0.6060	128,452.61
P	0.3087	65,434.52
SS	0.00252	534.2
BOD	0.0164	3,476.3
COD	0.0832	17,635.74

[9] The values obtained from the report were actualized to the present value since they were expressed in terms of 2010 euros.

Total	**1.107**	**215,533.37**

In the baseline condition, a part of the FS is being treated in the WWTP only partially and the rest is being discharged. In the alternative scenario, the FS in entirety is being utilised by the fortifier plant and hence the pollution of water (both surface and to certain extent groundwater) can be averted. The estimated benefits is shown in the above table (USD 215,533 per annum).

Reclamation of soil properties

The reclamation of soil properties is estimated by calculating the increase in agricultural productivity. In the alternate scenario, co-compost and fertilizer is being produced and utilized. Thus the net benefits accrue only to the alternate situation. The amount of co-compost/fortifier applied per hectare of land is assumed to 5 tons. According to Amindo et. al (2010), use of compost increases yield by 25-30%. The estimated benefits from using compost is thus estimated with the increased yield and the farm-gate prices of maize produced. The net benefits estimated for applying co-compost for maize production was thus calculated to be USD 241,418 per annum.

Economic Impact

This section presents the financial analysis of the introducing the business model in Kampala. In the financial assessment, a representative plant was assumed to produce 1000 tons of co-compost and fortifier (powdered and pelletized). The socioeconomic model however considers that the entire FS collected would be utilised for producing compost along with organic fraction of the municipal solid waste. It was estimated that given the capacity of the representative plant modelled for the financial assessment, 13 plants of similar capacity would be required in Kampala which would consume the entire collected FS of the city and part of the organic fraction of the MSW. The socioeconomic model assumes constant returns to scale to escalate the financial figures of a representative plant for that of 13 plants. The rationale behind such constant returns to scale is suitable particularly when the representative plant is earning profit such that it ensures a condition whereby at least as profitability as the representative plant is maintained. Assumption of constant returns to scale implies that inputs and outputs are scale up or down proportionately. Usually with increase in plant size, there are possibilities of increasing returns to scale. However, there also exists an optimal plant size for businesses after which decreasing returns set in. Therefore, if there is increasing returns to scale, and the representative plant is earning profit, when the plant size increases, the profitability increases given similar conditions of market conditions. Thus, constant returns ensures at least as profitability as the representative plant.

The following table (Table 69) provides the income statement for the 13 plants taken together. The production in the 13 plants would yield 13,000 tons of co-compost and fortifier which includes – (i) 7,800 tons of co-compost, (ii) 2,600 tons of fortifier (powdered form), and (iii) 2,600 tons of pelletized fortifier. In the socioeconomic model the market conditions used in the financial assessment have been retained. It is assumed that in the first year of production the firm would be able to create a demand for only about 50% of the market which would pick up in the later years but never reach 100%. Following the financial assessment of the representative firm it can be seen that excepting the first year, the business model earns a net profit. The table also illustrates that the financial assessment of the business model yields a positive NPV (USD 1,170,913) and an IRR above the discount rate with a 14% return on investment. The Benefit-cost ratio of the business model is also greater than 1 (1.27) implying that per dollar invested fetches 27 cents more than the dollar. The inference from observing the results for these parameters leads to the judgement that the business model operating at the city level at a higher scale is financially feasible even with a larger scale.

__Table 69: Financial Analysis of the Fortifier Business Model__

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Total Investment	**4,875,000**															
Revenue																
Sale of co-compost		438750	482040	558558	575315	592579	610363	628667	647530	666952	686959	707577	728793	750659	773188	796380
Sale of enriched co-compost		487500	535600	620633	639249	658424	678171	698516	719472	741065	763295	786188	809783	834067	859092	884871
Sale of pelletized co-compost		780000	856960	993005	1022788	1053481	1085084	1117636	1151163	1185691	1221272	1257906	1295645	1334515	1374542	1415778
Total Revenue		**1706250**	**2722472**	**3020065**	**3085231**	**3152351**	**3221486**	**3292694**	**3366039**	**3441584**	**3519395**	**3599541**	**3682091**	**3767117**	**3854695**	**3944899**
Expense																
Labour and Input costs		229320	236197	243282	250588	258102	265850	273819	282035	290498	299208	308191	317434	326950	336765	346866
Sales and Marketing costs		202566	208637	214903	221351	227994	234832	241878	249132	256607	264303	272233	280397	288808	297479	306397
Supplies, Utilities & Other costs		160719	170950	187694	192868	198211	203710	209378	215202	221208	227396	233779	240344	247104	254059	261235
O & M costs		141050	145288	149643	154128	158756	163514	168415	173472	178672	184041	189553	195247	201110	207142	213356
Total Expense		**733655**	**761072**	**795522**	**818935**	**843063**	**867906**	**893490**	**919841**	**946985**	**974948**	**1003756**	**1033422**	**1063972**	**1095445**	**1127854**
Profit before depreciation, interest and tax		**972595**	**1113528**	**1376674**	**1418417**	**1461421**	**1505712**	**1551329**	**1598324**	**1646723**	**1696578**	**1747915**	**1800799**	**1855269**	**1911377**	**1969175**
Depreciation		320671	320671	320671	320671	320671	320671	320671	320671	320671	320671	320671	320671	320671	320671	320671
Profit before interest and tax		**651924**	**792857**	**1056003**	**1097746**	**1140750**	**1185041**	**1230658**	**1277653**	**1326052**	**1375907**	**1427244**	**1480128**	**1534598**	**1590706**	**1648504**
Interest		804375	704275	546975	318175	46475	-	-	-	-	-	-	-	-	-	-
Profit before tax		**(152451)**	**88582**	**509028**	**779571**	**1094275**	**1185041**	**1230658**	**1277653**	**1326052**	**1375907**	**1427244**	**1480128**	**1534598**	**1590706**	**1648504**
Income tax		-	21268	122174	187096	262626	284414	295360	306644	318253	330213	342537	355238	368303	381771	395642
Net Profit		**(152451)**	**67314**	**386854**	**592475**	**831649**	**900627**	**935298**	**971009**	**1007799**	**1045694**	**1084707**	**1124890**	**1166295**	**1208935**	**1252862**
Cash Flow	**(4875000)**	168220	387985	707525	913146	1152320	1221298	1255969	1291680	1328470	1366365	1405378	1445561	1486966	1529606	1573533
Discounted Cash Flow		150,196	305,069	481,869	550,594	616,602	582,727	534,736	490,729	450,369	413,351	379,394	348,247	319,673	293,459	269,408
NPV	**1,170,913**															
IRR	**16%**															
ROI (Financial)		-3%	1%	7%	11%	16%	17%	18%	18%	19%	20%	20%	21%	22%	23%	24%
ROI (Financial Average)	**14%**															

Social Impact assessment

Impact on Employment

The business model involves utilization of two different waste streams – municipal solid waste and the faecal sludge. As mentioned previously, presently in Kampala there are 227 temporary storage sites of which more than 25% is being used for open dumping. In around 35 storage areas, wastes are being collected for landfilling. The collection rate of MSW is constrained to only 37 - 40% of the entire city waste. Faecal sludge management in Kampala is also in a similar state. The number of workers engaged in MSW collections and transportation was not available and hence it was assumed that about 50 workers are presently engaged for collection and transportation of waste. This assumption is made with a strong assumption that there is no handcart collection which is costlier to other forms of collection primarily due to higher labour costs associated with lower tonnage carried per load (around 120 Kg for 2 labours, Asia Foundation, 2008).

The data on faecal sludge (FS) provided by NWSC which was used to forecast the amount generated and collected shows that while 742 m^3/d is being generated only about 369 m^3/d (i.e. about 50%) is being collected and send to the Buglobi Wastewater Treatment Plant (WWTP). However, it has been estimated by EAWAG (2014) that the total volume of faecal sludge produces annually is around 546,439 m^3. Of this volume, about 483,697 m^3 is from onsite sanitation of which only 70% is accessible by the collecting trucks (338,588 m^3). However, only about 211,968 m^3 (62%) is collected and transported to the WWTP. This implies that about 927 m^3 of faecal sludge is produced daily and 580 m^3 is collected for the WWTP. The capacity of the WWTP constraints the amount that is treated which is about 400 m^3 per day. The truck counting study conducted by SANDEC (2014) indicates that at present there are 64 trucks of different capacity operating in Kampala for collection of the faecal sludge. It is being assumed that each of this truck employs two workers – a driver and an assistant to empty the pits and transport the faecal sludge to the WWTP. Based on this assumption, it can be estimated that the total number of employment generated by the business is about 128.

Given the baseline condition of the employment, to estimate the impact on employment due to introduction of the business model, it is imperative to consider the following issues –

- Number of additional jobs created in the collection and transportation of MSW
- Number of additional jobs created for collection and transportation of FS
- Number of the jobs created in the fortifier plants
- Number of the jobs lost – primarily since the rag pickers would lose their jobs.

The assumption made on the number of workers employed for MSW collection and transportation entails that each labour handles around 19 tons of waste per day. Therefore, to handle extra waste, the employment generated is marginal (about 4 extra labour). However, to collect and transport the faecal sludge, number of workers required is substantial compared to the additional jobs for MSW. The alternative scenario considers that additionally about 180 m^3 of faecal sludge is collected and the entire faecal sludge is used for co-compost and fortified fertilizer. In Kampala, the capacity of trucks emptying the pits varies between 1.8 – 10 m^3. The data from the Pit Emptying Association (PEA) shows that about 50% of these trucks have a capacity of 4 m^3. For the present study this capacity is assumed to determine the number of trucks required for collecting and transporting the additional faecal sludge. However, it is also assumed that there be no additional investments for the additional trucks. The additional labour required would use the existing trucks in different shifts scheduled. The additional costs for the owners would be the operation and maintenance of the trucks. Utilizing the assumptions mentioned above, it can be observed that the number of trucks required per day for 180 m^3 of FS would be 45 and hence the number of additional workers required is 90.

The financial analysis of the Fortifier plant shows that for each plant there is a requirement of 16 labours including managerial staff. Therefore total employment generated for the city considering 13 such plants which would absorb the entire FS for production gives an estimate of 208 labours. The job loss related to the business model is primarily due to the fact that some of the rag pickers would have reduced earnings due to reduction of waste in open dumps. The number of rag pickers losing livelihood earnings or displaced is assumed to be 20, due to unavailability of accurate data. To estimate the economic value of the additional labour requirement differential wage rate has been assumed. The wage rates for the additional labour to collect and transport FS is assumed to be same as that in the fortifier plant (i.e. USD 100 per month). The average wage rate of a worker in the fortifier plant was calculated to be USD 100, while it was observed that a truck driver receives USD 4 for a trip. Hence monthly wage rate would be around USD 120-150, and that of a helper would be with USD 100. Therefore on an average an equal rate is assumed to equal that of a worker in the fortifier plant which includes semi-skilled and skilled labour force. However, the wages for rag pickers are considered as that of the unskilled labour wage rates in Kampala (i.e. USD 65 monthly). The above figures shows that the net benefit for the society as a whole is USD 342,000 annually due to employment creation over and above the baseline situation.

Economic benefits to the truck operators

In Kampala, households are charged USD 72 each time their pits are being emptied. The following table (Table 70) shows the break-up of the charges/costs obtained from the PEA (EAWAG, 2014). The table indicates that for each trip, an owner of the truck receives USD 44. In the baseline situation assuming the truck volume to be 4 m^3, the number of trips were calculated, based on which the fraction accruing to the owner was determined. The costs associated with each trip was deducted and it was estimated that the net earnings for the society would be USD 500,800.

Table 70: Breakdown of fees paid by the households showing the fraction going to owner of the truck

Total Emptying fee paid by the household	USD 72
Fraction to the driver for services	USD 4
Fraction for PEA for membership	USD 4
Fraction to NWSC as discharge fee	USD 4
Fraction for fuel costs	USD 16
Fraction to owner of the truck	USD 44

In the alternative scenario, the assumption of the shares for different charges were retained. However, the number of trips to collect and transport the whole of the waste was additionally included. At the same time, an extra 2% O&M costs were added to the fraction of the costs shown above. This was primarily due to the reason that the owner had to increase the shifts/trips per day with the same truck (and the investment costs for additional trucks can be curtailed). The net benefit in the alternative scenario was calculated to be 846,872; which implies an annual net earnings for the truck owners over the baseline condition by USD 356,072.

Health benefits

The most common disease burden with poor FS management is diarrhea. For the socioeconomic analysis, it was assumed that the disease burden which is incurred in the baseline condition due to partial and no treatment could be averted. To estimate the economic value, DALYs was used along with the economic value of each DALY. The DALY values were used since the use of the cost-of-illness approach is not recommended (WHO, 2009) for macroeconomic studies. Traditional cost-of-illness studies employ a static, partial and inconsistent approach to estimating the macroeconomic impact of disease and injury at the societal level. The net health benefit that can be averted by treatment of FS is estimated to be USD 16,430,040 annually for Kampala. It can be calculated from these figure that the percapita value of health burden is USD 9.9.

In comparison to the DALY values, the WSP estimates has also been utilized for the study which provides a lower range for the health aversion costs. Uganda loses about 389 billion Uganda Shillings each year, which is equivalent to USD 5.5 per person (WSP[10], 2012). The costs included in the estimation are – (i) loss in access time (USD 8.1 million), (ii) premature death (USD 146 million), (iii) productivity losses whilst sick or accessing healthcare (USD 1.1 million), and (iv) expenditure on healthcare (USD 21 million). This estimates can be utilized to find out the health benefits by introduction of proper collection and reuse of the FS and reducing the disease burden arising from diarrheal diseases. However, all of the above mentioned cost categories are not used for calculating the disease burden, as shown in the following table (Table 71). The per capita cost due to poor sanitation is estimated to be USD 4.5 while using the DALY measure it is calculated to be USD 9.9 per capita. For the deterministic model, the lower range was used to calculate the value of health costs that can be averted and it was estimated to be USD 7,451,604 annually. In the stochastic socioeconomic assessment the upper range were also considered for deriving the sensitivity of the Net Present Value (NPV).

Table 71: Estimation of the cost per-capita for health losses

Cost categories	Cost per capita (USD/annum)
Premature death	3.9
Productivity losses whilst sick or accessing healthcare	0.03
Expenditure on healthcare	0.56
Total cost per capital (USD/annum)	**4.49**

Other Social benefits in alternative scenario

Saving of foreign exchange

Apart from employment, other social benefits of composting could be reduction in use of inorganic fertilizer and hence savings of foreign exchange due to reduction of import bill through reduced import of fertilizer. Uganda government does not provide any subsidy for producing inorganic fertilizer and the entire demand for inorganic fertilizer is met from imports. Import of inorganic fertilizer in Uganda is around 45,000 tons annually. We have assumed that use of 10 tons of co-compost (derived from organic fraction of MSW and FS) would substitute 1 ton of inorganic fertilizer, while fortifier would substitute 5 tons of inorganic fertilizer. Due to differential prices, the average price of imported fertilizers is assumed for the analysis and that importing price of one ton of fertilizer is USD. 893. The reduction in import bill for fertilizer is estimated to be USD. 1,625,260.

The net social benefits derived from – (i) employment generation, (ii) increased earnings for truck owners, (iii) aversion of health costs, and (iv) savings from foreign exchange are provided in the following table (Table 72).

Table 72: Estimation of the Social benefits for the fortifier business model

Parameters considered for societal benefits	Net Benefits (USD/annum)
Employment generation	342,000
Increased earnings for truck owners	346,072
Aversion of health costs	7,451,609
Savings from foreign exchange	1,625,260
Total	**9,764,936**

Socioeconomic Analysis

The socioeconomic analysis of Co-compost and fortifier business model is performed by putting monetary value on all quantifiable cost and benefits in order to calculate the NPV, benefit cost ratio (BCR) and ROI for the business model. The consolidated socio-economic results are presented in Table 73. The analysis looked at the potential impact of the business model including the direct and indirect

[10] https://www.wsp.org/sites/wsp.org/files/publications/WSP-ESI-Uganda.pdf

benefits and costs that affect the business entity with respect to other sectors. The annual social and environmental benefits and costs from the business were discounted at a rate of 12% to obtain the present value of social and environmental impacts.

The socioeconomic assessment of the compost and fortifier business model shows a gradual increase when only the direct benefits are accounted for results in negative NPV and BCR of less than 1 implying that the business model is not financially feasible. The business model performs better when the financial and environmental costs and benefits are taken into account. However, the net positive incremental benefits from the environmental impacts are not high enough to make the business model feasible as the NPV is still negative and the BCR is less than 1. The business model becomes economically feasible when all externalities are included in the analysis. The NPV when all externalities are considered is USD 108,883,864 and the BCR is 5.11. Thus, major contribution to the economic feasibility of the business is from the social benefits. The total value of the social benefits of the business is USD 108 million with major benefits coming from the additional income to farmers and jobs created for the local community which accounted for 86% of the total value of social benefits. Thus the ESCO business model is economically feasible but not financially feasible.

Table 73: Net socio-economic results of High value fertilizer model

Socio-economic result (USD/year)	Financial value	Financial and environmental value	Social, environmental and financial value
Financial result:			
NPV	1,170,913	1,170,913	1,170,913
Environmental benefit:			
Value of net GHG emission saving		2,811,661	2,811,661
Social benefit:			
Savings in energy costs for end users			4,686,365
Additional income to farmers and employment			10,439,936
Health Benefits			50,751,865
Benefit:Cost ratio (BCR)	**1.27**	**1.85**	**15.36**
NPV	**1,170,913**	**3,982,575**	**65,878,167**
ROI (average)	**14%**	**25%**	**224%**

Sensitivity analysis

Sensitivity analysis was performed to identify variables which have important effects on the socio-economic impacts of the business model. The variables which were used to construct the stochastic analysis were – (i) discount factor, (ii) carbon credit price, (iii) farm gate price of maize, (iv) increase in yield of maize due to use of compost, (v) fraction of price paid to truck owner for use of transportation of FS, and (vi) costs related to avert negative health impacts. Different values of these variables were used to assess the resulting effect on the overall socioeconomic feasibility of the business model. The following table (Table 74) elaborates the assumptions made on the stochastic variables.

Table 74: Variables taken to be stochastic for estimating the distribution function

Variable	Unit	Distribution assumed	Reference
Discount rate	%	Triangular (10, 12, 15%)	Assumed ranges between 10% to 15%
Economic values of the health aversion costs	USD/capita	Triangular (5.5, 6.5, 10)	Assumed 6.5, the lower and higher ranger is obtained from WSP and DALY estimates
Increase in yield due to compost	%	Triangular (25%, 29%, 30%)	Amindo et. al. (2010)

Farm-gate prices of the compost	USD/ton	Uniform (212, 220)	Assumed
Carbon prices	USD/ton CO2eq	Uniform (0.51, 1.50)	Assumed
Fraction paid to truck owner for FS transport	USD/trip	Uniform (44, 50)	Assumed

The above variables used to model estimate the following probability distribution shown in the fig (Figure 14). The stochastic model shows that the mean NPV is USD 115 million which can be achieved with 48% assurance level. The confidence interval (95%) of the NPV shows results obtained between (USD 67 – USD 179 million). If the NPV from the deterministic model is considered to be the benchmark (since most of the values of the variables are the present case scenario, particularly for the uniform distribution) the probability of achieving the NPV would be very high since the NPV derived from the deterministic model is just marginally higher than the minimum value obtained in the stochastic variation. Thus this implies a higher feasibility of the deterministic model.

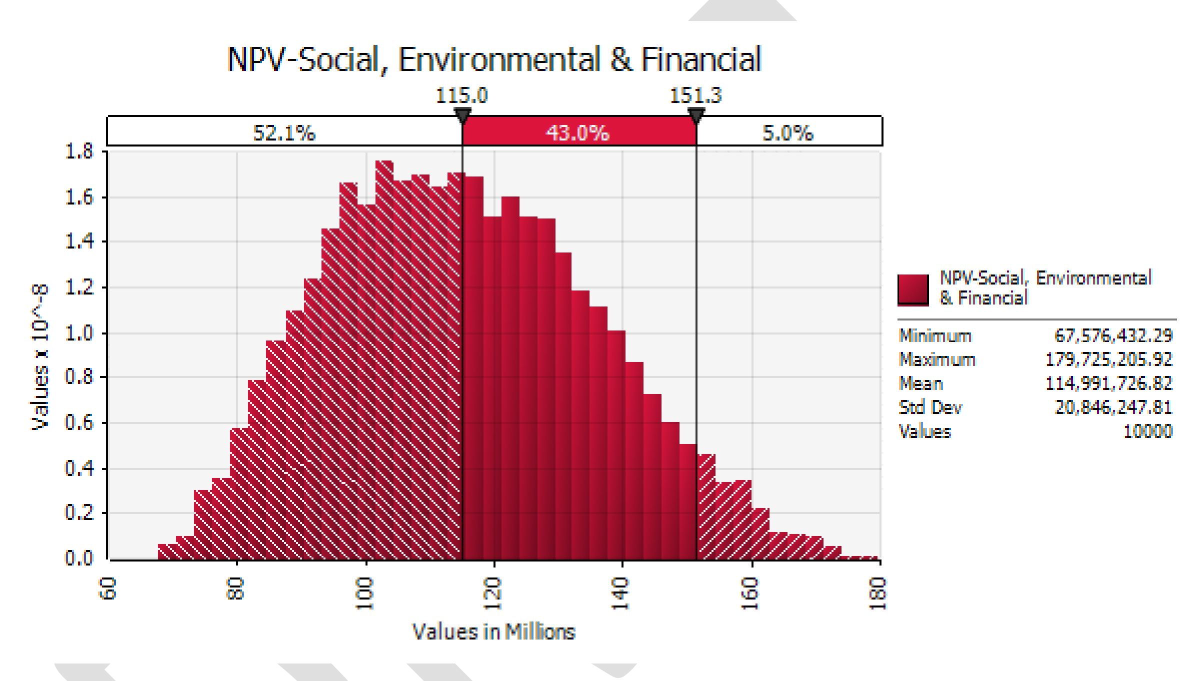

Figure 14: The Probability distribution of the NPV from the stochastic model

Conclusion

This study assessed the socio-economic impact of introducing a compost business which not only produces co-compost utilizing faecal sludge and municipal solid waste, but also earns revenue by producing high value branded fertilizer by fortification of the compost produced with inorganic minerals. The socio-economic analysis is conducted based on the valuation of net social and environmental benefits and also accommodating for the financial assessment of the business at a scale which assumed that the whole faecal sludge generated and accessible is utilized by the business. Given the capacity elaborated in the financial analysis, the socioeconomic model assumes a linear extension of 13 such fortifier plants established across the city to cater to the whole of FS generated and collected presently. The following conclusions can be drawn from the study:

- Composting plant can reduce the GHG gas emissions and leachate production and thus reduces the chances of air pollution, water pollution and soil pollution. All of these monetary values accruing as net benefits have been calculated and utilized for the final estimation of the net environmental benefit.

- Composting plant can produce sufficient revenue from collection of MSW and selling of compost.
- Use of compost may increase the soil productivity.
- Composting of MSW can reduce the health risks sufficiently as we increase the amount of composting.
- Composting can reduce the import of inorganic fertilizer and thus save foreign exchange.
- Composting plant can also raise the price of land in the adjacent area to landfill site or open dumping space.

Socio-economic analysis of Compost production for Sanitation Service Delivery in Kampala

Introduction

In Kampala about 84% of users have to share their toilet with on average 6.7 households (or 30.2 individuals) far below the required coverage benchmark (NADEL, ETZH, 2011). About two thirds of Kampala's slum dwellers use "shared toilet", and on average 4.3 neighboring households use a stance of a shared toilet. In addition about 14% of the people use public toilets. This business model tries to address this gap in the existing sanitation facilities in Kampala by developing and implementing a safe and sustainable sanitation service delivery system. The business concept is to set up an entity with the goal of developing sanitation products and services which can deliver safe and sustainable sanitation solutions and are scalable across locations. The business concept is thus threefold: first to provide sanitation services; second to manage and transform human excreta into safe fertilizer and soil conditioner for value creation along the sanitation value chain; and third to link the sanitation outputs with the agriculture sector to add further value with enhanced soil fertility and agricultural productivity – promoting organic food production with the reuse of nutrients recovered through innovate sanitation products and services, and linking the two sectors through win-win outcomes. The concept helps closing the nutrient loop and ensures sustainability of the sanitation products and services, (through continued use and waste collection), and its outputs (nutrient reuse) through value addition based on business principles. A unique feature of this model is that the constant revenue stream generated from the provision of toilet services could provide finance for running the composting section and safeguard the business against seasonal demand and delayed payment for compost from poor farmers.

Given the context of Kampala where a large number of households depend on public and shared toilets this report investigates the socio-economic impacts of producing compost through provision of sanitation services.

The potential economic, environmental, Social and health impacts of integrated sanitation cum composting plant needs to be assessed to ensure its sustainable development. In this study, we evaluated the socio-economic impacts of composting of faecal sludge from public toilets business with annual capacity of handling 150 tons of faecal sludge collected from 5 public toilets which has daily users of 600 each in Kampala. The socio-economic analysis is conducted based on the valuation of economic, Social, environmental and health benefits and costs associated with the business model.

Technological description for Composting from faecal sludge

Urine Diversion Dry Toilet (UDDT) operates by the principle of dehydration and composting. A UDDT separates urine from faeces at source and facilitates excreta reuse and promotes recycling of nutrients. Addition of lime, sawdust or ash after defecation leads to the sanitization of the faeces. The separated faeces is left for decomposition which lead to production of soil conditioners. UDDT is based on 3 fundamental principles of preventing pollution rather than attempting to control it, sanitizing urine and faeces and using the safe products for agricultural activities. It is an approach of "sanitize and recycle".

This business model utilizes this concept of new generation toilet which sanitizes feces and urine and recovers nutrients and other resources. The primary components of the business concept includes the development of urine diversion dry toilets, the waste collection and processing service, and its conversion into organic fertilizer for supply to farmers in the vicinity. Innovative toilet design along the line of ecological sanitation helps to separate urine and human feces at source while providing toilet services in the city centre to the general public, day-time visitors and migrants, and to inhabitants in slums, and to promote the reuse of source separated urine as urine based fertilizer, and excreta based soil conditioner product useful for the farmers.

Overall approach to socio-economic impact assessment

The socio-economic analysis of a project is concerned with its viability from a societal perspective and answers the questions of whether it is economically rational to proceed with the project (De Souza et al., 2011). In contrast to a financial analysis, socio-economic analysis provides a more comprehensive investigation on the effects of a proposed project, takes a broader perspective and determines the project's overall value to society. The analysis, therefore, includes benefits and costs that directly affect the business entity running the project and the effects of the project on households, governments and other businesses outside of the business.

First, we have evaluated the current scenario in Kampala which is denoted as baseline scenario with the help of cost-benefits analysis. In Kampala city the amount of solid faecal sludge generated daily is about 16 tons which is equivalent to 192 m3 of watered faecal sludge. We assume that only 60 percent of the total faecal sludge generated in Kampala city is being collected. Moreover, we assume that 60 percent is collected by municipality and 40 percent is collected by private operators. All collected faecal sludge is open dumped indiscriminately.

Second, we have assumed that a composting plant using faecal sludge of capacity 150 ton per year will be established. This amount of solid faecal sludge will be collected from 5 public toilets. We have assumed that per day user of each public toilet will be 600. We assume that an individual generate 140gm faces per day. Moreover, public toilet remains open for 365 days. Then the cost benefit analysis of this plant is being done and compared with the baseline scenario.

Third, we have increased the number of plants to such an extent so that all of the faecal sludge generated in Kampala can be handled. The cost-benefit analysis of this scenario is also being analyzed and compared with the baseline scenario.

In the following section describes the assumptions made, scenarios modelled and data sources used for assessing the Social, economic, environment and health impacts of the faecal sludge composting model.

Environmental Impact

The potential environmental impacts which has been considered for the present study includes –

- GHG emissions in the baseline and alternative scenario, and
- Increase in soil productivity due to use of compost

In Kampala, about 2.7% of the population is dependent on open defecation (EAWAG, 2014) while 2.5% depends on public toilets. Beyond health implications, open defecation leads to significant environmental damage due to large amounts of untreated sewage and faecal sludge discharged untreated into rivers, lakes and coastal areas. This type of pollution impacts the usability of ground and surface water, and leads to severe disruption of environmental processes and the destruction of ecosystems. However, the present study does not take into account the adverse impacts of unsafe excreta disposal on water resources since such cost figures are not available for Africa. The study conducted by Water and Sanitation Programme (WSP, 2012) estimates the costs associated with improper sanitation in Uganda. The estimated costs are USD 5.5 per capita per annum which does not include costs due to water pollution due to contamination resulted from open defecation. While conducting the sensitivity analysis, the present study assumes a value between USD 5.5 and USD 10 (which is obtained utilizing the DALY values for Uganda) to evaluate the health impacts. It is assumed that such higher estimates would also incorporate the costs arising from open defecation on environment particularly water pollution.

GHG emissions in the baseline and alternate scenario

The GHG emissions in the baseline situation is estimated from the amount of methane generated per person/day. A study conducted by Winrock International, India (2008) estimated the generation of methane which is about 0.00108 kg./person/day. This leads to an annual production of about 36 tons of CO_2 equivalent. Such costs are amended in the alternative scenario where public toilets are being constructed with an assumption that the densely populated central division of Kampala can be served along with the immigrants to the city particularly with jobs in the city during the daytime.

However, in the alternate scenario where the business model is being introduced there lies possibility of GHG emissions from the transportation of – (i) partial compost to the composting and packaging unit, and (ii) distribution of the compost to the retail/wholesale units. The transportation of the compost from the public toilets and from packaging units has been modelled utilizing the financial analysis for the business model. It has been assumed in the financial analysis that each month from each of the units the partially composted matter would be transported to the maturation and packaging unit which is about 15 kms from the city. Likewise it has been assumed that the total distance travelled to distribute the compost to the retailers and wholesalers, about 1000 kms is being travelled. The average mileage of trucks is considered to be 5 km/lt and the average CO_2 emission from burning diesel in these automobiles is about 3 kg/lt. The estimated GHG emissions thus calculated is 8.3 tons of CO_2.

In this study it is assumed that carbon credits will be traded in Voluntary Emission Reduction (VER) units as VER is suited for small scale projects and are sold in volumes that are targeted to clients seeking small reductions to offset their footprints. The VER unit is equivalent to a reduction of 1 ton of CO_2 equivalent emissions ((Reuster 2010). Based on the World Bank (2014), carbon credit prices in the EU ETS range about USD 5-9 ((€4-7) in 2014 while prices were USD 18 ((€13) in 2011. In this study it is assumed that carbon credits are worth on average USD 7 per ton of CO_2 equivalent (Table 75). The total annual value of carbon credit is USD 543. However value of the other emission savings that have acidification potential (NO_x) were not included in the analysis.

Table 75: Annual value of GHG emission reduction from sanitation services

Item	Amount
Total GHG emission (ton CO_2eq)	35.66
Total GHG emissions from transportation of compost (ton CO2 eq)	8.28
Net emission savings (ton CO_2eq/year)	27.39
Price of VER (USD/ton CO_2eq)	7
Total value of Carbon credit (USD/year)	**191.71**

Increased soil fertility in the alternate scenario

The increase in soil fertility is estimated indirectly based on assumption that due to increase in nutrient capture by the soil, the productivity of soil would increase and the marginal increase in the productivity is the value addition from the increase in soil fertility. Additionally, it is also being assumed that maize is being produced (since this is the major crop in Uganda) and the value added in terms of increase in soil fertility is thus dependent on the price of maize. The amount of compost applied per hectare is assumed to 5 tons which increases the productivity by 25-30% (Amindo et.al. 2010). The estimated benefits from using compost is thus estimated with the increased yield and the farm-gate prices of maize produced (USD 212 per ton). The net benefits estimated for applying co-compost for maize production was thus calculated to be USD 1,367 per annum.

Economic Impact

The financial analysis of the business incorporated the analysis from the perspective of the – (i) individual toilet unit and (ii) business as a whole. In the socioeconomic analysis, all the figures for the financial analysis is taken for the business as whole. The capital costs for the entire business includes – (i) construction of the 5 toilet facilities, (ii) storage site, (iii) machinery, equipments and tools for collection of compost and packaging, and (iv) investments towards logistic costs. Total investment cost for the entire facility is USD 57,950. It is assumed that the public toilets has a useful life of 15 years and toilet stances are assumed to have a useful life of 7 years after which they have to be replaced.

The toilet facility is assumed to have 8 toilet stances, each costing about USD 417 (NETWAS-U, 2011). Investment on toilet facility is done on the 7 and 14th year to replace toilet stances (Renwick et al., 2007; IRC, 1999). Therefore the additional investment for the 8 stances in the seventh year is included as the capital cost. In contrast, for modelling the financial viability of the public toilet, the capital cost of a constructing a public toilet is only included along with the replacement cost of the stances.

The annual operational costs of the public toilet include costs to run the toilet facility. This includes (i) cost incurred on purchasing lime which acts as a sanitizing agent, (ii) labour cost for cleaning the toilet complexes and caretaking it, (iii) cost on utilities such as electricity and water. Table 76 presents the operational costs which include toilet supplies (lime), employees to manage the facilities, utilities such as electricity and water, operation and maintenance of the facilities and annual depreciation on civil work. The average cost of toilet supplies is 1.5 USD/day based on the assumption that about 250 gms of lime is used by each individual after excretion and price of lime is 10 USD/ton. The business model assumes that every public toilet has 1 caretaker and 2 labour for cleaning the complexes. With reference to wage rate of unskilled worker employed in other businesses in Uganda, it is assumed that the monthly wages of the caretaker would be 70 USD while that of the works would be 50 USD. Prevailing tariffs for water of 0.002 USD/liter and for electricity of 0.20 USD/kwh are assumed. On the basis of established standards, the useful life of public toilet is considered to be 15 year and assuming a straight line method of depreciation, the corresponding annual depreciation is 5% (Singh and Sooch, 2004). Furthermore, annual operational and maintenance cost are assumed to be 5% of capital cost.

Table 76: Value of different parameters used in the financial model

Item	Unit	Amount	Reference
Toilet supplies	USD/day	4	Based on Umande Trust TOSHA, Kenya
Number of staff	#	3	Other Businesses employing unskilled workers
Labour rate	USD/day/person	6	Sustainable sanitation alliance, 2010
Water tariff	USD/liter	0.002	Water tariff in Uganda is USD 2 per 1000 liter
Electricity tariff	USD/kwh	0.20	Electricity tariff in Uganda
Annual exhaustion service	USD/year	380	Based on Umande Trust TOSHA, Kenya
Annual depreciation	%	5	Assuming useful life of 20 years for biogas system
O & M cost	%	5	Assumed

In addition to these costs, the operation costs of the business as a whole would include labour costs, packaging costs and transportation costs of the compost. The labour cost includes engagement of labour to collect the compost and transport it to the storage site. These labour requirements are assumed to be on a rotational basis for the 5 public toilets. In addition, it is assumed that two additional labours would also be required for packaging. This would require USD 825 monthly more than the operation of the public toilets. The packaging cost is assumed to be 0.5 USD/ 50 Kg. bag. The transportation cost includes both the transportation of the compost from the public toilet to the storage and also from the storage to different wholesalers. Based on the price of diesel in Kampala (USD 1.21/lts), the total transportation cost is being calculated, assuming that the distribution would coverage of 12000 Kms in a year. The primary income streams for the public toilets include fees from toilet use and revenue from rental space (Table 77).

Table 77: Revenue sources for the business model

Item	Unit	Amount	Reference
Toilet fee per use	USD/use	0.05-0.1	http://web.mit.edu/urbanupgrading/waterandsanitation/resources/caseExamples/narrative-form.html

Rental	USD/month	50-100	Sustainable sanitation alliance, 2010; Based on Umande Trust TOSHA business case, Kenya

The financial sustainability of the facility depends on the number of toilet users, the toilet fees, biogas use and the operation and maintenance costs. Additional revenue could be generated from selling the urine separated at source, however, in this analysis this is not considered. Daily toilet users of 500-700 persons is assumed. In the city core area, a public toilet facility of similar size serves about 70 clients per hour for an average of 11 hours per day (IRC, 1999). Demand for toilet use is low during the weekends, however, total number of operational days per year is assumed to be 365 days. Toilet fee per use in Uganda ranges from USD 0.05 to USD 0.1 based on peri-urban and urban areas. The following tables provides the financial statement which shows the profit and loss account of the public toilet and the business as a whole successively. The escalation rate assumed for the all input prices is 3% based on the inflation rate prevailing in Uganda. The financial statements of the business presented below shows that the major source of income for the business is from toilet services which accounts for 85% of the total revenues. Revenue from compost accounts for 6% and that from rent is 9%. The major costs include labour cost accounting for 60% of total cost, utilities and transportation cost accounting for 14% each and O&M cost and depreciation each accounting for 5% of total cost. The financial table also indicates a positive cash flow for the business and a net positive profit for the public toilet.

The financial statement for the business as a whole is summarized below showing all the income streams, operational costs and expenditures on interest and tax payment by the business entity (Table 78). The estimated NPV is USD 55,339 for the business is positive with an IRR of 26% greater than the discount rate (i.e. 12%). The Benefit-Cost Ratio (BCR) is 2.07 which implies that a dollar invested yields a positive return over the investment and as had been explained in the financial analysis, the business seems to financially feasible.

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Total Investment	**57,950**							16,680							16,680	
Revenue																
Total Revenue		**64,694**	**66,634**	**68,633**	**70,980**	**73,109**	**75,302**	**77,562**	**80,535**	**82,951**	**85,440**	**88,003**	**90,643**	**93,362**	**96,163**	**99,048**
Expense																
Labour and Input costs		28,388	29,239	30,116	31,020	31,950	32,909	33,896	34,913	35,960	37,039	38,150	39,295	40,474	41,688	42,939
Sales and Marketing costs		5,858	6,034	6,215	6,402	6,594	6,791	6,995	7,205	7,421	7,644	7,873	8,109	8,353	8,603	8,861
Supplies, Utilities & Other costs		6,530	6,715	6,906	7,102	7,305	7,513	7,728	7,949	8,177	8,411	8,653	8,902	9,159	9,423	9,695
O & M costs		2,078	2,140	2,204	2,270	2,338	2,408	2,481	2,555	2,632	2,711	2,792	2,876	2,962	3,051	3,142
Total Expense		**42,853**	**44,128**	**45,441**	**46,794**	**48,187**	**49,622**	**51,100**	**52,622**	**54,190**	**55,805**	**57,469**	**59,182**	**60,947**	**62,765**	**64,637**
Profit before depreciation, interest and tax		21,841	22,507	23,192	24,186	24,922	25,681	26,462	27,913	28,761	29,634	30,534	31,461	32,415	33,398	34,411
Depreciation		4,975	4,975	4,975	4,975	4,975	4,975	4,975	4,975	4,975	4,975	4,975	4,975	4,975	4,975	4,975
Interest		12,314	10,114	6,814	2,414	-		-	-	-	-	-	-	-	-	-
Income tax		1,092	1,780	2,737	4,031	4,787	4,969	5,157	5,505	5,709	5,918	6,134	6,357	6,586	6,822	7,065
Net Profit		**3,460**	**5,638**	**8,667**	**12,766**	**15,160**	**15,736**	**16,330**	**17,433**	**18,077**	**18,741**	**19,425**	**20,129**	**20,855**	**21,602**	**22,371**
Cash Flow	**(57,950)**	8,435	10,613	13,642	17,741	20,135	20,711	4,625	22,408	23,052	23,716	24,400	25,104	25,830	9,897	27,346
Discounted Cash Flow		7,531	8,460	9,710	11,275	11,425	10,493	2,092	9,050	8,313	7,636	7,014	6,444	5,919	2,025	4,996
NPV	**55,339**															
IRR	**26%**															
ROI (Financial)		4%	7%	10%	15%	18%	18%	19%	20%	21%	22%	23%	23%	24%	25%	26%
ROI (Financial Average)	**17%**															

Table 78: Income statement for the business model

Social Impact assessment

Employment generation

The alternate scenario in contrast to the baseline scenario generates employment through the introduction of the business model. The business model includes 5 public toilets which is being operated by a single entity. The individual public toilets employs labours and caretakers. Additionally there are persons employed for compost production, packaging and distribution employed in the composting and packaging unit. The financial analysis shows that the total number of jobs created in the business is 21 and assuming an average wage rate of USD 100 per month, the estimated total benefit for the business is USD 25,650.

Health Impacts

The health benefits of introducing the business of public toilets is estimated primarily for the Kampala central division, since it is assumed that it caters to the populace in the central division and also for job-immigrants from other parts of Kampala in the daytime. Water and Sanitation Programme (WSP, 2012) estimated the per capita costs for Uganda for poor sanitation facilities. The estimated cost by WSP is USD 5.5 per capita. This costs does not include (i) epidemic breakout, (ii) funeral costs, (iii) water pollution, (iv) cognitive development, (v) tourism. The DALY estimated shows that per capita health costs that can be avoided due to improved sanitation facilities is USD 9-10 per capita. For the present estimation, a conservative estimate has been used since the environmental impacts of open defecation is not included in the value suggested by WSP study. The present study assumes a value of USD 6.5 for estimating the health benefits – a dollar more than that suggested by WSP. The estimate provided by WSP is being later employed as a lower range in contrast to the higher range obtained using DALY values for the sensitivity analysis. The inclusion of the health benefits using DALY values also helps in accounting for the environmental benefits in an indirect way. The estimated health benefits are thus estimated to be USD 518,629 annually considering the entire population of the Kampala central division.

Other Social costs & benefits in Baseline and alternative scenario

Saving of foreign exchange

In the alternative scenario, apart from employment, other social benefits of composting could be reduction in fertilizer subsidy and saving of foreign exchange due to reduction of import bill through reduced import of fertilizer. Uganda government does not provide any subsidy for producing inorganic fertilizer. Import of inorganic fertilizer in Uganda is around 45,000 tons annually. The study assumes that application of compost produced can substitute inorganic fertilizer in the ratio 5:1 from importing i.e., 30 tons. We assume that importing price of one ton of fertilizer is USD. 893 (IFPRI, 2008). Hence, the reduction in import bill for fertilizer will be USD. 26,832.

Socioeconomic Analysis

The present summarizes the analysis presented in the above sections – (i) environmental impacts, (ii) economic/financial impacts and (iii) social impacts of introducing the business model at the city level. In the previous sections all the benefits and costs that could be valorized using a monetary value had been estimated and hence in the present section, the whole range of benefits and costs are evaluated calculating the NPV, benefit cost ratio (BCR) and ROI for the business model. The consolidated socio-economic results are presented in Table 79. The annual social and environmental benefits and costs from the business were discounted at a rate of 12% to obtain the present value of social and environmental impacts.

The business model involving the sanitation services and production of shows a positive NPV and BCR of more than 1 implying that the business model is financially feasible. The business model adds to positive results when the financial model is integrated with the environmental costs and benefits as well as the social aspects. However, the net positive incremental benefits from the social considerations are very high since it incorporates some of the negative environmental impacts in the baseline which are benefits earned from proper sanitary infrastructure in the alternative scenario. The business model is socioeconomically feasible when all externalities are included in the analysis. The NPV when all externalities are considered is USD 942,030 and the BCR is 69.38. Hutton, Haller and Bartram (2007) estimated the global benefits-costs of improved water and sanitation facilities as USD 3-34. Comparison of such results with that of introduction of financially feasible estimates leads to the inference that with positive environmental benefits attached to it, the returns for per dollar invested can go high up to USD 70. This is particularly because the major contribution to the economic feasibility of the business is from the social benefits. The total value of the social benefits of the business is USD 876,075 which is 93% of the entire benefits. The major social benefits coming from the aversion of the health costs followed by additional income to farmers and savings from foreign exchanges due to reduced inorganic fertilizers used.

Table 79: Net socio-economic results of business model delivering sanitation and marketing compost

Socio-economic result (USD/year)	Financial value	Financial and environmental value	Social, environmental and financial value
Financial result:			
NPV	55,339	55,339	55,339
Environmental benefit:			
Value of net GHG emission saving		10,617	10,617
Social benefit:			
Employment and savings of foreign exchanges			357,446
Health Benefits			518,629
Benefit:Cost ratio (BCR)	**2.07**	**2.25**	**69.38**
NPV	**55,339**	**65,955**	**942,030**
ROI (average)	**17%**	**19%**	**682%**

Sensitivity analysis

Sensitivity analysis was performed to identify variables which have important effects on the socio-economic impacts of the business model. To determine the sensitivity of the socioeconomic model the variables considered for the financial sensitivity was included along with other variables used to evaluate the environmental and social costs and benefits. The variables considered for the sensitivity analysis included – number of users per day, discount rate, the economic values of the health aversion costs, increase in yield due to compost, farm-gate prices of the compost and carbon prices. The following table (Table 80) elaborates the assumptions made on the stochastic variables.

Table 80: Variables used for stochastic simulations of the sanitary service model

Variable	Unit	Distribution assumed	Reference
Number of toilet users per day	users/day	Triangular (400, 600, 700)	Based on public toilets in Uganda and TOSHA bio-centre in Kenya
Discount rate	%	Triangular (10, 12, 15%)	Assumed ranges between 10% to 15%
Economic values of the health aversion costs	USD/capita	Triangular (5.5, 6.5, 10)	Assumed 6.5, the lower and higher ranger is obtained from WSP and DALY estimates
Increase in yield due to compost	%	Triangular (25%, 29%, 30%)	Amindo et. al. (2010)
Farm-gate prices of the compost	USD/ton	Uniform (212, 220)	Assumed
Carbon prices	USD/ton CO2eq	Uniform (7, 10)	Assumed

The above variables used to model estimate the following probability distribution shown in the fig (Figure 15). The stochastic model yields that the mean NPV is USD 1.036 million which can be achieved with 47% assurance level. The confidence interval (95%) of the NPV shows results obtained between (USD 675,462 – USD 1.53 million). If the NPV from the deterministic model is considered to be the benchmark (since most of the values of the variables are the present case scenario, particularly for the uniform distribution) the probability of achieving the NPV is around 28%.

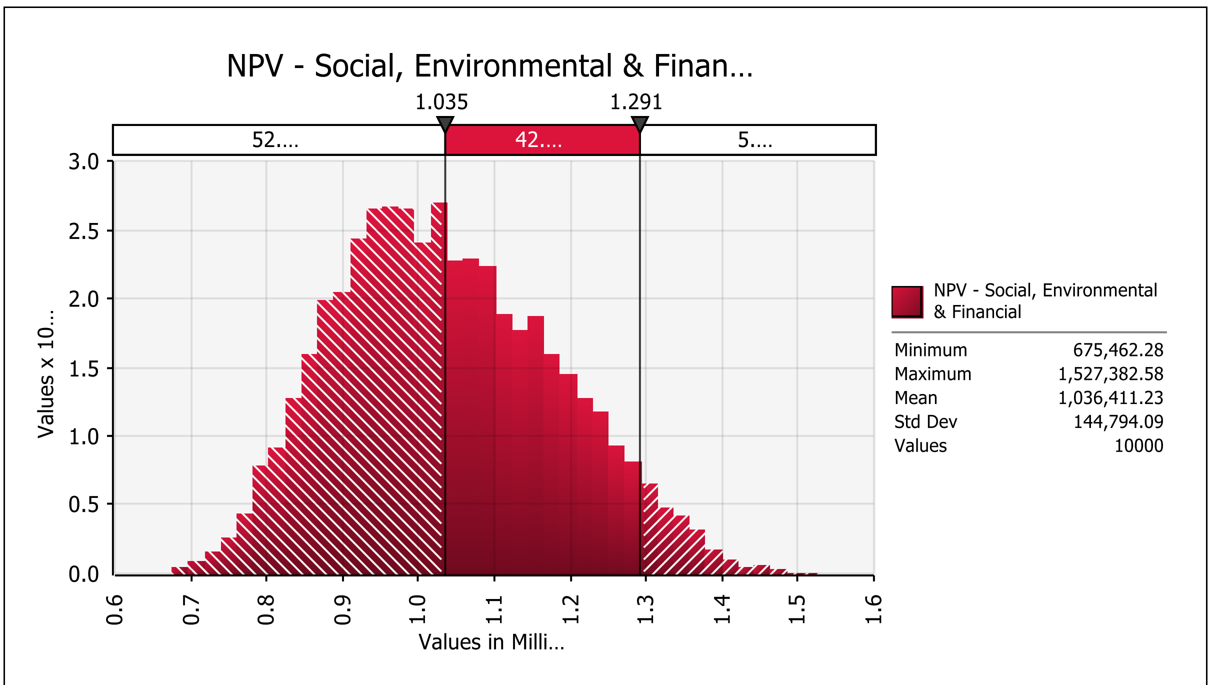

Figure 15: The Probability distribution of the NPV from the stochastic model

Conclusion

This study assessed the socio-economic impact of sanitation service Company which is also involved in compost business generated from the faecal sludge in Kampala, Uganda. The socio-economic analysis is conducted based on the monetary valuation of environmental and health benefits and costs associated with the business model and integrating it to the financial analysis of the business. The following conclusions can be drawn from the study:

- From the socioeconomic perspective, findings from the study indicate that the use of faecal sludge for composting has higher positive effects on health and environment. The health benefits estimated for the model includes to certain extent the environmental benefits of improved water supply. The socioeconomic analysis shows that major benefits achieved is through aversion of health costs (around 90%).
- Utilizing compost has positive effects on increase in future yields as the soil captures more of nutrient and in turn there is a net savings of foreign exchanges as inorganic fertilizers are not subsidised and hence farmers do not optimally use inorganic fertilizers. With soil reclamation and partial substitution of inorganic fertilizers the potential of yield rises addressing food security and higher income for the farming households.
- The introduction of compost in agriculture also has higher impacts on labour demand since it is labour intensive and thus the income generated in the agricultural sector is also circulated by consumption of labour for agricultural produce boosting the economy with employment generation.

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