2015

Resource Recovery and Reuse (RRR) Project

Socioeconomic Analysis of RRR Business Models, Hanoi City Report

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Swiss Agency for Development and Cooperation SDC

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Data used in the analysis is from 2013 and 2014.

Denomination: 1 USD = 1 USD (2014);

1 USD = 21,400 Vietnamese Dong

VND: Vietnamese Dong

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 Hanoi

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 6: Manure to Power	This business model can be initiated either by livestock processing factories such as meat or diary processing factories or by small, medium and commercial-sized livestock farms to utilize livestock waste to produce off-grid power for rural electrification with the support of regional government and NGOs. The business model can be commissioned by regional government in villages where there is no access or limited access to the national electricity grid and where the community's primary economic activity is livestock farming.
WASTEWATER REUSE	
Model 8: Beyond cost Recovery: the Aquaculture example	The business concept is to cultivate aquaculture while treating wastewater generated from the city. The process of treating wastewater is through cultivation of duckweed. The treated wastewater and duckweed as fish feed is used to cultivate fish
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.
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 16: Subsidy-free community based composting	The business concept is similar to Large-Scale composting for revenue generation except that the operation of the business model is at smaller scale and requires subsidy to make it viable.
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.

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 ofsocioeconomic impacts of similar business cases in Hanoi
- **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 Vietnam 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 Vietnam. 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 Vietnam, 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 Vietnam. 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 Hanoi. 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 Hanoi 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 Hanoi 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 Hanoi.

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

Business Models	Base case	Alternative	Remarks
System Boundary of the Energy Models			
Dry-fuel manufacturing (Agro-waste to briquettes)	3819 tons of organic waste accumulates daily in the peri-urban areas which includes wastes from rice husk and straw, corn, sweet potato, cassava waste, sugarcane waste, soya bean and peanut	The alternative scenario assumes that briquette plants targets the wastes from rice husk. Thus this assumption leads us to the fact that 15 large scale plants as had been considered in the financial analysis (consumption on 2222 tons of agro-waste per year) would be needed to consume the whole of the waste.	
Energy service companies at scale (Agro-waste to energy - electricity)	3819 tons of organic waste accumulates daily in the peri-urban areas which includes wastes from rice husk and straw, corn, sweet potato, cassava waste, sugarcane waste, soya bean and peanut	Financial analysis considers 8 MW plant utilizing 250 tons/ day. The alternative scenario assumes that electricity generating plant targets 75% of the wastes from rice husk. This implies that 10 plants have to be considered in SEA which takes up all of the organic waste generated.	
Manure to power	The 3 major livestock companies do not produce power from animal manure	The alternate scenario considers all the 3 major livestock companies produce electricity each with a capacity of 218 kW	
System Boundary for the Wastewater models			
Beyond cost recovery: the aquaculture example	Out of 651,400 m^3 of wastewater generated per day, 248,100 m^3/d is being treated. It has been planned that the remaining wastewater is to be treated in two WWTP of treatment capacity about 200,000 m^3 /d. No wastewater aquaculture is being practiced	In the alternate scenario, the socio-economic study models three different pond sizes – 14.4 ha. 4.5 ha. and 1 ha. Based on the capacity of the existing WWTP and the planned WWTPs, number of ponds required with their estimated size has been calculated. In each of these cases, while calculating the pond size (area) it has been assumed that aerobic maturation pond is used for the final level of treatment.	
On cost savings and recovery	Treated wastewater of volume 248,100 m^3/d is being discharged into waterbodies. The amount	In the financial analysis two scales of WWTP is being modelled – 42,000 m^3/d and 200,000 m^3/d. The alternate scenario considers 2 large	In the financial analysis no investments costs for setting up the WWTP is considered. It is being

Business Models	Base case	Alternative	Remarks
	of wastewater treated and planned to be treated is 651,400 m^3/d.	size and 3 medium sized treatment plant (following the financial analysis), treating 596,100 m^3/d.	assumed that the WWTP already exists and additional investments for electricity generation, water treatment and compost recovery is analyzed. Similarly in the socioeconomic assessment, the same assumption of existence of WWTP is maintained. In the socio-economic assessment the existing smaller plants of 13,000 m^3/d, 2,300 m^3/d & 3,700 m^3/d are not being considered since it is not technically feasible to produce electricity from these pilot small plants.
System Boundary for the Nutrient Models			
Large-scale composting for revenue generation	The municipal waste that is being collected is open-dumped and landfilled. In Hanoi, The total waste generated per day is 6500 tons of which 55-60% of the total generated amount of MSW (about 3600 tons) is actually collected and transported to landfill. The rest is open-dumped along banks and embankments of the rivers.	6 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)
Subsidy-free community based composting	The municipal waste that is being collected is open-dumped and landfilled. In Hanoi, The total waste generated per day is 6500 tons of which 55-60% of the total generated amount of MSW (about 3600 tons) is actually collected and transported to landfill. The rest is open-dumped along banks and embankments of the rivers.	The amount of waste targeted to be collected and composted through de-centralized operation is about 4500 tons per day. The alternate scenario assumes formation of 104 co-operatives at the ward levels and 7 such co-operatives are linked with a business entity responsible for collection of waste.	It is assumed that decentralized system of waste collection is more efficient and hence a greater amount of waste is being targeted.
High value fertilizer production for profit	Fecal sludge is dumped or being partially treated	The scale of operation for the fortifier is 9 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.	

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-waste to briquettes)	**Model 2A: Energy Service Companies at Scale - Agro-Waste to Energy (Electricity)**	**Model 6: Manure to power**
Scale of operation	15 plants, each having a production capacity of 2000 tons per year	10 plants each with a production capacity of 8 MW	8 plants each with a generating capacity of 218 kW
NPV Financial (in USD)**	3,125,002	(32,898,502)	1,004,009
NPV Financial & Environmental (in USD)**	4,971,054	27,976,857	727,503
NPV Financial, Environmental & Social (in USD)**	14,025,925	179,098,933	10,709,636
B:C Ratio	10.17	3.58	6.58
ROI	100%	53%	464%

** Calculated for life cycle term using Discount Rate of 12%

K = 1,000

Wastewater Reuse Business Models

In the context of Hanoi, 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 Hanoi which was from the waste supply and availability data based on sewer network in Hanoi. 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 8: Beyond cost recovery: the aquaculture example	Model 9: On cost savings and recovery
Scale of operation	An estimated 63 aerobic ponds of 14.4 ha. 4 ponds of 4.5 ha and 3 ponds of 1 ha. is being used for aquaculture within the existing and planned WWTPs.	The capacity of the wastewater treatment plant is considered to be 42,000 m^3 and 200,000 m^3. 2 large size plants and 3 medium sized plants are used for evaluation
NPV Financial (in USD)**	6,088,209	(14,848,445)
NPV Financial & Environmental (in USD)**	8,486,791	491,047,520
NPV Financial, Environmental & Social (in USD)**	53,232,036	679,337,423
B:C Ratio	8.8	27.63
ROI	155%	443%

** 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 16: Subsidy-free community based composting	Model 17: High value Fertilizer Production for Profit
Scale of operation	6 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	104 co-operatives with 15 business entities is said to serve about 70% of the population in Hanoi	9 plants are assumed to consume the entire faecal sludge produced and each with a production capacity of 1000 tons in a year
NPV Financial (in USD)**	(43,45,607)	(783,795)	(2,75,9413)
NPV Financial & Environmental (in USD)**	9,815,107	14,010,280	2,533,644
NPV Financial, Environmental & Social (in USD)**	60,789,713	74,502,891	21,770,187
B:C Ratio	4.81	14	7.77

ROI	31%	200%	74%

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

Summary assessment of financial feasibility of RRR Business Models

Table 6provides a summary overview of the criteria used for feasibility of RRR business models for Hanoi 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%	**Not Feasible**
$30\% < P (NPV < NPV_{mean}) < 50\%$	< 1	< 100%	
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 Hanoi 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 Hanoi. 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	49.4%	10.17	100%	**High**
Model 2A: Energy Service Companies at Scale - Agro-Waste to Energy (Electricity) – *8MW Profit Maximization Model*	55.1%	3.58	53%	**Low**
Model 6: Manure to power	53.9%	6.58	464%	**Medium**
WASTEWATER REUSE				
Model 8: Beyond cost recovery: the Aquaculture exampled	52.27%	8.8	155%	**Medium**
Model 9: On Cost Savings and Recovery	48.8%	27.63	443%	**High**
NUTRIENTS				
Model 15: Large-Scale Composting for Revenue Generation - 600 tons	50.1%	4.81	31%	**Low**
Model 16: Subsidy-free community based composting	53.8%	14	200%	**Medium**
Model 17: High value Fertilizer Production for Profit	48.4%	7.77	74%	**Low**

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

Model 1 A – Dry fuel Manufacturing – Agro-industrial waste to briquettes: The business model is economically and financially viable. Dry fuel manufacturing in Hanoi is economically more feasible compared to the other business models. 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 at scale (Agro-waste to energy - electricity): This business model has a lot of potential when we consider electricity generation which Vietnam imports from China. The total potential for all agrowaste being utilized for electricity generation in Hanoi 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 Vietnam (the price of the feed-in-tariff for renewable energy particularly agrowaste is yet to be decided in Vietnam), this model faces a stiff challenge financially. The next challenge for the business model is the accessibility of the agrowaste as mentioned previously.

Model 6 – Manure to power: This business model has a medium feasibility based on the socio-economic assessment of the model. The societal benefits are particularly high for the model boosting the benefit-cost ratio for the business. The primary benefits accruing to the business arises from savings in the import of electricity from China and also reduction in the wastewater run-off with a high BOD content from the farms.

Model 8– Beyond cost recovery: the aquaculture example: In the Phyto-remediative process it is assumed that the wastewater treatment plants already exists and the ponds used for aquaculture are aerobic maturation ponds. The business model has medium feasibility, but has a high potential of employment generation particularly among the fishing communities as it provides opportunity for them to rear fish in these ponds. At the same time, the potential undesirable outputs from wastewater can be flushed off during natural treatment.

Model 9 – On Cost savings and recovery: 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. 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. In Hanoi with the newly planned WWTPs coming up there is a lot of potential for electricity generation. 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. 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 not feasible. The socioeconomic assessment considered the 6 plants of same scale for absorbing the waste of the city. The economic feasibility of the model is similarly low in spite of the fact that there are savings in terms of GHG emissions. In fact the amount of GHG emissions are quite low to ensure the feasibility of the business.

Model 16 – Subsidy free community based composting: This is a similar model to that of Model 15 excepting for the fact that the collection is done in a decentralized system according to wards. The financial viability depends primarily on the user fees which in Hanoi is quite low. This business model although medium feasible socio-economically has a lot of potential with appropriate user fees among the communities for collection of waste. This business model increases the collection potential of the MSW and would also help in producing better quality of compost with segregation of the waste at the source.

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.

Socio-economic impact assessment of Dry Fuel Manufacturing (Agro-industrial waste to briquettes) Business model in Vietnam

Introduction

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 Hanoi include agricultural residues (such as maize cobs, rice husks, groundnut husks etc.), wood processing waste (such as sawdust) and organic municipal solid waste. Table 8 shows the characteristics of agricultural residue and the available amount in Hanoi.

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

Agricultural residue	Ash content[a] (%)	Annual production (tons/year)
Bagasse	1.8	2,900
Rice husks	22.4	1,200,000
Maize cobs	1.2	234
Ground nut shells	6.0	9,700

Source: EAWAG, 2014; [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 non-carbonized briquette making enterprise in Vietnam, 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).

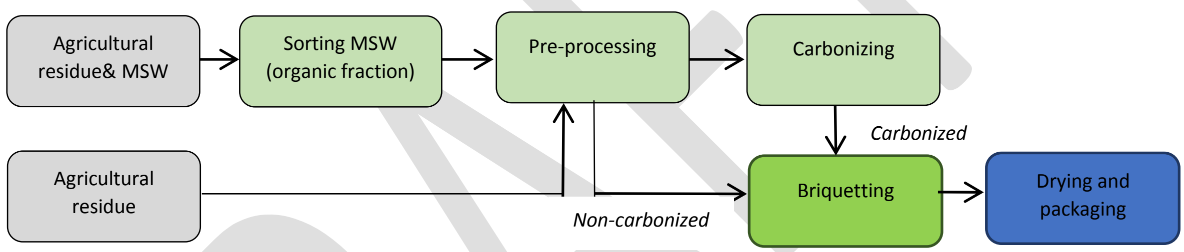

Figure 1: Process diagram of briquetting

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, 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 socioeconomic assessment targets the rice husk that is being produced in a huge quantity (1.2 million tons). The study assumes establishment of 15 plants with a capacity of producing 2000 tons of briquettes in each year utilizing rice husk as the main waste stream. 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.

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 Hanoi 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 4,000 ton briquette production, 4400 ton 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 gas turbine as Vietnam relies on electricity generated from gas turbine. The gas fired plants emit 0.35kg - 0.4kg CO2 per kWh.

Table 10: CO2 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
CO_2 emissions from electricity plant	Kg/kwh	0.4	

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 30% when wood is used and 50% when wood is replaced by briquettes (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 (Kg emission/kg of fuelwood)	Briquette use (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. 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 5. 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 6. 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 emission from the production and use of 4,000 tons of agro-residue briquette fuel is shown in Figure 2. GHG emissions avoided by reducing firewood combustion and burning of agro-waste are 7874 ton and 206 ton respectively. The savings are mainly from avoided fuelwood use. Under the briquette business scenario, the highest GHG impact is from briquette combustion which is around 3304 ton. GHG emission from transport and electricity use during production of briquette is around 22 tons. 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 4755 ton CO_2eq per annum.

Figure 3 shows other criteria emissions, SO2, NOx and CO under baseline and briquette business scenario (4000 tons of briquettes). The untreated or burning of agro-residue under the baseline scenario contributes the highest SO2 and NOx 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 emission 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 4,000 tons of briquette are respectively 8.8 tons of SO2, 13.06 tons of NOx and 152 tons CO per annum.

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_2equivalent 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 (NOx and SO2) were not included in the analysis.

Table 14: Annual value of GHG emission reduction from briquette business (4,000 tons)

Item	Amount
Total GHG emission savings (ton CO_2eq)	8,080
Total GHG emissions from briquette business (ton CO2 eq)	3,325
Net emission savings (ton CO_2eq/year)	4,755
Price of VER (USD/ton CO_2eq)	7
Total value of Carbon credit (USD/year)	**33,286**

Social impacts

Additional income from agricultural residue waste

As a predominantly agricultural country, Vietnam generates large quantities of agricultural residues. The major agricultural residues include rice husks. Data provided by the government indicated that annual agricultural wastes available is 2.2 million tonnes (Vietnam Environmental Monitor, 2004). 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. Farmers get 8 USD/ton by selling agricultural residue to briquette plant. Thus, on average, the briquette plant contributes to providing additional income to the farmer of 9.44 USD/ton of briquette produced, resulting in total annual additional income of 35,200 USD from 4,000 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 15 full time workers earning a total annual salary of USD 39,360.

Savings for end-users

A study by WHO and UNDP (2009) shows that 70% of the urban population in Vietnam uses Kerosene for cooking purposes. Replacing kerosene 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 kerosene is 43.1 MJ (IPCC/OECD methodology; Hu et al., 2014). In addition to the calorific value of the energy sources, the replacement value of briquettes depends on the efficiency of cook stoves used in institutions. Based on calorific value only, the use of 1 Kg of briquette would conserve 0.52 lts of kerosene. Assuming efficiency of stoves of 30% and 50% respectively when kerosene and briquettes are used for cooking, the actual price per MJ of useful energy is 0.055 USD in fuelwood equivalent and 0.034 USD in briquette equivalent. At the current price of fuelwood (0.24 USD/kg), using kerosene priced at 1.07 USD/lts has the potential cost saving of 13% as compared to fuelwood used in institutional stoves. Total annual cost savings for end users from utilizing 4,000 tons of briquettes is estimated to be USD 460,868 annually.

Table 15: Savings to end users from using briquettes

Item	Fuelwood	Briquette
Kerosene replaced by briquettes (lts) (A)	2,079,814	4,000,000
Heating value (MJ/kg) (B)	43.1	16.8
Price (USD/ton) (C)	1.07	0.282
Efficiency of stoves (%) (D)	30%	50%
Actual price per useful energy (USD/MJ) *(E= C/(B*D)*	**0.055**	**0.034**
Total energy value of kerosene replaced (1000 MJ) *(F=A*B*D)*	**40,338,000**	
Savings from briquette use (%) *(G= [E (Fuelwood)-E(Briquette)]/E(Fuelwood)*	**42%**	
Total savings from shifting to briquettes (USD/year) (E*F*G)	**460,868**	

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 (WHO, 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; WHO, 2002).

Briquettes are direct replacement to fuelwood used in institutions which have a combustion efficiency of 30%. 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. Health impacts associated with fuelwood and briquette use are not quantified in this study.

Financial analysis

In this section, the financial analysis of the briquette is presented. 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 186,700. The production capacity of the plant is 4,000 tons/year and 4,400 tons of agricultural residue will be purchased at a price of 29 USD/ton as feedstock. The selling price of briquettes is 150 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 3,200 USD. Other costs include marketing and distribution (9 USD/ton), packaging cost (4 USD/ton) and utilities (6 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 Vietnam 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. 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 2,70,327 while for second year where 85% of production is assumed to be sold, it is USD 50,998 and for the rest of the period mean net profit increases as proportion of sales to production increases to 95%. Assuming a discount rate of 12% and useful life of 15 years, the business model resulted in a mean NPV of USD 605,185 and IRR of 57% indicating that the business model is financially viable.

Table 16: Financial results of briquette business (USD)

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year12	Year 13	Year 14	Year 15
Total capital cost	1867000															
Total revenue		2482521	2833384	3410685	3649433	3904894	4178236	4470713	4783663	5118519	5476815	5860193	6270406	6709334	7178988	7681517
Total production and other cost		2341495	2513312	2707249	2895813	3097577	3313465	3544464	3791634	4056106	4339090	4641883	4965872	5312541	5683475	6080376
Depreciation		88920	88920	88920	88920	88920	88920	88920	88920	88920	88920	88920	88920	88920	88920	88920
Profit before interest and tax		**52105**	**231152**	**614517**	**664700**	**718396**	**775852**	**837328**	**903109**	**973494**	**1048805**	**1129389**	**1215614**	**1307874**	**1406592**	**1512221**
Interest payment		126023	121523	99023	54023	-	-	-	-	-	-	-	-	-	-	-
Profit before tax		**(73917)**	**109629**	**515494**	**610678**	**718396**	**775852**	**837328**	**903109**	**973494**	**1048805**	**1129389**	**1215614**	**1307874**	**1406592**	**1512221**
Income tax			21926	103099	122136	143679	155170	167466	180622	194699	209761	225878	243123	261575	281318	302444
Net profit		**(73917)**	**87704**	**412395**	**488542**	**574717**	**620681**	**669863**	**722487**	**778795**	**839044**	**903511**	**972491**	**1046299**	**1125274**	**1209777**
Cash flow	(1867000)	15003	176624	501315	577462	663637	709601	758783	811407	867715	927964	992431	1061411	1135219	1214194	1298697
Discount rate																
Discounted value of cash flows		15002.65	176624	501315	577462	663637	709601	758783	811407	867715	927964	992431	1061411	1135219	1214194	1298697
Present value of cash flows	11711463															
NPV	**$2083335**															
ROI (Financial)		**-4%**	**5%**	**22%**	**26%**	**31%**	**33%**	**36%**	**39%**	**42%**	**45%**	**48%**	**52%**	**56%**	**60%**	**65%**
ROI-average (Financial)	**37%**															
BCR-Financial	**6.27**															

Socio-economic results

The consolidated socio-economic results are shown in Table 10. 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 10.17, NPV of USD 14,025,925 and ROI of 100% when only direct benefits from the briquette production are taken into account[1]. The ROI increases from 37% to 51% when environmental benefits are taken into account and to more than 99% when the environmental and social impacts are taken into account. The ROI taking all externalities into account is 99% showing about 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 9,054,925 with major benefits coming from the savings in energy costs to end users accounting. 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	Social, environmental and financial
Financial result:				
	NPV	3,125,002	3,125,002	3,125,002
Environmental benefit:				
	Value of net GHG emission saving		1,846,051	1,846,051
Social benefit:				
	Savings in energy costs for end users			1,437,601
	Additional income to farmers			3,596,136
	Value of employment			4,021,134
Total social benefit				9,054,871
NPV		**3,125,002**	**4,971,054**	**14,025,925**
ROI		**37%**	**51%**	**100%**
BCR		**6.27**	**6.93**	**10.17**

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 elaborates the assumptions made on the stochastic variables.

[1]The NPV was calculated for the total capacity of 2,000 tons as the aim is to estimate the potential benefits and costs. In the financial analysis section (Table 9), the NPV was calculated assuming 75-90% of the total capacity are sold.

Table 18: Variables used in the stochastic analysis of the Briquette business 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

The below Figure (Figure 1) 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 13.6 million. The 90% confidence interval indicates values between USD 12.45 and USD 14.75 million. The above figure also shows that the probability that the net benefits will fall below the mean NPV is 49.4% which projects a higher variability of the NPV.

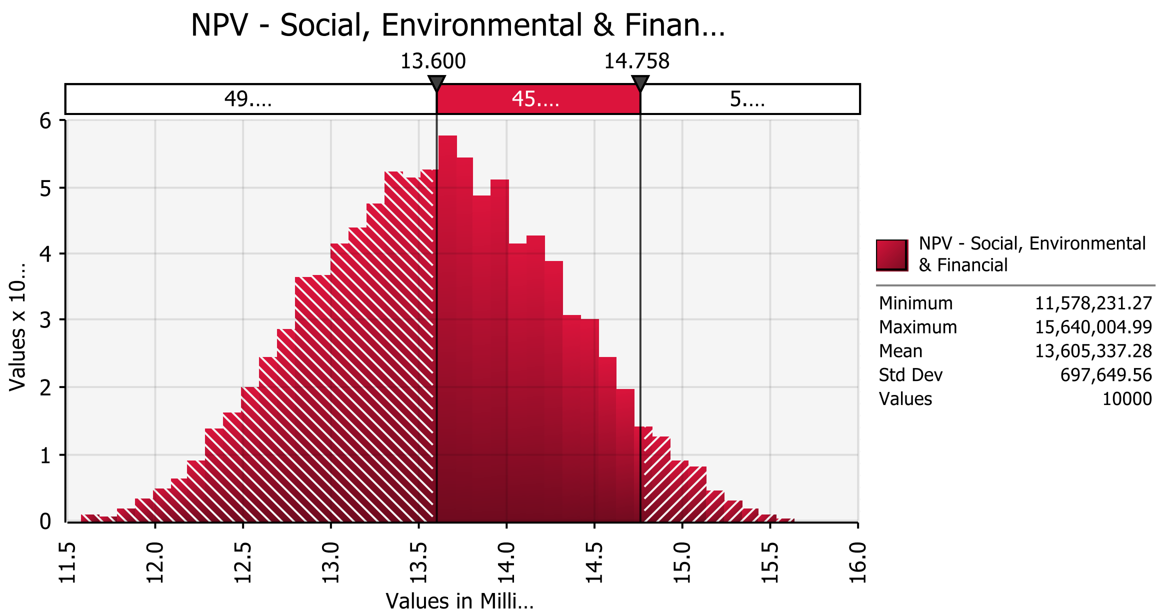

Figure 2: Probability Density of NPV of briquette business in Hanoi

Conclusion

This study assessed the socio-economic impact of a dry fuel manufacturing business model in Hanoi, Vietnam. 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:

- The environmental impacts associated with the business model were estimated based on emissions avoided from kerosene combustion and open burning of agricultural residues net of emissions from the briquette business which included agricultural residue transportation, briquetting and transportation and combustion of briquettes. The major contribution to GHG emission savings is from avoided use of fuelwood. 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 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 Energy Service Companies at scale (Agro-waste to energy - electricity) business model in Vietnam

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 Vietnam are rural dwellers with 84% of the population living in rural communities, however, connection to the nation's electrification grid is centered on the major cities leaving only 1% of the national electrification grid available to rural dwellers (Buchholz and Volk, 2012). Most Vietnamese rely on kerosene for energy and about 90% of the total energy needs of Vietnamese 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 Vietnam 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, Vietnam'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 Vietnam is no exception. This therefore makes such systems a potentially viable alternative off-grid electricity and energy solution to rural Vietnam.

This study sets out to conduct a socioeconomic impact assessment of a small scale energy service company in Vietnam 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 3).

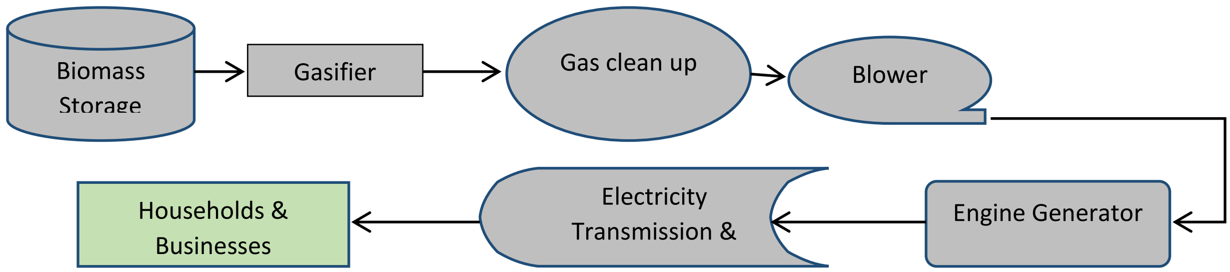

Figure 3: Process diagram of gasification

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).

Table 18: 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 Hanoi 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 Hanoi 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 Hanoi. 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 Vietnam, 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 **Error! Reference ource not found.**.

Table 19: 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 20).

Table 20: 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 30km 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. The table below 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 21: 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 22 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 22: 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 23 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 23: 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.

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_2equivalent emissions (Reuster 2010). Based on the World Bank (2014), carbon credit prices in 2013 is about USD 0.51 (€ 0.37) (Table 24). The total annual value of carbon credit is USD 4,355,359. However value of the other emission savings that have acidification potential (NOx and SO2) were not included in the analysis.

Table 24: Annual value of GHG emission reduction from ESCO model (120 KW)

Item	Amount
Total GHG emission savings (ton CO_2eq)	8,727,818
Total GHG emissions from business (ton CO2 eq)	187,899
Net emission savings (ton CO_2eq/year)	8,539,918
Price of VER (USD/ton CO_2eq)	0.51
Total value of Carbon credit (USD/year)	**4,355,359**

Social impacts

Savings for end-users

Using electricity from the gasifier in Vietnam can save electricity import from China. The cost of buying electricity from China is 0.0608 USD/kwh. The gasifier has a capacity of 8 MW which is equivalent to a total of 292,864,000 KWh electricity generated at the 10 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 annual savings from lesser import from China is 17,806,131 USD.

Table 25: General information on alternative energy use

	Unit	Value	Reference
Import reduction from China			
Amount of import reduced	Kwh/year	29,2864,000	Calculated
Price of buying electricity from China	USD/kwh	0.0608	
Total Savings	USD/year	17,806,131	Calculated

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. 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 agricultural waste for extra income. The value of additional income to farmers from the gasification plant is USD 9,750,000 per annum. The gasification plant on average contributes to providing additional income to the farmer of 15 USD/ton of agricultural residue. 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 110 with an annual income generation of USD 222,000. 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

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; WHO, 2002). Burning of agro-waste in the open field can cause health hazard and the whole population of Hanoi which is 6562000 is exposed. The DALY/1000 capita/year for outdoor air pollution as provided by WHO is 0.5. The population which is exposed to kerosene use is 135,373. The DALY/1000 capita/year for indoor air pollution is 2.8. The DALY value for Vietnam is 500 USD and we also assume that only 5 percent of the total health expenditure can be saved. Therefore, total health cost avoided due to production of electricity is 91,501 USD annually.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. Thus there is a need to provide workers with protective gears. Health impacts associated with power plant workers are not quantified in this study.

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 10 plants operating in the city shows positive net profit, however there is a negative NPV from the business. The rate of investment (ROI) is 3% implying that revenues are not high enough to recover all costs of the business. This is also observed that the benefit-cost ratio is less than 1 (0.415) indicating that financially the model is not viable.

Table 26: Financial results of ESCO model (USD)

	Years											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Total investment cost:	6,53,07,350											
Total revenues		3,07,30,050	1,22,92,020	1,22,92,020	1,22,92,020	1,22,92,020	1,35,21,222	1,35,21,222	1,35,21,222	1,35,21,222	1,35,21,222	....
Total production and other costs		1,64,29,600	67,61,430	69,56,707	71,57,843	73,65,013	75,78,398	77,98,185	80,24,565	82,57,736	84,97,903	....
Depreciation		43,53,000	17,41,200	17,41,200	17,41,200	17,41,200	17,41,200	17,41,200	17,41,200	17,41,200	17,41,200	....
Interest Payments		71,83,809	21,69,523	12,89,523	3,21,523	-	-	-	-	-	-	-
Profit before tax		27,63,642	16,19,867	23,04,589	30,71,453	31,85,807	42,01,624	39,81,837	37,55,457	35,22,286	32,82,119	....
Income tax		8,29,092	4,85,960	6,91,377	9,21,436	9,55,742	12,60,487	11,94,551	11,26,637	10,56,686	9,84,636	....
Net profit		19,34,549	11,33,907	16,13,213	21,50,017	22,30,065	29,41,137	27,87,286	26,28,820	24,65,600	22,97,483	....
Cash flow	(6,53,07,350)	62,87,549	28,75,107	33,54,413	38,91,217	39,71,265	46,82,337	45,28,486	43,70,020	42,06,800	40,38,683	....
Discount rate	12%											
Discounted cash flow		56,13,883	22,92,018	23,87,605	24,72,939	22,53,402	23,72,218	20,48,457	17,64,978	15,17,014	13,00,348	....
Present value of cash flow	2,71,02,997											
NPV	(3,28,98,502)											
IRR	-1%											
ROI (Financial)												....
ROI (Financial average)	3%											
BCR	0.415											

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 27. 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 174,098, 966 and the BCR is 3.58. 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 179 million with major benefits coming from the additional income to farmers and jobs created for the local community. Thus the ESCO business model is economically feasible but not financially feasible.

Table 27: 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	(32,898,502)	(32,898,502)	(32,898,502)
Environmental benefit:			
Value of net GHG emission saving		27,976,857	27,976,857
Social benefit:			
Savings in energy costs for end users			114,378,546
Additional income to farmers and employment			64,055,625
Health Benefits			587,762
Total Social Benefits			179,098,933
NPV	**(32,898,502)**	**(4,921,645)**	**174,098,372**
ROI (average)	**3%**	**12%**	**53%**
BCR	**0.42**	**0.84**	**3.58**

Sensitivity analysis

The estimated figures shown above represent the deterministic model and hence to understand the sensitivity of the model, some select variable were treated as stochastic and the probability distribution function of the NPV was derived. The following table (Table 28) shows the different variables selected for the stochastic analysis. The variables that were selected for the analysis are as follows – (i) capital cost of the gasifier – this was based on the unit investment cost made on the gasifier; (ii) Discount rate for the estimation of NPV; (iii) Carbon credit price which is assumed to vary between 0.51 – 3.8 USD/ tons of CO_2 equivalent; (iv) economic value of DALY[2].

Table 28: Table indicating the stochastic variables for the ESCO 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.	*Triangular:* (0.51, 1, 3.8)	Assumed
Distance travelled for transportation of agrowaste	Kms	*Triangular:* (25, 40, 50)	Assumed – distance increases with passage of time
Economic value of a DALY	USD	*Triangular Distribution* (250, 500,1300)	The lower range corresponds to estimates for cancer and higher range to gross national per capital income.

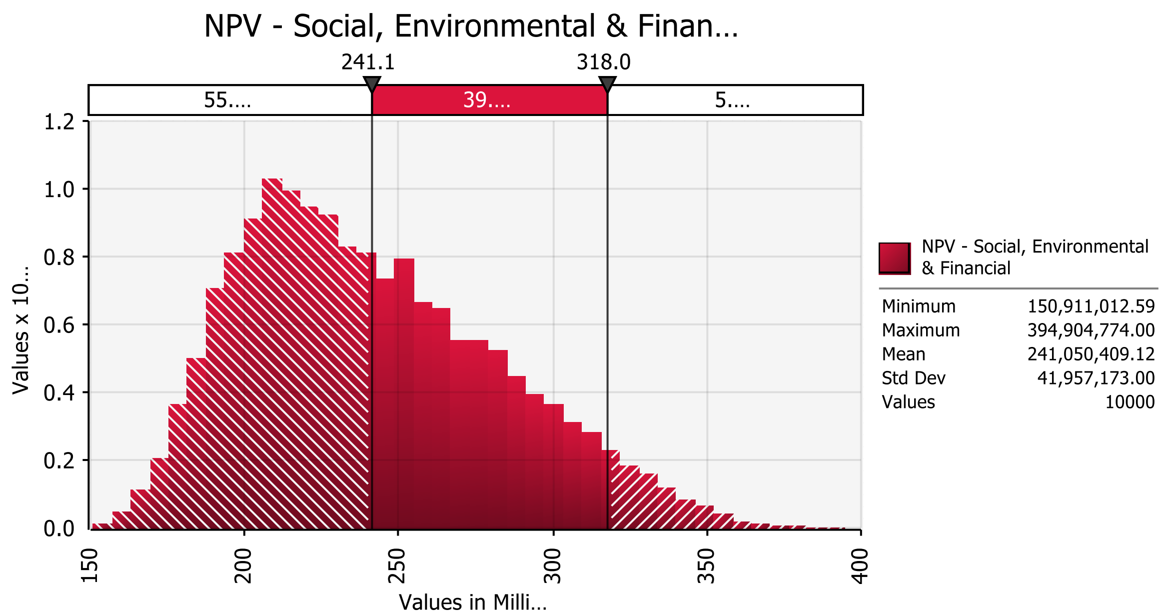

Figure 4: Probability density function of the NPV for ESCO model

The above figure (Fig.4) shows the probability density function of the NPV for the societal benefits. The mean NPV derived is 241.05 million which is higher than the deterministic model. The density function shows that to achieve the mean NPV the success rate is 45%.

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:

[2] In some studies a percentage value of DALY is also considered for the socio-economic analysis.

- 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 3.58 and ROI of 54% 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 118 million with major benefits coming from the additional income to farmers and jobs created for the local community.

Socio-economic impact assessment of Manure to Power business model in Hanoi

Introduction

This business model is initiated by agro industries such as piggeries, cattle farms, poultry, sugar processing factories, cassava or palm oil industrial factories and slaughter houses to generate energy from their by-products. The waste generated by these industries is used to generate electricity which is used in house for their own energy requirements. The technologies applied and the resulting energy products vary depending on the type of waste processed. These include co-generation unit to produce electricity, distillery unit to produce ethanol/alcohol and biogas unit to produce electricity and heat. Production technologies such as Covered Lagoon Bio-Reactor are also suitable for processing wastewater discharged from industrial factories such as starch and palm oil factories to produce biogas. The electricity produced by the cogeneration unit or by the covered lagoon bio-reactor is sold to the state utility on a long term power purchase agreement. The alcohol/ethanol produced from the distillery unit of sugar processing factory is sold to petroleum and pharmaceutical companies while the energy produced by the biogas unit is used onsite as input fuel to the cogeneration unit. The discharge from the biogas unit, which is high in organic matter can be distributed to farmers to be used as fertilizer.

The ownership and operation of the energy producing units take different forms. The energy production technologies are either designed, constructed, owned and operated by the agro-industrial processing factory or; are installed by an external private entity on a Build, Own, Operate, Transfer (BOOT) model. In the latter case, the private entity brings investment to set up the energy production technology while the concessionaries i.e. the agro-industrial factories provide land and inputs. The private entity designs, constructs and maintains the energy production unit until BOOT period is expired after which it assists the host company to operate the unit.

The business model tested for financial feasibility targets piggeries where the pig manure is used to generate biogas and the energy from biogas is used for internal energy requirement for running piggeries.

Technology

The technology comprises of a bio-digester and an electricity generation system. The biodigester is an anaerobic reactor which captures methane gas produced by fermentation of organic material from swine production. Within the bio-digester, the manure is transformed through a process called methanogenesis, in which the methanogenic bacteria transform organic particles into methane (CH_4). From this process, biogas is produced which is subsequently captured and directed to electricity generation or CHP (combined heat and power) unit. A biogas-cleaning unit will be incorporated before the generation unit if necessary.

Equipment and infrastructure required are:

- Bio-digesters
- Substrate mixing equipment and/or machinery

- Biogas storage and cleaning equipment
- Electricity generation or CHP unit
- Complementary equipment and facilities for the modular units

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 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 power capturing from pig slurry business model.

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 power generation from pig slurry model and a comparison of the costs and benefits of the business model vs. a business as usual scenario. Pig slurry from herd is often seen to be open dumped or thrown into water bodies in Hanoi and therefore, we have taken this as a baseline scenario for the cost-benefit analysis.

System boundary

The system boundary applied in this study contains establishment of biogas plant at the pig herd and production of electricity to self-consumption at herd and selling to households and business in rural areas. Since pig slurry is used as input in the power generation process, we assumed that under baseline, the pig slurry is open dumped or thrown into water bodies. Thus, emissions associated with this practice were accounted for when assessing the environmental impacts. There, is risk of emissions of methane in the production of electricity generation, but we ignore this aspect in this study. In per-urban areas of Hanoi presently there are 3 major livestock factories. The present study considers electricity generation from these 3 major plants given the plant size of rearing a herd size of 1,500 animals as done in the financial analysis of power capture from animal manure. The following table (Table 1) illustrates the plant capacity for the respective animal rearing companies (EAWAG, 2014).

Table 29: Major companies rearing animals in per-urban Hanoi

Company	Number of animals	Power plants that can be installed
National pig research and	Type of animal: Pig (feeding and	5 plants of 218 kWh capacity

development center	multiplication). 7,000-8,000 pig head/year	
Hanoi domestic animal breeding Center	Type of animal: Pig 2,500 pig head/year	2 plants of 218 kWh capacity
Co Dong service and livestock co-operative	Type of animal: Pig, 1,600 pig head/year	1 plants of 218 kWh capacity

Environmental impact assessment

Pig Slurry in the baseline scenario

In the base line scenario we evaluate the environmental impact of a pig herd consisting of 1500 pigs. Usually the pig slurry is either used as manure in the field or dumped into the water bodies indiscriminately which leads to surface and ground water pollution. Pig slurry contains pollutants like Nitrogen, Methane, Phosphorous, copper, copper, zinc, manganese, and calcium (See Table 1). Each pig produces slurry of 6.12 m^3 annually. Therefore, 1500 pigs produce pig slurry of 9180 m3 per year. We assume solid portion of pig slurry is 6 percent and density of pig slurry is 1010 kg/m^3. Hence, solid pig slurry produced annually is 556,308 kg/year. Given this one can easily estimate the emissions of pollutants from pig slurry and which is given in the last column of the Table 1. Open dumping of pig slurry produces 151,360 kg of methane.

Table 30: Chemical composition of Pig slurry

Parameter	Unit	Growing-finishing	Total Emissions (kg)
Ammonium nitrogen	mg/kg	2846	1583
Phosphorous	mg/kg	1690	940
Potassium	mg/kg	3405	1894
Copper	mg/kg	49.9	28
zinc	mg/kg	82.9	46
Manganese	mg/kg	29.85	17
calcium	mg/kg	1700	946
Magnesium	mg/kg	674	375
Methane	m^3/kg	0.243	151360

Surface and ground water Pollution under baseline

Only 6 percent of pig slurry is solid and therefore, 94 percent is liquid in nature. The pollutants contained in the liquid of pig slurry for ground water pollution are Ammonium Nitrate and Nitrate-N. Amounts of Ammonium Nitrate and Nitrate-N in pig slurry liquid are 4.25 mg/ltr and 0.33 mg/ltr respectively. Therefore, total ammonium nitrate and nitrate-N discharged by one pig heard are 37 kg and 3 kg annually. Similarly, components of surface water pollution are pH, DO, BOD, COD, NH_4, NO_3, PO_4 are 7.31, 2.72, 90, 124, 5.09, 1.85, 1.86 mg/ltr. Hence total amount of discharge of pH, DO, BOD, COD, NH_4, NO_3, PO_4 in surface water by a pig heard are 63, 23, 777, 1070, 44, 16, 16 kg annually. In the absence of abatement cost of these pollutants, the present study uses the pollution from common pollutants like nitrogen, phosphate, suspended solids, COD and BOD. It is assumed that for each of the animals 20 liters of wastewater is being generated which entails that 240 lts. of water is being produced. Based on the environmental pollution costs of the undesirable outputs as cited above (UNEP, 2010) the costs for groundwater and surface water pollution is estimated to be USD 712,587 annually.

Table 31: Components of ground and Surface water pollution in pig slurry

Ground water pollution	Unit		Unit	
NH4-N (Ammonium Nitrate)	Kg	37	mg/ltr	4.25
NO3-N (Nitrate-N)	Kg	3	mg/ltr	0.33
Surface water pollution				
DO	Kg	23	mg/ltr	2.72
BOD	Kg	777	mg/ltr	90
COD	Kg	1070	mg/ltr	124
NH4	Kg	44	mg/ltr	5.09
NO3	Kg	16	mg/ltr	1.85
PO4	Kg	16	mg/ltr	1.86

Environmental Benefits of Electricity generation from pig slurry under alternative

In the alternate scenario solid pig slurry produced by a pig heard i.e., 556,308 kg is being used to produce electricity. The quantity of methane produced by solid pig slurry is 0.4 m^3/kg. Hence, methane produced out of solid pig slurry is 222,523 m^3/year. Biogas constitutes 65 percent methane. Hence, total biogas produced is 342,343 m^3/year. Assuming 365 operating days, the biogas yield per day is 938 m^3/day. Energy yield from biogas is 5700 Kcal/m^3, and conversion factor from KCal to kWh is 0.001163. Hence, we get electricity production of 6218 kWh. We also assume that the power plant operates for 10 hrs in a day, therefore, in an hour 622 kW power is being generated. It is also assumed that efficiency of engine generator is 35 percent and therefore, the capacity of the power plant is 218 kWh. Therefore, total electricity which can be supplied annually in the market is 795,700 kW. The average requirement of electricity per household is 120 kWh/month. Therefore, with the produced electricity only 522 households can be served. 522 households can replace the use of kerosene by electricity and thus reduces the CO_2 emissions from kerosene by 94 tons annually. By producing electricity from pig slurry we can avoid the methane emissions and therefore CO_2. Power plant helps to reduce the CO_2 emissions by 3179 ton of CO_2 annually. In total through electricity production from pig slurry of one heard of 1500 pigs, 3273 tons of CO_2 emissions can be avoided annually. As there is a need for 8 plants to handle the problem of pig slurry in Hanoi, so 8 plants will help avoid emission and monetary value of that emission is 52,360 USD.

Table 32: GHG emissions avoided due to production of electricity from pig slurry

Emission saved from production of electricity	Unit	
Emissions from CH_4	Tons of CO_2/year	25,429
Emissions from Kerosene	Tons of CO_2/year	94
Total Emissions	Tons of CO_2/year	25,522
Price of carbon credit	USD/ton CO	0.51
Value of emission from a plant	USD	13,016

Social impacts

Wage income earned under alternative

The socioeconomic evaluation of the introduction of the power generation from the large pig farms assumes only the direct effects on the employment in terms of the employed staff (both shilled and semi-skilled) for the benefits. The indirect effects of power generation and effects within the economy for households and commercial purposes are not considered within the system boundary of the study. The power plant of 218 kWh can generate 3 additional employment. The monthly wage income of an employee of power plant is 168 USD. Therefore, total monthly wage income generated is 504 and annual income of 6048 USD. Hence, total income generated by 8 plants is 48,384 USD per annum.

Expenditure saved from importing electricity from China

Hanoi is a major imported of electricity from China. Therefore, another primary effect of generating renewable energy for resources with the economy provides a trade-off of substituting imported electricity and becoming self-dependent in power. Production of electricity from pig slurry replaces the need for importing electricity from China. One plant can produce 218 kwh/day. Therefore, 8 plants can produce 49,741 kwh/day. The number of operational days in a year is 300 and the importing price of electricity is 0.0628 USD/kwh. Therefore, total import bill saved stands out to be 937,119 USD.

Table 33: Net social gain under alternative scenario

Social Impact:		
	Unit	USD
Wage income for employees	USD/year	48,384
Expenditure saved from Importing of electricity from China	USD/year	937,119
Total money saved	USD/year	985,503
Net Gain	USD/year	985,503

Health impacts

Open dumping of pig slurry and run-off to water bodies may result in surface and ground water pollution which can cause serious health hazard to the population. Current population of Hanoi is 7,067,000 and according to the estimates given by WHO DALY /1000 capita/year for Indoor air pollution is 2.8 and economic value per DALY is 500. We assume that only 5 percent of total health cost calculated will be incurred. Therefore, under the alternative scenario health cost avoided annually is 494,690 USD.

Financial analysis

In this section, the financial analysis of the briquette is presented. 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 power plant primarily include capital investment and operating costs which include input cost, labour cost, O&M costs. The useful life of the power plant is assumed to be 15 years. Total investment cost is USD 390,259. The production capacity of the plant is 218 kwh.The selling price of electricity is 0.06kWh. The total number of full time workers is 3 and total monthly labor cost is 508 USD. 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 power capturing from pig slurry is presented in Table 5.

Results show that the business model resulted in a positive net profit. Assuming a discount rate of 12% and useful life of 15 years, the business model resulted in a mean NPV of USD 4,593,313 indicating that the business model is financially viable. The benefit-cost ratio for the business model is 2.69.

Table 34: Financial results of power capturing from pig slurry (USD)

Year	0	1	2	3	4	5	6	7	8	9
Total capital cost	2722072									
Total revenue		652574	694992	740166	788277	839515	894083	952199	1014092	...
Total production and other cost		258382	275177	289104	303937	319734	336558	354475	373557	...
Profit before interest and tax		394192	419815	451062	484340	519781	557526	597724	640535	...
Depreciation		68052	68052	68052	68052	68052	68052	68052	68052	...
Profit before tax		326141	351763	383010	416288	451729	489474	529672	572483	...
Income tax		65228	70353	76602	83258	90346	97895	105934	114497	...
Net profit		260913	281411	306408	333030	361383	391579	423738	457986	...
Cash flow	(2722072)	269419	289917	314915	341537	369890	400086	432244	466493	...
Discount rate	12%									
Discounted value of cash flows		269419	289917	314915	341537	369890	400086	432244	466493	...
Present value of cash flows	7315385									
NPV	1,004,009									
ROI (Financial)		10%	10%	11%	12%	13%	14%	16%	17%	...
ROI-average (Financial)	18%									
BCR-Financial	2.69									

Socio-economic results

The consolidated socio-economic results are shown in Table 6. The analysis looked at the potential impact of power capturing from pig slurry 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.

Table 35: Net socio-economic results of power capturing from pig slurry

Socio-economic result (USD/year)	Financial value	Financial & Environmental	Social, Environmental & financial
Financial result:			
NPV	1,004,009	1,004,009	1,004,009
Environmental benefit:			
Value of net GHG emission saving& Water pollution costs averted		727,503	727,503
Social & Health benefit:			
Total social (employment)& Health impact			9,878,124
Total social benefit			9,878,124
NPV	1,004,009	831,512	10,709,636
ROI	18%	20%	464%
BCR	2.69	2.95	6.58

The financial model generates a positive NPV and a benefit-cost ratio of 2.69. It becomes more profitable when environmental benefits are added with financial benefits and the benefit-cost ratio becomes 2.87. The largest contribution comes from social component when it was added together with financial and environment benefits. Taking into account all the components the BCR turns out to be 6.08. Thus from a socio-economic perspective, the power capturing from pig slurry model is very attractive.

Sensitivity Analysis

The primary variables selected for the stochastic model are explained in the following table (Table 8). The different variables that were identified to be stochastic are – (i) discount rate, (ii) price of electricity imported from China, (iii) price of the carbon credit and (iv) economic value of the DALY. Different values of these variables were used to assess the resulting effect on the overall socioeconomic feasibility of the business model. This was obtained through several iterations of the stochastic variables and derivation of the probability distribution of the NPV of the net benefits of introducing power generating plants within the animal rearing farms in the peri-urban areas of Hanoi.

Table 36: Variables selected for the stochastic model - Livestock waste to electricity

Variable	Unit	Distribution specified	Source
Discount rate	%	Triangular: (10%, 12%, 15%)	Assumed
Price of electricity imported from China	USD/kWh	Uniform: (0.0602, 0.0628)	Assumed as varying

Carbon Credit price	USD/t CO_2 eq.	Triangular: (0.51, 1, 3.8)	Assumed
Economic value of a DALY	USD	Triangular Distribution (250, 500,1300)	The lower range corresponds to estimates for cancer and higher range to gross national per capital income.

The following figure (figure 1) shows the probability distribution derived from the iterations of the different values of the stochastic variables and their respective distributions. The mean value estimated is 11.71 million USD and the distribution shows that 54% chance of failure exists to reach the mean value of the societal benefit. Considering the NPV and its mean, the chance of achieving the mean and the ROI, the economic feasibility is at medium level.

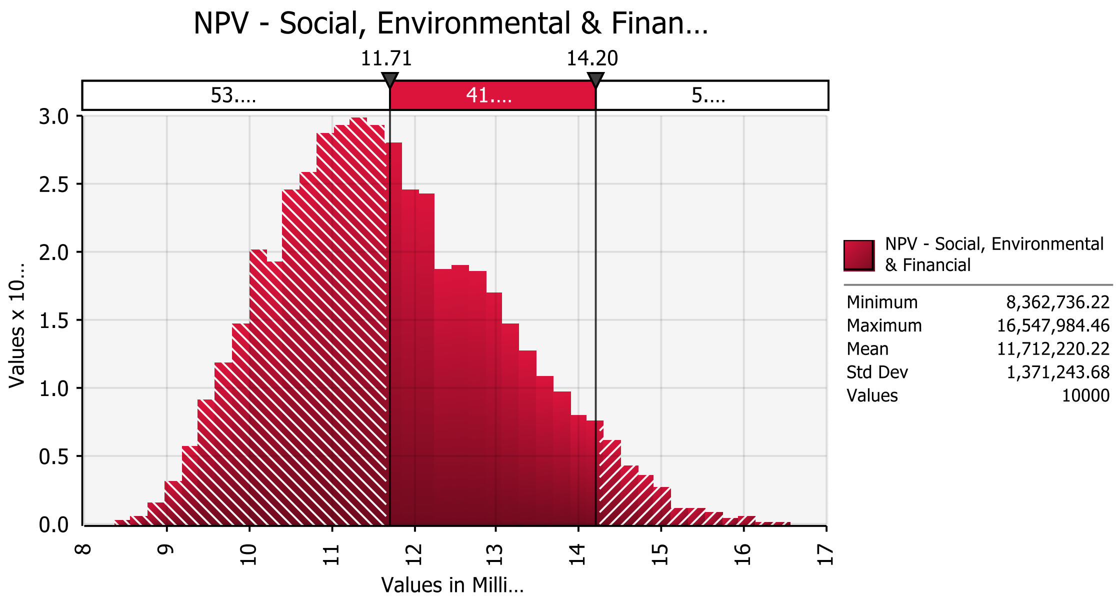

Figure 5: Probability Density function of the NPV for net benefits derived from the electricity generation form Livestock manure

Conclusion

This study assessed the socio-economic impact of a power capturing model from pig slurry in Hanoi, Vietnam. 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:

- The environmental impacts associated with the business model were estimated based on avoided surface and ground water pollution, methane emission from pig slurry. The major contribution to GHG emission savings is from avoided methane emission from open dumping of pig slurry. Compared to the baseline scenario, the power generation business results in net GHG and other criteria emission savings.

- The power generation business model, increases the rural electrification, creates additional jobs for local residents, and enables end users to save on energy costs as well as improves the indoor environment.

- Looking at the overall socio-economic impacts, the business model is financially and economically feasible. Given the huge environmental benefit associated with it, one can safely recommend to take up this project although the project is feasible in the medium range.

Socio-economic analysis for Beyond cost recovery – An aquaculture example businesses in Hanoi

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. Vietnam 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 phyto-remediative wastewater treatment model in Hanoi. It is known that Hanoi generates 615,400 m^3 of wastewater daily (EAWAG, 2014). 40 percent of the waste water generated is being treated and the rest remains untreated and flows to waterbodies in Hanoi (EAWAG, 2014). The amount of waste water generated in Hanoi can be used for aquaculture and subsequently treated wastewater can be used for irrigation purpose.

Given the context of Hanoi this report investigates the socio-economic impacts of phyto-remediative waste water treatment model in which waste water stream will be used primarily for aquaculture. The potential economic, environmental, Social and health impacts of phyto-remediative waste water treatment model needs to be assessed to ensure its sustainable development. In this study, we evaluated the socio-economic impacts of treating wastewater with pond capacity of 14.4 ha, 4.5 ha, and 1 ha. 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

Wastewater-fed aquaculture is increasingly being recognized as an innovative business-oriented reuse system. The business concept build on a public-private partnership that can be established between municipal wastewater management bodies or other public organizations with a need for wastewater treatment, and private entities proving the expertise, setting up an aquaculture business. While public entity/entities provide(s) wastewater and wastewater stabilization ponds, business entities can cultivate fish under specified safety procedures in the ponds. In this model wastewater is being treated to an advanced tertiary state and during that process produce fish for human consumption, using the same water flows. Duckweed is used to purify the wastewater. The duckweed is subsequently harvested and fed to fish fingerlings. Mature fish are caught and then sold both at pond side and to whole sellers. The advanced tertiary state treated water can be released safely in the environment, or, in areas where water is scarce and thus has value, can be sold for agricultural and other reuse. The business model has a very basic value chain in case of localized and small scale operations where fish and co-crops are sold in the local market.

The fish can be sold locally and in the export market. Profits will be divided amongst the partners depending on the partnership contracts. Usually the public entity will be responsible for maintaining, which typically is improved due to the business activity. The key players in the business set-up are the aquaculture business entity itself, local municipality and/or local public organization in need of wastewater treatment, duckweed-fish expertise provider, and of course produce buyers and consumers in the market.

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 Hanoi which is denoted as baseline scenario with the help of cost-benefits analysis. The wastewater in Hanoi mainly comes through industrial zones. Total wastewater generated in Hanoi is 615,400 m^3 daily and out of which only 40 percent is being treated and 60 percent remains untreated which goes to open environment.

Second, in the alternative scenario we have considered aquaculture business with different pond sizes such as 14.4 ha, 4.5 ha, and 1 ha to treat the waste water and produce fish for consumption.

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

Environmental Impact Assessment

Waste water generally flows directly to waterbodies without any treatment and therefore, creates a possibility of surface water pollution. The surface water pollution happens due to pollutants like Nitrogen, Phosphorous, Suspended Solids (SS), BOD, COD etc. The cost of pollution from Nitrogen, Phosphorous, Suspended Solids (SS), BOD, COD are 0.606, 0.3087, 0.00252, 0.0164, 0.083 USD/m^3 (Table 1). Hence, total surface water pollution caused by wastewater stream in Hanoi is 373,405 USD annually in the baseline scenario which can be avoided in the alternative scenario. Considering 12 percent discount rate, the present value of the environmental benefits stands around 2,398,582 USD.

Table 37: Surface water pollution due to wastewater - environmental value of pollution

Value for N	USD/m^3	0.606	UNEP, 2010
Value for P	USD/m^3	0.3087	UNEP, 2010
Value for Suspended Solids	USD/m^3	0.00252	UNEP, 2010
Value for BOD	USD/m^3	0.0164	UNEP, 2010
Value for COD	USD/m^3	0.083	UNEP, 2010
Total value of pollution due to undesired outputs	USD/year	**373,405**	

Social Impact Assessment

The amount of wastewater generated in Hanoi is 615,400 m^3 each day. Presently about 248,100 m^3 of water is treated while there has been a plan to set up three WWTPs which would further treat 367,300 m^3 per day. The existing and operational WWTPs are situated at North Thang Long, Kim Lien, Truc Bach, Hoang Mai, while the 3 WWTPs planned are at Hai Ba Trung, Tu Liem, and Thanh Tri. The capacity of treatment of waste water in different places are 42,000, 3,700, 2,300, 200,000, 13,300, 84,000, 270,000 m^3 daily (Table 2). In order to treat these amount of waste water at different places of Hanoi, one can construct ponds of 14.4 ha (large), 4.5 ha (medium), and 1 (small) ha for aquaculture which will produce fish that can be sold in the local as well as global market. Assuming that a large, medium, and small pond can handle on an average 9300 m^3, 3700 m^3, and 700 m^3 daily, the number of ponds required is calculated which is being provided in Table 3.

Table 38: Capacity of the treatment plant in different places of Hanoi

Amount of wastewater treated at North Thang Long, Van Tri	m^3/day	42000	Existing and operating since 2009

Amount of wastewater treated at Kim Lien	m^3/day	3700	Operating since 2005
Amount of wastewater treated at Truc Bach, Ba Dinh	m^3/day	2300	Operating since 2005
Amount of wastewater treated at Yen So, Hoang Mai	m^3/day	200000	Operating since 2012
Amount of wastewater treated at Bay Mau, Hai Ba Trung	m^3/day	13300	Planned - to be established
Amount of wastewater treated at Phu Do, Tu Liem	m^3/day	84000	Planned
Amount of wastewater treated at Nxen Xa, Thanh Tri	m^3/day	270000	Planned

Table 39: Required number of ponds of different size at different places

Number of ponds required for North Thang Long, Van Tri	5	Pond size - 14.4 ha.
Number of ponds required for Kim Lien	1	Pond size - 4.5 ha.
Number of ponds required for Truc Bach, Ba Dinh	3	Pond size - 1 ha.
Number of ponds required for Yen So, Hoang Mai	21	Pond size - 14.4 ha.
Number of ponds required for Bay Mau, Hai Ba Trung	3	Pond size - 4.5 ha.
Number of ponds required for Phu Do, Tu Liem	9	Pond size - 14.4 ha.
Number of ponds required for Nxen Xa, Thanh Tri	28	Pond size - 14.4 ha.

Given the fact that North Thang Long, Van Tri, Yen So, Hoang Mai, Phu Do, Tu Liem, and Nxen Xa, Thanh Tri treats large amount of waste water larger ponds are required at these places. The number of ponds required in these places are 5, 21, 9, and 28 respectively. Kim Lien, Bay Mau, Hai Ba Trung needs medium size plant and the number of plants required are 1, and 3 respectively. The amount of wastewater treated in Truc Bach, Ba Dinh is small and hence 3 small ponds are sufficient to treat the wastewater stream. Therefore, total number of large, medium, and small sized pond required are 63, 4, and 3 respectively. It has been assumed that on an average 4-5 fishermen are required for 1 ha of pond. Hence, total number of employment created in the alternative scenario is 3,713. We assume that per-capita income for fishermen is 1303 USD annually which is based on the percapita income in the present situation in Hanoi. Hence, annual income of all fishermen is 4,938,024 USD. The present value of annual wage income for fishermen is 31,719,636 USD. Apart from fishermen, there would also be breeding and maintenance workers and size wise employment of these workers are given in Table 4. Assuming a wage rate of 100 USD per month the value of employment for breeding and maintenance workers is 1,501,440 USD annually. The present value of which turns out to be 9,644,573 USD.

Table 40: Employment Generated

Employment Generated		
Number of workers employed in pond size of 14.4 ha		11
Number of workers employed in pond size of 4.5 ha		7
Number of workers employed in pond size of 1 ha		5
Total workers employed for the ponds		736
Wage rate per month	USD/month	170
Employment generated in terms of the fishing activities		3,713
Per-capita income	USD/annum	1330

Health Impact

Wastewater stream can cause illness related to water, sanitation, and hygiene- which is diarrhoea. According to the latest Census total population in Hanoi is 7,067,000. The DALY/1000/per-capita annually is 2.8. Moreover, it is also being conservatively assumed that only 2% of the population is exposed to diarrhoea therefore, the total health expenditure in Hanoi annually is 526,350 USD. The present value of health costs avoided in the alternative scenario is 3,381,036 USD.

Financial Analysis

In this section, the financial analysis of the phyto-remediative wastewater treatment is presented. The financial viability is analyzed based on Return on Investment (ROI), Net Present Value (NPV) and Internal Rate of Return (IRR) valuation criteria. Initially we have done financial viability analysis for large, medium, and small sized ponds and then consolidated the financial analysis of three different sized firms by considering the number of plants. The initial investment costs of a large, medium, and small sized firms are 95,988, 45,812, and 22,901 USD. The revenue for large, medium, and small sized ponds are 127,334, 57,874, and 18,081 USD respectively. Total production and other costs are 105,688, 45,378, and 24,051 USD respectively. The net profits for large, and medium sized ponds are 10,982, 6,404. We observe loss of 7,044 USD for the first year of business in case of small sized firms, but second year onwards we observe it starts making profit of 6526 USD. Adding back the depreciations to the net profit we arrive at the cash-flow which are 12,421, and 7,802 USD for large and medium sized business. Cashflow for small sized business second year onward is 7,600 USD. A straight line method of depreciation is used for depreciable capital costs assuming a useful life of 15 years with a salvage value of 5% of total depreciable cost. Current tax for similar businesses in Hanoi is 20%. Table 5 presents the results of financial analysis. Since there are 63 large number of firms, 4 medium sized firms, and 3 small sized firms we have scaled up the cashflows by considering these facts and the consolidated cashflow for the business is 8,00,050 USD and thus considering discount rate of 12 percent we obtain present value of cash-flow as 2,76,44,548 USD. The Net Present Value of cash-flows is 60, 88,209 USD. The internal rate of return is 24 percent, ROI is 34 percent and BCR is 1.01. Therefore, the financial analysis of phyto-remediative wastewater treatment indicates that the business model is financially viable.

Table 41: Consolidated Financial Analysis of Phyto-remediative wastewater treatment ponds

Financial results (aquaculture):		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11
Total investment cost:	6,047,244											
Total revenues		8307748	881531	923355	975401	10315987	10877792	11472749	12102914	12770475	13477756	--
Total production and other costs		6912013	7190679	7480047	7782308	8098493	8429388	8775780	9138502	9518440	9916529	--
Depreciation		99491	99,491	99,491	99,491	99,491	99,491	99,491	99,491	99,491	99,491	--
Interest Payments		420545	420545	420545	420545	408177	408177	-	-	-	-	--
Profit before tax		875698	1090815	1283271	1483056	1709825	1940735	2597477	2864920	3152543	3461735	--
Income tax		175140	218163	256654	296611	341965	388147	519495	572984	630509	692347	--
Net profit		700558	872652	1026617	1186445	1367860	1552588	2077982	2291936	2522034	2769388	--
Cash flow	(6047244)	800050	972144	1126109	1285937	1467352	1652080	2177474	2391428	2621526	2868880	--
Discount rate	12%											
Discounted cash flow		800050	972144	1126109	1285937	1467352	1652080	2177474	2391428	2621526	2868880	--
Present value of cash flows	27,644,548											
NPV	**6,088,209**											
IRR	**24%**											
ROI (Financial)		12%	14%	17%	20%	23%	26%	34%	38%	42%	46%	--
ROI (Financial average)	**34%**											
BCR-Financial	**1.01**											

Socio-economic Results

The consolidated socio-economic results are shown in Table 5. The analysis looked at the potential impact of aquaculture 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.

Table 42: Net socio-economic results

Socio-economic result (USD/year)	Financial value	Financial & Environmental	Social, Environmental & Financial
Financial result:			
NPV	6,088,209	6,088,209	6,088,209
Environmental benefit:			
Value of net GHG emission saving		2,398,582	2,398,582
Social benefit:			
Direct Employment generated in terms of the fishermen communities			31,719,636
Value of jobs created (workers in the breeding and maintenance)			9,644,573
Savings in health expenditure			3,381,036
Total social benefit			**44,745,245**
NPV	**6,088,209**	**8,486,791**	**53,232,036**
ROI	**32%**	**44%**	**155%**
BCR	**1.01**	**1.40**	**8.80**

The aquaculture business results in cost benefit ratio (CBR) of 1.01, NPV of USD 6,088,209 and ROI of 32% when only direct benefits from the briquette production are taken into account. The NPV increases to 8,486,791 USDwhen environmental benefits are taken into account and to **53,232,036** USD when the environmental and social impacts are taken into account. The ROI taking all externalities into account is 155%. The major contribution to the economic feasibility of the business is from the social benefits. Thus from a socio-economic perspective, the aquaculture business model is highly attractive.

Sensitivity Analysis

The following variables shown in the following table has been considered for the stochastic analysis. The following figure (Figure 1) shows the probability distribution of the NPV of the net benefits from introducing the business model.

Table 43: Selected variables for the stochastic analysis of the business 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	USD	*Uniform Distribution* (4.49 –	The lower range corresponds to estimates for cancer and higher range to gross national per

diseases		9.5)	capital income.

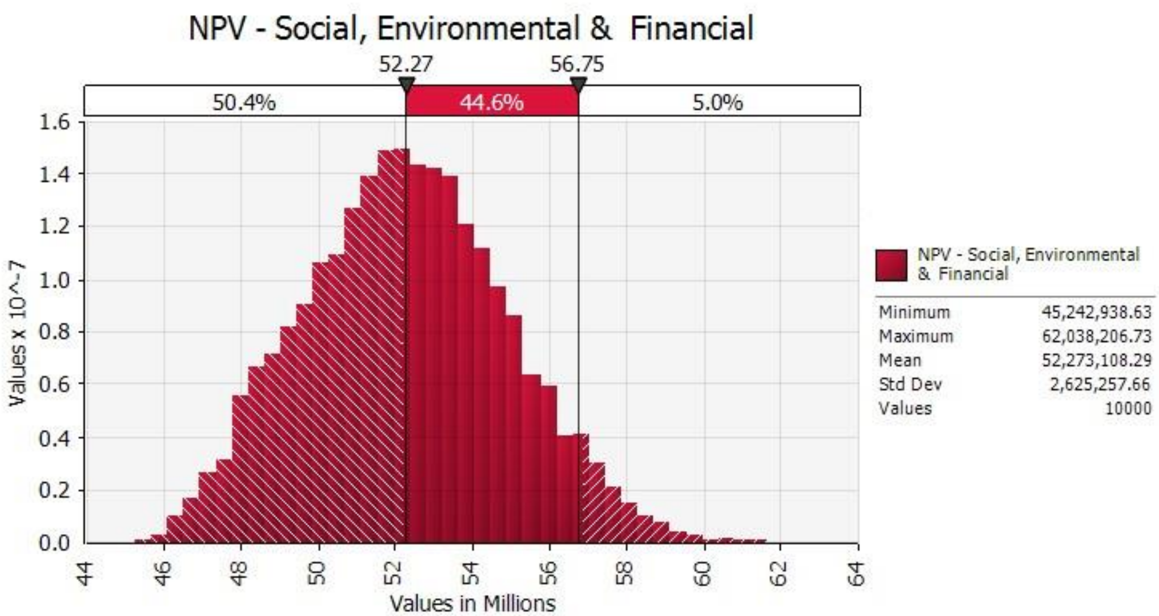

Figure 6: The probability distribution of the NPV of the net benefits derived from wastewater aquaculture

The above figure shows that the mean NPV is 52.27 million with a certainty of achieving it at 50%. Based on the ROI and the Benefit-Cost Ratio, it can be assessed that the business model of treated wastewater for aquaculture is feasible in the medium range.

Conclusion

This study assessed the socio-economic impact of phyto-remediative wastewater treatment business model in Hanoi, Vietnam. 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:

- The environmental impacts associated with the business model were estimated based on surface water pollution from pollutants like N, P, SS, BOD, COD etc. We have seen that by treating wastewater stream in this model we can avoid the surface water pollution caused by wastewater stream in Hanoi.
- It helps in generating large number of employment and thus adds to the social benefits.
- Through this model we can save a large chunk of health expenditure made by residents of Hanoi.
- 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 major contribution to the economic feasibility of the business is from the social benefits with major benefits coming from employment generation of fishermen and breeding persons in the business process. Thus from a socio-economic perspective, the phyto-remediative wastewater treatment business model is highly attractive.

Socio-economic impact assessment of Cost savings and Recovery businesses in Hanoi

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 Vietnam is not different from any developing country. Policy makers are engaging relevant stakeholders to explore effective and efficient options for wastewater management. Vietnam's urban population currently stands at 32% 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 Vietnam is mainly generated from domestic and municipal waste. It is estimated that about 224 million m^3 of wastewater is generated in Hanoi every year. 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 Vietnam 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 Hanoi 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 Vietnam 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 assuming a daily flow of 0.61million m^3. In order to treat these amount of waste water 2 large sized plant and 3 medium sized plants are required. 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 wastewater treatment plants in Hanoi. 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 Hanoi in 2013 was approximately 248,100 m^3/day of which 42,000 m^3/day is being treated - at North Thang Long, Van Tri, 3,700 m^3 is being treated at Kim Lien, 2,300 m^3 is being treated at Truc Bach, Bah Din, and 200,000 m^3 is being treated at Yen So, Hoang Mai. Thus 363,700 m^3/day flows to the nearby waterbodies, streams and polluting these water sources. For the financial analysis, 2 large size and 3 medium sized treatment plant 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 wastewater generated.

Environmental impact assessment

Reduced pollution of the surface 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. In the baseline scenario about 248,100 m^3 wastewater is being treated in four WWTPs around Hanoi of while the rest of the untreated water is drained off towards the nearby waterbodies, streams. The alternate scenario however considers that the wastewater generated in Hanoi (651,400 m^3) is entirely treated before being discharged into the nearby water courses (primarily the four main rivers of Hanoi). In other words, in addition to the existing WWTPs, there are other 3 WWTPs which have been planned to treat about 367,300 m^3 of water daily. 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 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: Environmental costs of the undesirable outputs

Parameters	Shadow prices for undesirable outputs (USD/m^3)
N	0.606
BOD	0.0164
COD	0.083
Total Pollution load from undesirable outputs (USD/Year)	**77,728,026**

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 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 results shows that discharge of 363,700 m^3 of wastewater per day have environmental costs amounting to USD 77.72 million per year. 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 considers that in total 596,100 m^3 of waste water is being treated which is greater than the baseline scenario. It has been calculated that 1 m^3 of wastewater generates 0.853 ton CO_2 equivalent i.e., 508,388 ton CO_2 equivalent. The basis of this calculation that the wastewater treatment system employs an aerated active sludge unit and an anaerobic digester to reduce the quantity of sludge requiring disposal. The activated sludge unit has an average flow rate of 1 million gallons per day and an inlet BOD5 of 500 mg/L (=g/m^3) and also that the unit achieves a 95%BOD5 reduction. Given the price of CER at 0.51 USD/ton we calculated the total averted emission in the alternative scenario is of value of 259,278 USD annually.

Soil Amelioration

We assume that a medium sized plant can produce compost of 445 ton/day and a large sized plant can produce compost of 2199 ton/day. Therefore, total compost production annually is 769,161 ton. Moreover, we assume that compost is being applied on the field as 10 ton/ha and as result of application of compost the income of the farmer will increase by 10 USD/ha. Therefore, the area covered by the compost produced is 76,916.1 ha. Thus total increase in income which can be considered as the proxy of soil amelioration stands valued at 769,916 USD annually.

The total environmental impact of 2 large and 3 medium sized treatment plants can be summarized in the table below.

Table 45: Estimation of the potential environmental impacts

Indicators	Value (USD)
Surface water Pollution	77,728,026
Reduced GHG gas emissions	259,278
Soil improvement	7,69,916

Social impacts

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 medium sized plant employs 8 workers and large sized plant employs 20 workers. Thus 2 large sized plants will employ 40 workers and 3 medium sized plants will employ 24 workers. Therefore, total number of additional jobs created by wastewater treatment plants is 64. Given a wager rate of 170 USD/month, value of additional jobs created annually is 130,560 USD. However, other indirect impacts to the local economy in terms of employment 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. It is assumed that in Hanoi net income from rice production per ha 49.5 USD. The wastewater treated can bring 10,836 ha under rice cultivation assuming the water requirement per ha is

16,500 m^3/ha. We assume that yield per ha is 5.34 ton. Hence, the additional income accrued to the farmers is 2,864,376 USD.

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). The current population of Hanoi is 7,067,000. WHO (2009) provides an estimate of 2.8 DALYs per 1000 population in terms of burden of diseases from environmental pollution (particularly water, health and hygiene) for Vietnam and economic values of DALY per-capita is 1330 USD. The total health cost arises due to diarrhea is 26,317,508 USD annually.

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. 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 363,700m^3/day. 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 also assumed that there are 3 medium and 2 large sized treatment plants.

Table 46: 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 Vietnam). 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%. It is assumed that the total quantity of wastewater treated and reuse is about 363,700 m3 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.

The financial estimates and an assumption of 12% discount rate the NPV of the investment is negative and IRR is 12 percent. BCR for this financial model is less than 1 (0.60). Hence, the financial analysis suggests that model is not financially feasible.

Table 47: Financial results of Wastewater Treatment and cost savings model (USD)

		Year 0	Year 1	Year2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Total investment cost:	24590741										
Total revenues		10416576	11027389	11089997	11156988	11228669	11305367	11387434	11475245	11569204	...
Total production and other costs		6845274	7283746	7752910	8254916	8792062	9366809	9981788	10639815	11343904	...
Profit before tax		3571302	3743643	3337087	2902072	2436606	1938558	1405646	835430	225299	...
Income tax		714260	748729	667417	580414	487321	387712	281129	167086	45060	...
Net profit		2857042	2994915	2669670	2321658	1949285	1550846	1124517	668344	180239	...
Cash flow	(24590741)	2857042	2994915	2669670	2321658	1949285	1550846	1124517	668344	180239	...
Discount rate											
Discounted cash flow		2550930	2387528	1900218	1475456	1106077	785707	508674	269933	64996	...
Present value of cash flows	9494610										
NPV	**(14848445)**										
ROI (Financial)		12%	12%	11%	9%	8%	6%	5%	3%	1%	
ROI (Financial average)	**3%**										
BCR-Financial	**0.60**										

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 12. 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 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. 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 19.97. This implies that per dollar invested gives a return of USD 20. The business model becomes economically more feasible when all externalities are included in the analysis. The NPV when all externalities are considered is USD 679,337,423 and the BCR is 27.63. 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 27 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.

Table 48: Net socio-economic results of Wastewater treatment plant model

Socio-economic result (USD/year)	Financial value	Financial and environmental	Social, environmental and financial
Financial result:			
NPV	(14,848,445)	(14,848,445)	(14,848,445)
Environmental benefit:			
Value of net GHG emission saving		505,895,965	505,895,965
Social benefit:			
Direct Employment generated			838,658
Increase in farmer income			18,399,458
Savings in health expenditure			169,051,787
Total social benefit			188,289,203
Net NPV	**(14,848,445)**	**491,047,520**	**679,337,423**
ROI	**5%**	**321%**	**443%**
BCR	**0.60**	**19.97**	**27.63**

Sensitivity analysis

The stochastic analysis helps in determining the uncertainty of the socioeconomic model based on deterministic assumption. For the present study the following variables have been considered as stochastic with the respective distributions as described in the following table.

Table 49: Selected variables for the stochastic analysis

Variable	Unit	Distribution specified	Source
Discount rate	%	*Triangular*: (10%, 12%, 15%)	Assumed
Carbon Credit price	USD/t CO_2 eq.	*Uniform* (0.51- 3.8)	Assumed
Yield per hectare of rice	tons/ha.	*Uniform :* (5.34, 6.5)	Present scenario in Hanoi, upper limit is the amount produced from hybrid rice
Net income from per hectare of land in paddy cultivation	USD/ha.	*Uniform:* (40, 49.5)	The lower range is the conservative estimate, the upper range is base case scenario
Increase in income due to application of compost	USD/ha.	*Uniform:* (5, 10)	The lower range is the conservative estimate, the upper range is base case scenario
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.

The following figure (figure 1) shows the probability distribution of the NPV estimated through numerous iterations of the stochastic variables. The derived stochastic mean is 673.7 million which can be achieved with a success rate of 49%.

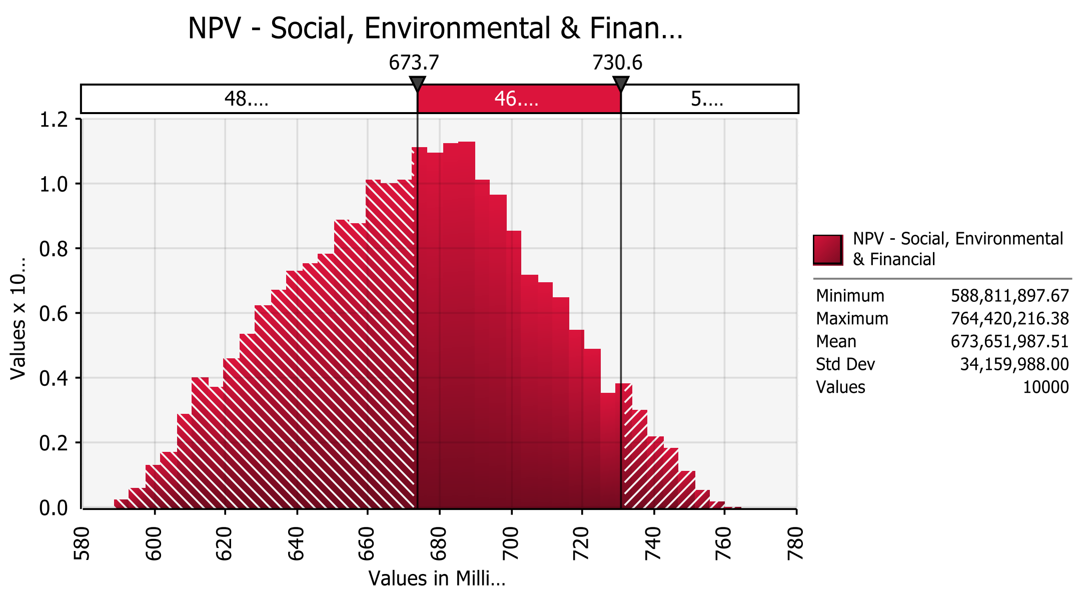

Figure 7: Probability Density Function of the NPV derived for Wastewater treatment and cost savings business model

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 Hanoi, Vietnam. The model includes the 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 21 from per dollar invested. The business model resulted in a BCR of 27.63 and ROI of 443% 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 and is highly feasible.
- 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 assessment of Large Scale Composting for revenue generation in Hanoi

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 Hanoi6500 tons of Municipal Solid waste is generated daily and out of this about 55 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 plant capacity of handling 600 tons of MSW in Hanoi daily. 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. 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 55% of the municipal solid waste is collected and landfilled. 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 alternative scenario in contrast considers establishment of composting plant which can handle 600 tons of MSW and can produce compost up to 50 tons daily. It has been assumed that the entire waste in the baseline scenario which is being presently landfilled can be utilized for composting. Therefore in the alternate situation 3575 tons of waste is utilized which is accommodated in 6 composting plants since each has a capacity of 600 tons. Thus the socioeconomic assessment of the centralized compost business model considers upscaling of the project for the entire city based on providing an alternative solution to the bassline situation.

Environmental Impact Assessment

The alternate situation considered in the case of centralized large scale composting is contrasting to the baseline scenario since the entire waste which is being landfilled in the baseline scenario is being composted in the alternate scenario the main environmental impacts of which are as follows –

- Avoided GHG emissions due to open dumping in the landfills,
- 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 open-dumping of waste as 0.152 tons Co_2-eq/ton, the annual savings in terms of GHG savings is calculated to be 202,168 ton Co_2 equivalent which implies a monetary benefits ofUSD 120,086 annually.

Cost of leachate treatment

The leachate potential from a MSW landfill primarily depends on the precipitation and thus is influenced by the climatic conditions such as rainfall and evaporation. On an average leachate produced per tons of MSW is considered to be 87.2 - 100 lts which depends on the climatic factors and the characteristics of the waste. Therefore, the total amount of leachate produced annually can be calculated to be 111,828 lts. Considering the treatment cost of leachate to be USD 20 per litre (Johannessen, 1999; which on average ranges between 9 -30 USD/m^3), the annual cost of leachate treatment can be estimated to be USD 2,236,555. 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.

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 Vietnam had been considered. The application of compost at the rate of 5 ton per ha will increase the income of the farmers by 10 USD/ha. The area which can be covered by applying compost is 31,317 ha. Therefore, the increase in income due to increase in productivity is 313,170 USD.

The following tables 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 50: Estimation of the net Environmental Impacts of large scale composting

Environmental Benefits	Valuation (USD/annually)
Avoided GHG emissions	102,086
Cost of leachate treatment averted	1,789,245
Soil amelioration	313,170
Total environmental benefits	**2,204,500**

Social Impact assessment

Employment

The total amount of MSW generated in Hanoi is about 6500 tons daily and only 55 percent of it being collected i.e., 3575 tons (Waste Supply Report, 2014). The entire waste collected is being sent to landfill.

In the baseline condition where a part of the waste is being landfilled, the number of labours engaged is 10. Based on an average wage rate ofUSD. 170 per month for labour in the unskilled category the annual wage income is USD 20,258.

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 715 tons). In the alternative scenario thus the labour employment by each plant is 47 which is quite high as compared to the baseline scenario as it adds 37 additional labourers. Thus, as there are 6 plants the total amount of employment that will be created is 282. The average wage rate per worker is 217 USD/month. Therefore, income generation from additional employment is 733,211 USD annually.

Saving of Landfill area & disposal cost

The other costs related to the landfill which can be saved is by increasing the life of the landfill since there would be a restricted use of the landfill. In the baseline scenario since the entire waste is being landfill, there is a greater requirement of land compared to the alternate scenario where about 60% of the organic fraction of the waste is utilized for compost production and additionally 20% is being recycled. It is being assumed here that the recycling business which is quite a dominant informal sector engagement is being kept intact and the same amount of waste which can be recycled in the baseline scenario is being recycled in the alternate scenario. Therefore, the remaining 20% of the MSW find its way to the landfill in the alternate scenario reducing the amount of land required. In other words, while 3575 tons of waste is landfilled every day in the baseline scenario, in the alternate scenario only 20% of the waste is being landfilled (about 715 tons per day).

The land required for landfilling 1 ton of waste per day for a period of one year ranges from 0.01 – 0.03 hectares (Rawat and Ramanathan, 2011). The cost of landfill operations as estimated by Johannessen 1999 is around 10-15 USD per ton annually. Given these figures it is easy to estimate the amount of costs that are being averted by reducing the amount of waste that is being landfilled.The amount of land saved due to reduced landfilling is about 7.2 ha. the estimated savings of which is around USD 664,950 based on the fact that land prices in Hanoi is USD 9.3 per m^2. However, this is considered as savings on initial investment and is not discounted annually. The additional costs of operation and maintenance costs saved due to reduced amount of waste being landfilled amount of USD 11,172 per day assuming USD 12.5 is spend per day on waste disposal and landfilling. Thus the amount of landfill and disposal costs saved is estimated to be around USD 4,077,734 over and above the land savings as mentioned above.

Reduction in externalities

The health cost per ton of MSW is estimated to be 11 USD. It has been assumed that in the alternative scenario externality can only be reduced to 25 percent of the MSW landfilled. Therefore, the amount of health expenditure avoided in the alternative scenario is 3,588,406 USD.

Other Social & Environmental costs which are not considered in the Social Impact

In the socioeconomic assessment the following costs and benefits are not being considered for the assessment –

- Investments in the transportation vehicles for the MSW
- GHG emissions from transportation

The unit costs of transportation of the MSW in Hanoi can be estimates using the following assumptions – (i) trucks owned by URENCO - there are 178 trucks employed by URENCO to collect municipal solid waste, (ii) price of each truck - the price of a truck is 40,000 USD and therefore, total investment needed is 7,120,000, (iii) total investment for the period of 5 years, considering the high depreciation of the vehicles used for MSW collection and transportation. This investment is five years and in five years amount of waste produced is 6,656,174 ton. Therefore, unit cost of handling MSW by truck is 1.07 USD. The number of households in Hanoi is 1,812,051 and one handcart can serve 56 households. Assuming handcarts collects waste twice, the number of handcarts required in Hanoi is 16,179. The cost of a handcart is 400 USD. Thus total cost needed to be incurred to buy handcart is 6,471,612 USD.To collect 3575 tons of MSW daily 238 trips are required. The average distance travelled by a truck is 50 km and millage of truck is 5 km/ltr. Hence, amount of diesel required daily is 2383 ltr and the cost of diesel is 1.05 per ltr. Total cost of transportation incurred annually is 913,413 USD.

The alternate scenario provides an alternate in the sense that the waste of 3275 tons produced per day which is being collected and landfilled is being collected in the alternate scenario and is send to the 6 compost plants instead of the landfill. Only about 15-20% of the inert waste which cannot be composted is send to the landfill. In the socio-economic assessment a simplistic assumption is being made that compost plants and the landfill used for disposal are at the same distance from the primary/secondary transfer stations in the city and hence the disposal cost and the GHG emissions from transportation in the baseline and alternate scenario does not vary much. This serves as the rationale for not considering the benefits in the social assessment of introducing large scale composting for Hanoi.

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, 6 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 6 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 plantconsidered is taken to be USD 6141 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 6 plants operating in the city shows positive net profit excepting for the first year. The IRR of the proposed business is 8% which is below the discount rate and the Rate of Investment (ROI) is 6% implying that revenues are not high enough to recover all costs of the business. This is also observed that the benefit-cost ratio is less than 1 (0.78) indicating that financially the model is unviable.

Table 51: Financial results of Large Scale Centralized Compost Business Model (USD)

	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 cost:	22106400															
Total revenues		5202656	6816901	7282057	7674498	8013751	8699566	8977787	9233965	9473413	9700101	9917045	10126570	10330500	10530287	10727105
Total production and other costs		35,88,896	38,07,105	39,74,048	41,43,821	43,17,691	45,15,950	47,01,208	48,93,074	5092161	5,299,031	5514,212	5,738,218	5,971,553	6,214,721	6468235
Depreciation		14,73,760	14,73,760	14,73,760	14,73,760	14,73,760	14,73,760	14,73,760	14,73,760	1473760	1,473,760	1473760	1,473,760	1,473,760	1,473,760	1473760
Interest Payments		13,92,703	12,57,703	11,22,703	8,52,703	-	-	-	-	-	-	-	-	-	-	-
Profit before tax		(1252703)	278333	7,11,546	12,04,214	22,22,300	27,09,856	28,02,820	28,67,131	2907492	2,927,310	2929073	2,914,592	2,885,187	2,841,805	2785111
Income tax		-	83,500	2,13,464	3,61,264	6,66,690	8,12,957	8,40,846	8,60,139	8,72,248	878,193	878722	874,378	865,556	852,542	835533
Net profit		(12,52,703)	1,94,833	4,98,082	8,42,950	15,55,610	18,96,899	19,61,974	20,06,992	2035244	2,049,117	2050351	2,040,214	2,019,631	1,989,264	1949578
Cash flow	(2,21,06,400)	2,21,057	16,68,593	19,71,842	23,16,710	30,29,370	33,70,659	34,35,734	34,80,752	3509004	3,522,877	3524111	3,513,974	3,493,391	3,463,024	3423338
Discount rate	12%															
Discounted cash flow		1,97,373	13,30,192	14,03,518	14,72,311	17,18,946	17,07,681	15,54,151	14,05,817	1265382	1,134,272	1013098	901,950	800,595	708,603	625431
Present value of cash flows	1,72,39,321															
NPV	**(43,45,607)**															
IRR	**8%**															
ROI (Financial)		-6%	1%	2%	4%	7%	9%	9%	9%	9%	9%	9%	9%	9%	9%	9%
ROI (Financial average)	**6%**															

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 6 large scale plants of 600 tons to produce compost). The consolidated socio-economic results are presented in Table 12. 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 negative NPV when only the direct economic/financial benefits are accounted and also has BCR is less than 1 implying that the business model is financially infeasible. The business model additionally performs better when the social and environmental costs and benefits are taken into account. The business model becomes economically feasible when all externalities are included in the analysis. The NPV when all externalities are considered is USD 60,789,734 and the BCR is 4.81. Thus, major contribution to the economic feasibility of the business is from the social benefits - employment generation, and health expenditure saved. Thus the large scale compost business model is socially feasible though it is financially infeasible.

Investment for the land made by the local body to ensure operations of the compost plants has also been included in the costs to derive the benefit-cost ratio for the socio-economic assessment.

Table 52: Net socio-economic results of Large-Scale Compost model

Socio-economic result (USD/year)	Financial value	Financial & environmental	Social, Environmental &Financial
Financial result:			
NPV	(43,45,607)	(43,45,607)	(43,45,607)
Environmental benefit:			
NPV of environmental benefits		14,160,714	14,160,714
Social benefit:			
Employment generation			4,709,818
Reduction in externalities			46,264,809
Reduction in Landfill O&M costs			27,772,896
Increase in Landfill life			664,950
Total social benefit			79,412,474
NPV	**(43,45,607)**	**9,815,107**	**60,789,734**
ROI	**6%**	**17%**	**31%**
BCR	**0.78**	**1.36**	**4.81**

Sensitivity Analysis

The following table shows the stochastic variables with their respective distribution used for determining the probability distribution of the NPV derived from benefits in introducing the compost model. The variables used for the analysis includes – (i) discount rate, (ii) application rate of the compost, (iii) leachate production, (iii) treatment costs of the leachate, (iv) average increase in income due to application of compost, (v) investments and operational costs of the landfill.

Table 53: Selected variables for stochastic analysis

Variable	Unit	Distribution specified	Source
Discount rate	%	*Triangular*: (10%, 12%, 15%)	Assumed
Application of compost	ton/ha	*Uniform Distribution*: (5, 10)	Assumed
Leachate production	m^3/ton	*Triangular distribution:* (80, 85, 100)	Safari and Baronian (undated)
Cost of leachate treatment	USD	*Triangular*: (9, 20, 30)	Johannessen 1999
Average increase in income due to application of compost	USD/ha	*Uniform*: (5, 10)	Conservative estimate based on
Landfill area saved per unit	ha/ton	*Uniform*: (0.01 – 0.03)	Johanssen , World Bank
Investments and operational costs of landfill	USD/ton	*Triangular:* (10, 12.5, 15)	Johanssen , World Bank
http://www.worldbank.org/urban/solid_wm/erm/CWG%20folder/uwp5.pdf			

The figure below shows the probability distribution of the NPV with a mean of 60.29 million and a certainty of 50% to achieve the mean NPV. The combination of certainty of the NPV, benefit-cost ratio and a lower ROI makes the feasibility of the business low socioeconomically.

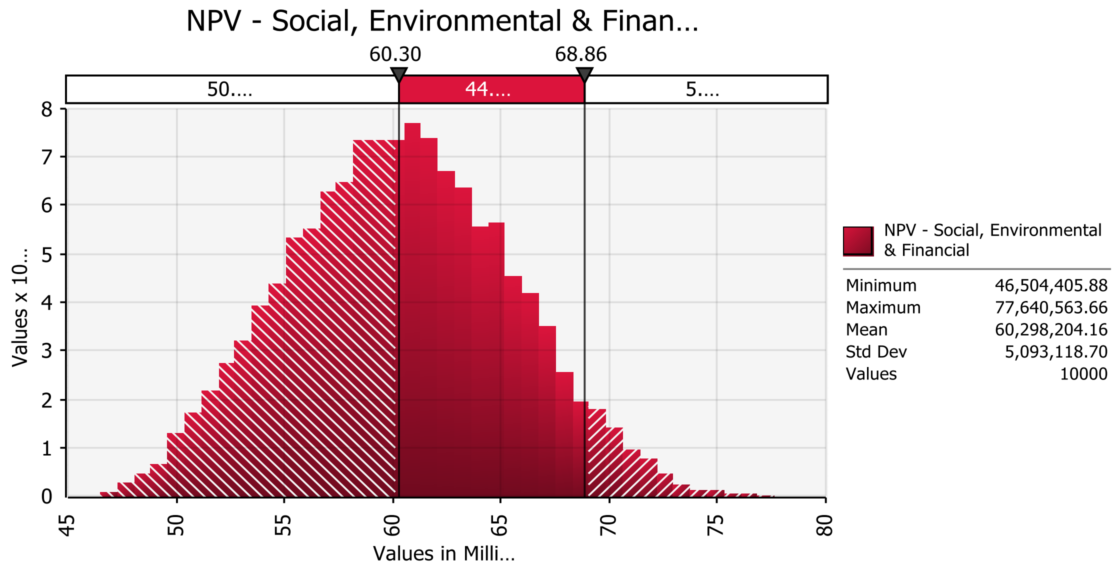

Figure 8: Probability density function of the NPV of large scale composting

Conclusion

This study assessed the socio-economic impact of a composting business model in Hanoi, Vietnam. 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.

However, even with a greater than 1 benefit-cost ratio, the certainty of achieving the mean level of NPV is lower which makes the business less feasible for Hanoi.

Socio-economic impact assessment of subsidy-free community based composting business model in Hanoi

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 Hanoi 2500 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 decentralised composting of MSW business with plant capacity of 10 tons MSW each daily i.e., 3650 tons MSW annually. Through decentralised composting 18 communities with 300 households in each community i,e., 5400 persons will be served. 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 Decentralized 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.

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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 many developing countries large centralized and highly mechanizedcomposting plants have often failed to produce good qualitycompost. In Hanoi of the 6500 tons of waste generated per day, about 3625 tons of waste is landfilled and the rest is open-dumped without being disposed in the landfill. The present chapter discusses the socioeconomic feasibility of decentralized composting in Hanoi. The alternative situation of setting up decentralized collection of the organic waste and composting is being evaluated against the baseline scenario. In the alternative situation, the targeted waste collection is 50% of the waste disposed in the landfilled and the entire waste of 2875 tons which is not disposed in the landfills. Decentralized composting is thought of as a remedy where waste generation is relatively higher and there exists a financial burden in terms of collection of the waste for disposal and treatment. Considering the situation in Hanoi where some of the landfills are approaching their lifetime, it has been assumed that 50% of the waste presently collected can be suitably collected and composted through decentralized approach. The areas away from the landfill sites (or are away from newly planned landfill sites) are assumed to be brought under decentralized collection and compost stations. However, this study does no delve into the demarcation of the zone which would come under the ambit of the decentralized collection and compost production. The present study is more oriented to evaluate whether an extensive decentralized composting is socio-economically feasible in the context of Hanoi such that it reduces the budgetary pressure of the local body in terms of waste collection and disposal delivery.

The objective of the alternative scenario is to set up community based smaller compost plants of 3 tons. It is being calculated based on waste generation and characteristics that collection of the organic fraction of the waste from 2000 households would lead to a collection of 3 tons of waste. It is assumed that these households would form a co-operative among themselves for collection and composting of the organic fraction of the waste. The business models also assumes that each of these co-operatives is linked to a business entity which takes up the compost and plays an important role in marketing the compost. For simplicity the business entity related to the co-operatives are homogenous in sense that each of the business entity is linked with 7 of such co-operatives from which the compost is procured for further sell either in wholesale or retail. Thus for Hanoi the number of business entities engaged for decentralized composting is 15. Based on the waste collection of 4600 tons per day in Hanoi, it has been calculated that there is a requirement of 104 co-operatives for collection of the waste. The chapter evaluates the socioeconomic costs and benefits of all the co-operatives and the associated business together. The following section describes the assumptions made, scenarios modelled and data sources used for assessing the social, economic, environment and health impacts of the large scale composting model from MSW.

Environmental Impact assessment

As mentioned in the previous section the baseline scenario considers that the total Municipal Solid Waste generated in Hanoi is 6500 tons daily. In contrast the alternative scenario considers that 4600 tons of waste is collected and composted through decentralized co-operatives based at the community level. Decentralized composting helps in local collection of the waste and provides savings in terms of the transportation cost of the waste. At the same time with 60% of the organic fraction of the waste being diverted to the compost plant, the environmental effects of landfills are also restricted. The potential effects on environment which are estimated for the impact assessment in case of decentralized composting are as follows -

- 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 collected and transported to the landfill while part of it remain uncollected and is usually open dumped. In the alternative scenario 50% of the waste presently collected from sites away from landfills are brought under decentralized co-operatives. This has implications in reduction of the present level of the GHG emissions resulting from the transportation of the waste. The GHG emission savings has been estimated 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, (iii) average distance travelled for waste disposal by each of the truck is 50 kms., and (iv) GHG emissions from the automobile diesel is about 2.67 kg Co_2/lt. (World Resource Institute). The amount of GHG emissions from transportation of 3625 tons of waste daily is estimated to be 2,086,700 tons of CO_2 equivalent. Thus the conservative of the transportation of 50% of the waste is around 1,043,350 tons of CO_2 equivalent.

However, there are GHG emissions from the transportation of the compost from each of the respective 104 co-operatives to the main packaging unit. Based on the assumptions mentioned, the GHG emissions were calculated which amounts to 465,888 tons of CO_2 equivalent. Further, open dumping also leads to GHG emissions of about 0.1523 tons of CO_2 equivalent per ton of MSW in a year. In the alternative scenario where open-dumping of 4600 tons of waste is averted, the net GHG savings would amount to 261,058 tons of CO_2 equivalent. The net savings in terms of the GHG emissions saved by introducing decentralized collection and composting in Hanoi amounts to 838,520 tons of CO_2 equivalent (Table 1).

Table 54: Value of Net GHG emissions in introducing decentralized collection and composting of MSW

	Unit	Value
Avoided GHG emissions from open dumping	tons of CO_2 equivalent	261,058
Net GHG emissions from transportation	tons of CO_2 equivalent	577,462
Value of CERs	USD/ tons of CO_2 equivalent	0.51
Value of GHG emissions averted	**USD/annum**	**427,645**

To estimate the total value of the GHG emissions the CER values per tons of CO_2 equivalent has been used. The conservative estimates of CERs through CDM has been considered as 0.51 USD/ton CO_2 eq. The above table (Table 1) shows the estimated value of the GHG emissions that can be averted.

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 Vietnam, the average leachate produced per tons of MSW is considered to be 87.2 - 100 lts. Whereas in the baseline scenario the entire daily waste of 3625 tons is being landfilled, the alternate scenario considers the landfilling of the 20% of the 4600 tons waste that is being collected. The basis of the assumption is based on the fact that 60% of the waste which is organic is taken up for composting while 20% of it is being recycled. Recycling is an important source of livelihood in Hanoi where it employs many wageworkers. It is assumed in the model that since waste segregation takes place at source (the household level), the informal recycling industry can be kept intact without any social impacts of loss of livelihood. The only change is that, in the baseline scenario they are based at the landfills whereas in the alternate scenario they are able to collect it from the household level. Therefore, considering the lower range, the net amount of leachate production which can be averted annually can be calculated to be 82658.7 m^3 annually. Considering the treatment cost of leachate to be USD 20 per m^3 (Johannessen, 1999; ranges between 9 – 30 USD/m^3), the annual cost of leachate treatment can be estimated to be USD 1,653,174 per annum.

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 Hanoi has been considered. Application of compost in tomato farms increase the net income by USD 10/ha of application. In Hanoi vegetable production is the main source of income for farmers engaged in peri-urban agriculture. The value provided by the above study is used for measuring the shadow price of increase in soil fertility. However, conservative estimates are obtained for the deterministic model since there might be variances in the net farm income from vegetable production in different areas. The conservative estimates of USD 5/ha. is thus assumed to take care of difference in farm gate prices for different vegetables across different regions and also the present condition of the soil characteristics. The increase in the net farm income is also based on the application rate of compost between a range of 5-10 tons/ha. The estimated increase in the value of the soil fertility is estimated as USD 666,841 per annum with about 66,000 hectares where compost is being applied.

The following table (Table 55) 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 55: Estimation of the environmental benefits due to utilization of MSW for producing compost

Environmental Benefits	Valuation (USD/annually)
Avoided GHG emissions	427,654
Cost of leachate treatment averted	1,653,174
Soil amelioration	668,841

Total environmental benefits	**2,747,661**

Employment

Decentralized collection of household waste is more labour intensive compared to centralized composting. The amount of labour required for collection of the organic fraction of waste of 3 tons from a particular ward of 2000 households is based on the following assumption presented in the following table (Table 3). The other assumptions with regards to the trips made each day is based on time of work for each team. Each team comprised of the 2 members collects waste for 6 hours a day where collection time from 60 households is completed in 10 minutes. This is achieved as the collectors would generally wait for the households in a common collection point to dump their household waste in the collection vehicle for 10 minutes. The collection point would be identified such that it is accessible to the households and reachable within the waiting period of the collection team.

Table 56: Calculations showing the labour requirement for collection of waste

	Unit	Value
Volume of the collection vehicle	m^3	1
Density of waste	kg / m^3	350
Number of trips by the collection van		2
Number of vans required		4
Number of labours per van		2
Total labours for a particular ward		8

In each of the ward level composting station, 3 semi-skilled labours sort the entire waste collected each day and are responsible for compost production. Each of business entity linked with 15 such co-operatives employs 2 labours for collection and transportation of the compost, 2 labour to collect and store the compost and package it, and one plant manager. The total of employment generated in each of the ward is 11 amounting to 1144 labours getting employed. Likewise in the 15 businesses the total employment generated is 75 resulting in 1219 number of skilled and semi-skilled workers for the entire city. The average monthly wage rate for workers in Hanoi is around USD 170. Therefore the amount of monetary benefits generated in terms of the monthly income of the workers is estimated to be USD 2478,033 per annum.

Saving of Landfill area & disposal cost

The other costs that can be saved from composting the MSW are cost of landfilling area that is saved due to reduction in the amount of waste that is collected and disposed. Similarly, reduction in disposal cost from reduced collection and landfilling also accrues as benefits for the municipalities. The land required for landfilling 1 ton of waste per day for a period of one year ranges from 0.01 – 0.03 hectares (Rawat and Ramanathan, 2011). The cost of landfill operations as estimated by Johannessen 1999 is around 10-15 USD per ton annually. The alternate scenario considers reduces waste disposed off to the landfill. The amount of land saved due to reduced landfilling is about 9.3 ha. the estimated savings of which is around USD 867,225 based on the fact that land prices in Hanoi is USD 9.3 per m^2. However, this is considered as savings on initial investment and is not discounted annually. The costs saved on reduced operations on the landfill amount to USD 3,262,188 annually. The disposal costs per ton of MSW collected was calculated to be 0.67 USD. Hence the amount of savings in terms of waste disposal amounts to USD 437,133 annually.

Costs on sensitizing households for segregation of waste

The pertinent benefit obtained from decentralized composting is that of tapping the organic fraction ready for use from the households. However, to obtain such benefits, the households especially in the lower income areas needs to be sensitized about the utility of segregating waste at source such that it can be easily available for composting. However, such Information, Education and Communication (IEC) or Behavioral Change Communication (BCC) Programs need to run over a period of time such that changes in Knowledge, Attitude and Practice of the individuals change over time. For the present study a five year period of such campaigns among the households is assumed with an initial higher investment in the first year followed by reduction in those costs. The investment made in the first year includes both the campaigning costs and the costs of providing households with the bins such that they are able to segregate the waste at source. The conservative estimate used for the socio-economic analysis is that primarily USD 10 per household is budgeted which is substantially reduced over the years to USD 2.5 per household from year 2 to year 5.

Profit for the co-operatives

The financial analysis shows that the decentralized collection and composting of the organic fraction at the ward level is sustainable financial and each of the co-operative earns a positive Net Present Value (NPV) of USD 28,278 with an Internal Rate of Return (IRR) higher than the discount rate 35%. The revenue of these co-operatives come from two sources – (i) sell of compost and (ii) user fees from the households. In fact the user fees from the households helps in the financial sustenance of the co-operatives. Thus for the entire city where 104 co-operatives are assumed to be operating, the profit accrues as societal benefits for collection, disposal and treatment of the household wastes. The figures for a representative co-operative is being shown in the financial, however the financial analysis of the business mainly revolves around the business entity procuring compost and marketing it. The investments made by the co-operatives are however used to determine the final benefits and costs along with the investments made from business entity.

Other externalities from the landfilling and composting

A report by the European Commission (2000) on externalities arising from the landfills estimates the value of the negative externalities incurred by the households. The reports estimates the value of the negative externalities as valued by individuals is around 11 USD/ton which implies that the total burden of externalities averted due to reduced landfilling is around USD 3,588,406 per year.

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

	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	**21,382**															
Revenue																
Total Revenue		**30,435**	**32,115**	**33,913**	**35,836**	**37,894**	**40,096**	**42,453**	**44,974**	**47,671**	**50,558**	**53,647**	**56,951**	**60,488**	**64,271**	**68,320**
Expense																
Labour and Input costs		20829	22287	23847	25516	27302	29213	31258	33446	35787	38292	40973	43841	46910	50194	53707
Supplies, Utilities &Other costs		500	535	572	613	655	701	750	803	859	919	984	1052	1126	1205	1289
O & M costs		404	432	463	495	530	567	607	649	694	743	795	851	910	974	1042
Total Expense		**21733**	**23254**	**24882**	**26624**	**28487**	**30481**	**32615**	**34898**	**37341**	**39955**	**42752**	**45744**	**48946**	**52372**	**56039**
Profit before tax		**8702**	**8861**	**9031**	**9213**	**9407**	**9615**	**9838**	**10076**	**10331**	**10603**	**10895**	**11207**	**11541**	**11899**	**12281**
Income tax		1740	1772	1806	1843	1881	1923	1968	2015	2066	2121	2179	2241	2308	2380	2456
Net Profit		**6962**	**7089**	**7225**	**7370**	**7526**	**7692**	**7870**	**8061**	**8265**	**8483**	**8716**	**8966**	**9233**	**9519**	**9825**
Cash Flow	**(21,382)**	**6962**	**7089**	**7225**	**7370**	**7526**	**7692**	**7870**	**8061**	**8265**	**8483**	**8716**	**8966**	**9233**	**9519**	**9825**
Discounted Cash Flow		6,216	5,651	5,142	4,684	4,270	3,897	3,560	3,256	2,980	2,731	2,506	2,301	2,116	1,948	1,795
NPV	**28,278**															
IRR	**34%**															

Table 57: Financial of the co-operative for decentralized composting

	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	**222,600**															
Revenue																
Total Revenue		**125,483**	**167,833**	**179,581**	**192,152**	**205,602**	**249,327**	**266,780**	**285,455**	**305,437**	**326,817**	**349,694**	**374,173**	**400,365**	**428,391**	**458,378**
Expense																
Input costs		96525	103282	110511	118247	126525	135381	144858	154998	165848	177457	189879	203171	217393	232610	248893
Labour costs		20400	21828	23356	24991	26740	28612	30615	32758	35051	37505	40130	42939	45945	49161	52602
Sales and Marketing costs		21703	23222	24847	26587	28448	30439	32570	34850	37289	39899	42692	45681	48878	52300	55961
Supplies, Utilities &Other costs		1680	1798	1923	2058	2202	2356	2521	2698	2887	3089	3305	3536	3784	4049	4332
O & M costs		3888	4160	4451	4763	5096	5453	5835	6243	6680	7148	7648	8184	8757	9369	10025
Total Expense		**144196**	**154289**	**165090**	**176646**	**189011**	**202242**	**216399**	**231547**	**247755**	**265098**	**283655**	**303510**	**324756**	**347489**	**371813**
Profit before depreciation, interest and tax		**-18713**	**13544**	**14492**	**15506**	**16591**	**47085**	**50381**	**53908**	**57682**	**61719**	**66040**	**70663**	**75609**	**80902**	**86565**
Depreciation		8664	8664	8664	8664	8664	8664	8664	8664	8664	8664	8664	8664	8664	8664	8664
Income tax			976	1166	1368	1585	7684	8343	9049	9804	10611	11475	12400	13389	14448	15580
Net Profit		**-27377**	**3904**	**4662**	**5474**	**6342**	**30737**	**33374**	**36195**	**39214**	**42444**	**45901**	**49599**	**53556**	**57790**	**62321**
Cash Flow	**(57,950)**	-18713	12568	13326	14138	15006	39401	42038	44859	47878	51108	54565	58263	62220	66454	70985
Discounted Cash Flow		(16708)	10,019	9,485	8,985	8,515	19,962	19,016	18,118	17,265	16,456	15,686	14,955	14,259	13,598	12,969
NPV	**34,734**															
IRR	**10%**															
ROI (Financial)		-12%	2%	2%	2%	3%	14%	15%	16%	18%	19%	21%	22%	24%	26%	28%
ROI (Financial Average)	**11%**															

Table 58: Financial of the business entity linked with the co-operatives for decentralized composting

Socioeconomic Analysis

The following section discusses about the socio-economic evaluation in a nutshell. The following table indicates that there is low financial viability without subsidy for the business. However, inclusion of environmental and societal benefits enhances the net positive earnings of the business. The ROI for the business is 200% with a benefit-cost ratio of 14 and a net NPV of 74,502,891. Apparently, from the deterministic model the business seems economically feasible although not financially.

Table 59: Socio-economic analysis of the decentralized business model

Socio-economic result (USD/year)	Financial value	Financial and environmental value	Social, environmental and financial value
Financial result:			
NPV	(783,795)	(783,795)	(783,795)
Environmental benefit:			
Value of net GHG emission saving		14,794,075	14,794,075
Social benefit:			
Savings in landfill operational costs			22,218,317
Profit of the co-operatives			2,929,900
Reduction of externalities			46,204,809
Value of employment			15,917,767
Savings in disposal costs			2,977,254
Benefit:Cost ratio (BCR)	**0.74**	**3.11**	**14**
NPV	**(783,795)**	**14,010,279**	**74,502,891**
ROI (average)	**10%**	**81%**	**200%**

Sensitivity Analysis

To evaluate the uncertainty associated with the business particularly the environmental and social aspects, some of the selected variables were treated to be stochastic. These variables had their own distribution such that it might vary across different ranges and hence help in the iterations of determining the NPV. The different NPV along with their frequencies forms the probability distribution of the NPV derivable from the business as a whole.

Table 60: Selected variables for the stochastic analysis of the decentralized model

Variable	Unit	Distribution assumed	Reference
Discount rate	%	*Triangular* (10, 12, 15%)	Assumed ranges between 10% to 15%
Application of compost	ton/ha	*Uniform Distribution*: (5, 10)	Assumed
Leachate production	m^3/ton	*Triangular distribution:* (80, 85, 100)	Safari and Baronian (undated)
Cost of leachate treatment	USD	*Triangular*: (9, 20, 30)	Johannessen 1999
Average increase in income due to application of compost	USD/ha	*Uniform*: (5, 10)	Conservative estimate based on
Landfill area saved per unit	ha/ton	*Uniform*: (0.01 – 0.03)	Johanssen , World Bank
Price of CERs	USD/ton CO_2 eq.	*Triangular:* (1, 3.8, 5)	Assumed considering the volatility of the market

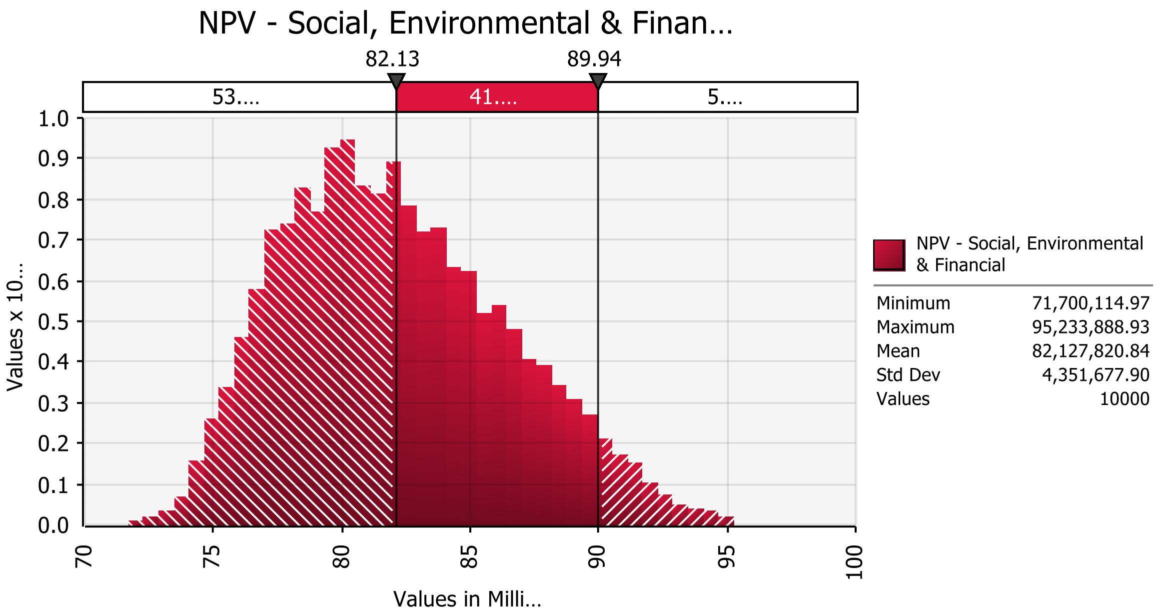

Figure 9: Probability density function of the NPV derived for the decentralized model

The figure above shows the probability density function of the NPV for introducing the decentralized business in Hanoi. The higher ROI and benefit-cost ratio shows that the business is feasible in a medium range of uncertainty. In fact the chances of attaining the mean level of NPV is 54%. However, it is to be noted that decentralized model fares better than the centralized model for Hanoi.

Conclusion

This study assessed the socio-economic impact of decentralized composting business model in Hanoi, Vietnam. 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.

Therefore, composting of MSW from perspective of socio-economic analysis is attractive.

Socio-economic impact assessment of High Value fertilizer production for profit

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 Hanoi 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 1000 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 Hanoi which is denoted as baseline scenario with the help of cost-benefits analysis. Total Municipal Solid Waste generated in Hanoi is 6500 tons daily. It is assumed that 55 percent of solid waste generated is collected i.e., 3575 tons are collected. Out of these 3575 tons 100 percent of this MSW generated goes to landfill. In Hanoi city the amount of faecal sludge generated daily is about 1600 m^3 daily and 388 m^3 is collected which produces dewatered faecal sludge of 7.76 tons daily. Second, we have assumed that a composting plant produces 1000 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 Hanoi can be handled. The cost-benefit analysis of this scenario is also being analysed and compared with the baseline scenario.

In the following section we describe 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

The baseline condition considers that 55% of the MSW is being collected and landfilled. The rest of the MSW about 2925 tons of waste in open dumped without being disposed off in the landfill. In contrast, the alternative scenario where high value is being produced, the organic fraction of the MSW is being diverted to 9 plants each producing 1000 tons of high valued fertilizer. This entails a requirement of 11,640 tons of MSW along with 2328 tons of dewatered faecal sludge annually. The waste which can otherwise be utilized, stay in the open dumps and one of the primary cause for emission of 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 Hanoi. This is derived from the first order decomposition equation as recommended by UNFCC.

Similarly, estimation of the GHG emissions from faecal sludge which is presently directly discharged has also been estimated based on the following assumptions. Based on the study by Bond and Templeton, 2011 it is assumed that biogas production per capita is 0.04 m^3/person/day. Therefore the amount of biogas produced is 107,178,200 m^3 per annum. The methane content in biogas is 65% while carbon-dioxide percentage is 30%. The density of methane and that of carbon dioxide is 0.71 kg/m^3 and 1.98 kg/m^3. This implies that the amount of methane and carbon dioxide generated is respectively 49,462,739 Kg and 63,663,850 kg respectively. However, 90% of Hanoi's population is connected to septic tanks and there are also leakages during the co-composting. To make the estimations more realistic the study assumed that 50% GHG emissions cannot be averted by introduction of high value fertilizer business. Thus this implies the total GHG emissions (converting the methane generated into carbon dioxide equivalent) 530,620 tons of CO_2 equivalent.

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 per kgCO_2 - equivalent. Therefore, the amount of greenhouse gases which can be averted by co-composting MSW as well as fortifying from each plant is estimated to be USD 271,527 annually.

Cost of leachate treatment

The leachate potential from a MSW landfill primarily depends on the precipitation and thus is influenced by the climatic conditions such as rainfall and evaporation. On an average, leachate produced per tons of MSW is considered to be 87.2 lts. Therefore, the total amount of leachate production avoided annually can be calculated to be 200 lts from each plant. Considering the treatment cost of leachate to be USD 20 per litre (Johannessen, 1999; the range provided by the study varies between 9 – 20 USD/ton of waste), the annual cost of leachate treatment can be estimated to be USD 3990 annually.

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 environmental value of pollutions for pollutants like N, P, SS, BOD and COD is provided by a study by UNEP (2010). The following table 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 61: Environmental costs of the undesirable outputs

Pollutants	Environmental value of pollution (USD/m^3)[3]	Environmental value of pollution (USD/year)
N	0.6060	70,538.40
P	0.3087	35,932.68
SS	0.00252	293.33
BOD	0.0164	1,908.96
COD	0.0832	9,684.48

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

Total	1.107	1,18,357

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 utilized by the fortifier plant and hence the pollution of water (both surface and to certain extent groundwater) can be averted. The estimated benefits from each plant is shown in the above table (USD 118,357 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. Use of compost increases income by USD 10 per ha. Therefore, area that can be covered by compost application is 1800 ha. The net benefits estimated for applying co-compost was thus calculated to be USD 18,000 per annum.

Economic Impact

This section presents the financial analysis of the introducing the business model in Hanoi. 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 utilized 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, 9 plants of similar capacity would be required in Hanoi 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 9 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 provides the income statement for the 9 plants taken together. The production in the 9 plants would yield 9,000 tons of co-compost and fortifier which includes – (i) 5,400 tons of co-compost, (ii) 1,800 tons of fortifier (powdered form), and (iii) 1,800 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 four years, the business model earns a net profit. The table also illustrates that the financial assessment of the business model yields a negative NPV (USD 2,753,941) and an IRR of -8 %. The Benefit-cost ratio of the business model is less than 1 (0.144) implying that per dollar invested fetches 0.144 cents. 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 infeasible.

Table 62: Financial Analysis of the Fortifier business

	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	**2,940,750**															
Revenue																
Total Revenue		**360450**	**440573**	**530146**	**721887**	**772419**	**826489**	**884343**	**946247**	**1012484**	**1083358**	**1159193**	**1240337**	**1327160**	**1420061**	**1519466**
Expense																
Total Expense		**501774**	**538879**	**578773**	**626255**	**669329**	**715418**	**764733**	**817501**	**873962**	**934375**	**999018**	**1068185**	**1142194**	**1221384**	**1306117**
Depreciation		129717	129717	129717	129717	129717	129717	129717	129717	129717	129717	129717	129717	129717	129717	129717
Interest payments		1,98,501	1,82,301	1,41,801	81,051	1,98,501	-	-	-	-	-	-	-	-	-	-
Profit before tax		(469,541)	(410,324)	(320,145)	(115,135)	(26,626)	(18,646)	(10,107)	(971)	8,805	19,266	30,459	42,435	55,249	68,961	83,632
Income tax		-	-	-	-	-	-	-	-	2,642	5,780	9,138	12,730	16,575	20,688	25,090
Net Profit		**(469,541)**	**(410,324)**	**(320,145)**	**(115,135)**	**(26,626)**	**(18,646)**	**(10,107)**	**(971)**	**6,164**	**13,486**	**21,321**	**29,704**	**38,674**	**48,273**	**58,542**
Cash Flow	**(2940750)**	**(339,824)**	**(280,607)**	**(190,428)**	**14,582**	**103,091**	**111,071**	**119,610**	**128,746**	**135,881**	**143,203**	**151,038**	**159,421**	**168,391**	**177,990**	**188,259**
Discounted Cash Flow		**(339,824)**	**(280,607)**	**(190,428)**	**14,582**	**103,091**	**111,071**	**119,610**	**128,746**	**135,881**	**143,203**	**151,038**	**159,421**	**168,391**	**177,990**	**188,259**
NPV	**2,753,941**															
IRR	**-8%**															
ROI (Financial)		-16%	-14%	-11%	-4%	-1%	-1%	0%	0%	0%	0%	1%	1%	1%	2%	2%
ROI (Financial Average)	**-3%**															

Social Impact assessment

Impact on Employment

The business model involves utilization of two different waste streams – municipal solid waste and the faecal sludge. The collection rate of MSW is constrained to only 55% of the entire city waste. The number of workers engaged in a composting plant is 8 and monthly wage rate is USD 206. Thus, additional income generated in the alternative scenario is USD 14,805 monthly i.e., 177,660 USD annually.

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 population in the Hanoi city is 7,067,000. The DALY for the selected risk factor is 2.8 for Hanoi and economic value of DALY is USD 1330. Assuming only 5 percent of the population will be affected by diarrhea the net health benefit that can be averted by treatment of FS is estimated to be USD 1,315,875 annually for Hanoi.

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. Import of inorganic fertilizer in Vietnam is around 431,000 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. 688. The reduction in import bill for fertilizer is estimated to be USD. 378,180.

The net social benefits derived from – (i) employment generation, (ii) aversion of health costs, and (iii) savings from foreign exchange are provided in the following table.

Table 63: Societal benefits of the fortifer business

Parameters considered for societal benefits	Net Benefits (USD/annum)
Employment generation	177,660
Aversion of health costs	1,315,875
Savings from foreign exchange	378,180
Total	**1,871,715**

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 below. The analysis looked at the potential impact of the business model including the direct and indirect 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 21,770,187 and the BCR is 7.77. 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 21,685,196 with major benefits coming from the health expenditure averted and foreign exchange saved due to lower import of inorganic fertilizer. Thus, the fortifier business model is economically feasible but not financially feasible.

Table 64: Socio-economic analysis of the fortifier business

Socio-economic result (USD/year)	Financial	Financial & Environmental	Social, Environmental & Financial
Financial result:			
NPV	(2,753,941)	(2,753,941)	(2,753,941)
Environmental benefit:			
Value of net GHG emission saving		2,838,932	2,838,932
Social benefit:			
Reduced use of inorganic fertilizer			2,429,258
Value of jobs and additional income to workers			2,290,545
Savings in health expenditure			16,965,394
Total social benefit			21,685,196
NPV	**(2,753,941)**	**2,533,644**	**21,770,187**
ROI	**-3%**	**12%**	**74%**
BCR	**0.14**	**1.11**	**7.77**

Sensitivity analysis

The selected variables for the stochastic models are shown below in the following table. The variables have respective distribution functions depending on the values in the baseline or futuristic and are based on literature survey. The variables which are considered as stochastic are similar to that of the compost models.

Table 65: Selected variables for the stochastic model

Variable	Unit	Distribution assumed	Reference
Discount rate	%	*Triangular* (10, 12, 15%)	Assumed ranges between 10% to 15%
Amount of dewatered faecal sludge obtained from faecal sludge	ton/m^3	*Triangular* (0.017, 0.02, 0.028)	
Application of compost	ton/ha	*Uniform Distribution*: (5, 10)	Assumed
Leachate production	m^3/ton	*Triangular distribution:* (80, 85, 100)	Safari and Baronian (undated)
Cost of leachate treatment	USD	*Triangular*: (9, 20, 30)	Johannessen 1999
Average increase in income due to application of compost	USD/ha	*Uniform*: (5, 10)	Conservative estimate based on
Landfill area saved per unit	ha/ton	*Uniform*: (0.01 – 0.03)	Johanssen , World Bank
Price of CERs	USD/ton CO_2 eq.	*Triangular:* (1, 3.8, 5)	Assumed considering the volatility of the market

The probability density function of the net benefits of the NPV is derived from the iterations of each of the stochastic variables in determining the NPV. The distribution shows that there is a certainty of 48% to achieve the mean NPV level, however, the ROI is less than 100% which makes the business less attractive for the city.

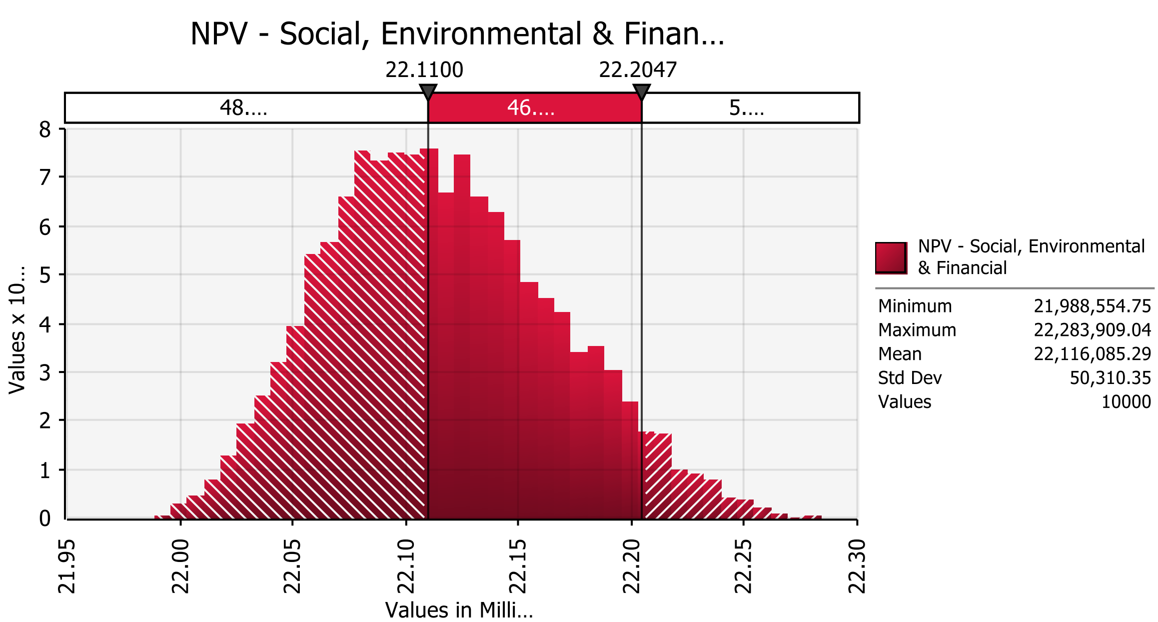

Figure 10: Probability density function of the NPV for the fortifer model

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 9 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.

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