2015

Resource Recovery and Reuse (RRR) Project

Socioeconomic Analysis of RRR Business Models, Bangalore City Report

Authors: Taron, A. [a,b], M. H. Bala Subrahmanya[c], and H.S. Sudhira[c]
Correspondence: M. Otoo[a]

[a] International Water Management Institute
[b] Tata Institute of Social Science
[c] Indian Institute of Science

Supported by:

RESEARCH PROGRAM ON Water, Land and Ecosystems
CGIAR

IWMI International Water Management Institute

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

Contents

List of Tables

List of Figures

Data used in the analysis is from 2013 and 2014.

Denomination: 1 USD = 1 USD (2014); 1 USD = 63.16 INR (2014)

INR: Indian Rupees

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 Bangalore

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 6: Manure to Power	The business process manure waste from agro-industries such as livestock, poultry, piggeries etc. to generate electricity which is internally used and excess energy is sold to households, business or local electricity authority.
Model 4: Onsite Energy Generation by Sanitation Service Providers	The business model is initiated by either enterprises providing sanitation service such as public toilets or by residential institutions such as hostels, hospitals and prisons with concentrated source of human waste. The business concept is to process and treat human waste in a bio-digester to generate biogas to be used for lighting or cooking.
WASTEWATER REUSE	
Model 9: On Cost Savings and Recovery	The business concept is to treat wastewater for safe reuse in agriculture, forestry, golf courses, plantations, energy crops, and industrial applications such as cooling plant. The sludge from the treatment plant could be used as compost and soil ameliorant and energy generated can be used for internal purpose resulting in energy savings.
Model 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 10: Informal to Formal Trajectory in Wastewater Irrigation - Incentivizing safe reuse of untreated wastewater	Informal reuse of wastewater is commonly practiced by farmers in developing countries but it also entails significant health costs, often borne by the public and are of social nature. This social nature of these costs justifies public investments in incentives to promote safe reuse of wastewater and minimize risk along the entire value chain as such incentives could potentially turn this unsafe informal activity into a safe and formal one with shared rewards for all the stakeholders.
Model 11: Inter-sectoral Water Exchange	In a water scarce situations, a sustainable approach to ensure safe and adequate water supplies for the society is through inter-sectoral water transfers (water swaps), which aims at the provision of treated water to farmers for irrigation, in exchange for freshwater for domestic purpose. The

	business model has high applicability to other water-intensive users such as industries, golf course etc.
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 model 8, except that the scale of operations is smaller at community level which includes door to door collection of MSW.
Model 17: High value Fertilizer Production for Profit	Similar to Model 8 in concept but in addition to MSW, the business uses fecal sludge from onsite sanitation which is rich in nutrients as input. The business also develops enriched compost and pelletized compost which has higher nutrient content with improved and efficient delivery of nutrient to crops.
Model 20: Outsourcing fecal sludge treatment to the farm	The business concept is around the partnership between vacuum truck operators that empty fecal sludge from onsite sanitation systems and farmers in peri-urban areas. The vacuum truck operator charges a fees for emptying of sludge from household and fees to the farmers to deliver the fecal sludge to the farm where the sludge is treated and converted into compost.

Methodology

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

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

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

- Step 1: Identification of socioeconomic impacts of similar business cases in Bangalore
- 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 India 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 India. 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 India, 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 India. 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 Bangalore. 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 Bangalore 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 Bangalore 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 Bangalore.

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			
Model 1A: Dry Fuel Manufacturing - Agro-industrial Waste to Briquettes	Baseline considers burning of the agrowaste at the farm.	The alternate scenario consists of 15 plants with a production capacity of 4080 tons in a year.	
Model 6: Manure to Power	The baseline assumes that presently there are no power generating livestock farm in Bangalore.	In absence of the data about livestock farms, the study considers 10 representative farms with 2,500 pigs producing 550,000 m^3 of biogas in a year.	
Model 4: Onsite Energy Generation by Sanitation Service Providers	In Bangalore community, paid toilets do exist however, there utilization of biogas is yet to come up	In Bangalore there are 600 slums and 34,656 households without a toilet. It is assumed that the onsite sanitation facilities would be provided across the city with a user capacity ranging from 400-700, to cater to the slums and the migrating population related to jobs in Bangalore	
System Boundary for the Wastewater models			
Model 9: On Cost Savings and Recovery	Presently none of the 14 WWTPs in Bangalore generates electricity	7 WWTPs with more than 18 MLD treatment capacity is considered to produce electricity. The business model as such assumes the existence	The feasibility of electricity generation from WWTPs requires a capacity to treat more than 5 MGD.

Business Models	Base case	Alternative	Remarks
		of the WWTP and the electricity generation unit is an addition.	Based on this fact and the financial analysis, the WWTPs with a capacity more than 18 MLD has been considered for WWTP with electricity, irrigation and compost. In fact, 15 units of such electricity generation is assumed within 7 WWTPs. All the other WWTPs are considered to be linked with aerobic ponds where aquaculture can be practiced.
Model 8: Beyond Cost Recovery: the Aquaculture example	Aquaculture utilizing wastewater is being practiced in Bangalore. The baseline however, do not consider the existence of such cases.	The wastewater treated in the smaller WWTPs are being diverted towards aerobic ponds of 2 - 4 ha. where aquaculture is being done.	
Model 10: Informal to Formal Trajectory in Wastewater Irrigation - Incentivizing safe reuse of untreated wastewater	This business model has not been evaluated for the socio-economic assessment primarily because of health related data with respect to use of wastewater in the context of Bangalore.		
Model 11: Inter-sectoral Water Exchange	The business model has not been evaluated for the socio-economic assessment since a technical study is required to understand the advantages and disadvantages for agriculture with respect to use of wastewater from urban areas. At the same time the social perspectives of such water exchanges are quite complex to be handled by quantitative models as had been done in the study for other business models		
System Boundary for the Nutrient Models			
Model 15: Large-Scale Composting for Revenue Generation	In Bangalore 4000 tons of waste is being produced. Of this 80% is being collected and disposed to the landfill and the other waste is being illegally dumped/burned.	The Large scale centralized model assumes that 10 plants, each with a capacity of 200 tons is established to target the organic fraction of the MSW (50% of 4000 tons).	
Model 16: Subsidy free community based composting		The decentralized model of community composting assumes that the communities will form co-operatives among themselves for collection of waste and the waste would be segregated at the source (household level). The representative size used for the socio-economic analysis is 3 ton plant and there exits 89 such co-operatives which can handled the entire waste of the city	

Business Models	Base case	Alternative	Remarks
Model 17: High value Fertilizer Production for Profit	The production of faecal sludge in Bangalore is around 340 m^3. About 140 m^3 of faecal sludge is being collected. However, it is being collected and either disposed or sold off to the farmer. For the present socio-economic study it is assumed that no faecal sludge is being utilized for co-composting or Fortifer production.	In the alternate scenario it is being assumed that the entire faecal sludge is being collected and utilized for Fortifer or compost production. 4 plants each with a capacity of production of 2400 tons of co-compost and Fortifer is being assumed.	
Model 20: Outsourcing fecal sludge treatment to the farm	This business model has not been evaluated for the socio-economic assessment primarily because of paucity of scientific data on health and environmental related issues with respect to on farm practices with faecal sludge in the context of Bangalore.		

Synopsis of the socioeconomic assessment of the RRR business models

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

Energy Business Models

The following table (*Table 3*) provides key highlights of Energy business models. To iterate, the table indicates the NPV of the three components of each of the energy business model. It can be seen from the table, that the energy models have a Benefit-Cost ratio (BCR) greater than 1. However, the changes in integrating the environmental and social components has contrasting impacts for different models. It can be observed that the ESCO model has a higher return in terms of environmental and social benefits over the other two models although there are possibilities of losses based on the financial assessment of the model.

Table 3 Energy Business Models

	Model 1A: Dry Fuel Manufacturing - Agro-industrial Waste to Briquettes	**Model 6: Manure to Power**	**Model 4: Onsite Energy Generation by Sanitation Service Providers**
Scale of operation	15 plants, each having a production capacity of 4080 tons per year	2,500 animals producing 550,000 m^3 of biogas per year. For the entire city 10 representative plants were considered each with a	Establishment of 500 units with a capacity for accommodating 400 users per day and about 8,400 m^3 of biogas is produced per year

		production capacity of 325 KW	
NPV Financial (in USD)**	5,207,046	1,121,327	4,419,267
NPV Financial & Environmental (in USD)**	5,722,335	12,379,798	4,443,139
NPV Financial, Environmental & Social (in USD)**	53,402,383	36,945,495	19,725,199
B:C Ratio	9.78	16.21	6.26
ROI	108%	175%	103%

** Calculated for life cycle term of 15 years using Discount Rate of 8%
K = 1,000

Wastewater Reuse Business Models

In the context of Bangalore, 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 Bangalore which was from the waste supply and availability data based on sewer network in Bangalore. 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	The existing WWTPs with a capacity of less than 25,000 m^3 is assumed to be utilized for Phyto-remediative treatment and fish production	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)**	32,492	1,143,197
NPV Financial & Environmental (in USD)**	2,986,798	11,583,276
NPV Financial, Environmental & Social (in USD)**	6,706,600	318,984,382
B:C Ratio	35.83	29.22
ROI	359%	382%

** 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	10 plants each with a handling capacity of 200 tons of MSW is assumed.	89 co-operatives with 15 business entities is said to serve about 70% of the population in Bangalore	4 plants are assumed to consume the entire faecal sludge produced and each with a production capacity of 2400 tons in a year
NPV Financial (in USD)**	2,699,111	169,004	(448,862)
NPV Financial & Environmental (in USD)**	68,113,876	15,388,013	2,301310
NPV Financial, Environmental & Social (in USD)**	113,261,861	70,500,833	21,595,127
B:C Ratio	6.94	18.66	15.54
ROI	116%	164%	141%

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

Summary assessment of financial feasibility of RRR Business Models

Table 6 provides a summary overview of the criteria used for feasibility of RRR business models for Bangalore 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 Bangalore 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 Bangalore. 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	50.7%	9.78	108%	**Medium**
Model 6: Manure to Power	54.2%	16.21	175%	**Medium**

Model 4: Onsite Energy Generation by Sanitation Service Providers	48.9%	6.26	103%	**Medium**
WASTEWATER REUSE				
Model 9: On Cost Savings and Recovery	54.7%	35.83	359%	**Medium**
Model 8: Beyond Cost Recovery: the Aquaculture example	49.7%	29.22	382%	**Medium**
NUTRIENTS				
Model 15: Large-Scale Composting for Revenue Generation	51.1%	6.94	116%	**Medium**
Model16: Subsidy free community based composting	53.5%	18.66	164%	**Medium**
Model 17: High value Fertilizer Production for Profit	50.8%	15.54	141%	**Medium**

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

Model 1 – Dry fuel Manufacturing: The business model is economically and financially viable. Dry fuel manufacturing in Bangalore 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 3– Power capture model – Livestock waste to energy: 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 electrification of rural areas which is more deprived than the urban areas and also reduction in the wastewater run-off with a high BOD content from the farms.

Model 6– Onsite Energy Generation by Sanitation Service Providers: This business model has a better feasibility in terms of the deviation from the mean societal benefits. The chance of success as compared to the other energy models are marginally higher. The major significance of the model lies with the sanitation provision for the slum dwellers and in exchange providing them biogas for cooking purposes. The sanitation services also caters to the large number of migrant population usually for jobs towards Bangalore.

Model 16– Phyto-remediative wastewater treatment and fish production: 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 17– 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 favourable. In Bangalore 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 8 – Large scale composting for revenue generation: The financial analysis shows that large sized compost plants of 200 tons/day is feasible in the medium to high range. The socioeconomic assessment considered the 10 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 9 – Decentralized community based composting: This is a similar model to that of Model 8 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 Bangalore 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 11 – 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 socioeconomic terms since it provides better sanitation and helps environmentally. 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 and in relation to this financially the business is also not viable.

Socio-economic impact assessment of Dry Fuel manufacturing: Agro-waste to Briquette business model in Bangalore

Introduction

The business model that seeks to manufacture dry fuel from agro waste seeks to take advantage of the over dependence on bio-mass fuel for energy needs. For the poor in developing countries like India, urban as well as rural, wood is usually the principal source of energy for cooking food and for keeping warm. In these countries an estimated 86 percent of all the wood consumed annually is used as fuel. As populations have grown, this dependence has led inexorable pressures on the wood resource which all too often have resulted both in the destruction of the forest and in a worsening of the situation of the hundreds of millions of people whose life is conditioned by the products of the forest.

By finding out the ways and means of utilizing the inherent economic value in solid waste, city administration can reduce expenditure and solid waste impact on human health and environment. One such option is using the dry agro-waste (waste from food processing industries, agro-industries, agricultural farms in the periphery of Bangalore city) to manufacture fuel briquettes. Briquettes offer alternative to pricey charcoal. Fuel briquettes can be made from easily available waste materials. In urban areas this can be saw dust and Shredded paper. In rural areas and villages they can be made from leaves, grass, rice husks and other agricultural wastes in many combinations.

Biomass briquettes are a form of solid fuel that can be burned for energy. They are created by compacting loose biomass residues into solid blocks that can replace fossil fuels, charcoal and natural firewood for domestic and institutional cooking and industrial heating processes. Briquettes have the potential to be a source of renewable energy if they are made from sustainably harvested biomass or waste agricultural residues. Opportunities exist for all scales of business to grow and tap into the available markets and with targeted support the Indian briquette industry can be developed from a sporadic spread of small enterprises into a widespread and self-supporting industry.

This agro-waste briquetting industry can have significant impact on the health of the users of bio-mass based energy sources like wood and cow dung. Further the environmental impact of the agro-waste briquette could be significantly lower when compared with the traditional bio-mass fuels. The potential economic, environmental and social impacts of the dry fuel manufacturing business model need to be assessed to ensure its sustainable development of this industry. In this study, we evaluated the socio-economic impacts of dry fuel manufacturing business with a capacity to handle 16 tons per day of agro-waste producing a total of around 4080 tons of briquettes annually. The socio-economic analysis is conducted based on the valuation of financial, environmental and health benefits and costs associated with the business model.

Technological options for briquette business

Raw materials used for briquette production

Briquettes can be produced from various raw materials such as agricultural residues, organic municipal solid waste, sawdust from timber mills and other woody biomass. However, the quality of the briquette which is measured by its energy content, depends on the raw materials used. The selection of suitable input materials, in addition to availability, is based on the input's desirable characteristics such as low moisture content (10-15%), low ash content (4%) and uniform or granular flow characteristics of the raw material (Tripathi et al., 1998). The main sources of input for briquette production in Uganda include agricultural residues (such as maize cobs, rice husks, coffee husks, groundnut husks etc.), wood processing waste (such as sawdust) and organic municipal solid waste.

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 Uganda, for example invented a low-cost kiln made out of old oil drums to carbonize its agricultural waste to produce charcoal powder. Non-carbonized briquettes on the other hand are made directly by solidifying/compacting the raw material. They are used by industrial and commercial processes such as brick manufacturing, lime production, fish smoking, tobacco curing, beer brewing, coffee and tea drying which rely on charcoal and firewood for cooking and heating purposes. They can also be used as a replacement fuel among rural populations where firewood is still dominant (Ferguson, 2012).

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 objective of the socio-economic impact assessment is to provide a summary of the effects (benefits and costs) of the proposed business model. When compared with the financial analysis this is more comprehensive as it also incorporates the effect of the proposed business model on the environment, society, and health. All the different stakeholders such as the society, government, and the environment is considered. 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 present study evaluates the economic costs and benefits by accounting for the cost of starting the business and operating the business and the economic benefits to be derived from the sale of the dry fuel. The social angle of the problem is incorporated by the number of jobs created. Further the environmental impact is considered by estimating the value of the GHG emissions saved.

The base case considers a plant with a capacity to handle 16 tons of dry agro waste per day. This plant will have to capacity to manufacture about 4080 tons of briquettes annually. The alternative scenario scales up the production through installation of 15 such plants to be able to handles all the agro-waste generated in the districts of Ramanagara, Bangalore Rural and Bangalore Urban which covers the BMRDA region.

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

Environmental impact assessment

The environmental impact of the dry fuel business model was assessed through the Greenhouse gas emissions that are released into the environment through open burning in the field. It is a common practice in the agricultural fields around Bangalore to burn the waste openly in the field before the start of the next growing season. This releases a large quantity of carbon into the environment. It has been estimated that on an average 19% of the waste burnt on the field gets released into the environment as Greenhouse gas emissions. If the agro-waste to briquette business model could divert the waste from the open field burning practice the impact on the environment could be significantly reduced.

The agricultural waste used in the briquette making enterprise is assumed to be sourced from the three districts mentioned earlier. Considering the cereals, pulses, oil seeds, and sugar cane grown primarily in this area the agricultural produce is approximately 505252 tons per year. Assuming 25% of it to be the dry waste that is disposed using the open burning technique, the total waste generated is approximately 126000 tons annually. Open burning of this waste will generate approximately 24000 tons of GHG emissions. With the cost of these emissions being valued at 25 USD, the total cost of these GHG emissions is 91,198 USD. With one 16 TPD plant in operation the value of the GHG emissions saved from release into the environment is 22,800 USD and the rest when released into the environment is costed at 577187 USD.

Social impacts

Additional income from agricultural residue waste

There are some small agro waste briquetting units that are currently operational around Bangalore. Many of them use corn cobs and coconut coir as the raw material. The supplier of these raw materials charge about 58 USD per ton for these materials. If the briquetting practice were to be established in large scale so that the agro waste generated could be fully absorbed it could provide some additional income to the farmers in the region. The net benefit for the farmers supplying raw materials to the plants would accumulate to be USD 7,238,400 annually. 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 11 full time workers earning a total annual salary of USD 18,744.

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).

Officials estimate shows that over 7,000 kiloliters of kerosene is used per month in Bangalore by the poor families to whom it is sold through the public distribution system. They also estimate that around 400,000 households in the city use kerosene for cooking. Briquettes are direct replacement to kerosene and fuelwood used in institutions which have a combustion efficiency of 30% and is one of the primary cause of indoor air pollution resulting in respiratory illness among women and children (Choi et al 2015) in Bangalore. 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.

Given the above figures, if it is assumed that the average family size is 5 in Bangalore, it can be estimated that 20 million people are susceptible towards respiratory illness. Use of briquettes reduce this risk and hence DALY values have been used for monetizing the health benefits in using briquettes. The value of DALY/1000 per capita from indoor air pollution in India is 8 and the GDP per capita in India is USD 5,417 annually, the net health benefit can be estimated. The present study considers only 1% affected population through which it can be calculated that the net benefits are USD 866,720.

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 other countries 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 56-78 USD/ton as feedstock. The selling price of briquettes is 93.25 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 India is 30.9% (Corporate tax - Refer to financial analysis document for details).

The financial analysis of a briquette business is presented in Table 9. 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, the business incurs net loss and consecutively for the second year even with sales increase. However, the firm breaks even in the third year 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 51,477 and IRR of 10.35% indicating that the business model is financially viable.

Table 8: Financial results of briquette business (USD)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Revenue															
Sale of Briquette	285,357	325,688	392,046	419,490	448,854	480,274	513,893	549,865	588,356	629,541	673,609	720,761	771,215	825,200	882,964
Total Revenue	**285,357**	**325,688**	**392,046**	**419,490**	**448,854**	**480,274**	**513,893**	**549,865**	**588,356**	**629,541**	**673,609**	**720,761**	**771,215**	**825,200**	**882,964**
Expense															
Labour and Input cost	226,762	242,635	259,620	277,793	297,239	318,045	340,308	364,130	389,619	416,893	446,075	477,300	510,711	546,461	584,713
O & M Cost	2,666	2,853	3,052	3,266	3,494	3,739	4,001	4,281	4,581	4,901	5,244	5,611	6,004	6,424	6,874
Supplies and Other Costs	65,212	70,767	77,871	83,294	89,097	95,306	101,950	109,059	116,665	124,804	133,512	142,830	152,800	163,469	174,884
Total Expense	**294,640**	**316,255**	**340,543**	**364,353**	**389,830**	**417,091**	**446,259**	**477,469**	**510,865**	**546,597**	**584,831**	**625,742**	**669,516**	**716,354**	**766,471**
Profits before depreciation, interest and tax	**(9,283)**	**9,433**	**51,503**	**55,136**	**59,024**	**63,183**	**67,634**	**72,396**	**77,491**	**82,944**	**88,778**	**95,020**	**101,699**	**108,846**	**116,493**
Depreciation	5,429	5,429	5,429	5,429	5,429	5,429	5,429	5,429	5,429	5,429	5,429	5,429	5,429	5,429	5,429
Profits before interest and tax	**(14,712)**	**4,004**	**46,075**	**49,708**	**53,595**	**57,755**	**62,205**	**66,967**	**72,063**	**77,515**	**83,349**	**89,591**	**96,270**	**103,417**	**111,064**
Interest Payments	21,656	26,469	28,531	25,781	21,656	16,156	9,969	2,406	-	-	-	-	-	-	-
Profit before tax	**(36,368)**	**(22,465)**	**17,544**	**23,927**	**31,939**	**41,598**	**52,237**	**64,561**	**72,063**	**77,515**	**83,349**	**89,591**	**96,270**	**103,417**	**111,064**
Income tax	-	-	5,421	7,393	9,869	12,854	16,141	19,949	22,267	23,952	25,755	27,684	29,748	31,956	34,319
Net profit	**(36,368)**	**(22,465)**	**12,123**	**16,533**	**22,070**	**28,745**	**36,095**	**44,612**	**49,795**	**53,563**	**57,594**	**61,907**	**66,523**	**71,461**	**76,745**

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 9.78, NPV of USD 53,402,383 and ROI of 108% when only direct benefits from the briquette production are taken into account[1]. The ROI increases from 18% to 19% when environmental benefits are taken into account and to more than 100% when the environmental and social impacts are taken into account. The total value of the social benefits of the business is USD 48,549,338 with major benefits coming from the additional income to farmers. Thus from a socio-economic perspective, the dry fuel manufacturing business model is highly attractive.

Table 9: 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	5,207,046	5,207,046	5,207,046
Environmental benefit:			
Value of net GHG emission saving		515,289	515,289
Social benefit:			
Additional income to farmers & employment			
Health benefits			
Total social benefit			73,295,461
NPV	**5,207,046**	**5,722,335**	**53,402,383**
ROI	**18%**	**19%**	**108%**
BCR	**0.95**	**1.04**	**9.78**

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 price of briquette and the agrowaste were varied to assess the resulting effect on the overall socioeconomic feasibility of the business model. The following table (**Error! Reference source not found.**) elaborates the ssumptions made on the stochastic variables.

Table 10: Stochastic variable used for the analysis

Variable	Unit	Distribution specified	Source
Price of briquette	USD/Kg	*Triangular:* (0.25 , 0.282, 0.35)	Based on existing business
Price of agrowaste	USD/ton	*Uniform:* (58 – 75)	Based on existing prices

[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.

Discount rate	%	*Triangular*: (10%, 12%, 15%)	Assumed
Carbon Credit price	USD/t CO_2 eq.	*Triangular Distribution* (5,7,10)	Assumed

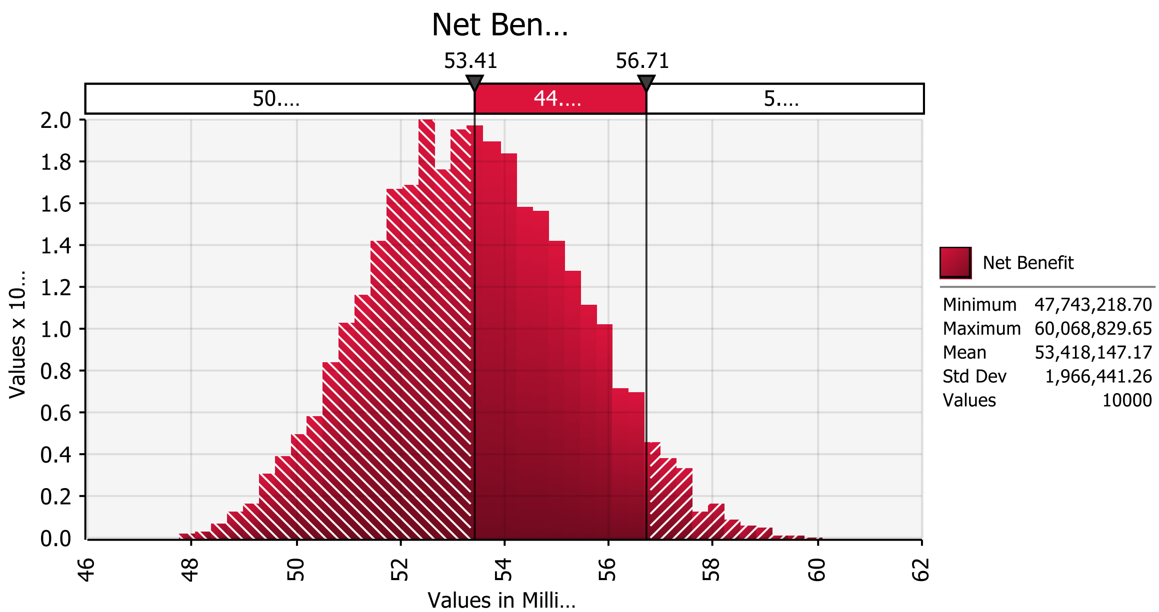

Figure 1: Probability distribution of the NPV of the briquette business

The above 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 53.41 million. The 90% confidence interval indicates values between USD 48 and USD 58 million showing a little standard deviation from the mean value. The above figure also shows that the probability that the net benefits will fall below the mean NPV is 50.7% which projects a higher viability of the NPV.

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 fuelwood 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 the Manure to Power businesses in Bangalore

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-digestors
- 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 Bangalore 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 Bangalore the information about large pig farms are limited. In the financial analysis, a representative farm rearing 2,500 pigs has been considered. The present socio-economic study to evaluate the societal benefits of such businesses assumes a scaling up of such farms for the city as a whole. The socio-economic assessment considers 10 such representative pig farms in the peri-urban areas of Bangalore.

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 11: 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. 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 1,113,418 annually.

Table 12: 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., 927,180 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 370,872 m^3/year. Biogas constitutes 65 percent methane. Hence, total biogas produced is 570,572 m^3/year. Assuming 365 operating days, the biogas yield per day is 1563 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 10,363 kWh. We also assume that the power plant operates for 10 hrs in a day, therefore, in an hour 1,036 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 363 kWh. Therefore, total electricity which can be supplied annually in the market is 1,324,950 kWh. The average requirement of electricity per household is 120 kWh/month. Therefore, with the produced electricity only 920 households can be served. 920 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 52,976 ton of CO_2 annually. In total through electricity production from pig slurry of one heard of 1500 pigs, 53,133 tons of CO_2 emissions can be avoided annually including the emissions from the kerosene used by the households for lighting. As there is a need for 10 plants to handle the problem of pig slurry in Bangalore, so 10 plants will help avoid emission and monetary value of that emission is 201,904 USD considering a price of USD 3.8 per ton of CO_2 equivalent .

Table 13: 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	52,976
Emissions from Kerosene	Tons of CO_2/year	157
Total Emissions	Tons of CO_2/year	53,133
Price of carbon credit	USD/ton CO	3.8
Value of emission from a plant	**USD**	**201,904**

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 363 kWh can generate 8 additional employment. The monthly wage income of an employee of power plant is 225 USD. Therefore, total monthly wage income generated is 1,800 and annual income of 18,000 USD. Hence, total income generated by 10 plants is 216,000 USD per annum.

Expenditure saved from using kerosene as alternative source of lighting

In rural Bangalore electricity is a major problem. 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 using kerosene lamps. The differences in prices between use of electricity and kerosene as a source of lighting is calculated to be INR 14.75 (USD 0.23) each hour. Utilizing this value, the yearly estimate with 8 hrs every day can be calculated as USD 683.65. Considering 920 households as the primary beneficiaries, the net benefits can be calculated as USD 628,959 annually.

Table 14: Net social gain under alternative scenario

Social Impact:		
	Unit	USD
Wage income for employees	USD/year	216,000
Expenditure saved from kerosene use	USD/year	628,959
Total money saved	USD/year	**844,959**
Net Gain (NPV over the life cycle)	USD/year	**2,729,999**

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 Bangalore using kerosene is estimated to be 400,000 and according to the estimates given by WHO DALY /1000 capita/year for Indoor air pollution is 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 140,000 USD annually.

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 0.06 kWh. 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 corporate tax for similar businesses in India is 30.9% (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 for the 10 farms together. Assuming a discount rate of 8% and useful life of 15 years, the business model resulted in a mean NPV of USD 1,121,327 indicating that the business model is financially viable. The benefit-cost ratio for the business model is 2.79.

Table 15: Financial results of power capturing from pig slurry (USD)

	0	1	2	3	4	5	6	7	8	9	10	11
Total capital cost	2,670,000											
Total revenue		966,795	1,024,803	1,086,291	1,151,469	1,220,557	1,293,790	1,371,418	1,453,703	1,540,925	1,633,381	…
Total production and other cost		450,591	480,305	512,070	546,028	582,330	621,139	662,628	706,982	754,400	805,094	…
Profit before interest and tax		**516,204**	**544,498**	**574,221**	**605,441**	**638,227**	**672,651**	**708,790**	**746,720**	**786,525**	**828,287**	**…**
Depreciation		151,333	151,333	151,333	151,333	151,333	151,333	151,333	151,333	151,333	151,333	…
Profit before tax		**364,871**	**393,164**	**422,888**	**454,107**	**486,893**	**521,318**	**557,456**	**595,387**	**635,191**	**676,953**	**…**
Interest		72,974	78,633	84,578	90,821	97,379	104,264	111,491	119,077	127,038	135,391	
Net profit		**291,897**	**314,532**	**338,310**	**363,286**	**389,515**	**417,054**	**445,965**	**476,310**	**508,153**	**541,563**	**…**
Cash flow	(2,670,000)	298,572	321,207	344,985	369,961	396,190	423,729	452,640	482,985	514,828	548,238	…
Discount rate	8%											
Discounted value of cash flows		298,572	321,207	344,985	369,961	396,190	423,729	452,640	482,985	514,828	548,238	…
Present value of cash flows	7,455,511											
NPV	**$1,121,327**											
ROI (Financial)		**11%**	**12%**	**13%**	**14%**	**15%**	**16%**	**17%**	**18%**	**19%**	**20%**	**…**
ROI-average (Financial)	**18%**											
BCR-Financial	**2.79**											

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 8% to obtain the present value of social and environmental impacts.

Table 16: 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	1,121,327	1,121,327	1,121,327
Environmental benefit:			
Value of net GHG emission saving & Water pollution costs averted		11,258,471	11,258,471
Social & Health benefit:			
Total social (employment) & Health impact			24,565,697
Total social benefit			
NPV	**1,121,327**	**12,379,798**	**36,945,495**
ROI	**18%**	**68%**	**175%**
BCR	**2.79**	**7.01**	**16.21**

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 the carbon credit and (iii) economic value of the DALY and (iv) differences in the prices of kerosene and electricity for lighting 1 hour. 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. The primary variables selected for the stochastic model are explained in the following table (Table 8).

Table 17: Variables selected for the stochastic model – Livestock waste to electricity

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

Carbon Credit price	USD/t CO_2 eq.	Triangular: (0.51, 1, 3.8)	0.51 was the lowest value reached during 2014
Economic value of a DALY	USD	Triangular Distribution (250, 500,1400)	The lower range corresponds to estimates for cancer and higher range to gross national per capital income.
Differences in prices between kerosene and electricity for 1 hour lighting	USD/hr	Uniform distribution (0.23 to 0.3)	Assumed

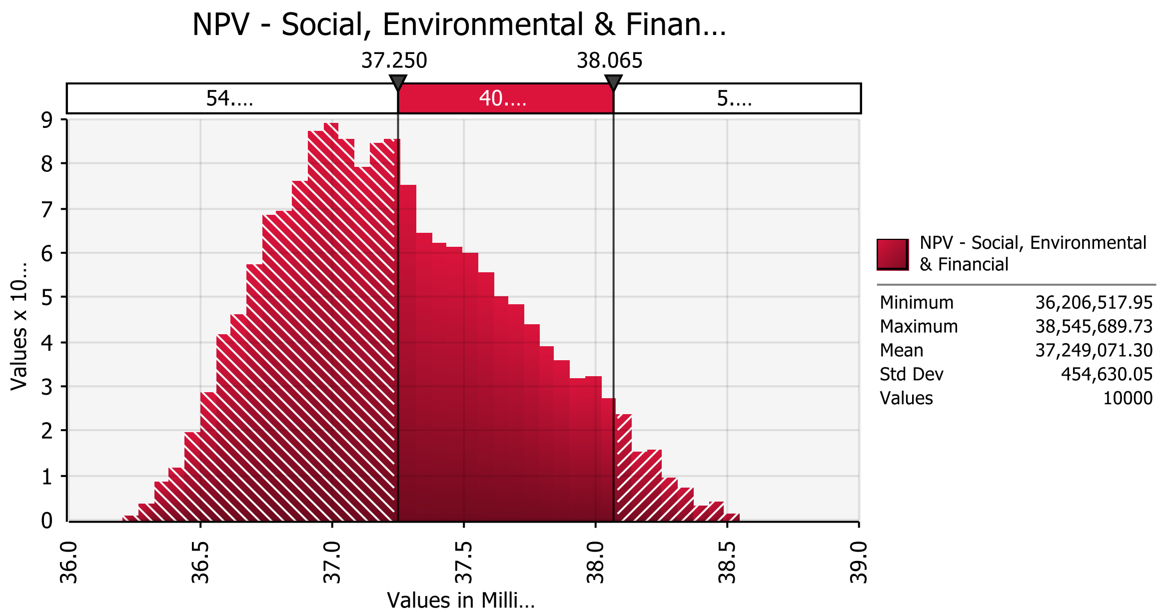

Figure 2: Probability Density function of the NPV for net benefits derived from the electricity generation form Livestock manure

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 37.25 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.

Conclusion

This study assessed the socio-economic impact of a power capturing model from pig slurry in Bangalore, India. 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.

Socio-economic impact assessment of Onsite Energy generation by Sanitation Service providers in Bangalore

Introduction

To address the sanitation and liquid and solid waste management challenges, during the past decade a number of business oriented solutions to sanitation have been implemented in various developing countries. In Kenya, the Athi Water Service Board (AWSB)[2] have developed and implemented projects that are aimed at improving access to safe water and sanitation for the informal settlements by building toilet facilities with biogas systems. Such facilities are also referred to as B*io-centres* (AFD and AWSB, 2010). These bio-centers provide, not only toilet services but also cooking services to different users by using the biogas generated from bio-digesters fed with faecal sludge from the toilet facilities. A number of biogas systems have also been constructed in institutions such as schools, hospitals, prisons and other institutions in Rwanda, Nepal and Philippines. The institutional biogas systems, in addition to improving waste management, are primarily applied to save on fuelwood energy used for cooking. This business model can be implemented in institutions with large number of residents (schools, prisons, hospitals) or as a separate business enterprise i.e. toilet complex with biogas system. In this report, we focus on the later.

The objective of this study is to assess the potential socio-economic impacts of onsite energy generation system serving a target population of 3,190 people in central zone of Kampala, Uganda. The socio-economic analysis is conducted based on the valuation of financial, environmental, social and health benefits and costs associated with the business model.

Description of technology

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

Various types of organic waste can be used to produce biogas. Table 1 presents biogas yields of different types of organic waste (mainly dung). The hydraulic retention time (HRT) ranges from 15 to 25 days depending on the climatic conditions. Average HRT is 20 days at an ambient average temperature of 25 °C. The biodigester unit, in addition to biogas, produces a digested slurry that can be used as liquid fertilizer.

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

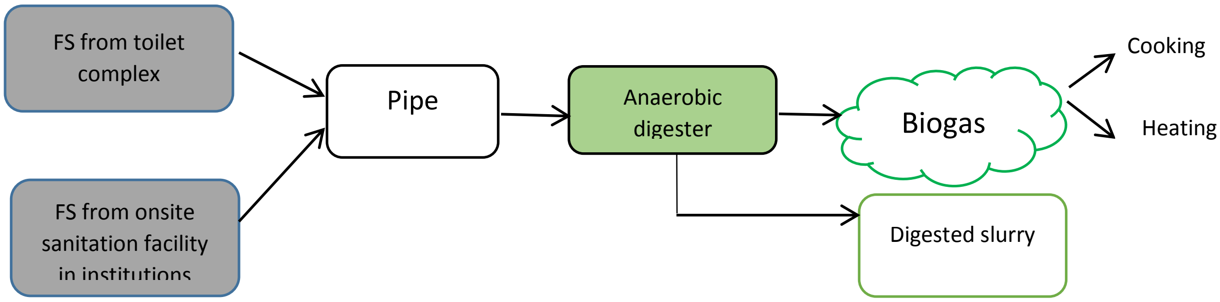

Figure 1 schematic of onsite energy generation business model

Table 18: Gas yield potential of dung

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

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

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

Overall approach to socioeconomic analysis

In this study, the economic analysis of onsite energy generation in enterprises providing sanitation services is conducted based on the valuation of socio-economic, environmental and health benefits and costs associated with the business model. It is assumed that public toilet complexes will be concentrated in the slum areas where there is high population density. According to the official estimates, there are about 600 slums in Bangalore and about 34,656 households devoid of any toilets. The present study considers sanitation services around the slums such that access to such toilets can be increased.
The economic analysis of a project is concerned with its viability from a societal perspective and answers the questions of whether it is economically rational to proceed with the project (De Souza et al., 2011). In contrast to a financial analysis, economic analysis provides a more comprehensive investigation on the effects of a proposed project, takes a broader perspective and determines the project's overall value to society (Raucher et al., 2006). The analysis, therefore, includes benefits and costs that directly affect the business entity running the project and the effects of the project on households, governments and businesses outside of the agency.

Environmental impact assessment

The environmental impact assessment of a public toilet complex with a biogas plant capacity of 54 m3 per plant is carried out to identify the impact on the environment of using human excreta to produce biogas for institutional heating or cooking and also to compare these impacts with those created through the existing mode of disposal of human excreta. The public toilet with a biogas plant has the potential to mitigate the GHG and other emissions through the i) avoided emissions from open defecation, ii) replacing fuelwood for cooking in commercial entities. Environmental impacts considered in this study include GHG and other criteria emissions (Table 2).

Table 19: Environmental impact categories

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

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

Baseline scenario

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

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

System boundary

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

Human excreta under baseline

The practice of open defecation which some city dwellers resort to in the quest for a place of convenience results in human excreta being left in the open environment indiscriminately and the decomposition of which emits methane into the atmosphere. The GHG and other emission effects from open defecation were estimated based on the findings of the study conducted by Winrock International India, 2008 (Table 4).

Table 20: Methane emission from human excreta

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

Source: Winrock International India, 2008

Environmental impact results

This section presents the GHG and other criteria emissions under baseline and alternative scenario. The emissions under baseline are the emissions avoided as a result of employing biogas as the energy source for cooking in institutions thereby replacing the use of fuelwood. The emissions from the business are the total of emissions associated with emission during biogas production and combustion process. Total emission savings is the total avoided emissions net of the emissions from the biogas plant. Under the baseline scenario, the total emissions are those attributed to emission from open defecation. A sum of all these emission levels across individuals without toilet gives total avoided emissions due to biogas use.

The toilet complex will serve the population which previously resorted to open defecation, the methane emissions of which is 1,178,997 Kg CO_2-eq. In this study it is assumed that carbon credits will be traded in Clean Development Mechanism (CDM) units as CER is suited for small 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 the USD 3.8 - 5 per ton in 2014 while prices were USD 18 ((€13) in 2011. In this study it is assumed that carbon credits are worth the lower range on average USD 3.8 per ton of CO_2 equivalent. The total annual value of carbon credit is USD 4480. However value of the other emission savings that have acidification potential (NO_x) were not included in the analysis.

Social impacts

Health expenditure savings

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

Improvement in water and sanitation facilities has the major advantage of cost savings related to health care mainly due to the reduced number of treatments of diarrhea (Hutton and Haller, 2004).

Time savings from access to toilet service

Having access to toilet services results in saving in time spent in accessing a place of convenience away from home or public place or work such as associated with open defecation (Renwick et al., 2007). Based on a study by Renwick et al. (2007) and Hutton and Haller (2004), it is estimated that 75% will quit open defecation and 30 minutes will be saved per person per day due to the provision of public place of convenience compared to the baseline situation of open defecation. In order to value the time gained, an hourly rate of 0.22 USD which is equivalent to unskilled rural labor wage rate in Uganda can be used to estimate the economic value of time gained (Renwick et al., 2007). Based on these assumptions, the public toilet complexes with a potential to serve a total of 3,190 persons per day have the potential to result in time savings of 470,525 hours per year which is valued at USD 5,718,240.

Financial analysis

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

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

Table 10 presents the financial results of 443 public toilet complexes with an onsite energy generation serving a total of 173,280 people. Results show that the target onsite energy generation businesses have the potential to operate under profit and result in a NPV of USD 4,419,267 and IRR of 25%.

Table 21: Financial analysis of power capture business model

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Total capital cost	6743624							4469324			
Revenue per plant (users' fee, biogas, rental)		13212	13401	13604	13822	14054	14303	14569	14854	15159	...
Total revenue from 4 plants		5723438	5805677	5893672	5987828	6088573	6196372	6311716	6435134	6567191	...
Total operational costs		8528	9125	9764	10448	11179	11961	12799	13695	14653	...
Total operational costs for 4 plants		3694491	3953106	4229823	4525911	4842724	5181715	5544435	5932546	6347824	...
Operating profit		**2028947**	**1852572**	**1663850**	**1461917**	**1245849**	**1014657**	**767281**	**502588**	**219367**	**...**
Cash flow	-6743624	3241907	3065532	2876810	2674877	2458809	2227617	-2489084	1715548	1432327	...
Discount rate	12%										
Present value of cash flows	**11693204**	2894560	2443823	2047656	1699933	1395194	1128580	-1125935	692881	516512	...
NPV	**4419267**										
ROI- Financial		30%	27%	25%	22%	18%	15%	11%	7%	3%	...
ROI-Financial (average)	**18%**										
BCR-Financial	**1.73**										

Socio-economic results

The potential socio-economic impact of the onsite energy generation model serving 173,280 end users is presented in Table. The socio-economic impact includes not only cost and benefits that directly affect the business entity but also cost and benefits that impact parties outside the entities i.e. externalities. The consolidated socio-economic results are presented in Table 11. The analysis looked at the potential impact of onsite energy generation model at three levels where the levels range from including the direct benefits and costs that affect the business entity to including indirect benefits and costs to other sectors. The annual social and environmental benefits and costs from the business were discounted at a rate of 8% to obtain the present value of social and environmental impacts. The business model is financially and economically feasible showing positive NPV and BCR of greater than 1. Moving from the financial results to including the environmental impacts, the incremental benefit from the GHG emission savings (benefit from carbon credit) is minor showing an increase in NPV of only 2% (USD 23,872). In contrast, the NPV of the target onsite energy generation businesses after including the social impacts is USD 18,735,199 and the ROI is 103%. The social benefits associated with time savings for end users accounted for in determining the NPV and ROI gave the highest benefits. The public toilet complexes with a potential to serve a total of 173,280 persons per day have the potential to result in time savings of 470,525 hours per year which is valued at USD 103,516, assuming a 0.22 USD/hour wage rate for unskilled labour in India.

Table 22: Socio-economic results of onsite energy generation model

Socio-economic result (USD/year)	Financial value	Financial and environmental value	Social, environmental and financial value
Financial result:			
NPV	4,419,267	4,419,267	4,419,267
Environmental benefit:			
Value of net GHG emission saving		23,872	23,872
Social benefit:			
Value of employment			47,954
Savings in time of access			30,486,221
Benefit : Cost ratio (BCR)	**1.73**	**1.74**	**6.26**
NPV	**4,419,267**	**4,443,139**	**19,735,199**
ROI (average)	**18%**	**22%**	**103%**

Sensitivity analysis

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

Table 23: Selected stochastic variables for sensitivity analysis of the benefits

Variable	Unit	Distribution specified	Source
Number of users	#	*Triangular:* (600, 800, 1000)	Assumed
User fees	USD/user	*Triangular Distribution:* (0.09, 0,10, 0,14)	Assumed
Biogas production	m^3/person/day	*Triangular:* (0.35, 0,4, 0.5)	Bond and Templeton, 2011
Discount rate	%	*Triangular*: (10%, 12%, 15%)	Assumed
Carbon Credit price	USD/t CO_2 eq.	*Triangular Distribution* (5,7,10)	Assumed
Economic value of a DALY	USD	*Triangular Distribution* (245, 300, 500)	The lower range corresponds to estimates for cancer and higher range to gross national per capital income.

To perform a stochastic analysis different variables were assigned with different probability distribution and the NPV was calculated through iterations. The above table shows the stochastic variables used and the values considered for determining the probability distribution of NPV. The following figure presents the probability distribution of the NPV, along with the probability of achieving a NPV above the calculated mean value. The probability associated with the NPV reaching below the mean is 49% and the lower and higher limits of 90% confidence interval for the distribution is USD 17.9 and 25.6 million respectively.

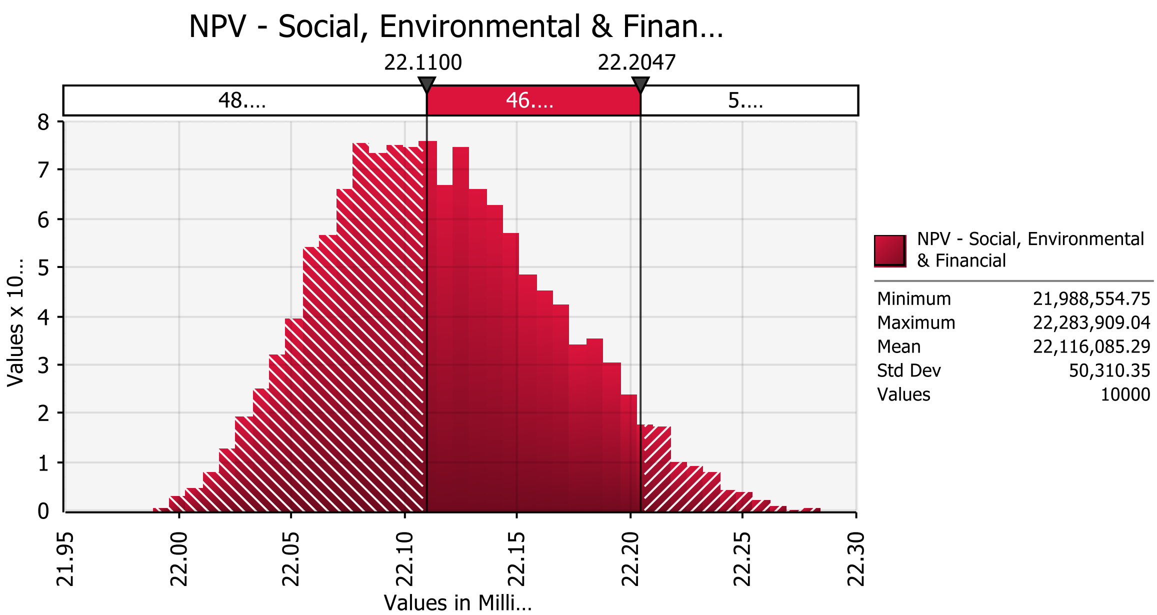

Figure 3: Probability Distribution of the NPV of the net benefits accruing from the biogas plants

Conclusion

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

- The environmental impacts associated with the business model were estimated based on emissions avoided from fuelwood combustion and open defecation net of emissions from the business model. Emissions from the business model accounted in this study include emissions associated with methane leakage, biogas production and combustion. The major contribution to GHG emission savings and other criteria emission is from avoided use of fuelwood which accounted for 81% of the avoided GHG emissions. The combustion of biogas in stoves contributes the highest GHG. Compared to the baseline scenario, the business model results in net GHG and other criteria emission savings.
- Although there is a need for additional investment in cooking stoves for end users when shifting to biogas, the estimated value of net savings in energy costs is higher than the one time investment in cooking stoves.
- The business model has a positive social impact to end users thorough the delivery of improved sanitation services which result in cost savings for end users from avoided expenditures on health expenditures, saving in time spent accessing a place of convenience and savings in time spent cooking.
- Looking at the overall socio-economic impacts, the business model is both financially and economically feasible. There is a significant increase in the economic feasibility of the business due to social and environmental benefits associated with the business. The business model has a potential to result in social NPV of USD 19 million and ROI of 103%.

Socio-economic analysis of beyond cost recovery: the aquaculture example in Bangalore

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. India 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 Bangalore. It is known that Bangalore 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 Bangalore (EAWAG, 2014). The amount of waste water generated in Bangalore can be used for aquaculture and subsequently treated wastewater can be used for irrigation purpose.

Given the context of Bangalore 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 medium sized aerobic pond capacity (2-4 ha.) where water is being diverted from the WWTP. 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 Bangalore which is denoted as baseline scenario with the help of cost-benefits analysis. The wastewater in Bangalore mainly comes through household and industrial zones. Total wastewater generated in Bangalore is 1000 million litres daily and out of which about 70 percent is being treated and 30 percent remains untreated which goes to open environment. The 70% of the wastewater is being treated in the existing 14 WWTPs while to treat the remaining 30%, 11 WWTPs have been planned for the future. Second, in the alternative scenario we have considered aquaculture business with medium-sized pond of 2-4 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 Bangalore can be handled. The cost-benefit analysis of this scenario is also being analyzed and compared with the baseline scenario. The existing WWTPs are of different capacities in terms of wastewater treatment. While conducting the socioeconomic assessment for Bangalore, the WWTPs which have a capacity of more than 18 million litres were assumed to be utilized for electricity generation since capacity of less than 5 MGD is economically infeasible for electricity generation. Therefore of the 14 WWTPs, 6 such plants were assumed for the cost recovery model and the other 6 WWTPs were considered for the Phyto-remediative and aquaculture business model.

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 Bangalore 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 24: 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 Bangalore is 1000 million litres daily. 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. All the 6 ponds assumed for aquaculture is of size 2-4 hectare. 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 144. We assume that per-capita income for fishermen is 1498 USD annually which is based on the per capita income in the present situation in Bangalore. Hence, annual income of all fishermen is 215,640 USD. The present value of annual wage income for fishermen is 1,704,370 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 25: Employment Generated

Employment Generated		
Number of workers employed in pond size of 2 - 4 ha		7
Total workers employed for the ponds		42
Wage rate per month	USD/month	170
Employment generated in terms of the fishing activities	USD/year	57,120

Health Impact

Wastewater stream can cause illness related to water, sanitation, and hygiene- which is diarrhoea. According to the latest Census total population in Bangalore devoid of proper sanitation and water facilities is 173,250. The DALY/1000/per-capita annually is 14. Moreover, it is also being conservatively assumed that only 1% of the population is exposed to diarrhoea therefore, the total health expenditure in Bangalore annually is 197,876 USD. The present value of health costs avoided in the alternative scenario is 1,563,968 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 medium sized firms is 23,400 USD. The revenue for medium is 57,874 USD. Total production and other costs are about 45,378, 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 Bangalore is 20%. Table 5 presents the results of financial analysis. Since there are 6 medium sized we have scaled up the cash flows by considering these facts and the consolidated cash flow for the business and thus considering discount rate of 8 percent we obtain present value of cash-flow is 35,492 USD. The internal rate of return is 11 percent, ROI is 8 percent, however the BCR is just more than 1 (1.06). Therefore, the financial analysis of phyto-remediative wastewater treatment indicates that the business model is financially just viable at a large scale.

Table 26: 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:	187,200											
Total revenues		63,492.06	67,936.51	72,692.06	77,780.51	83,225.14	89,050.90	95,284.47	101,954.38	109,091.19	116,727.57	…
Total production and other costs		44,020.75	47,102.21	50,399.36	53,927.32	57,702.23	61,741.38	66,063.28	70,687.71	75,635.85	80,930.36	…
Depreciation		12,480.00	12,480.00	12,480.00	12,480.00	12,480.00	12,480.00	12,480.00	12,480.00	12,480.00	12,480.00	…
Interest Payments		-	-	-	-	-	-	-	-	-	-	-
Profit before tax		6,991.31	8,354	9,813	11,373	13,043	14,830	16,741	18,787	20,975	23,317	…
Income tax		-	1,671	1,963	2,275	2,609	2,966	3,348	3,757	4,195	4,663	…
Net profit		6,991	6,683	7,850	9,099	10,434	11,864	13,393	15,029	16,780	18,654	…
Cash flow	(187,200)	19,471	19,163	20,330	21,579	22,914	24,344	25,873	27,509	29,260	31,134	…
Discount rate												
Discounted cash flow		18,028.99	16,429.56	16,138.74	15,860.88	15,595.11	15,340.61	15,096.62	14,862.44	14,637.42	14,420.96	…
Present value of cash flows	198,453											
NPV	**35,492**											
IRR	**11%**											
ROI (Financial)		4%	4%	4%	5%	6%	6%	7%	8%	9%	10%	**…**
ROI (Financial average)	**8%**											
BCR-Financial	**1.06**											

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 8% to obtain the present value of social and environmental impacts.

Table 27: Net socio-economic results

Socio-economic result (USD/year)	Financial value	Financial & Environmental	Social, Environmental & Financial
Financial result:			
NPV	35,492	35,492	35,492
Environmental benefit:			
Value of net GHG emission saving		2,951,306	2,951,306
Social benefit:			
Direct Employment generated in terms of the fishermen communities			1,704,370
Value of jobs created (workers in the breeding and maintenance)			451,464
Savings in health expenditure			1,563,968
Total social benefit			**3,719,801**
NPV	**35,492**	**2,986,798**	**6,706,600**
ROI	**7%**	**122%**	**359%**
BCR	**1.06**	**15.96**	**35.83**

The aquaculture business results in cost benefit ratio (CBR) of 1.06, NPV of USD 35,492 with medium sized plants and ROI of 7% when only direct benefits from the briquette production are taken into account. The NPV increases to 2,968,798 USD when environmental benefits are taken into account and to 6,706,600 USD when the environmental and social impacts are taken into account. The ROI taking all externalities into account is 359%. 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 28: 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 diseases	USD	*Uniform Distribution* (4.49 – 9.5)	The lower range corresponds to estimates for cancer and higher range to gross national per capital income.

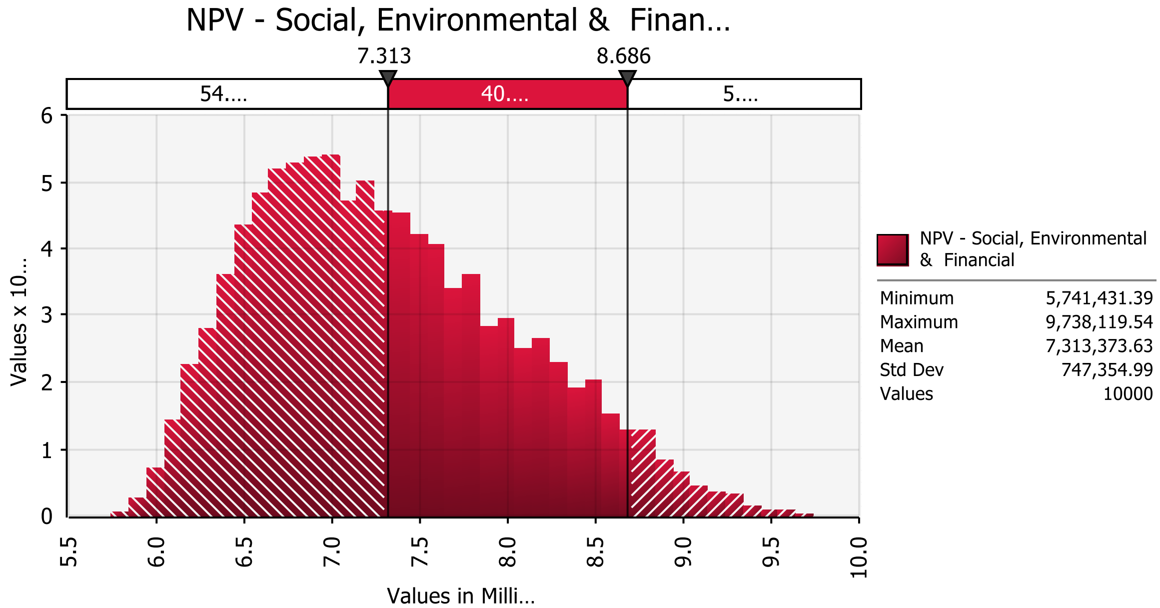

Figure 4: The probability distribution of the NPV of the net benefits derived from wastewater aquaculture

The above figure shows that the mean NPV is 7.3 million with a certainty of achieving it at 55%. 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 Bangalore, India. 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 Bangalore.

- 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 Bangalore.

- 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 of treated wastewater for irrigation, fertilizer and energy in Bangalore

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 India is not different from any developing country. Policy makers are engaging relevant stakeholders to explore effective and efficient options for wastewater management. India'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 India is mainly generated from domestic and municipal waste. It is estimated that about 224 million m^3 of wastewater is generated in Bangalore 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 India 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 Bangalore 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 India 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 0.61 million 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 Bangalore 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 Bangalore. 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).

First, we have evaluated the current scenario in Bangalore which is denoted as baseline scenario with the help of cost-benefits analysis. The wastewater in Bangalore mainly comes through household and industrial zones. Total wastewater generated in Bangalore is 1000 million litres daily and out of which about 70 percent is being treated and 30 percent remains untreated which goes to open environment. The 70% of the wastewater is being treated in the existing 14 WWTPs while to treat the remaining 30%, 11 WWTPs have been planned for the future. Second, in the alternative scenario we have considered the 8 plants which are feasible for producing electricity. The cost-benefit analysis of this scenario is also being analyzed and compared with the baseline scenario.

The existing WWTPs are of different capacities in terms of wastewater treatment. While conducting the socioeconomic assessment for Bangalore, the WWTPs which have a capacity of more than 18 million litres were assumed to be utilized for electricity generation since capacity of less than 5 MGD is economically infeasible for electricity generation. Therefore of the 14 WWTPs, 6 such plants were assumed for the cost recovery model and the other 6 WWTPs were considered for the Phyto-remediative and aquaculture business model. However, the benchmark capacity is based on the financial analysis where the size of the WWTP is assumed to be 25,000 m^3. Therefore, for the bigger plant it is assumed that more than 1 unit can be established. It has been calculated that 15 such units of electricity generating units can be installed.

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 70% wastewater is being treated in fourteen WWTPs around Bangalore 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 Bangalore is treated before being discharged into the nearby water courses. In other words, in the 8 existing WWTPs with capacity of treatment of more than 18 million liters per day, it is assessed that electricity generation is feasible mainly because of the size of the plant.

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 29: Environmental costs of the undesirable outputs

Parameters	Shadow prices for undesirable outputs (USD/m^3)
N	0.606
BOD	0.0164
COD	0.083
SS	0.00252
P	0.3087
Total Pollution load from undesirable outputs (USD/Year)	**292,459**

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 339,000 m^3 of wastewater per day have environmental costs amounting to USD 0.3 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 819,000 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., 698,607 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 3.8 USD/ton we calculated the total averted emission in the alternative scenario is of value of 2.67 million USD annually.

Soil Amelioration

We assume that a plant can produce compost of 445 ton/day. Therefore, total compost production annually is 133,500 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 75,000 ha. Thus total increase in income which can be considered as the proxy of soil amelioration stands valued at 750,000 USD annually.

Table 30: Estimation of the potential environmental impacts

Indicators	Value (USD)
Surface water Pollution	292,459
Reduced GHG gas emissions	2,674,706
Soil improvement	750,000

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 each plant employs 8 workers. Thus 15 plants will employ 120 workers. Therefore, total number of additional jobs created by wastewater treatment plants is 120. Given a wager rate of 200 USD/month, value of additional jobs created annually is 288,000 USD. However, other indirect impacts to the local economy in terms of employment are not accounted for in this study.

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 Bangalore with poor water and sanitation facilities is considered for calculating the health benefits. This population is about 173,250. WHO (2009) provides an estimate of 14 DALYs per 1000 population in terms of burden of diseases from environmental pollution (particularly water, health and hygiene) for India and economic values of DALY per-capita is 1500 USD. The total health cost arises due to diarrhea is 35,898,007 USD annually. A conservative estimate that 5% population is significantly affected has been utilized to reach the 35 million USD estimate.

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 363,700 m^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 31: 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 India). 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 for an individual plant shows feasibility, however, when all the WWTPs are considered to operate simultaneously, it is found that they earn a positive NPV with an assumption of 8% discount rate and IRR is 10 percent but BCR for this financial model is less than 1 (0.97). Hence, the financial analysis suggests that business at the city level model may not be financially feasible.

Table 32: Financial results of Wastewater Treatment and cost savings 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:	10916250															
Total revenues		**4256329**	**4554272**	**4873071**	**5214186**	**5579179**	**5969722**	**6387603**	**6834735**	**7313166**	**7825088**	**8372844**	**8958943**	**9586069**	**10257094**	**10975090**
Total production and other costs		**3323354**	**3555989**	**3804908**	**4071251**	**4356239**	**4661176**	**4987458**	**5336580**	**5710141**	**6109851**	**6537540**	**6995168**	**7484830**	**8008768**	**8569382**
Depreciation		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Interest Payments		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Profit before tax		932975	998284	1068163	1142935	1222940	1308546	1400144	1498155	1603025	1715237	1835304	1963775	2101239	2248326	2405709
Income tax		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Net profit		**932975**	**998284**	**1068163**	**1142935**	**1222940**	**1308546**	**1400144**	**1498155**	**1603025**	**1715237**	**1835304**	**1963775**	**2101239**	**2248326**	**2405709**
Cash flow	(10916250)	932975	998284	1068163	1142935	1222940	1308546	1400144	1498155	1603025	1715237	1835304	1963775	2101239	2248326	2405709
Discount rate																
Discounted cash flow		863866	855867	847943	840091	832313	824606	816971	809406	801912	794487	787130	779842	772621	765467	758380
Present value of cash flows	**10627055**															
NPV	**1143197**															
IRR	**0**															
ROI (Financial average)	**0**															
BCR-Financial	**(0)**															

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 8% 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 1.06. This implies that per dollar invested gives a return of more than 1 dollar. The business model becomes economically more feasible when all externalities are included in the analysis. The NPV when all externalities are considered is USD 318 million and the BCR is 29.22. 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 an increased farm income with more land coming under irrigation.

Table 33: 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	1,143,197	1,143,197	1,143,197
Environmental benefit:			
Value of net GHG emission saving		10,440,080	10,440,080
Social benefit:			
Total social benefit			307,401,105
Net NPV	**1,143,197**	**11,583,276**	**318,984,382**
ROI	**13%**	**26%**	**382%**
BCR	**0.97**	**1.06**	**29.22**

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 34: 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 Bangalore, 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 325 million which can be achieved with a success rate of 49%.

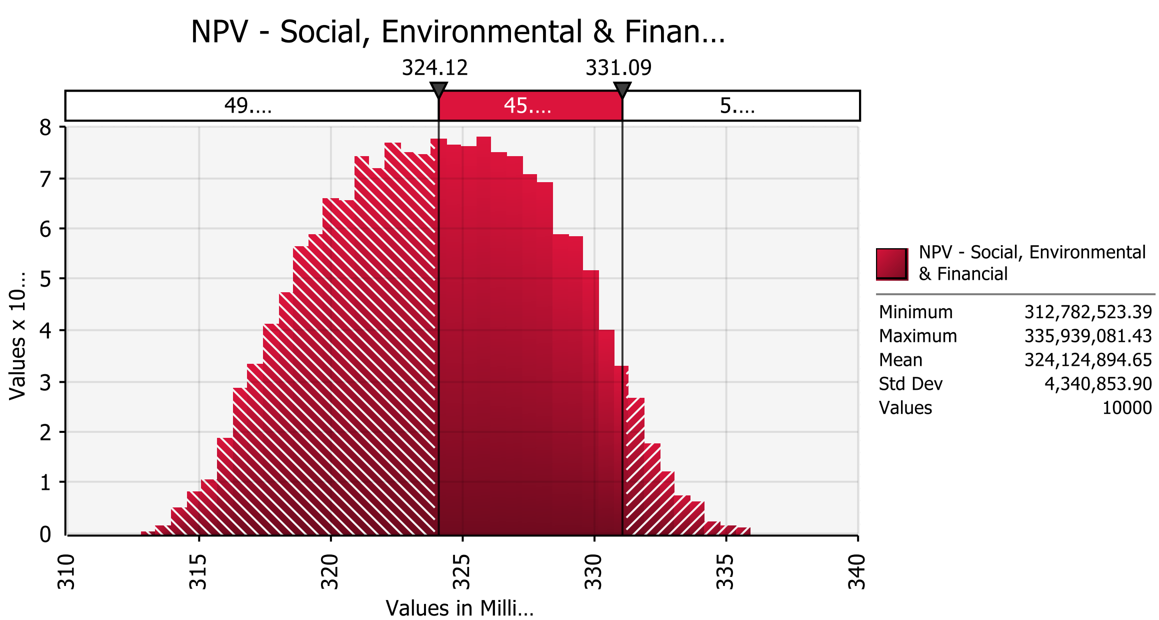

Figure 5: Probability Density Function of the NPV derived for Wastewater treatment and cost savings business model

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 Bangalore, India. 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.

Corcoran, E., C. Nellemann, E. Baker, R. Bos, D. Osborn, H. Savelli (eds). 2010. Sick Water? The central role of wastewater management in sustainable development. A Rapid Response Assessment. United Nations Environment Programme, UN-HABITAT, GRID-Arendal. www.grida.no

Research Triangle Institute (2010); Greenhouse Gas Emissions Estimation Methodologies for Biogenic Emissions from Selected Source Categories: Solid Waste Disposal, Wastewater Treatment, Ethanol Fermentation (*Draft Report)* submitted to U.S. Environmental Protection Agency. Available and accessed from - http://www.epa.gov/ttnchie1/efpac/ghg/GHG_Biogenic_Report_draft_Dec1410.pdf

Socio-economic impact assessment of Large Scale Composting of Municipal Solid Waste for revenue generation in Bangalore

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 Bangalore 6500 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 unauthorized 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 Bangalore 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 emerging economies like India, cities experience generation of urban waste at a steadily increasing rate. This poses a serious challenge to the policy makers on how to deal with them effectively so that it would not cause any steady deterioration of urban environment (Oyoo, 2010). In India, Bangalore generates on an average, 4000 tons of solid waste per day, of which about 80% is generally collected by the BBMP personnel, and the remaining 20% waste is either dumped in an un-authorised manner discretely or burnt conveniently by households and/or enterprises in open spaces, both of which can cause health hazards and environmental problems, apart from creating unpleasant surroundings. If an appropriate system for the collection and disposal of municipal solid waste is put in place, it can be an important source of fertilisers and energy production (Komakech, 2014). Of the two, collecting and converting waste into composting is a widely practised system with immense potential for positive socio-economic impacts.

The urban waste can be systematically collected for composting either in a centralised location or in a de-centralised manner in different locations. If the socio-economic potential of de-centralised composting of municipal solid waste (MSW) has to be exploited adequately for sustainable development, an assessment of compositing feasibility has to be made in terms of composting plants and their capacity. Accordingly, we have evaluated the socio-economic impacts of compositing of MSW business with an annual capacity of handling 146,000 tons of MSW in Bangalore. The socio-economic analysis is done based on the evaluation of financial, environmental and health benefits and costs associated with the business model.

In the baseline scenario it is assumed that about 80% 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 10 composting plant which can handle 200 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 organic fraction of 4000 tons of waste is utilized which is accommodated in 10 composting plants since each has a capacity of 200 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 3.8 (ton Co_2 equivalent). Utilizing the above procedure and also considering the emissions from open-dumping of waste as 0.1532 tons Co_2-eq/ton, the annual savings in terms of GHG savings is calculated to be 190,070 ton Co_2 equivalent which implies a monetary benefits of USD 722,266 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 342,800 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 6,856,000. 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 India 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 29,952 ha. Therefore, the increase in income due to increase in productivity is 299,520 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 35: Estimation of the net Environmental Impacts of large scale composting

Environmental Benefits	**Valuation (USD/annually)**
Avoided GHG emissions	722,266
Cost of leachate treatment averted	6,856,000
Soil amelioration	299,520
Total environmental benefits	**7,877,786**

Social Impact assessment

Employment

The alternative situation considers that the whole of the MSW would be utilised for the compost business. This implies that 50% of the waste which comprises the organic fraction would be required for the compost and the rest landfilled (about 715 tons after sorting of the recycables). 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 additional labourers. Thus, as there are 10 plants the total amount of employment that will be created is 470. The average wage rate per worker is 217 USD/month. Therefore, income generation from additional employment is 1,222,019 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 3200 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 24 ha. the estimated savings of which is around USD 7,548,000 based on the fact that land prices in Bangalore 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 30,000 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 7,578,000 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 2,745,600 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 Bangalore can be estimates using the following assumptions – (i) trucks operated by BBMP, (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 Bangalore is 1,812,051 and one handcart can serve 56 households. Assuming handcarts collects waste twice, the number of handcarts required in Bangalore 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 4000 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 Bangalore.

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, 10 large scale plants of 200 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 plant considered 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 more than 1 (1.274) indicating that financially the model is viable.

Table 36: 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**
Total investment cost:	10642000											
Total revenues		4404762	5350000	6746732	7219003	7724334	8265037	8843590	9462641	10125026	10833778	
Total production and other costs		4238349	4543327	4877360	5214331	5574890	5960688	6373491	6815191	7287810	7793513	
Depreciation		446878	446878	446878	446878	446878	446878	446878	446878	446878	446878	
Interest Payments		1097460	-	-	-	-	-	-	-	-	-	
Profit before tax		(1377926)	359794	1422493	1557794	1702565	1857471	2023220	2200571	2390337	2593387	
Income tax		-	107938	426748	467338	510770	557241	606966	660171	717101	778016	
Net profit		(1377926)	251856	995745	1090456	1191796	1300230	1416254	1540400	1673236	1815371	
Cash flow	(10642000)	(931047)	698734	1442624	1537334	1638674	1747108	1863132	1987278	2120114	2262249	
Discount rate												
Discounted cash flow												
Present value of cash flows	13557040	(862081)	599052	1145201	1129986	1115254	1100974	1087120	1073665	1060585	1047859	
NPV	**2699111**											
IRR	**11%**											
ROI (Financial)	**12%**											
ROI (Financial average)		-13%	2%	9%	10%	11%	12%	13%	14%	16%	17%	
B:C ratio	**1.274**											

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 10 large scale plants of 200 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 8% to obtain the present value of social and environmental impacts.

The large-scale compost model, has a positive NPV following the financial model when the direct economic/financial benefits are accounted and also has BCR is more than 1 implying that the business model is financially feasible. 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 113,261,861 and the BCR is 6.94. 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 along with financial feasibility.

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 37: Net socio-economic results of Large-Scale Compost model

Socio-economic result (USD/year)	Financial value	Financial & environmental	Social, Environmental & Financial
Financial result:			
NPV	2,699,111	2,699,111	2,699,111
Environmental benefit:			
NPV of environmental benefits		65,414,765	65,414,765
Social benefit:			
Employment generation			
Reduction in externalities			9,658,563
Reduction in Landfill O&M costs			35,489,422
Increase in Landfill life			45,147,985
Total social benefit			
NPV	**2,699,111**	**9,815,107**	**113,261,861**
ROI	**12%**	**91%**	**116%**
BCR	**1.27**	**7.42**	**6.94**

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 38: Selected variables for stochastic analysis

Variable	Unit	Distribution specified	Source
Discount rate	%	*Triangular*: (5%, 8%, 10%)	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 117.95 million and a certainty of 51% 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.

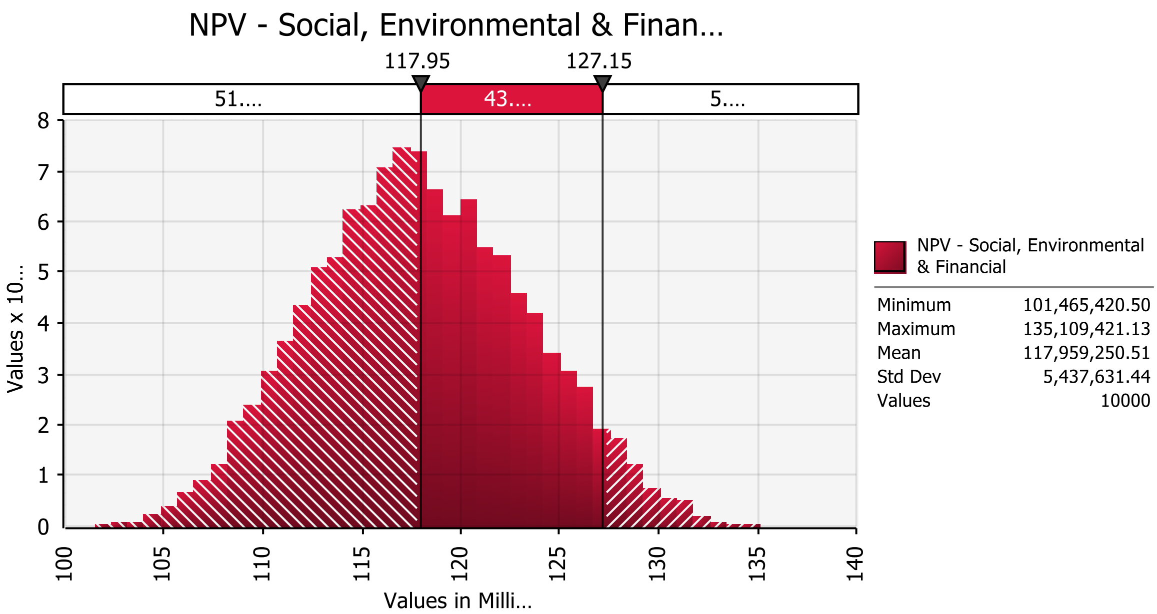

Figure 6: Probability density function of the NPV of large scale composting

Conclusion

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

Socio-economic impact assessment of Subsidy free community based composting (of Municipal Solid Waste) business model in Bangalore

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 Bangalore 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 unauthorized 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 decentralized composting of MSW business with plant capacity of 10 tons MSW each daily i.e., 3650 tons MSW annually. Through decentralized 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 India based on operation costs. While operating costs usually start at US $ 40 per ton, for the least expensive variant; more expensive systems can cost up to US $ 100 per ton, operational costs for windrow composting is comparatively lower around US $ 5 to US $ 20 per ton.

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

This aerobic degradation is exothermic in nature which generates heat within the pile. To ensure that aerobic degradation can continue a sufficient supply of oxygen must be ensured. Turning of the windrows also enhances oxygen supply. In the first weeks of the process it is recommended that the heap be turned 3 times weekly as temperatures such that higher temperatures are avoided as it will inhibit microbial activity. In such cases, turning can be an appropriate measure to cool the heap. After the first 2 weeks the turning frequency can be reduced to weekly turning and the pile can then be turned once every ten days. High temperatures and microbial activity during the thermophilic phase will lead to moisture losses. When moisture levels fall below 40 % additional water must be added to the heap with each turning. The moisture content should be maintained ideally between 40 and 60%.

It takes about 5-6 weeks from the day piling takes place for the temperature of the pile to fall below 50°C and the maturation phase to set in. The material is characterized by a soil like colour. Mesophilic microorganisms become active and further stabilize the immature compost within approximately 15 days. Turning is no longer necessary and only little watering is required if the piles are very dry. After a total of about 8 weeks the mature compost material is characterized by a dark brown colour, an earthy smell and a crumbly texture. The final mature compost can then be sieved to obtain the required particle size which depends on the customer requirements. Sieving can help remove still remaining inorganic particles in the compost. The coarse rejects form sieving can be added to the fresh incoming waste. Sieving can be performed using a flat frame sieve operated with manual labour or using mechanical rotating drum sieves. Depending on the marketing and sales strategy, the final compost product can be either stored or sold in bulk or else be packaged in bags of different volumes. The moisture content should be below 40% before bagging and the final product should be stored in a dry and sheltered location.

Overall approach to socio-economic impact assessment

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

In many developing countries large centralized and highly mechanized composting plants have often failed to produce good quality compost. In Bangalore of the 4000 tons of waste generated per day, about 3200 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 Bangalore. 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 4000 tons of the waste disposed in the landfilled through decentralized collection and disposal leading to compost of the organic fraction in smaller units compared to the large scale composting. 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 Bangalore where some of the landfills are approaching their lifetime, it has been assumed that 100% 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 Bangalore 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 Bangalore the number of business entities engaged for decentralized composting is 15. Based on the waste collection of 4000 tons per day in Bangalore, it has been calculated that there is a requirement of 89 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 Bangalore 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 the entire waste of the city is 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 4000 tons of waste daily is estimated to be 1,043,350 tons of CO_2 equivalent.

However, there are GHG emissions from the transportation of the compost from each of the respective 89 co-operatives to the main packaging unit. Based on the assumptions mentioned, the GHG emissions were calculated which amounts to 399,689 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 233,964 tons of CO_2 equivalent. The net savings in terms of the GHG emissions saved by introducing decentralized collection and composting in Bangalore amounts to 867,625 tons of CO_2 equivalent (Table 1).

Table 39: 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	233,964
Net GHG emissions from transportation	tons of CO_2 equivalent	867,625
Value of CERs	USD/ tons of CO_2 equivalent	3.8
Value of GHG emissions averted	**USD/annum**	**3,296,975**

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 3.8 USD/ton CO_2 eq. (average value in 2014) 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 India, 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 4000 tons is being landfilled, the alternate scenario considers the landfilling of the 20% of the 4000 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 Bangalore 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 111,828 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 2,236,555 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 Bangalore has been considered. Studies related to application and yield increase shows that application of compost in tomato farms increase the net income by USD 10/ha of application. In Bangalore vegetable production is one of 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 381,390 per annum with about 38,139 hectares where compost is being applied.

The following table (Table 40) 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 40: Estimation of the environmental benefits due to utilization of MSW for producing compost

Environmental Benefits	Valuation (USD/annually)
Avoided GHG emissions	3,293,975
Cost of leachate treatment averted	2,236,555
Soil amelioration	381,390

Total environmental benefits	**5,911,920**

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 41: Table elaborating the collection mechanism

	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 Bangalore 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 1,994,667 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 744,000 based on the fact that land prices in Bangalore 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 89 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

This section presents the financial feasibility analysis and results of business model considering production of from large scale centralized compost plant for the city as a whole. In other words the financial model considers the 89 co-operatives engaged in decentralized collection of waste and composting it. The financial analysis incorporated in the socioeconomic analysis escalates linearly the economic and financial costs presented in the financial analysis of a single co-operative engaged in decentralized composting of 3 tons of waste each. The financial viability of all these decentralized plants operating simultaneously are based on Return on Investment (ROI), Net Present Value (NPV) and Internal Rate of Return (IRR) valuation criteria. The capital cost for each of the compost plant considered is taken to be USD 14,115 per ton a large part of which includes investment on the means for collection of waste. 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 12% which is above the discount rate of 8% and the Rate of Investment (ROI) is 14% implying that revenues are high enough to recover all costs of the business. This is also observed that the benefit-cost ratio is also higher than 1 (2.01) indicating that financially the model is self-sustainable.

Table 42: Financial analysis of the co-operatives engaged in 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
Total investment cost:	3768889											
Total revenues		4666667	5054476	5604558	5996877	6416659	6865825	7346432	7860683	8410930	8999696	...
Total production and other costs		4494300	4807951	5146260	5504325	5887455	6297404	6736049	7205400	7707605	8244965	...
Profit before tax		172367	246526	458298	492552	529204	568421	610383	655283	703325	754731	....
Income tax		34473	49305	91660	98510	105841	113684	122077	131057	140665	150946	...
Net profit		137894	197221	366639	394042	423363	454737	488307	524226	562660	603785	....
Cash flow	(3768889)	137894	197221	366639	394042	423363	454737	488307	524226	562660	603785	...
Discount rate	8%											
Discounted cash flow		137894	197221	366639	394042	423363	454737	488307	524226	562660	603785	....
Present value of cash flows	7896775											
NPV	**169004**	4%	5%	10%	10%	11%	12%	13%	14%	15%	16%	..

Socioeconomic Analysis

The following section discusses about the socio-economic evaluation in a nutshell. The following table indicates that decentralized composting is self-sustainable financially without subsidy. Additionally the inclusion of environmental and societal benefits enhances the net positive earnings of the business. The ROI for the business is 165% with a benefit-cost ratio of 18.66 and a net NPV of 70,500,833. The social benefit provided in the table includes the following – (i) landfill costs saved along with disposal costs, (ii) generation of employment which is one of the major component of the model since it includes door-to-door collection of waste, (iii) reduction of the externalities like foul smell from landfill and areas where MSW is illegally dumped. Apparently, from the deterministic model the business seems economically feasible.

Table 43: Socio-economic results of the community based composting

Socio-economic result (USD/year)	**Financial value**	**Financial & Environmental value**	**Social, Environmental & Financial value**
Financial result:			
NPV	169,004	169,004	169,004
Environmental benefit:			
Value of net GHG emission saving		15,219,009	15,219,009
Social benefit:			55,112,820
Benefit: Cost ratio (BCR)	**2.01**	**4.04**	**18.66**
NPV	**169,004**	**14,010,279**	**70,500,833**
ROI (average)	**14%**	**77%**	**164%**

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 44: Selected variables for the stochastic analysis of the NPV from benefits

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

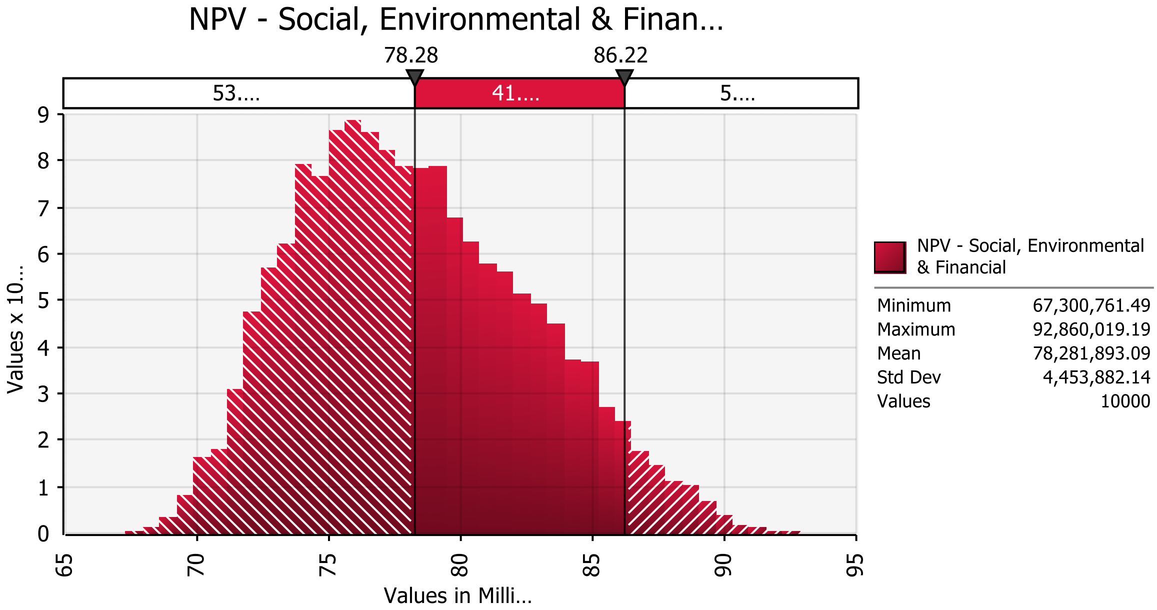

Figure 7: Probability distribution of the NPV of the benefits obtained from community based composting

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 (USD 78.28 million) is 54%.

Conclusion

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

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 Bangalore 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 2 tons 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.

For the present study, the current scenario in Bangalore with regards to faecal sludge management is denoted as baseline scenario for the social cost-benefits analysis. Total Municipal Solid Waste generated in Bangalore is about 4000 tons daily. It is assumed that 80 percent of solid waste generated is collected i.e., 3200 tons are collected. Out of these 3200 tons 100 percent of this MSW generated goes to landfill. In Bangalore city the amount of faecal sludge generated daily is about 350 m^3 daily and about 140 m^3 is collected which can produce dewatered faecal sludge of 2.8 tons daily. However, in the alternate scenario it is being assumed that the entire faecal sludge would be utilized for co-composting or fortifer production. Second, we have assumed that a composting plant produces 2400 tons of fortifiers annually using municipal solid waste and faecal sludge will be established. This plant is a representative plant. To utilize the entire faecal sludge, 4 plants of similar size are considered for the scale of operation for the city in the third step. 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 Bangalore can be handled. The cost-benefit analysis of this scenario is also being analyzed 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 80% of the MSW is being collected and landfilled. The rest of the MSW about 800 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 4 plants each producing 2400 tons of high valued fertilizer. This entails a requirement of 10,500 tons of MSW along with 2100 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 Bangalore. 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 Bangalore'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) 532,230 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 3.8 per ton CO_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 2,022,474 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 3599 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 45: Estimate of impacts on water pollution

Pollutants	Environmental value of pollution (USD/m^3)[3]	Environmental value of pollution (USD/year)
N	0.6060	70,538
P	0.3087	35,932
SS	0.00252	293

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

BOD	0.0164	1,908
COD	0.0832	9,684
Total	**1.107**	**106,766**

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 106,766 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 1920 ha. The net benefits estimated for applying co-compost was thus calculated to be USD 19,200 per annum.

Economic Impact

This section presents the financial analysis of the introducing the business model in Bangalore. In the financial assessment, a representative plant was assumed to produce 2400 tons of co-compost (2000 tons) and fortifier (400 tons of which 200 tons of powdered and pelletized respectively). 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, 4 plants of similar capacity would be required in Bangalore 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 4 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 4 plants taken together. The production in the 4 plants would yield 9,600 tons of co-compost and fortifier which includes – (i) 8,000 tons of co-compost, (ii) 800 tons of fortifier (powdered form), and (iii) 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 448,862) and an IRR of 7 % which is less than the discount rate of 8%. The Benefit-cost ratio of the business model is less than 1 (0.42) implying that per dollar invested fetches 0.42 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 46: 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	**1,561,000**															
Revenue																
Total Revenue		**405,000**	**462,240**	**556,421**	**595,371**	**637,047**	**681,640**	**729,355**	**780,410**	**835,038**	**893,491**	**956,036**	**1,022,958**	**1,094,565**	**1,171,185**	**1,253,168**
Expense																
Total Expense		**347,847**	**372,562**	**400,653**	**427,621**	**456,475**	**487,350**	**520,386**	**555,734**	**593,557**	**634,027**	**677,330**	**723,664**	**773,242**	**826,290**	**883,052**
Depreciation		92460	92460	92460	92460	92460	92460	92460	92460	92460	92460	92460	92460	92460	92460	92460
Interest payments		-	4592	4592	-	-	-	-	-	-	-	-	-	-	-	-
Profit before tax		(35,307)	(7,734)	58,356	75,290	88,112	101,830	116,509	132,216	149,022	167,004	186,246	206,834	228,863	252,434	277,655
Income tax		-	-	17,507	22,587	26,433	30,549	34,953	39,665	44,707	50,101	55,874	62,050	68,659	75,730	83,297
Net Profit		**(35,307)**	**(7,734)**	**40,849**	**52,703**	**61,678**	**71,281**	**81,557**	**92,551**	**104,315**	**116,903**	**130,372**	**144,784**	**160,204**	**176,704**	**194,359**
Cash Flow	**(2940750)**	57,153	84,726	133,309	145,163	154,138	163,741	174,017	185,011	196,775	209,363	222,832	237,244	252,664	269,164	286,819
Discounted Cash Flow		57,153	84,726	133,309	145,163	154,138	163,741	174,017	185,011	196,775	209,363	222,832	237,244	252,664	269,164	286,819
NPV	**(448,862)**															
IRR	**7%**															
ROI (Financial)		-2%	0%	3%	3%	4%	5%	5%	6%	7%	7%	8%	9%	10%	11%	12%
ROI (Financial Average)	**5%**															
BCR	**0.42**															

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 6,580 monthly i.e., 78,960 USD annually.

Health benefits

The most common disease burden with poor FS management is diarrhoea. 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 Bangalore city without toilet facilities and are prone to diseases caused due to weak infrastructure is 173,250. The DALY for the selected risk factor is 14 for India and economic value of DALY is USD 1500. Assuming only 5 percent of the population will be affected by diarrhoea the net health benefit that can be averted by treatment of FS is estimated to be USD 1,315,875 annually for Bangalore.

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 India 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. 800. The reduction in import bill for fertilizer is estimated to be USD. 204,000.

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 47: Estimates of social impacts

Parameters considered for societal benefits	Net Benefits (USD/annum)
Employment generation	78,960
Aversion of health costs	1,315,875
Savings from foreign exchange	204,000
Total	**1,598,835**

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 8% 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 21,595,127 and the BCR is 15.54. 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 19,293,817 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 48: Results from socio-economic analysis of the business model

Socio-economic result (USD/year)	Financial	Financial & Environmental	Social, Environmental & Financial
Financial result:			
NPV	(448,862)	(448,862)	(448,862)
Environmental benefit:			
Value of net GHG emission saving		2,750,172	2,750,172
Social benefit:			
Reduced use of inorganic fertilizer			1,310,404
Value of jobs and additional income to workers			1,018,020
Savings in health expenditure			16,965,394
Total social benefit			19,293,817
NPV	**(448,862)**	**2,301,301**	**21,595,127**
ROI	**5%**	**12%**	**141%**
BCR	**0.14**	**3.18**	**15.54**

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.

Table 49: Selected variables for the stochastic analysis with the distribution functions

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 variables which are considered as stochastic are similar to that of the compost models. 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.

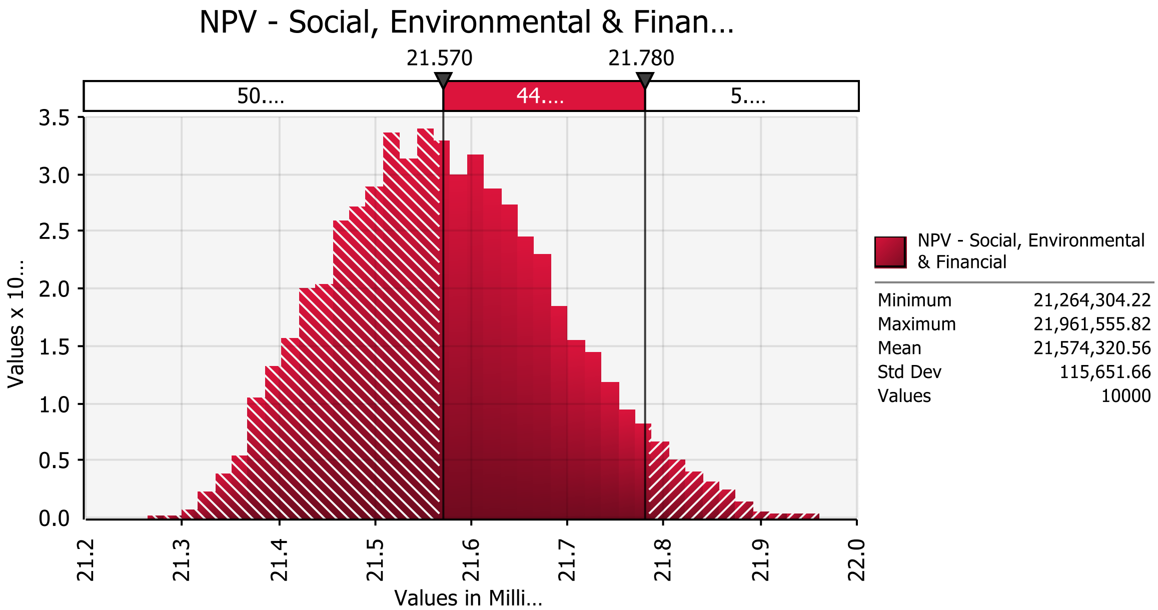

Figure 8: Probability distribution of the NPV of net benefits

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.

References

Aboah J, 2014. Financial feasibility analysis of the fortifer business model in cape coast metropolitan assembly in Ghana; MSc. Thesis Business Economics Wageningen University; Accessed from http://edepot.wur.nl/298273 on 15.01.2015.

Abu-Madi, M. 2004. Incentive systems for wastewater treatment and reuse in irrigated agriculture in the MENA region: Evidence from Jordan and Tunisia. PhD Dissertation, Delft University of Technology, Delft, the Netherlands

Agence Française de Développement (AFD) and Athi Water Services Board (AWSB), 2010. Evaluation report: Assessment of impacts of ablution blocks project in informal settlements of Nairobi.

Agence Française de Développement (AFD) and Athi Water Services Board (AWSB), 2010. Evaluation report: Assessment of impacts of ablution blocks project in informal settlements of Nairobi.

Amiguna, B., Musango, J K., and Stafford, W. 2010. Biofuels and sustainability in Africa. Renewable and Sustainable Energy Reviews xxx (2010) xxx–xxx – Article in press doi:10.1016/j.rser.2010.10.015

Arthur R., Baidoo M.F., Antwi E., 2011. Biogas as a potential renewable energy source: A Ghanaian case study. Renewable Energy 36:1510-1516.

Arthur R., Baidoo M.F., Antwi E., 2011. Biogas as a potential renewable energy source: A Ghanaian case study. Renewable Energy 36:1510-1516.

Bates, L. (2007). Biogas. Rugby: Practical Action.

Bingh LP. (2004) Opportunities for utilizing waste biomass for energy in Vietnam. Masters' thesis. Norway: Norwegian University of Science and Technology.

Bruce, N., Rehfuess, E., Mehta, S., Hutton, G., and Smith, K.R., 2006. "Indoor air pollution", in Jamison, D.T., Breman, J.G., Measham, A.R., Alleyne, G., Claeson, M., Evans, D.B., Jha, P., Mills, A., and Musgrove, P., (eds.), Disease Control Priorities in Developing Countries, (2nd ed.), World Bank and Oxford University Press, Oxford

Buchholz and Da Silva (2010) Potential of distributed wood-based biopower systems serving basic electricity needs in rural Vietnam

Buchholz T and Volk T. (2007) Designing short-rotation coppice based Bioenergy Systems for Rural Communities in east Africa BIOSYRCA project (Final report)

Buchholz T, and Da Silva I, 2010. Potential of wood-based bio-power systems serving basic electricity needs in rural Vietnam; Energy for Sustainable Development, Vol 10, pp 56-61.

Buchholz T, Volk TD. (2012) Considerations of project scale and sustainability of modern bioenergy systems in Vietnam. *J Sustain Forest*; 31(1 - 2):154 - 73.

Burtraw D., Szambelan J.S., 2009. U.S. emissions trading markets for SO2 and NOx. Resource for the future, Washington DC.

Buxton D. and Reed B., 2010. Disposal of latrine waste: Is biogas the answer? A review of literature. In EWB-UK National Research Conference, 19 Feb, 2010, UK.

Cairncross, S., Hunt, C., Boisson, S., Bostoen, K., Curtis, V., Fung, I C H., and Schmidt, W P. (2010): Water, sanitation and hygiene for the prevention of diarrhea. *International Journal of Epidemiology*; 39:193–205 doi:10.1093/ije/dyq035

Chaney J., 2010. Combustion characteristics of biomass briquettes Accessed at http://core.kmi.open.ac.uk/download/pdf/18159.pdf on Oct 21, 2014

Christensen S, 2012. Comparing the Sustainability of Biomass Fuel Supply Options for a Small Scale Gasification Project in Rural Vietnam; MSc Thesis submitted to Department of Energy and the Environment, Division of Energy Technology, CHALMERS UNIVERSITY OF TECHNOLOGY Göteborg, Sweden.

Collingwood Public Utilities 2013. Collingwood wastewater treatment plant cogeneration plant feasibility study. #080988-10 Report number 2.

Co-composting faecal sludge & organic solid waste Kumasi, Ghana: Case study of sustainable sanitation projects obtained from: http://www.sswm.info/sites/default/files/reference_attachments/OLUFUNKE%20and%20KONE%202009%20CoComposting%20of%20faecal%20sludge%20and%20organic%20solid%20waste%20Kumasi%20Ghana.pdf

Corcoran, E., C. Nellemann, E. Baker, R. Bos, D. Osborn, H. Savelli (eds). 2010. Sick Water? The central role of wastewater management in sustainable development. A Rapid Response Assessment. United Nations Environment Programme, UN-HABITAT, GRID-Arendal. www.grida.no

De Souza S., Madellin-Azuara J., Burley N., Lund J.R., and Howitt R.E., (2011) Guidelines for preparing economic analysis for water recycling projects. University of California, Davis.

E. Görgun, G. Insel "Cost evaluation of sludge treatment options and energy recovery from wastewater treatment plant sludge treating leather tanning wastewater"

EEP (Energy and Environment Partnership), 2013. Analyzing briquette markets in Tanzania, Kenya and Vietnam.

EPA, 2006. Biosolids technology fact sheet: Multi-Stage Anaerobic Digestion. Accessed on September 12, 2012. Retrieved from: http://water.epa.gov/scitech/wastetech/upload/2006_10_16_mtb_multi-stage.pdf

ERG (2011), Eastern Research Group, Inc. (ERG) and Resource Dynamics Corporation (RDC) for the U.S. Environment Protection Agency, Combined Heat and Power Partnership.

FAO, 1990. The briquetting of agricultural waste for fuel. Rome: Food and Agriculture Organization of the United Nations; Environment and Energy Series.

FAO. 1997. *Proceedings of the Second Expert Consultation on National Water Policy Reform in the Near East*, Cairo, Egypt.

Ferguson H., 2012. Briquette Businesses in Vietnam. The potential for briquette enterprises to address the sustainability of the Vietnam biomass market.

Ferguson H., 2012. Briquette Businesses in Vietnam. The potential for briquette enterprises to address the sustainability of the Vietnam biomass market.

Fewtrell L, Kaufmann RB, Kay D, Enanoria W, Haller L, Colford JM Jr. Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. Lancet Infect Dis 2005; 5: 42–52.

GIZ (2011): Solar lamps field test Vietnam final report

Grover P.D. and Mishra S.K., 1996. Biomass briquetting. Technology and practices. FAO regional wood energy development programme in Asia, Bangkok Thailand. https://www.pik-potsdam.de/members/reuster/Masterthesis_LenaReuster.pdf

Gude, V.G. 2015. Energy and water autarky of wastewater treatment and power generation systems. Renewable and Sustainable Energy Reviews 45:52-68.

GVEP International, 2010. Kenya briquette industry study. Accessed at http://www.gvepinternational.org/sites/default/files/kenya_briquettereport_2010.pdf on Oct 12, 2014.

Habermahl (2008) Economic evaluation of the component "Promotion of efficient institutional cook stoves" of the Programme for Biomass Energy Conservation (ProBEC) in Malawi in the years 2004 to 2007

Habermehl, H (2007): Economic evaluation of the improved household cooking stove dissemination programme in Vietnam. Dissemination of the Rocket Lorena stove in the districts of Bushenyi and Rakai and dissemination of the improved charcoal stove in Bangalore in the years 2005 and 2006. https://www.pik-potsdam.de/members/reuster/Masterthesis_LenaReuster.pdf

Hazelton J A., Windhorst K and Amezaga J M. (2013) Forest based biomass for energy in Vietnam: Stakeholder dynamics in feedstock production; biomass and bioenergy. 59pp 1 0 0 - 1 1 5. https://www.pik-potsdam.de/members/reuster/Masterthesis_LenaReuster.pdf

Hazelton J A., Windhorst K and Amezaga J M., 2013. Forest based biomass for energy in Vietnam: Stakeholder dynamics in feedstock production; biomass and bioenergy 59: 100-115. http://www.economywatch.com/economic-statistics/Vietnam/Corporate_Tax_Rate/ accessed on 4/01/2015.

Hu J., Lei Z., Wang Z., Yan X., Shi X., Li Z., He X., Zhang Q., 2014. Economic, environmental and social assessment of briquette fuel from agricultural residues in China–A study on flat die briquetting using corn stalk. Energy 64:557-566.

Hutton G and Haller L (2004): Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level. Water, Sanitation and Health Protection of the Human Environment World Health Organization Geneva

Hutton G, Haller L, Bartram J. (2007) Global cost–benefit analysis of water supply and sanitation interventions. Journal of Water and Health, 5(4):481–502.

IDS (Integrated Development Society) Nepal, 2008. Bio-briquette in Nepal: Lessons learned. Accessed at http://rbmsystems.net/cms/wp-content/uploads/2011/06/IDS_Annual_Report_2007_08.pdf on Oct 21, 2014.

IEA, 2006. Energy for cooking in developing countries. World Energy Outlook 2006. IEA: Paris, France.

IFAD, 2010. The Regional Cassava Processing and Marketing Initiative (RCPMI). The use of cassava wastes to produce energy: outcomes of a feasibility study implemented in Ghana.

International Water and Sanitation Centre (IRC), 1999. Small scale independent providers of water and sanitation to the urban poor. The case of Bangalore, Vietnam.

IPCC (2001). Climate change 2001, the scientific basis. Cambridge: Cambridge University Press.

IPCC/OECD methodology. Accessed at http://www.fao.org/docrep/x2740e/x2740e60.pdf accessed on March 5, 2015.

IRENA, 2012. Renewable Power Generation Costs in 2012: An Overview http://costing.irena.org/media/2769/Overview_Renewable-Power-Generation-Costs-in-2012.pdf (accessed 03/31/2015).

Izrail S. Turovskiy, D. Sc. and Jeffrey D. Westbrook, P.E. (2002), Recent Advancements in Wastewater Sludge Composting obtained from http://www.wwdmag.com/waste-treatment-disposal-services/recent-advancements-wastewater-sludge-composting

JC Agunwamba, Analysis of Socioeconomic and Environmental Impacts of Waste Stabilization Pond and Unrestricted Wastewater Irrigation: Interface with Maintenance: Environmental Management [Environ. Manage.]. Vol. 27, no. 3, pp. 463-476. Mar 2001.

Katusiimeh, Mesharch W, (2012), Public and private service provision of solid waste management in Bangalore, Vietnam, Habitat International, Vol. 36, Issue. 2, Page 247-252.

Kayombo, Sixtus, and Jorgensen E. S (2006), Lake Victoria: Experience and lesson learned brief obtained from http://www.worldlakes.org/uploads/27_Lake_Victoria_27February2006.pdf

Kfouri, C. Mantovanic, P. and Jeuland, M. 2009. Water Reuse in the MNA Region: Constraints, Experiences, and Policy Recommendations. In Water in the Arab World. Management Perspectives and Innovations. Middle East and North Africa Region. The World Bank.

Kimming et al. (2011) Biomass from agriculture in small scale combined heat and power plants – a comparative life cycle assessment

Kinobe, J.R., Gebresenbet, G., Vinnerås, B., Niwagaba, C. B., Komakech, A. (2013), Mapping out the current waste collection system in Bangalore City. Manuscript submitted for publication.

KIST (Kigali Institute of Science and Technology), 2006. Impact assessment of the CITT disseminated technologies in Rwanda. Kigali, Rwanda.

Lam, N L., Smith, K R., Gauthier, A and Bates, M N. 2012. Kerosene: A Review of Household Uses and Their Hazards in Low- And Middle-Income Countries. J Toxicol Environ Health B Crit Rev. 15(6): 396–432. doi:10.1080/10937404.2012.710134.

Lena Reuster (2010) Regulation of Markets for Privately Provided Public Goods: The Case of Voluntary Carbon Offsets - Master Thesis. Technische Universitat Berlin School VII Economics and Management M.Sc. Program Industrial and Network Economics & Potsdam Institute for Climate Impact Research (PIK)

Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. The Lancet. 2012; 380(9859):2224-60. doi: 10.1016/S0140-6736(12)61766-8.

Maninder, Kathuria R.S., Grover S., 2012. Using agricultural residue as a biomass briquetting: An alternative source of energy. Journal of Electrical and Electronics Engineering, 5: 11-15.

Masiga, Moses, (2013), Proposal for: Nationally Appropriate Mitigation Action NAMA Seeking Support for Implementation Integrated Bio-Wastewater Treatment for agro-process wastewater.

MEMD (2008) Vietnam energy balance for 2008. Bangalore Vietnam: Ministry of Energy and Mineral Development

Metcalf and Eddy Inc, Wastewater Engineering, Treatment and Reuse, 4th Edition, McGraw-Hill, 2003. Degrémont, 2005 Degrémont SA, Mémento Technique de L'Eau, 10ème Edition, 2005

Modi V, MCDade S, Lallement D and Saghir J., 2006. Energy and the Millennium Development Goals, New York; Energy Sector Management Assistance Programme, United Nations Development Programme, UN Millennium Project and World Bank.

Murungi, C, and Dijk P V, Meine (2013), Emptying, Transportation and Disposal of faecal sludge in informal settlements of Bangalore Vietnam: The economics of sanitation, *Habitat International*, Volume 42, April 2014, Pages 69–75

NETWASS-U (Network for water and sanitation Vietnam), 2011. Ecological sanitation in Vietnam. Inspirational success stories from the field. Accessed at http://www.wsscc.org/sites/default/files/publications/ecosan_node_case_study_booklet_final.pdf on Oct 21, 2014.

Nikiema, J., Olufunke, C., Impraim, R., & Adamtey, N. 2013. Processing of faecal sludge to fertilizer pellets using a low cost technology in Ghana. Environment and Pollution, 2(4)

Nounia M.R., Mullickb M.R. and Kandpalb T.C. (2007) Biomass gasifier projects for decentralized power supply in India: A financial evaluation; Energy Policy; 35 pp1373–1385

Okello C, Pindozzi S, Faugno S, Boccia L. (2013) Development of bioenergy technologies in Vietnam: a review of progress. Renew Sust Energy Rev 18:55 - 63.

Okello C., 2014. Assessing sustainability of bioenergy systems in developing countries: Methodological development and application. University of Naples Federico II. Accessed at http://www.fedoa.unina.it/10041/1/C_Okello_2014.pdf on March 2, 2015.

Pangare G & Pangare V (2008), Informal water Vendors and service providers in Vietnam: The ground reality; The Water Dialogues available and accessed (on 15/4/2015) from: Pathak H., Jain N., Bhatia A., 2009. Global warming mitigation potential of biogas plants in India. Environ Monit Assess 157: 407-418.

Rawat M and Ramanathan A.L. (2011) Assessment of Methane Flux from Municipal Solid Waste (MSW) Landfill Areas of Delhi, India. Journal of Environment Protection; Vol 2; pp 399-407; doi: 10.4236/jep.2011.24045

Raucher, R., K. Darr, J. Henderson, et al. 2006. An Economic Framework for Evaluating the Benefits and Costs of Water Reuse. Alexandria, VA: Water Reuse Foundation.

Renwick M., Subedi P.S. and Hutton G., 2007. Cost Benefits Analysis of National and Regional Integrated Biogas and Sanitation Program in Sub-Saharan-Africa. WINROCK International Draft Final report. Dutch ministry of foreign affairs.

Reuster L, (2010) Regulation of Markets for Privately Provided Public Goods: The Case of Voluntary Carbon Offsets - Master Thesis. Technische Universitat Berlin School VII Economics and Management M.Sc. Program Industrial and Network Economics & Potsdam Institute for Climate Impact Research (PIK)

Roy M.M., Corscadden K.W., 2012. An experimental study of combustion and emissions of biomass briquettes in a domestic wood stove. Applied Energy 99: 206-212.

Ruiz J.A., Juarez M.C., Morales M.P., Munoz P, Mendıvil M.A., 2013. Biomass logistics: Financial & environmental costs. Case study: 2 MW electrical power plants. Biomass and Bioenergy 56: 260-267.

Schirnding Y.V., N. Bruce, K. Smith, Berkeley, G. Ballard-Tremeer, M. Ezzati, K. Lvovsky, (2002): Addressing the Impact of Household Energy and Indoor Air Pollution on the Health of the Poor: Implications for Policy Action and Intervention Measures (Working group 5: Improving Health Outcomes of the Poor)

Schubeler P., Wehrle K., Christen J., 1996. Conceptual Framework for Municipal Solid Waste Management in Low-Income Countries. UNDP/UNCHS (Habitat)/World Bank/SDC, Working paper 9.

Shafie, S M., Masjuki, H., and Mahlia, T M I. (2014) Life cycle assessment of rice straw-based power generation in Malaysia

Singh K.J. and Sooch S.S., 2004. Comparative study of economics of different model of family size biogas plants for state of Punjab, India. Energy conservation and management 45: 1329-1341.

Smith, K.R., Mehta, S., and Maeusezahl-Feuz, M., 2004. "Indoor air pollution from household use of solid fuels", in Ezzati, M., Lopez, A.D., Rodgers, A.D., and Murray, C.J.L., (eds.), Comparative Quantification of Health Risks: Global and Regional Burden of Disease Due to Selected Major Risk Factors, Vol. 2, pp. 1435-1493, World Health Organization, Geneva.

Sparrevik M, Lindhjem H., Andria V., Magerholm AF, Cornelissen G., 2014. Environmental and socioeconomic impacts of utilizing waste for biochar in rural areas in Indonesia−A systems perspective. Environmental Science and Technology 48: 4664-4671.

Sparrevik M., Field J.L., Martinsen V., Breedveld G. D., Cornelissen G., 2012. Life cycle assessment to evaluate the environmental impact of biochar implementation in conservation agriculture in Zambia. Environ. Sci. Technol. 47: 1206−1215.

Stillwell, A.S., Hoppock, D.C. and Webber, M.E. 2010. Energy recovery from wastewater treatment plants in the United States: A case Study of the Energy-Water Nexus. Sustainability 2010.

Sustainable Sanitation Alliance, 2010. Public toilet with biogas plant and water kiosk Naivasha, Kenya. Accessed at: http://www.sswm.info/sites/default/files/reference_attachments/RIECK%202010%20Public%20toilet%20with%20biogas%20plant%20and%20water%20kiosk%20Naivashsa%20Kenya.pdf on Oct 21, 2014.

Sustainable Solutions for the Environment (EVI), 2013. Technologies for energy recovery from feacal sludge: Technical and financial analysis- Anaerobic digestion. Bill and Melinda Gates Foundation.

Tennigkeit T, Kallweit K and Buchholz T. (2006) Decentralised rural electricity production from energy forests — investigating the feasibility of business models for a demonstration project. Report to the Sawlog Production Grant Scheme (SPGS), EU Forest Resource Management and Conservation Programme Vietnam. Bangalore, Vietnam.

Stefan Diener, Swaib Semiyaga, Charles B. Niwagaba, Ashley Murray Muspratt, Jean Birane Gning, Mbaye Mbéguéré, Joseph Effah Ennin, Christian Zurbrugg, Linda Strande, (2014), A value proposition: Resource recovery from faecal sludge—Can it bethe driver for improved sanitation?, Resources, Conservation and Recycling**,** Volume 88, July 2014, Pages 32–38

Todd, B., Patrick, L., Stephen, B., Tewodaj, M., Julian, N., (2012), The supply of inorganic fertilizers to smallholder farmers in Vietnam: *Evidence for fertilizer policy development,* IFPRI Discussion Paper-1228.

Tripathi A.K., Iyer PVR, Kandpal T.C., 1998. A techno-economic evaluation of biomass briquetting in India. Biomass and Bioenergy 14: 479-488.

Winrock international India (2008) Feasibility study for developing proposal under clean development mechanism (CDM) for claiming carbon credit for leach pit toilets and toilet linked bio gas plants. Final report

World Bank, 2008. The welfare impact of rural electrification: a reassessment of the costs and benefits. An IEG impact evaluation 2008. The World Bank Washington, D.C. http://www.worldbank.org/ieg

World Bank, 2014. State and trends of carbon pricing. Washington DC. Doi: 10.1596/978-1-4648-0268-3

World Resources Institute. Greenhouse gas protocol. <http://www.ghgprotocol.org/calculation-tools/all-tools accessed (03/16/2015)

Young P., Khennas S., 2003. Feasibility and impact assessment of a proposed project to briquette municipal solid waste for use as a Cooking Fuel in Rwanda. Accessed at http://cleancookstoves.org/resources_files/feasibillity-and-impact.pdf on March 10, 2015.

Zanchi, G., Frieden, D., Pucker, J., Bird, D N., Buchholz, T., and Windhorst, K. 2012. Climate benefits from alternative energy uses of biomass plantations in Vietnam - Article in press. Biomass and bioenergy xxx (2012) 1-9

Zhang L and Wang C, 2014. Energy and GHG Analysis of Rural Household Biogas Systems in China

Zhu, Tingju, Ringler Claudia, Cai Ximing, (not-dated) Energy Price and Groundwater Extraction for Agriculture: Exploring the Energy-Water-Food Nexus at the Global and Basin Levels; accessed from http://www.iwmi.cgiar.org/EWMA/files/papers/Energyprice_GW.pdf; on 15/03/2015.

Websites accessed and other resources:

http://www.iwmi.cgiar.org/Publications/Books/PDF/groundwater_availability_and_use_in_sub-saharan_africa_a_review_of_15_countries.pdf

http://www.ajol.info/index.php/wsa/article/viewFile/91097/80532

http://www.iwmi.cgiar.org/EWMA/files/papers/Energyprice_GW.pdf

https://rwsnforum.files.wordpress.com/2011/11/91-xenarios-long-paper.pdf

http://metameta.nl/wp-content/uploads/2012/09/Managed_Groundwater_Development_in_Vietnam.pdf

http://www.wageindicator.org/documents/publicationslist/publications-2012/AIAS_WI_countryreports_f2f_report_Vietnam_final_20121211.pdf

http://www.fao.org/nr/water/cropinfo_maize.html

http://www.wastewaterinfo.asia/sites/default/files/tech-sheets/waste-stabilization-ponds.pdf

http://www.sswm.info/category/implementation-tools/wastewater-treatment/hardware/semi-centralised-wastewater-treatments/w

Vietnam Investment Authority, 2010. http://www.Vietnaminvest.go.ug/

Vietnam Renewable Energy Policy, 2007. http://eneken.ieej.or.jp/data/3963.pdf

http://www.sswm.info/sites/default/files/reference_attachments/RIECK%202010%20Public%20toilet%20with%20biogas%20plant%20and%20water%20kiosk%20Naivashsa%20Kenya.pdf on Oct 21, 2014.

http://www.waterdialogues.org/documents/InformalWaterVendorsandServiceProvidersinVietnam.pdf

Sanitation updates accessed at https://sanitationupdates.wordpress.com/tag/pay-per-use-public-toilets/ on Oct 21, 2014.

World Bank, (2013), About the second economic update. http://www.tradingeconomics.com/Vietnam/employment-in-agriculture-percent-of-total-employment-wb-data.html accessed on 27.03.2015.

World Bank, (2012), Vietnam Tourism Sector Situational Assessment: Tourism Reawakening.

UNEP, Chapter 5: Economic aspects of eutrophication obtained from http://www.unep.or.jp/ietc/publications/techpublications/techpub-11/5-6.asp

http://en.wikipedia.org/wiki/National_Water_and_Sewerage_Corporation accessed on 15.03.2015.

Wastewater characteristics and effluent quality parameters accessed from http://www.fao.org/docrep/t0551e/t0551e03.htm.