Resource Recovery and Reuse (RRR) Project

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

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Abbreviations

AIW	Agro-Industrial Waste
AM	Animal Manure
BBMP	Bruhat Bengaluru Mahanagara Palike
BCR	Benefit to Cost Ratio
BMDT	Business Model Development Training
BMs	Business Models
BWSSB	Bangalore Water Supply and Sewerage Board
CCPs	Critical Control Points
CDD Society	Consortium for DEWATS Dissemination Society
CSR	Corporate Social Responsibility
CTW	Constructed Treatment Wetland
DALYs	Disability Adjusted Life Years
DOE	Department of Energy
DWCC	Dry Waste Collection Centres
DWCC	Decentralised Waste and Composting Center
ECOSAN	Ecological sanitation
eERG	Energy and Environment Resource Group Inc.
EIA	Environmental Impact Assessment
ESCO Model	Energy Services Company Model
FGDs	Focus group discussions
FS	Faecal Sludge
HIA	Health Impact Assessment
HRA	Health Risk Assessment
HRIA	Health Risk and Impact Assessment
iDeCK	Infrastructure Development Corporation (Karnataka) Ltd.
INR	Indian Rupees
IRR	Internal Rate of Return
KCDC	Karnataka Compost Development Corporation
KREDL	Karnataka Renewable Energy Development Limited
KSBDB	Karnataka State Bio-fuel Development Board
KSDA	Karnataka State Department of Agriculture
KSPCB	Karnataka State Pollution Control Board
KUIDFCL	Karnataka Urban Infrastructure Development and Finance Corporation Limited
LPG	Liquid Petroleum Gas
MC	Market Concentration
MCA	Multi-criteria Assessment
MID	Minor Irrigation Department
MLD	Million Litres per Day
MNRE	Ministry of New & Renewable Energy
MSW	Municipal Solid Waste
MW	Market Waste
NFHS	National Family Health Survey

NGOs	Non-governmental Organizations
NMP	National Master Plan
NPV	Net Present Value
OFMSW	Organic Fraction Municipal Solid Waste
P&L	Profit and Loss
PIL	Public Interest Litigation
PM	Particulate Matter
PPE	Personal Protective Equipment
R&D	Research and Development
RoI	Return on Investments
RRR	Resource Recovery and Reuse
SCP	structure–conduct–performance
SS	Sewage Sludge
SSP	Sanitation Safety Plan
STEP	Specific Topic Entry Page
STH	Soil-transmitted Helminthic
STPs	Sewage Treatment Plants
SW	Solid Waste
SWM	Solid Waste Management
ULBs	Urban Local Bodies
WHO	World Health Organization
WTE	waste-to-energy
WTP	Willingness To Pay
WW	Wastewater
WWTPs	Wastewater Treatment Plants

Executive Summary

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

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

Twelve (12) business models were selected for feasibility testing in Bangalore, covering several waste streams (faecal sludge, municipal solid waste (MSW), wastewater, agro-industrial waste) and resulting end-products categorized into energy and nutrient recovery and wastewater use. The business models were selected based on information from: a) a pre-feasibility study, b) feedback from stakeholder workshops and c) a no-go analysis based on information from baseline surveys. The selected business models had to have at least triple bottom line targets: high impact from a scalability and replicability perspective and catalyze innovation adoption. The feasibility of each model was then analyzed based on the MCA framework and for its overall potential feasibility based on a 4-level ranking system, i.e. whether it has:

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

The notion behind the ranking of the RRR business models is to provide different stakeholders, in particular, investors with an overview of the potential feasibility for implementation of the business models. Particularly, it provide insights on constraints, if any, possibly related to key resource factors, and the level of risk associated with their potential investments.The overall feasibility of the selected RRR business models is presented in Table 1 below. It is noted that the **dry fuel manufacturing (agro-waste to briquettes)**, **wastewater use for irrigation, energy and nutrient recovery**, and **MSW-based compost** (models 15 and 16) have the highest feasibility potential for implementation in Bangalore. It is important to note however that some of the feasibility of some of the business models can be improved with some adaptation (e.g. use of strategic partnerships, consideration of alternative waste streams and institution of supportive policies).

Only one of the energy business models was noted to be feasible for implementation in Bangalore - *dry fuel manufacturing (agro-waste to briquettes*). Its feasibility is attributable to several factors including: a) availability of waste input; b) growing market demand among households and industries; c) supportive institutional environment; and d) high financial viability. The results indicate that there is a fair market demand for agro-waste briquettes in Bangalore, although not substantial. Among the surveyed households (both urban and rural), none were currently noted to be using briquettes. Appropriate planning and marketing strategy will be required for new briquette businesses to gain a share of the market, especially given that there is no significant demand supply gap for briquettes, although the estimated demand exceeds estimated supply. New briquette businesses also will need to accommodate customer expectations in terms of credit, delivery, and near nil expenditure for marketing by the current market players. Differential pricing can be instrumental in gaining market share, although its implementation needs to be studied in greater detail. There are also both policy induced factors and environmental factors that are representative of entry barriers for briquettes to penetrate the household sector. Government subsidies for existing competing products in the energy market (LPG and Kerosene) may pose a challenge to new briquette businesses, and thus appropriate product positioning and customer targeting would be essential to overcome the challenges posed by the subsidy. From an institutional perspective, there are supportive legislations and incentives for private sector engagement in the sector. The briquette business has been operational in India for some time now and these businesses have performed consistently well over a number of years resulting in a relatively stable market environment for the business model. The biggest challenge faced by these business has been the price of raw material (agro-waste) and a key necessity will be for future briquette businesses to build strong partnerships with farmers to supply agro-waste at a set price to reduce high input supply volatility.

The low feasibility of the *Onsite Energy Generation by Sanitation Service Providers (faecal sludge to electricity)* model is mainly driven by a constraining market and institutional environment. Whilst the legislation permits the reuse of faecal sludge and also provides financial incentives for biogas plants from human waste, a key challenge primarily lies in the capacity of BBMP to actually manage the public toilets. Additionally, the electricity market is heavily regulated and monopolized by state agencies. Private participation although present is very limited and permitted only for certain aspects of power generation. Pricing of electricity is negotiated between the private entrepreneurs and the respective electricity reforms commission. As private electricity suppliers do not supply directly supply to households but rather to the national grid, the only direct market/ consumer is with the latter. Thus, any potential for sale of excess electricity to the national grid will be limited by a price setting environment.

The low feasibility potential of *Model 6 - Power Capture Model (livestock to energy)* is mainly driven by the distortions in the electricity market. As with model 4, any new waste-to-energy business will face an electricity market that is heavily regulated and monopolized by state agencies. Private participation although present is very limited and permitted only for certain aspects of power generation. Additionally, as private electricity suppliers do not directly supply to households but rather to the national grid, the only direct market/ consumer is with the latter. Thus, any potential for sale of excess electricity to the national grid will be limited by a price setting environment. From an institutional perspective, there are existing supportive policies for waste-to-energy initiatives although mainly for MSW-based initiatives and does not specify the scale of operation or offer detailed guidance for on-site technologies. There is a general positive consensus for this business model across the board from communities to NGOs and government officials but it is noted that there needs to be more support, particularly provision of financial incentives to potential businesses. Thus an improved enabling environment from an institutional perspective will generally improve the feasibility of this model.

The high feasibility for implementation of *Models 9 & 12 - On Cost Savings and Recovery (wastewater use for irrigation, energy and nutrient recovery*) is driven by key factors related to: a) high financial viability, b) supportive institutional environment and c) wastewater availability and access. There is significant wastewater generated and treated in Bangalore (at approx. 457 Million litres per Day (MLD) of treated wastewater from 14 WWTPs and 1000 m^3 of wet sludge per day) that can be reused at some level. The results from the WTP assessment show that the majority of farming households are willing to use and pay for treated wastewater for irrigation purposes, especially during the drier seasons. A lower percentage (63%) was however noted to be willing to pay for treated wastewater during the monsoon season. On average, 89% of these farmers were willing to pay for using treated wastewater for irrigation. The farmers were willing to pay Rs.482/- per 10,000 litres (10 m^3) of treated/partially treated wastewater. For the surveyed businesses, the results showed that on average 84% of the surveyed enterprises were willing to pay for treated wastewater. The average WTP value was Rs.455/- per tanker of treated/partially treated wastewater. However, among the larger enterprise respondents, they were willing to pay an average of Rs.1, 160/- per 8,000 litre tanker. Demand for treated wastewater among businesses was found to be specific to the enterprise type and use. From an institutional perspective, there are supportive policies for the use of treated wastewater and there are quite a number of existing reuse cases. It is however noted that the initiatives occur as single-activity entities and not in combination yet (wastewater reuse, energy generation and sludge treatment and reuse). There are opportunities for these initiatives to be combined and explored together as whole as in this model, however considerable institutional changes would be required.

Model 8 - Beyond cost recovery (wastewater-fed aquaculture) has a potential for implementation given: a) available wastewater treatment plants and city lakes for integrated aquaculture, and b) strong financial viability but the model is largely limited by the market demand. The results show that consumers derive a negative utility from wastewater-fed fish. The results show the WTP for wastewater-fed fish among consumers to be estimated at Rs.63.97/Kg which is lower than the current market price of non-certified fish with no information on the medium used to raise the fish. The market prospect for wastewater-fed fish has some promise but will face social barriers and consumer perceptions in the initial stages. Innovative marketing strategies including pricing and product promotion strategies will be required to facilitate the entry of new businesses into the market. It is suggested that food products made from fish harvested in treated wastewater must be priced differentially lower than that of food products of freshwater fish, in order to capture a share of the market. An aggressive marketing strategy for the promotion of treated wastewater fish is also recommended. From a financial perspective, the business of wastewater-fed fish is highly sensitive to the scale of operations. At lower fish production levels, the business model is not viable as the cost of labor to manage the production activities is high and drives the investment to be unviable. The implementation of this business model may also face some institutional hurdles as such initiatives are not fully supported by the law, institutional arrangements or public perceptions. Given the importance of the institutional and legal environment for the implementation of this model, there will be the need for a revision of the policies and regulations to incentive the implementation of such initiatives, especially given that this model has the greatest potential for having a positive health impact from a reduction in exposure to pathogens at the community level.

The infeasibility of *Model 10 - Informal to Formal Trajectory in Wastewater Irrigation - Incentivizing safe reuse of untreated wastewater* is driven mainly by the institutional regulations which notes that the use of untreated wastewater for irrigation is not permissible under the city and national policies on wastewater and irrigation. The key challenge with this model is the lack of treatment - which is confirmed by the results from the health risk and impact assessment which notes that it is not recommended to promote the reuse of untreated wastewater for irrigation purposes in Bangalore.

The feasibility assessment for *Model 11 - Wastewater and drinking water exchange* was difficult to undertake both from the market and financial perspective. This business model has potential to be feasible but would require significant negotiation and contractual arrangements to make it possible. BWSSB and MID will need a capacity strengthening of staff to undertake the operations as well as contracting and negotiation. Given the importance of the institutional and legal environment for the implementation of this model, there will be the need for some revision of the policies and regulations to incentive the implementation of such initiatives, especially to facilitate the negotiation of water rights.

The MSW-based compost nutrient business models *(Model 15 - Large-Scale Composting for Revenue Generation (municipal solid waste to compost) and Model 16 - Subsidy-free Community Based Composting (municipal solid waste to compost)]* were noted to be highly feasible in the context of Bangalore. The feasibility of the models are driven mainly by: a) high financial viability, b) supportive institutional and legislative environment, c) significant market demand and d) available technologies. The potential market for MSW-compost is noted to be substantial with the demand estimated at 578,400 tons/year, with an adoption rate of 20% and application rate of 12.5 tons/ha/year. The results indicate that farmers are willing to pay 1.458 INR/kg more to know the source of the waste input used to produce the compost; and an even higher premium of 5.359 INR/kg for pelletization and 14.397 INR/kg for certification. Given these marginal estimates, the full analysis shows the estimated WTP for compost to be 61.214 INR/kg, which is significantly higher than the current market of competitive products. The results suggest that the demand for compost could increase if the abovementioned attributes are factored into the final product for the market. In the instance where such product differentiation is not cost-effective, it is important to explore the opportunities that partnerships can offer and also those related to some form of government subsidization. From a financial perspective, the model is highly dependent on the scale of operations. It is noted that as the scale of the waste processed increases, the feasibility of the compost production plant improves. It is important to note that the decision of a business to operate at a certain scale will be determined by several factors: a) demand, b) price of the compost, c) economies of scale, among others. Whilst the current production level of compost is unknown, it is clear that the compost sector is a burgeoning industry with some entry barriers but supportive and existing policies encouraging business development.

Model 17 - High value Fertilizer Production for Profit (combination of municipal solid waste and faecal sludge to organic fertilizer) is similar to model 15 in concept but in addition to MSW, the business entity uses faecal sludge as a waste input from onsite sanitation which is rich in nutrients. There are opportunities for pelletization and blending of faecal sludge-based compost with rock-phosphate, urea/struvite or NPK which is an additional value proposition that can be explored under this business model, allowing the product to have nutrient levels specific for target crops and soils, and a product structure improvement (pellets) to improve its competitive advantage, marketability and field use. Although there is a substantial market demand for Fortifer, supportive policies and availability of the waste input, this model has no feasibility for implementation and this is mainly driven by the limited financial viability. The business model shows a limited financial viability because of a low product price and limited expected quantity of sales. The business model will require a capital subsidy and it is unlikely to achieve capital cost recovery even with a higher compost price.

Model 20 - Outsourcing Faecal Sludge Treatment to the Farm, although applicable to regions with high onsite sanitation system coverage has a low feasibility potential. The challenge with this model is related to the incomplete regulatory framework for truck operators, permits/licenses issuing processes for private businesses, amongst others. Currently most of the on-going operations are done on an informal basis and based on a market-driven response to the demand for emptying septic tanks. This type of business is completely viable from emptying fees but currently faces the challenge of accessing waste disposal sites. From an institutional perspective, this model has a low ranking given that it operates in a grey area although it is being very effectively practiced by the private sector and the number of people involved appears to be growing. Changes to the institutional arrangements in the system could possibly result in a workable, legal model, but caution needs to be taken to ensure that legitimizing the practice does not make it unviable in the process. This business model does pose some potential health risks but if appropriately regulated following WHO 2006 guidelines and sanitation safety practice, these risks can be mitigated.

It is important to note that the feasibility potential of some of the business models can be significantly improved with some adaptation (e.g. use of strategic partnerships, consideration of alternative waste streams and institution of supportive policies).

Table 1: Overall feasibility ranking of the business models

		Level of feasibility of the business models										
Ranking criteria		**ENERGY**			**WASTEWATER**				**NUTRIENT**			
	Outputs	**BM1a**	**BM4**	**BM6**	**BM8**	**BM9 and 12**	**BM10**	**BM11**	**BM15**	**BM16**	**BM17**	**BM20**
1	Waste supply and availability											N/C
2	Market assessment							N/C				
1	Institutional analysis											
3	Technical assessment											
4	Financial assessment						N/C	N/C				
5	Health risk& impact assessment											N/C
	Environmental risk and impact assessment											
6	Socio-economic assessment											
	Overall ranking of BM											

Legend:

- **BM 1a:** Dry Fuel Manufacturing: Agro-Waste to Briquettes
- **BM 4:** Onsite Energy Generation by Sanitation Service Providers (faecal sludge to electricity)
- **BM 6:**Power Capture Model (livestock to energy)
- **BM 8:** Beyond cost recovery: wastewater-fed aquaculture
- **BM 9:** On Cost Savings and Recovery (wastewater use for irrigation, energy and nutrient recovery)
- **BM 10:** Incentivizing safe reuse of untreated wastewater
- **BM 11:** Wastewater and drinking water exchange
- **BM 12:** Wastewater treatment for carbon emissions reduction
- **BM 15:** Large-Scale Composting for Revenue Generation (municipal solid waste to compost)
- **BM 16:** Subsidy-free Community Based Composting (municipal solid waste to compost)
- **BM17:** High value Fertilizer Production for Profit (combination of municipal solid waste and faecal sludge to organic fertilizer)
- **BM 20:** Outsourcing Faecal Sludge Treatment to the Farm

Legend
High feasibility
Medium feasibility
Low feasibility

No feasibility

N/C - Assessment not conducted

1 Introduction

1.1 Overview of Research Project

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

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

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

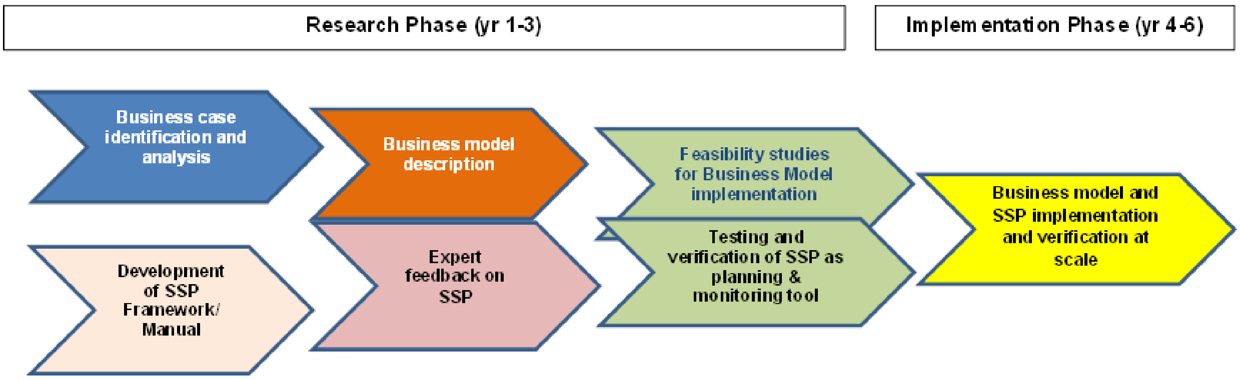

Figure 1: Research Framework for the Project

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

RR&R which include recommendations for investment options and related health risk monitoring and mitigation measures aligned to the *Sanitation Safety Plan (*SSP).

1.2 Methodology for Feasibility Studies

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

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

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

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

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

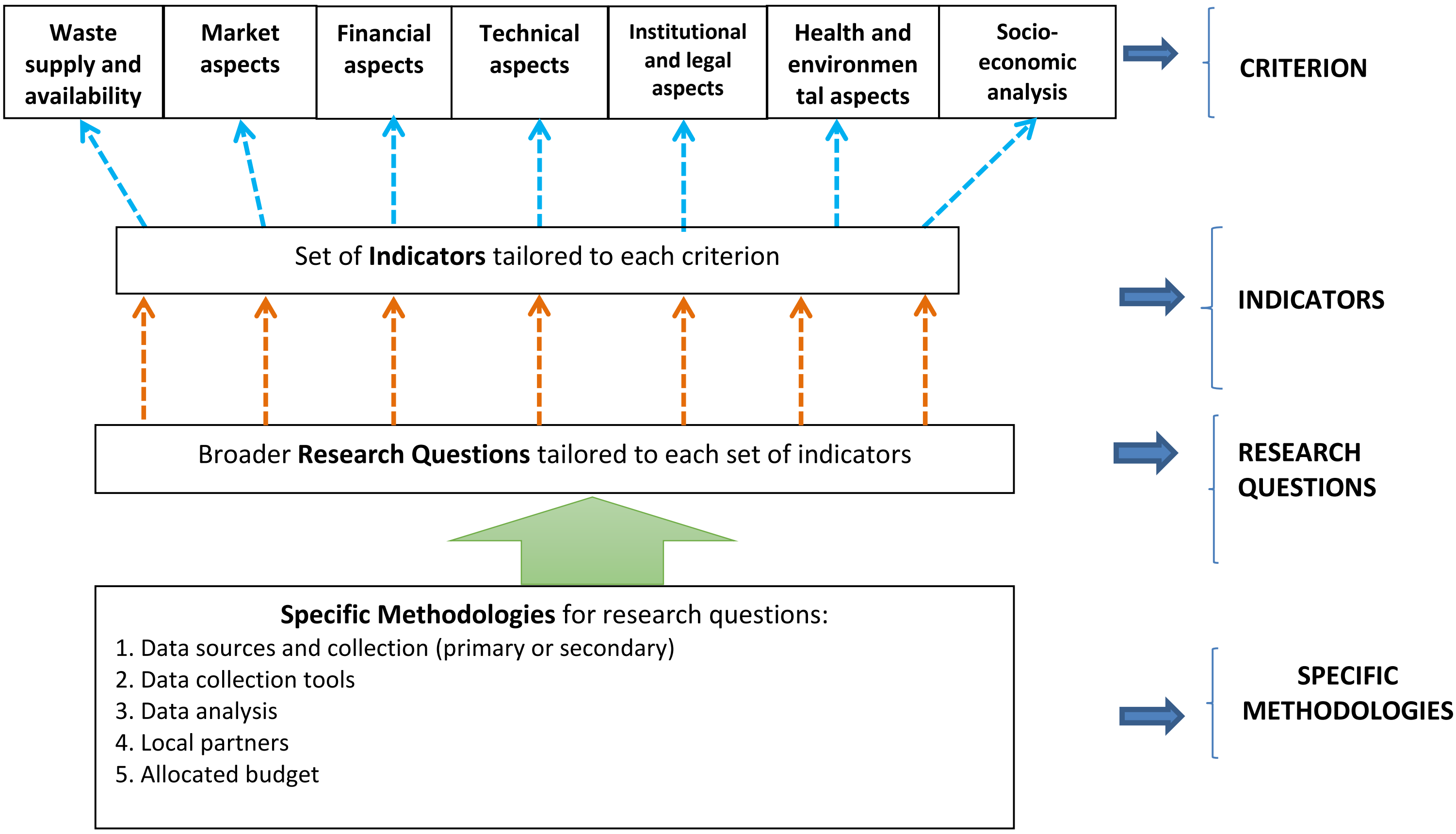

Figure 2: Framework for Feasibility Studies

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

- to consolidate the baseline survey reports provided by the consultants with complementary dimensions (if the former proved to have insufficient information)
- to meet key authorities on one-to-one base to align the project with their needs;
- to visit existing treatment or reuse cases in the city and discuss with the respective operators the options for RRR;
- to pre-select the number and types of possible BMs that locally made sense;
- to have first contacts with potential partners for the different dimensions of the feasibility phase.

The final feasibility city selection criteria was based on: a) confirmed official interest, b) supporting policies, c) local partner capacity to carry out feasibility and health studies, d) urban and peri-urban farming sector in need of resources, and e) already ongoing reuse activities to test the SSP. The final selected cities were Kampala, Uganda; Lima, Peru; Bangalore, India; and Hanoi, Vietnam. This report focuses on the results from the feasibility studies conducted in Bangalore, India. It is important to note that the feasibility studies considered an urban - peri-urban system boundary and defined based on the specific context and city under consideration. Twelve (12) business models selected for feasibility testing in Bangalore are presented in Table 2. The selection process of the business models was based on three components: a) a pre-feasibility study, b) feedback from stakeholder workshops and c) a no-go analysis based on information from the baseline survey.

Table 2: Selected RRR Business Models for Feasibility Testing in Bangalore

RRR Business Models	Brief Description
ENERGY	
Model 1a: Dry Fuel Manufacturing: Agro-Waste to Briquettes	The business entity processes crop residues like wheat stalk, rice husk, maize stalk, groundnut shells, coffee husks, saw dust etc. (any agro-based waste) and converts them into briquettes as fuel to be used in households, large institutions and small and medium energy intensive industries.
Model 4: Onsite Energy Generation by Sanitation Service Providers	The business model is initiated by either enterprises providing a sanitation service such as public toilets or by residential institutions such as hostels, hospitals and prisons with a concentrated source of human waste (i.e. faecal sludge). The business concept is to process and treat human waste in a bio-digester to generate biogas to be used for lighting or cooking.
Model 6: Power capture model - Livestock waste to energy	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.
WASTEWATER REUSE	
Model 8: Beyond cost recovery: the aquaculture example	The business concept is to treat wastewater to an advanced tertiary state and during that process produce fish for human consumption. The concept offers business opportunities at medium scale, where existing in-use treatment plants can be used to raise fish for sale into the market, providing avenues for cost recovery to municipal wastewater management entities.
Model 9&12: On Cost Savings and Recovery - Wastewater treatment for irrigation/ fertilizer	The business concept is to treat wastewater for safe reuse in agriculture, forestry, golf courses, plantations, energy crops, and industrial applications such as cooling plant. The sludge from the treatment plant can be used as compost and soil ameliorant and energy generated can be used for internal purpose resulting in energy savings.
Model 10: Informal to Formal Trajectory in Wastewater Irrigation - Incentivizing safe reuse of untreated wastewater	Informal reuse of wastewater is commonly practiced by farmers in developing countries but it also entails significant health costs, often borne by the public and are of social nature. This social nature of these costs justifies public investments in incentives to promote safe reuse of wastewater and minimize risk along the entire value chain as such incentives could potentially turn this unsafe informal activity into a safe and formal one with shared rewards for all the stakeholders.
Model 11: Inter-sectoral Water Exchange	In a water scarce situation, 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) and recover valuable nutrients from the waste that would otherwise be unmanaged and disposed on streets and landfills without reuse. Compost from MSW is sold to farmers, landscaping, and plantations and other entities.
Model 16: Subsidy-free community based composting	The business concept is similar to model 15, 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 15 in concept but in addition to MSW, the business uses faecal sludge as an input from onsite sanitation systems which is rich in nutrients. There are opportunities for pelletization and blending of faecal sludge-based compost with rock-phosphate, urea/struvite or NPK which is an additional value proposition that can be explored under this business model, allowing the product to have nutrient levels specific for target crops and soils, and a product structure improvement (pellets) to improve its competitive advantage, marketability and field use.
Model 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.

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

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

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

2 Key findings of Waste and Availability Analysis

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

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

Table 3 provides a summary of the key findings for each business model under consideration. The waste streams and end-products are listed, including a ranking of feasibility for implementation (high/medium/low) and recommendations for adaptations to increase feasibility. Detailed analysis were conducted for each waste stream on:

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

The information was collected through review of secondary data, interviews, field observations and collection of primary data. Detailed information, data analyses and data sources are available in: "*Resource, Recovery and Reuse Project. From Research to Implementation. Component 1 - Waste Supply and Availability: Bangalore, India. Internal report,* available for download on www.sandec.ch/rrr

Table 3: Rating of feasibility of business models from a 'Waste Supply and Availability' perspective and recommendations for Bangalore

Business Model	Waste stream	End-product	Feasibility	Comments
1 (a)	• MSW • AIW	• Briquettes	**Low** (MSW): MSW is too wet to be processed(high confidence) **Medium** (AIW): although the presence of many agro-processing industries surrounding the city (Bangalore Urban District), there is lot of competition for agro-waste given that its reuse is already happening.	Briquette from OFMSW is not recommended given the high moisture content of OFMSW, which would require extensive land use for drying.
4	• Feces • Urine • FS	• Biogas -> Cooking fuel	**High** (FS): quantity of FS hauled in the city may be between 300-700 m^3/d (low confidence). Only a small percentage of which is safely disposed/reused and may be potentially diverted towards RRR (low-medium confidence). **Medium-High**: There are very few experiences of ECOSAN toilets. However, access to toilets services may be required particularly in the city slums (low confidence).	This model may focus on slums areas by providing integrated sanitation services (e.g. toilets/showers).
6	• AM	• Biogas -> Electricity	**Medium** (AIW) – Although a substantial generation of manure (and agro-industrial waste, the majority of this is already reused in agriculture (medium confidence).	
8	• WW	• Fish • Treated WW	**Medium-High** (Treated WW): ~457 MLD of treated WW from 14 WWTPs, discharged into the city's lakes (high confidence).	Aquaculture may be carried out in city lakes and integrated or internalized into WWT businesses for cost recovery. This may require coordination with the authority responsible to issue fishing licenses.
9	• WW • WW sludge	• Electricity • Soil conditioner • Water (for reclamation)	**High** (Treated WW): ~457 MLD of treated WW from 14 WWTPs (high confidence). **High** (WW sludge): the city may generate ~1000 m^3 of wet sludge per day (low-medium confidence). Its disposal is a major challenge for the city.	The location of WWTP and treated WW is available on a geo-referenced Google map file.
10	• WW	• Water (for reclamation) • Water for groundwater recharge	**High** (WW): the city roughly generates ~1000 MLD between treated and untreated WW (medium-high confidence) **High** (Treated WW): ~457 MLD of treated WW, discharged into the city's lakes (high confidence).	Lakes and groundwater replenishment look very promising alternatives given the high amount of wastewater generated and treated in the city and the increasing groundwater use (water scarcity in general). However, the location and recharge options should be further analyzed given that in some areas of the city groundwater has already reached high nitrate concentration.

11	• Treated WW	• Water (for reclamation)	**Medium-High** (Treated WW): ~457 MLD of treated WW, discharged into the city's lakes (high confidence).	The location of WWTP and treated WW is available on a geo-referenced Google map file.
15	• MSW	• Soil Conditioner	**High** (mixed-MSW): total MSW amount to ~4500 t/d and roughly 70% of which is organic (medium-high confidence). 15-20% of which remains uncollected in the streets.	
16	• MSW	• Soil Conditioner	**High** (mixed-MSW): total MSW amount to ~4500 t/d and roughly 70% of which is organic (medium-high confidence). 15-20% of which remains uncollected in the streets. **Medium** (OFMSW-only): source segregated OFMSW is ~10% of total waste. However, there is a big potential for organic waste recovery, particularly at market level. ~600 t/d is generated by market (90% organic) (low confidence). Also, hotel/restaurants waste (food) is another good source for OFMSW. However, competition for it is growing.	Source-segregated OFMSW may increase in the future due to several orders from courts and city council. However competition on OFMSW is growing.
17	• MSW • FS	• Fertilizer (NPK added)	**Medium** (OFMSW-only): source segregated OFMSW is ~10% of total waste. However, there is a big potential for organic waste recovery, particularly at market level. ~600 t/d is generated by market (90% organic) (low confidence). Also, hotel/restaurants waste (food) is another good source for OFMSW. However, competition for it is growing. **High** (FS): quantity of FS hauled in the city may vary between 300-700 m^3/d (low confidence). Only a small percentage of which is safely disposed/reused (low-medium confidence).	P-enrichment may be considered given the P-deficient quality of soil in the surrounding area.
20	NA	NA		

3 Key findings of Market Assessment

3.1 Introduction

A key component of the feasibility studies is the market assessment of the RRR business models as functioning markets, an enabling institutional environment and positive economic and financial conditions are essential for sustainable business activity in any sector including the waste reuse sector. The set-up of any RRR business and the commercialization of a new product in a new market requires an accurate or close to accurate estimation of the relative market size for the new product. The successful development of any subsector market depends among other factors particularly on market demand. Specifically, the question of whether a demand actually exists and the price end-users are willing to pay for this new product needs to be explored. For this reason, the market assessment set out to evaluate the current and potential market for the recovered resource and the effect of different factors (e.g. socio-cultural aspects and perceptions, price of substitute products, etc.) on market demand. Information on market segments, potential clients of the RRR product, their actual and potential number and resource absorption capacity and their willingness-to-pay (WTP) were assessed.

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

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

A total of 12 RRR business models were selected for the feasibility studies in Bangalore. For the purposes of the market assessment, an end-use typology of the business models was employed as although the underlying concepts of the business models were different, a number of the end-products were the same across different business models. Thus for some business models, the related customer segments and relevant actors along the value chain considered would be the same. In that regard, for the selected business models, the following 6 value-added products were considered: 1) briquettes, 2) electricity, 3) wastewater-fed fish, 4) treated wastewater, 5) MSW-based compost and 6) faecal sludge-based compost.

Untreated wastewater is not considered a marketable commodity as it is considered to increase human health risk and environmental pollution and thus potential users' valuation was not assessed.

Table 4: List of RRR business models and related products

Business Model	Value-added product	Recovered resource
Model 1a: Dry fuel manufacturing: agro-waste to briquettes	Briquettes	Energy
Model 4: Onsite energy generation by sanitation service providers	Electricity	
Model 6: Power capture model - Livestock waste to energy		
Model 8: Beyond cost recovery: the aquaculture example	Wastewater-fed fish	Fish
Model 9 and 12: On cost savings and recovery (treated wastewater for irrigation, energy, fertilizer)	Treated wastewater	Wastewater
Model 10: Informal to formal trajectory in wastewater irrigation	Untreated to partially treated wastewater	
Model 11: Inter-sectoral Water Exchange		
Model 15: Large-scale composting for revenue generation (MSW to compost)	MSW-based compost	Nutrients
Model 16: Subsidy-free community based composting		
Model 17: High value fertilizer production for profit (faecal sludge to compost)	Faecal sludge-based compost	
Model 20: Outsourcing faecal sludge treatment to the farm	Farm treated faecal sludge	

3.2 Methodology

3.2.1 Overview of Methodology

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

3.2.1.1 Willingness-to-pay and Market size estimation

Stated and revealed preference methodologies have gained immense popularity in eliciting consumers' valuation of new products (Lusk and Hudson, 2004; Kimenju and Groote, 2008). The choice between the uses of stated or revealed preference methods is dependent on the RRR product under consideration.

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

3.2.1.2 Market structure assessment

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

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

3.2.1.3 Market outlook assessment

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

3.2.2 Study Area and Data

The primary survey covered several key districts in Bangalore (urban, peri-urban and rural). For the WTP and market size assessment, primary data on price offers from market experiments, information on demographics and socio-economic factors were collected from different groups of respondents depending on the RRR product. Data on price of substitute products, macro-economic factors, amongst others were collected from secondary sources. WTP measures were derived directly from the purchase price and additional econometric analysis. For the market structure, both primary and mostly secondary data were collected and used for the supply chain analysis, although this was dependent on the RRR product. Data on the number and size of key players, players' characteristics (e.g. economies of scale, access to financing, marketing and distribution costs, and level of integration and nature of contractual agreements) were collected from primary sources. For the market outlook assessment, data on market demand and market share were obtained from the WTP and market structure assessment components. Additional secondary data on alternative products, prices and quantity of sales of existing competing products in the market was collected from relevant institutions (e.g. marketing boards and departments).

3.3 Results of the Market Assessment

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

The results indicate that there is a fair market demand for agro-waste briquettes in Bangalore, although not substantial. Among the surveyed households (both urban and rural), none were currently noted to be using briquettes. Furthermore, the estimated supply of agro-waste for the generation of briquettes and the estimated demand for briquettes from the identified segments of the economy broadly reveal that there is no significant demand supply gap for briquettes, although the estimated demand exceeds estimated supply. This suggests that an appropriate planning and marketing strategy will be required for new briquette businesses to gain a share of the market. New briquette businesses also will need to accommodate customer expectations in terms of credit, delivery, and near nil expenditure for marketing by the current market players. Differential pricing can help in gaining market share, although its implementation needs to be studied in greater detail. Across all the studied markets product promotion and marketing is close to nil. New briquette businesses would need to invest in R&D in order to mitigate the effects of high social barriers. This would place them at a competitive disadvantage compared to their competitors.

There are also both policy induced factors and environmental factors that are representative of entry barriers for briquettes to penetrate the household sector. Government subsidies for existing competing products in the energy market (LPG and Kerosene) can pose a challenge to new briquette businesses, and thus appropriate product positioning and customer targeting would be very essential to overcome the challenges posed by the subsidy. Additionally, the extensive established network of LPG has improved the product's accessibility not only in urban areas but also in rural areas - thus a significant competitor for briquettes. Similarly, the steady improvement of electrification has resulted in households relying on electricity at least for lighting. In addition, urban low income households have the access to kerosene both through public distribution system and open markets; and in the rural areas, households have the luxury of collecting firewood free of cost.

- ***Model 4: Onsite energy generation by sanitation service providers and Model 6: Power capture model - Livestock waste to energy***

The electricity market is heavily regulated and monopolized by state agencies. Private participation although present is very limited and permitted only for certain aspects of power generation. Pricing of electricity is negotiated between the private entrepreneurs and the respective electricity reforms commission. As private electricity suppliers do not supply directly supply to households but rather to the national grid, the only direct market/ consumer is with the latter. In that regard, a willingness-to-pay assessment was not conducted for business models 4 and 6. An assessment of the market structure and outlook is provided in detail in the 'Institutional analysis' report.

- ***Model 8: Wastewater-fed Aquaculture (phyto-remediative wastewater treatment and fish production)***

The results show that consumers derive a negative utility from wastewater-fed fish and wild fish. The primary survey shows that wastewater-fed fish is presently not consumed by the surveyed households. In absence of the revealed preference data an approximate price of wastewater-fed fish with information about the source and certification is Rs. 173.6/Kg (which considers only the information price and certification price). The actual payment for wastewater-fed fish among the consumers was estimated to be Rs. 63.97/Kg which is lower than the current market price of non-certified fish with no source information. The results show that consumers are willing to pay Rs.37.25/kg to know the source of the fish (i.e. which medium the fish was reared in) and Rs. 136.36/kg for certification.

The market prospect for wastewater-fed fish has some promise but will face social barriers and consumer perceptions in the initial stages. Innovative marketing strategies including pricing and product promotion strategies will be required to facilitate the entry of new businesses into the market. It is suggested that food products made from fish harvested in treated wastewater must be priced differentially lower than that of food products of freshwater fish, in order to capture a share of the market. An aggressive marketing strategy for the promotion of treated wastewater fish is also recommended. Overall, wastewater-fed fish has a good market outlook but will have to compete aggressively with their alternative products to sustain in the market eventually. Freshwater fish is a very a close substitute for fish from treated wastewater. Therefore, this product will offer a high degree of competition to the RRR product. With an ever-expanding cultivation of freshwater fish and with an ever increasing level of income and population, the demand for freshwater fish will grow steadily. However, if proper labelling is done by appropriate regulatory authorities to educate the prospective consumers that the consumption of fish reared from treated wastewater will not pose any health risks, and if it is sold at a competitive price, it will find its way into the market, though gradually and steadily.

- ***Model 9: Cost recovery - Treated wastewater for irrigation, fertilizer and energy and Model 10: Informal to formal trajectory in wastewater irrigation***

The results from the WTP assessment show that the majority of farming households (93% of surveyed respondents) are willing to use and pay for treated wastewater for irrigation purposes, especially during the drier seasons (summer months). A lower percentage (63%) was however noted to be willing to pay for treated wastewater during the monsoon season. On average, 89% of these farmers were willing to pay for using treated wastewater for irrigation. The farmers were willing to pay Rs.482/- per 10000 litres (10 m^3) of treated/partially treated wastewater. The results also showed that the farmers place a higher value on treated wastewater under a scenario of 'increased water scarcity' compared to any increment in cost of water supply. The bids offered by the farmers for an increase in cost of water at the initial levels (10% to 25%) are similar in terms of the average value (Rs.315.38). This increases marginally by Rs. 66 when an option of 100% cost increment is faced by the farmers. In comparison, the marginal change in the bid offered when scarcity of water increases from 25% to 50% is about Rs. 210 per $100m^3$ which is 3 times the increase in the bid offered for cost changes. The results also showed that farmers with more farming experience were willing to pay a relatively higher fee than the other groups. It is however important to note that the standard deviation for these farmers was also higher in comparison to the other groups. Additionally, farmers dependent on rainwater for irrigation were willing to pay a higher fee for wastewater for irrigation than farmers utilizing groundwater. This might be due to the fact that farmers practising rain-fed farming are willing to hedge the risk of vagaries of rainfall and hence have a higher willingness to pay. The farmers dependent on groundwater pay a relatively higher price for water compared to the other group of farmers and may not consider treated wastewater a substitute with the assured water supply they presently receive. Another reason for lower preference for payments is due to the fact that farmers who have already invested for groundwater are reluctant to phase it out completely since it entails a higher establishment cost.

In regards to the businesses, the results showed that on average of 84% of the surveyed enterprises were willing to pay for treated wastewater. The average WTP value was Rs.455/- per tanker of treated/partially treated wastewater. However, among the larger enterprise respondents, they were willing to pay on an average of Rs.1160/- per 8,000 litre tanker. The results also indicated that the enterprises value treated wastewater relatively higher under the scenarios of 'increment in cost of water supply' than that of 'water. Under the water scarcity scenario, it was found that the payments offered by the enterprises were relatively lower. In fact even with a 10% scarcity of water, the enterprises were willing to pay about the same charges as when there was no water scarcity. Another important consideration is that while for the first 15% increase in scarcity of water the WTP for treated wastewater (a substitute) rises by Rs.50 (a rise of 10%) and for the next 75% increase in scarcity of water, the WTP rises by about Rs. 141 (about 28%). Thus the changes in the WTP move in an opposite direction (as availability decreases, WTP rises) although not proportional to the change in the scarcity of water (which would become dearer which scarcity of water). This implies that the enterprises do consider wastewater as a substitute to water although not a perfect substitute. The enterprises included in the survey comprised of institutional houses (*Kalynmantapas*), hotels, car services, washer-man and industries (like brick manufactures, chemicals and garments). Except for the industries, it was found that other businesses incur water costs less than Rs.5000 and hence have lower payments for wastewater. Similarly, the consumption of these businesses are lower than that of the industries and hence have a lower preference for WTP for treated wastewater. These smaller (and some medium) enterprises thus have a lower substitutability for treated wastewater rather than the larger industries and hence their demand curves are more inelastic to price changes of water.

It is clear that there is a fair demand for treated wastewater. In particular, the demand is higher among farmers but characterized by a WTP lower during the monsoon seasons that the summer season. Demand for treated wastewater among businesses was found to be specific to the enterprise type and use. Demand for water is expected to grow exponentially in the future particularly in the agricultural and industrial sectors. In terms of the structure of the water market, it is a well-regulated market and it is foreseen that the supply and distribution of wastewater and the related market structure will most likely follow a similar pattern.

- ***Model 15: Large-scale composting for revenue generation (MSW-based compost), Model 16: Decentralized MSW composting and Model 17: High value fertilizer production for profit (faecal sludge-based fertilizer)***

The analysis shows that there is a significant demand for MSW compost and Fortifer. The potential market for MSW-compost is noted to be substantial with the demand estimated at 578,400 tons/year, with an adoption rate of 20% and application rate of 12.5 tons/ha/year. The total cultivated area is 231,377 ha[1]. The results indicate that farmers are willing to pay 1.458 INR/kg more to know the source of the waste input used to produce the compost; and an even higher premium of 5.359 INR/kg for pelletization and 14.397 INR/kg for certification. Nutrient content and quality which have direct positive effects on farm yields and profits are preferred attributes. Given these marginal estimates, the full analysis shows the estimated WTP for compost to be 61.214 INR/kg, which is significantly higher than the current market of competitive products. The results suggest that the demand for compost could increase if the abovementioned attributes are factored into the final product for the market. From a business perspective, it is pertinent to evaluate the costs of introducing any of these attributes as against the benefits, which are measured through the WTP estimates. In the instance where such product differentiation is not cost-effective, it is important to explore the opportunities that partnerships can offer and also those related to some form of government subsidization.

The potential market for Fortifer is noted to be substantial with the demand estimated at 54,249 tons/year, assuming an adoption of 40% and application rate of 0.59 tons/ha/year. The total cultivated area considered is 231,377 ha[2]. Chemical fertilizer application rates were used as a basis for the calculation of the application rates of Fortifer (IFPRI, 2012). The average chemical fertilizer applications were estimated at 117 kg/ha and Fortifer at 5 times this estimate as Fortifer is considered a close competitive substitute product. The results indicate that farmers are willing to pay 10.63 INR/kg more for fortification and an even higher premium of 14.97/kg for pelletization. Interestingly, the farmers were however noted to have a lower valuation for the certification attribute and would need a compensation of 0.77 INR/kg for certification. Nutrient content and quality which have direct positive effects on farm yields and profits are preferred attributes. It is important to note that the premiums are slightly lower when socio-economic variables are factored into the choice set. Given these marginal estimates, the full analysis shows the estimated WTP for fortified and certified Fortifer to be 67.06 INR/kg, which is significantly higher than the current market of competitive products.

The market structure assessment suggests an oligopolistic fertilizer market, plagued by market distortions attributable to limited infrastructure (installed capacity); high energy requirements for production and a growing organic agricultural sector which has created an opportunity for business development in the organic fertilizer sub-sector. The chemical fertilizer sector is also a capital-intensive industry. Thus, limited

[1]http://agcensus.dacnet.nic.in/districtT1table1.aspx
[2]http://agcensus.dacnet.nic.in/districtT1table1.aspx

access to financing at a large scale further exacerbates supply-related constraints (IFDC and CHEMONICS, 2007). There is however a large-scale government fertilizer program that provides subsidized fertilizer to farmers and a fairly active private fertilizer sector that supplies fertilizer at competitive prices; this represents a potential limitation for market entry of organic fertilizer businesses. It is important to note that there could be a potential revision to the current subsidy regime in the instance that the national budget deficit continues to grow. On the other hand, the growing organic foods market will increase the demand for organic fertilizers and the respective producers certainly have an opportunity to play a key role in filling this gap in the fertilizer market.

The overall feasibility of the business models was then evaluated based on the different aspects (market demand, market structure and market outlook). It was noted that models 1a, 9, 15/16, 17, have a medium feasibility from a markets' perspective (Table 5). On the other hand, waste-to-energy models, in particular agro-waste and faecal sludge to electricity have a low feasibility potential as is the wastewater-fed fish business model from a market perspective.

Table 5: Overall feasibility of the selected RRR business models from a market perspective

Business model	WTP and Market Demand	Market Structure	Market Outlook	Cumulative feasibility score	Value-added product/recovered resource
Model 1a – Dry fuel manufacturing: agro-waste to briquettes	WTP > Current market price of substitute product	1. Fairly easy market entry 2. Low-to-medium level of concentration 3. Limited to no product differentiation 4. Price setter 5. Potential net profit margins	5 -6 years to reach growth stage in business life cycle	**Medium feasibility**	**Briquettes**
Model 4 – Onsite energy by sanitation service providers	Consumers are price-takers. As electricity is subsidized - we assume that WTP = current market price	1. Medium to difficult market entry - regulated market 2. Medium to high level of concentration (oligopolistic market) 3. No product differentiation 4. Price taker 5. Potential negative profit margins (without subsidies)	Future demand scenario assessment indicates fair possibility for the government to fulfill supply gap	**Low feasibility**	**Electricity**
Model 6 – Power capture model - Livestock waste to energy					
Model 8 – Beyond cost recovery: the aquaculture example	WTP < Current market price of substitute product	1. Medium level of ease for market entry 2. Low to medium levels of market concentration 3. Limited to no product differentiation 4. Oligopolistic fertilizer market but potential price setter 5. Potential net profit margins –positive	10 -11 years to reach growth stage in business life cycle	**Low feasibility**	**Wastewater-fed fish**
Model 9& 12 – On cost savings and recovery (wastewater reuse)	WTP > Current market price (among farming households)	1. Medium level of ease for market entry 2. Low to medium levels of market concentration 3. Limited to no product differentiation 4. Oligopolistic fertilizer market but potential price setter 5. Potential net profit margins –positive	Anticipated exponential growth in demand esp. in agricultural and industrial sectors	**Medium feasibility**	**Wastewater**
Model 10 – Informal to formal trajectory in wastewater irrigation	Not evaluated as policies, legislations and organizational structures are not supportive of this practice.			**No feasibility**	
Model 15 – Large-scale composting for revenue generation (MSW to compost)	WTP > Current market price of competitive/ substitute products	1. Medium level of difficulty for market entry 2. Fair level of concentration 3. Fair level of product differentiation 4. Oligopolistic fertilizer market but potential price setter 5. Potential net profit margins –positive	6 -7 years to reach growth stage in business life cycle	**Medium feasibility**	**MSW-based Compost**
Model 16– Subsidy-free community based composting (decentralized composting)					
Model 17 – High value fertilizer production for profit	WTP > Current market price of competitive/ substitute products	1. Easy entry 2. Fair level of concentration 3. Fair level of product differentiation 4. Oligopolistic fertilizer market but potential price setter 5. Potential net profit margins –positive	6 -7 years to reach growth stage in business life cycle	**Medium feasibility**	**Faecal sludge-based organic fertilizer**
Model 20– Outsourcing faecal sludge treatment to the farm	Although practiced in the private sector, disposal of raw faecal sludge on farmland is illegal.			**Low feasibility**	

4 Key findings of the Institutional and Legal Analysis

This chapter presents the review of the institutional arrangements around resource recovery and reuse (RRR) in Bangalore and an assessment of the feasibility, in terms of institutional viability and acceptability, of introducing new RRR options or of expanding existing ones. Bangalore was selected because there are already a number of existing RRR practices observed in the city, both formal and informal, large and small. Furthermore Bangalore's resource use is set in the context of increasing population pressure and growing demand on existing resources such as water supply, availability of nutrients for agriculture and energy for domestic and industrial use. The population growth is also straining waste management infrastructure and administration, resulting in inadequate collection, treatment and disposal of wastewater, faecal sludge (FS) and municipal solid waste (MSW).

The analysis considers a suite of waste streams (wastewater, MSW, FS and sewage sludge) and end uses (irrigation, aquaculture, energy and compost). A variety of waste streams and end-use combinations are possible, for example MSW for compost production and energy generation; and wastewater for energy generation and irrigation. The institutional analysis of RRR options in Bangalore is based on a review of the stakeholders and the institutional arrangements that govern their actions. This includes government and non-government, formal and informal organizations and individuals that have a part to play in elements of RRR and the written laws and policies that govern them, as well as the informal arrangements that shape their modes of operation. The stakeholder list, derived from literature review, workshops and the knowledge of the project team, included: government organizations that affect policy and legislation (national, state and city); government organizations that implement or enforce these; non-governmental organizations (NGOs) that influence policy and practice; private sector players such as technology and service providers; and the wider public who benefit from services and RRR products or who suffer due to poor management and infrastructure. From this list, key informants were interviewed to understand their roles, relationships and opinions about RRR. The formal institutional arrangements were understood through an extensive review of national and local laws and policies, academic literature and media opinion, as well as interviews with key stakeholders.

The analysis focused on providing a general description of government structure, laws, policies and stakeholders. This was followed by a detailed review of those laws, policies and practices in the context of waste streams and reuse products or practices. A triangular analysis was used, which considers the institutional arrangements in terms of content (e.g. of written laws and policies), structure (the set up for implementing laws and policies) and culture (the less tangible opinions, beliefs and practices of stakeholders).The final element of the analysis used the results from the triangular analysis to assess the feasibility of the selected business models. This was also conducted based on a content, structure and culture concept but used a matrix to arrive at a final 'high', 'medium', 'low' or 'no' feasibility, for each model. Several factors such as legality (something forbidden by law would be deemed unfeasible), available budget, private sector interest, ease of establishing the business, community acceptability and government structure were considered.

4.1 Institutional Arrangements for Waste Management

The institutional environment in Bangalore is shaped by the interplay of the formal government structure, policy and legislation; private sector activity; civil society pressure; and the judiciary. In the government sector many of the powers have been decentralized to local levels, including the state and municipality. Policy and legislation still predominately emanate from the national level[3] but generally require local level adaptation. The local level is also the point at which management actually takes place and practical decisions are taken about waste and resource management. In Bangalore, the main implementing government agencies with mandates relevant to RRR are: the Bangalore Water Supply and Sewerage Board (BWSSB); the Karnataka State Pollution Control Board (KSPCB); and the Bruhat Bengaluru Mahanagara Palike (BBMP), which is responsible for SWM.

The BWSSB is required to supply water and provide sanitation facilities to the citizens of Bangalore. It is interested in water reuse from both a water supply and sanitation perspective and is actively pursuing a reuse agenda, albeit through a small department. The 'New Initiative and Design Cell' is implementing projects to treat wastewater in central sewage treatment plants (STPs) and sell it to industrial users. The cell is relatively new but similar projects have been undertaken in Bangalore for decades with mixed results. The new cell hopes to create greater awareness and public support. Reuse is beneficial because it is less costly for the BWSSB to treat and reuse wastewater than to pump it from the Cauvery River, Bangalore's main water supply, and it could potentially generate a net income for the BWSSB. It may also provide a means by which BWSSB can reach the as yet unserved periphery of the city.

The KSPCB is stimulating on-site treatment and reuse through its local adaptations of national environmental and pollution management rules. Under these, certain bulk wastewater generators, such as residential apartments and commercial establishments, must have on-site STPs and use the treated wastewater within the premises, for activities like watering gardens and toilet flushing. At present the approach is not working optimally as many STPs are not functioning for reasons that include lack of expertise, cost (or perceived cost), the absence of dual plumbing and inadequate enforcement. However, this is changing, not least because of the water shortages across the city and the cost of obtaining water from tankers. This is encouraging improved STP management, especially in areas where BWSSB has not been able to provide services. The demand for STPs and improved management is, in turn, driving expansion in the number of private companies offering STP services.

The BBMP is responsible for SWM in Bangalore, as are urban local bodies (ULBs) in other towns and cities. They must implement the Municipal Solid Waste Management and Handling (MSW) Rules, 2000 and enforce the Manual Scavengers and Construction of Dry Toilets (Prohibition) Act, 1993. However, the system is not functioning well and there have been protests in the past two years. This has expedited a change in the system to introduce better separation of waste at source as a means to facilitate recycling and composting. There are still problems, for example the new dry waste collection centres (DWCC) mainly receive low grade or non-recyclable material, while informal scrap dealers and waste pickers benefit from the trade in higher value recyclables. Processes are evolving, for example the BBMP is engaging with the informal sector and NGOs, but more needs to be done. One suggestion by the BBMP Expert Committee is to create a cell within BBMP dedicated to SWM because at present the staff have

[3] Key national policies and legislation include: the National Water Policy, 2002 and 2012; the Municipal Solid Waste (Management and Handling Rules) (MSW Rules), 2000; the Environment (Protection) Act, 1986, and Rules, 1986; and the Water (Prevention and Control of Pollution) Act, 1974, and Rules, 1975.

multiple responsibilities. They also suggest encouraging private sector participation and a "vendor empanelment process" to provide a framework for this.

The Karnataka Compost Development Corporation (KCDC) is another important link in the SWM chain. It is a government owned company producing organic manure and vermi-compost. Their plant has been beset by problems but now appears to be making a profit, and could offer a model for other companies. Part of their success is that they supply the Karnataka State Department of Agriculture (KSDA) which then sells the compost to farmers at a 50% subsidy. They have also entered the private market and are now competing with commercial fertilizer producers.

The Department of Energy (DOE), the Karnataka Renewable Energy Development Limited (KREDL) and the Karnataka State Bio-fuel Development Board (KSBDB) are all important players in the energy sector in Bangalore. The sector is subject to the Karnataka Renewable Energy Policy 2009-14, which includes biomass, biogas and waste-to-energy (WTE). Their effectiveness in terms of WTE is difficult to assess because it is only a small part of their work and the WTE strategy for BBMP was only proposed by KSBDB in 2012 and has yet to be formally accepted. Furthermore there is currently a national debate about what forms of WTE are acceptable, with incineration proving controversial.

Financial and technical assistance exists for RRR projects through a number of agencies and programmes, for example the Karnataka Urban Infrastructure Development and Finance Corporation Limited (KUIDFCL) and Infrastructure Development Corporation (Karnataka) Ltd. (iDeCK). However, the systems are complex and it was not possible to assess their effectiveness and reach. Certain projects have been noted such as a small scale infrastructure development loan for a company establishing a biogas project.

Non-government stakeholders, including formal organizations, informal groups and individuals, must not be overlooked as they have critical roles as waste managers, resource users and in influencing policies and practices. For example, public interest litigation (PIL) has been instrumental in changing SWM laws and processes and lake management. Faecal sludge evacuation service providers, known locally as 'honey suckers' are invaluable, meeting the needs of the population who are not served by the government sewage system. They often dispose of the FS on agricultural land, at the request of the farmers, thereby helping to close the nutrient loop. There are also many companies engaging in composting (at various scales), biogas generation and wastewater treatment or related services. Like FS use, wastewater use has been observed to take place informally, for instance, when farmers tap into untreated wastewater flows or fishing takes place in lakes receiving wastewater.

4.2 Institutional Support for RRR

The institutional support for RRR was considered for each waste stream and the following was found.
a) Wastewater reuse after treatment is supported by the National Water Policy, while environmental legislation provides details of the quality of wastewater that can be disposed of to land and water bodies and therefore the uses to which it can be put. Much of the reuse structure is already in place but the extent of the reuse is low: the BWSSB implements reuse projects but only covers a proportion of the total waste generated; the KSPCB oversees compliance with environmental legislation but appears over stretched; formal government water supply and sanitation service gaps are filled by the informal sector (e.g. tankered water supplies, honeysuckers and private STP operators). There is limited use of treated wastewater and poor compliance with rules on private STPs. This is changing though as water becomes

more scarce and costly. Reuse markets for treated waste water are expected to grow with increasing population and economic growth. Informal use of waste water irrigation indicates there is demand for wastewater for irrigation.

b) Use of SS and FS in agriculture is not endorsed by any policy or legislation. Fertilizer and agriculture policy support the use of organic manure but not explicitly from FS and SS. Furthermore, these policies recommend subsidies for chemical fertilizers. Consequently no government structure exist to support FS and SS reuse although some universities are beginning to look into it. Culturally many farmers appear to be willing to use FS and SS on their land and have evolved their own methods to reduce risks.

c) Recovery of energy from WW is supported by the National Master Plan (NMP) for Waste-to-Energy and KREDL exists to provide financial incentives and subsidies but so far there has not been much uptake and projects have been limited in scale and/or unsuccessful.

d) Recovery of nutrients from solid waste can take the form of household or on-site composting, centralized composting or delivery of waste to farmers' fields. The third option has been tested, facilitated by the BBMP, but was not successful as the waste was insufficiently separated. The composting options are mandated under the MSW Rules, 2000. The BBMP provides subsidies and capital investment for centralized composting units. No government organization is responsible for organizing on-site composting but many private companies and NGOs are engaged in this work and many bulk waste generators are practicing composting. The KCDC and some private companies are involved in centralized composting, receiving fees from bulk generators and the BBMP. They may also derive an income from selling the product. Compost is well accepted but bottlenecks include concerns over contamination and conflict between residents and operators. Biomethanation for energy recovery from waste can be done on-site or in centralized plants. Both methods are supported by policy. Various electricity policies and acts also support electricity production and sale to the grid. The Ministry of New & Renewable Energy (MNRE) is responsible for developing renewable energy and provides subsidies for biogas generation from waste. Other support for the sector comes from the KSBDB, which is also overseeing implementation of the Karnataka Biofuel Policy; iDeCK which supports infrastructure projects; and BBMP, which is providing land for WTE projects. Private sector involvement appears to be the modus operandi with companies entering the market to supply households with biogas systems or to establish large-scale collection and biogas production. End users are increasingly interested in biogas generation as a means to access energy or reduce energy costs, as well as an effective way to deal with solid waste, however, technologies are only just being made available.

4.3 Business Models

The analysis considered a variety of factors to rank the business models and found that three had a high institutional feasibility. Those were: large scale composting; community-based composting; and manure to power. In all three solid waste cases the MSW Rules, 2000 provided backing for the businesses. In these business models the main implementing agents were private sector organizations with government agencies playing only a small part, primarily through the BBMP. This meant that the businesses were not reliant on an effective government structure, making them easier to establish and more 'feasible'. Public support for composting resulted in a ranking of high cultural feasibility. The onsite energy project had similar cultural and legal support but more needs to be done in terms of structure to support businesses trying to establish themselves. Only one business model was ranked as unfeasible, that being use of untreated wastewater. This is because, legally, water cannot be disposed of to land unless it meets certain water quality parameters. The outsourcing of FS treatment to farms (i.e. vacuum trucks delivering FS to farms) should also have received a ranking of unfeasible because disposal of untreated FS is not permitted, however, other aspects of the model, principally private sector involvement in septic tank emptying and the public support for this resulted in a low feasibility rating. It should be noted that whilst these models were ranked unfeasible or feasible, in terms of institutional arrangements, that is only part of a much bigger story, because they are already taking place and logically cannot therefore be unfeasible. The lack of legal support for the practices has resulted in these rating and these need to be addressed as a way to enable the businesses to grow and provide safe services and products.

Table 6: Feasibility Assessment of Business Model from an Institutional Perspective

Business models	Content	Structure	Culture	Overall institutional feasibility and comments
Model 1a: Dry Fuel Manufacturing – Agro-waste to Briquette	**High**	**Medium**	**Low to Medium**	**Medium**: In terms of policy, legislation and government arrangements for briquette there is much scope for such a business. Challenge is the collection of agro-waste and price viability factor. Needs increased private sector participation and scale. The business customers are primarily from rural areas and with commercial entities in urban areas.
Model 4: Onsite Energy Generation by sanitation service providers	**Low to Medium**	**Low**	**Low**	**Low**: The challenge primarily lies in the capacity of BBMP to manage public toilets. The legislation allows reuse and also provides financial incentives for biogas plants from human waste
Model 6: Manure to Power: ***Onsite energy generation from municipal solid waste***	**High**	**Medium**	**High**	**High**: Policy supports WTE from MSW but does not specify scales of operation or offer detailed guidance for on-site technologies. Generally good support across the board from communities to NGOs and government officials but more needs to be done to officially support businesses offering WTE solutions and households or bulk generators investing in the projects. Financial incentives could be improved.
Model 15: Large-Scale Composting for Revenue Generation	**High**	**Medium**	**High**	**High**: The use of MSW is well accepted in policy, by authorities, by private sector players, farmers and communities. Many different types of businesses are being established in this sector. Many private sector organizations are already in the composting business for profit.
Model 16: Subsidy-free community based composting	**Medium**	**High**	**Medium**	**High**: The use of MSW is well accepted in policy, by authorities, by private sector players, farmers and communities. Many private social businesses and NGOs are active in the sector and have a wide-support base. Some problems still exist such as willingness to separate waste, collection systems etc. which means that the sector remains small but the institutional setting is conducive to expansion if the BBMP encourages and supports the practice further.

Model 17: High Value Fertilizer Production for Profit	**Medium to High**	**Medium**	**Low**	**Medium** The legislation and policy supports co-compost but there are limited guidelines on enrichment. Also the awareness is low on enriching compost. The focus of stakeholders is currently to improve the awareness on standalone compost.
Model 20: Outsourcing faecal sludge treatment to the farm	**No**	**Medium**	**Medium**	**Low**: This is an interesting model and has been ranked low, despite the individual sector rankings being no and medium. This is because it is legally in a grey area but is being very effectively practiced by the private sector and the number of people involved appears to be growing. In terms of legality, FS collection by non-manual means is very much supported but disposal to farm land is illegal. Certain changes to the institutional arrangements in the system could result in a workable, legal model, but care would need to be taken to ensure that legitimizing the practice did not make it unviable in the process.
Model 9: On Cost Savings and Recovery: ***Treated wastewater for irrigation and compost and/or energy***	**Medium**	**Low**	**High**	**Medium**: Most elements already practiced but not in combination - BWSSB currently supplies treated wastewater to industries; individuals/private operators take trucks of SS and sell it to farmers; energy generation has been tried unsuccessfully. Considerable institutional changes could be required to marry these into one business model.
Model 8: Beyond Cost Recovery: the Aquaculture example	**Medium**	**Low**	**Medium-High**	**Medium:** At present the framing of this business model causes problems because it is not fully supported by law, institutional arrangements or public perception. However it would take only limited effort to change this, for example, by providing information to the public and by clearly defining the management, especially for private CTWs. Furthermore, there is already an example of fish production in Jakkur lake, which receives wastewater but the water has already received secondary treatment before flowing into a wetland and onto the lake. Such a system would be more costly but more acceptable.
Model 10: Informal to Formal Trajectory in Wastewater Irrigation:	**No**	**No**	**Low**	**Not Feasible**: The main problem with this option is the lack of treatment. Although the health issues could be managed it is not well supported by policy, legislation or organizational structures. Furthermore public perception is not positive. Engagement of the energy sector, the involvement of large biomass businesses who would use the water for irrigation and stakeholder awareness raising could overcome the issues. Removing the recharge element could also improve uptake. Another option is to introduce

				treatment prior to irrigation and recharge, as happens in Jakkur. The model would then require a means of circulating the income back to the STP, which currently does not happen in Jakkur.
Model 11: Inter-sectoral Water Exchange: ***Irrigation and drinking water***	**Medium**	**Medium**	**Medium**	**Medium**: This business model is feasible but would require some negotiation and contractual arrangements to make it possible. BWSSB and MID may also need strengthening in terms of staff to undertake the work and capacity for contracting and negotiation. Funding for infrastructure (water pipes) is also required. Private sector could potentially enter the market by agreement with BWSSB or through groundwater sales. The business model could also be based around farmers agreeing to provide land for STPs if they receive some or all of that treated water.

4.4 Conclusion

Institutionally there is high feasibility for a number of SW and wastewater projects. Wastewater treatment is increasingly taking place in multiple occupancy premises and it is required by law, and supported by government agencies but it is primarily driven by necessity due to water shortages. A similar picture exists for centralized treatment and reuse in industry, although the industries have been slower in taking up the offer. Reuse in irrigation is less feasible mainly as a result of structures for implementation but it is still an option if water quality requirements can be met. Production of compost from MSW has support at the policy and legislative level as well as in the community, with civil society pushing changes in SWM through demonstrations and PIL. However, the structures for implementing composting projects are still nascent and much more needs to be done to make them highly feasible at scale. Energy generation from MSW is also advocated in recent policies and legislation but as with SWM the sector in its current form is relatively young and more needs to be done to provide guidance, mechanisms for the private sector to develop businesses and financial support. There is evidence that this is happening with the creation of various agencies and recent approval of biogas generation projects.

Overall it appears to be an exciting and dynamic time for Bangalore in terms of institutional arrangements for RRR. Legislation is largely supportive of reuse, provided certain quality standards are adhered to and although structures for implementation and enforcement are still relatively weak they do exist and are being strengthened. Community support is also growing as a direct result of inadequate service provision. Now is a good time for the private sector to establish themselves and for the public sector to change their mode of operation. However, issues to keep in mind are:

a) Multiple government institutions are involved and coordination issues may make it difficult to capture economic value and plug it back into value chains. This poses challenges for both pure public sector models and public-private partnerships.
b) Many things are institutionally in flux right now (e.g. in SWM and renewable energy). This makes it a good time for private sector players to be first movers but also creates uncertainty and risks.

c) Formal private sector participation, that is institutionalized, may affect the way informal markets operate which can have implications for the livelihoods of many poor people. An obvious example of this is the honeysuckers and farmers using FS and wastewater.

5 Key findings of Technology Assessment

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

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

At this stage of the assessment, the technical feasibility of the business models cannot be judged in detail, as information on facility scale, specific location in the city and market demand is not available. Therefore, all business models are ranked “medium feasibility” in

Table 22: Level of feasibility of the business models The required treatment infrastructure can only be clearly defined after the market demand of end-products and the corresponding specific goal of treatment is determined. This would also include detailed laboratory analysis of the waste to be treated, so that treatment technologies can be selected and designed accordingly. This was not available within the scope of this report, given the size and complex waste management infrastructure of the feasibility study cities.

Feasibility of a treatment technology depends strongly on the enabling environment (i.e. institutional, legal and political concerns), supporting such an implementation. The technology assessment therefore cannot be regarded as a stand-alone component, but is highly dependent on other components of the feasibility analysis. The “Technology Assessment” report is a guidance document for the decision making process, as the implementing business can use the technology and process descriptions, proposed mitigation measures, technology score cards and context specific information to identify the constraints certain technologies have.

Table 7 provides a summary of all business models, including the input waste stream, the anticipated end-product, technologies under consideration, and conversion processes. Detailed information is available in: “*Resource, Recovery and Reuse Project. From Research to Implementation. Component 4–Technology Assessment: Bangalore, India; Hanoi, Vietnam; Kampala/Uganda; Lima, Peru. February (2015)”. Available* for download on www.sandec.ch/rrr.

Table 7: Summary of business models under consideration for Bangalore

Business Model	Waste stream	End-product	Technologies	Process
1 (a, b)	• AIW • MSW	• Briquettes	• Carbonized - low pressure • Raw - mechanized high pressure, • Carbonized - mechanized	• Briquetting
4	• Feces • Urine • FS	• Biogas -> Cooking fuel	• Single stage • Multi-stage • Batch	• Anaerobic digestion
6	• AM	• Biogas -> Electricity	• Single stage • Multi-stage • Batch • Biogas conversion technologies	• Anaerobic digestion • Biogas to electricity conversion
8	• WW	• Fish • Treated WW	• Duckweed • Aquaculture	• Pond treatment
9	• WW • WW sludge	• Electricity • Soil conditioner • Water (for reclamation)	• Conventional wastewater treatment technologies • Biogas conversion technologies	• Conventional WW treatment • Biogas to electricity conversion
10	• WW	• Water (for reclamation) • Water for groundwater recharge	• Slow rate infiltration • Rapid infiltration • Overland flow • Wetland application	• Land treatment
11	• Treated WW	• Water (for reclamation)	• Slow rate infiltration • Rapid infiltration • Overland flow • Wetland application	• Land application through irrigation
12	• WW • WW sludge	• Biogas -> Electricity	• Conventional WW treatment including anaerobic digestion technologies	• Conventional WW treatment
15	• MSW • FS	• Soil Conditioner	• Solid/liquid separation • Drying beds • Co-composting	• Co-composting (MSW + FS)

16	• MSW	• Soil Conditioner	• Windrow (static/turned) • In-Vessel • Inclined step grades • Vermi-composting	• Composting
17	• MSW • FS	• Fertilizer (NPK added)	• Solid/liquid separation • Drying beds • Co-composting	• Co-composting (MSW + FS)
20	• NA	• NA	• NA	• NA

6 Key findings of the Financial Analysis

6.1 Introduction

The section presents the financial feasibility assessment of the selected RRR business models. The financial analysis of the RRR business models considered all the business models described in Table 7 except for Model 10, which is a social model driven by policies for the region based on socio-economic benefits. The financial analysis of the RRR business models selected for Bangalore considered all the business models described in Table 7 except for Model 10 and Model 11, which is a social model driven by policies for the region based on socio-economic benefits. In the case of Model 10, due to the informal nature and practice of the business model, it does not have a clear ownership structure, operator, and in the process no direct revenue attributable to a specific entity and thus limits the ability to conduct a financial assessment of the business model. Similarly for Model 11, while there is a clear ownership structure and operator, the implications are largely from a water transfer rights issue and require a complex agreement between multi-parties – farmers, treatment plant, water department, irrigation department and city authorities to ensure water swap which has minimal financial implications in comparison to socio-economic benefits.

6.2 Methodology

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

- **Step 1:** Identification of business cases in Bangalore a similar to the generic RRR business models.
- **Step 2:** Development of scenarios wherever necessary to mirror the business model to local context based on the local business cases identified. Development of scenarios for different scale based on business cases across developing countries in Asia, Africa and Latin America and from literature review.
- **Step 3:** Description of the technology for the RRR business models based on the technical assessment report and as observed from the business cases in the region.
- **Step 4:** Identification of key input data points based on scenarios developed, type of technology used and scale of the business.
- **Step 5:** A mix of primary and secondary data was also used for this analysis. Data from the waste supply, market demand, technical aspects and health assessments of the RRR business models fed into the financial analysis. The analysis took into consideration investment and production cost data of similar business models in the selected city. Where the business models under study do not currently exist in the selected city, the analysis was based on secondary data. Data on economic indicators such as interest rates, inflation, tax, escalation, annual write off, insurance and debt-equity ratios were obtained from published data reports by Bank of India and industrial benchmarks for the region.

- **Step 6:** The profitability and financial viability of an RRR business model was analyzed based on the Profit and Loss Statement (P&L), Operational Breakeven, net present value (NPV), internal rate of return (IRR) and Payback period valuation criteria. For the financial risk assessment of the business models, a Monte Carlo risk analysis method was used. Microsoft Excel was used for the financial analysis and an Excel add-in, @Risk, used to execute the Monte Carlo simulations.

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

Data limitations: In any research, data access and availability is critical. The fact that the RRR sector is gradually developing in India, suggests data availability and research on financial viability are limited. Additionally, significant challenges were encountered in obtaining data relevant to the context of Bangalore. As much as possible, input data were collected from business cases identified in Bangalore, however when data was not available or not provided by the businesses, data collected from similar business cases operating in Asia, Africa and Latin America was verified and used; and also supplemented with data from literature and actualized for Bangalore. Data was also validated from the data collected by other components of the feasibility study – market, waste supply and availability, technical, and institutional assessment.

6.3 Financial Synopsis of the RRR Business Models

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

6.3.1 Energy Business Models

Table 8 provides key highlights of the energy business models. Model 1 – Dry fuel manufacturing, Model 6 - Manure to Power and Model 4 - onsite energy generation by sanitation service providers have positive NPV and IRR greater than 8% which is the discount rate in India.

Table 8: 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	16 tons of briquette per day	2,500 animals producing 550,000 m3 of biogas per year	700 users per day and about 8,400 m3 of biogas per year
Investment required (in USD)	210,000	267,000	16,000 and additional investment of 11K once every 7 years
Operations Cost (in USD/year)*†	295K to 766K	45K to 112K	8K to 13K
Revenue (in USD/year)*	285K to 882K	97K to 219K	13K to 15K
NPV @ discount rate 8%**	$51,477	$399,513	$11,150
IRR**	10.35%	25%	92%

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

6.3.2 Wastewater Reuse Business Models

Table 9 presents the key highlights of the 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.

Table 9: Wastewater Reuse Business Models

	Model 9 & 12: On Cost Savings and Recovery			**Model 8: Beyond cost recovery: the Aquaculture example**	**Model 10: Informal to Formal Trajectory in Wastewater Irrigation**	**Model 11: Inter-sectoral Water exchange**
Scale	20,000 m3 for irrigation	441 tons of sludge per day	693,000 kWh/year	10 tons of fish per year	Financial analysis was not done for this business model	Financial analysis was not done for this
Investment required (in USD)	312.5K	106K	309K	23K		
Operations Cost (in USD/year)*†	115K to 273K	23K to 50K	120K to 285K	5.5K to 14K		

Revenue (in USD/year)*	120K to 309K	26K to 68K	127K to 354K	7.9K to 20K		business model
NPV @ discount rate 8%**	($43,468)	$45,817	$975,504	$2,435		
IRR**	6%	12%	40.27%	10%		

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

Models 10 and 11 were not considered for financial analysis. In the financial analysis of model 9, the assessment assumed investment of reuse infrastructure in an existing treatment plant. The financial assessment takes into consideration additional investment required to incorporate recovery of energy, nutrient and treated wastewater for irrigation and related operation cost and revenue for the treatment plant. All three recovery options shows positive NPV and IRR greater than discount rate.

6.3.3 Nutrient Business Models

Table 10 presents the key highlights of the nutrient business models. As seen from the Table 10 below, for Model 15 - large scale composting plants as the scale increases the NPV and IRR also increases. For all three scenarios, NPV is positive and IRR is equal to above discount rate. In the case of high value fertilizer production and compost production for sanitation service delivery, they both have positive NPVs and IRR greater than discount rate.

Table 10: Nutrient Business Models

	Model 15: Large-Scale Composting for Revenue Generation	**Model 16: Subsidy-free community based composting**	**Model 17: High value Fertilizer Production for Profit**	**Model 20: Outsourcing fecal sludge treatment to the farm**
Scale	200 tons of MSW per day	3 tons of MSW per day	2,400 tons of compost per year	1 truck doing 5 trips per day
Investment required (in USD)	1.06 million	42,400	390,000	22,000
Operations Cost (in USD/year)*†	424K to 1.09 million	51K to 130K	87K to 221K	32K to 82K
Revenue (in USD/year)*	440K to 1.5 million	53K to 142K	101K to 313K	37K to 96K
NPV @ discount rate 8%**	$256,806	($777)	($37,409)	$26,217
IRR**	11%	8%	6.58%	21%

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

6.4 Summary assessment of financial feasibility of RRR Business Models

Table 12 provides a summary overview of the feasibility of RRR business models for Bangalore. As mentioned earlier in the methodology, a Monte Carlo risk analysis was done for the financial models for variable parameters with a high level of uncertainty. A stochastic simulation model was run for a large number of iterations to generate empirical estimates of probability distributions for NPV and IRR, to guide investors, donors and entrepreneurs to evaluate the probability of success for an RRR business model. This simulation results evaluated several aspects: a) a probability of NPV < 0, mean NPV and IRR, pessimistic and optimistic NPV and IRR values. The mean NPV and IRR is the net average of the lowest and highest NPV and IRR value for various iterations. The results from the simulation exercise formed the basis for the selection of key indicators to assess the feasibility of the RRR business model. The indicators used to assess the feasibility of the RRR business models were based on: P (NPV<0), *Mean NPV* been positive or negative and a *Mean IRR* greater than or less than the discount rate in India (8%). The methodology used to define the feasibility is as described in Table 11 below.

Table 11: Feasibility ranking methodology

<table>
<tr><th>P (NPV < 0)</th><th>Mean NPV</th><th>Mean IRR</th><th>Feasibility</th></tr>
<tr><td>0 < P (NPV) < 30%</td><td>+</td><td>Greater than discount rate</td><td>High</td></tr>
<tr><td>30% < P (NPV) < 50%</td><td>+</td><td>Greater than discount rate</td><td>Medium to High</td></tr>
<tr><td>0 < P (NPV) < 30%</td><td>+</td><td>Less than discount rate</td><td rowspan="2">Medium</td></tr>
<tr><td>50% and above</td><td>+</td><td>Greater than discount rate</td></tr>
<tr><td>0 < P (NPV) < 30%</td><td>-</td><td>Greater than discount rate</td><td rowspan="2">Low to Medium</td></tr>
<tr><td>30% < P (NPV) < 50%</td><td>+</td><td>Less than discount rate</td></tr>
<tr><td>30% < P (NPV) < 50%</td><td>-</td><td>Greater than discount rate</td><td rowspan="2">Low</td></tr>
<tr><td>50% and above</td><td>+</td><td>Less than discount rate</td></tr>
<tr><td>0 < P (NPV) < 30%</td><td>-</td><td>Less than discount rate</td><td rowspan="4">Not Feasible</td></tr>
<tr><td>30% < P (NPV) < 50%</td><td>-</td><td>Less than discount rate</td></tr>
<tr><td>50% and above</td><td>-</td><td>Greater than discount rate</td></tr>
<tr><td>50% and above</td><td>-</td><td>Less than discount rate</td></tr>
</table>

Using the methodology defined in Table 11 above, the RRR business models were assessed for their viability to Bangalore context. As observed, the energy and wastewater business models show either medium to high or high feasibility and only two of the nutrient models have a medium to high feasibility. Model 17 – High value fertilizer production for profit as seen from Table 12 is not feasible while Model 16 – Subsidy free community based composting shows a low feasibility. The models with high feasibility are Model 36 – Manure to Power, Model 4 – Onsite energy generation by sanitation service providers, and Model 9 – On cost savings and recovery – electricity for onsite use. The remaining models show medium to high feasibility. Model 4, 8, 9, 15, 16 and 17 are public-private partnership (PPP) models where mostly it is assumed that land (except for Model 15) is provided by the municipality. Models 1a, 6, and 20 are sole private sector management.

Table 12: RRR Business Models Feasibility

RRR Business Models	P (NPV< 0)	Mean NPV	Mean IRR	Feasibility
ENERGY				
Model 1a: Dry Fuel Manufacturing - Agro-industrial Waste to Briquettes	44.3%	$27,694	11.04%	Medium to High
Model 4: Onsite Energy Generation by Sanitation Service Providers	20.7%	4,972	67.8%	High
Model 6: Manure to Power	0%	$400,677	25.09%	High
WASTEWATER REUSE				
Model 8: Beyond Cost Recovery: the Aquaculture example	18.6%	$37,359	26.01%	High
Model 9: On Cost Savings and Recovery – Irrigation reuse	37.8%	$288,927	24.91%	Medium to High
Model 9: On Cost Savings and Recovery – sludge recovery as soil conditioner	41.5%	$62,142	15.88%	Medium to High
Model 9: On Cost Savings and Recovery – electricity for onsite use	0%	$661,037	31.08%	High
Model 9: On Cost Savings and Recovery – combined energy, water and nutrient recovery	30.3%	$421,794	14.94%	Medium to High
Model 10: Informal to Formal Trajectory in Wastewater Irrigation - Incentivizing safe reuse of untreated wastewater	*Financial Feasibility not undertaken*			
Model 11: Inter-sectoral water exchange	*Financial Feasibility not undertaken*			
NUTRIENTS				
Model 15: Large-Scale Composting for Revenue Generation	39.7%	$229,950	10.3%	Medium to High
Model 16: Subsidy-free community based composting	53.2%	($12,923)	14.18%	Low
Model 17: High value Fertilizer Production for Profit	67.2%	($37,913)	6.09%	Not Feasible
Model 20: Outsourcing fecal sludge treatment to the Farm	38.4%	$11,985	20.92%	Medium to High

While the Table 12 attempts to give a snapshot on the potential of the RRR business models for context, it however needs to be noted that all the business models under specific conditions can be found to show high or medium feasibility. For example, Model 15 – Large scale composting, becomes increasingly viable when it reduces its debt component or is able to increase the percentage of sales above 90%. It warrants to be noted that, a number of the business models are highly dependent on the availability of land and the optimality of location – closer to waste raw material availability. In addition, the debt to equity ratio has a significant impact on the viability with greater equity ratio improving the viability and higher debt reducing the viability due to high debt rates at 13.75%. In addition to interest rates, product price and percentage of sale of product plays a significant role in the viability. Below is brief overview of the key aspects that will influence the feasibility of each of the business models in Bangalore:

Model 1 – Dry fuel Manufacturing: The briquette business has been operational in India for some time now and these businesses have performed consistently well for a number of years resulting in a relatively stable market environment for the business model. The biggest challenge faced by these business has been the price of raw material (agro-waste) and a key necessity will be for future briquette businesses to build strong partnerships with farmers to supply agro-waste at an agreed price and thus decrease high input supply volatility. Additionally, the quality of raw material also affects the quality of briquette and hence determines the price of briquette in the market.

Model 4 – Onsite energy generation by sanitation service providers: The primary revenue of the business is from toilet user fees and revenue from reuse is significantly low. The business model viability is highly dependent upon the location of the public toilet, typically such as bus stands and market areas where one could have significant customers using the toilets. The business cannot be viable solely based on its feasibility from sale of biogas.

Model 6: Power capture model - agro-industrial waste: This business model is based on a private ownership structure, on energy savings and sale of energy only in the case of excess energy produced. The model is viable based on the internal energy requirements met and has a complete win-win proposition. The only challenge it faces is limited land availability for the construction of the anaerobic digester. The agro-waste generated from any medium or large agro-industry is high and enough to cover internal energy requirement.

Model 8 – Beyond cost recovery - aquaculture: The financial analysis of the model assumed that there is no additional investment and the cultivation of the fish occurs in an existing treatment plant that has a waste stabilization pond system, with production activities occurring in the tertiary treatment pond. Another approach that can be considered is the investment in a pond system which is fed with secondary treated water to cultivate duckweed for tertiary treatment, which is fed to the fish. The business is highly sensitive to the scale of operations. At lower fish production levels, the business model is not viable as the cost of labor to manage the production activities is high and drives the investment to be unviable. Additionally, the price of inputs (fingerlings) and the price of fish also determine the business viability. The concern of market acceptability is minimal as consumers are rarely aware of the source of water used for aquaculture.

Model 9 and 12 – On Cost savings and recovery: The financial analysis of this model focused on the reuse component and does not take into account the setting up of a new wastewater treatment plant. Three scenarios were developed based on the type of resource recovered (energy including carbon credits, water and nutrient). The key assumption in the case of water and nutrient recovery is the sale of treated wastewater for irrigation (or industry) or sale of sludge as soil conditioner. We acknowledge that these assumptions of sale is the riskiest aspect of this business model as farmers rarely pay for freshwater in developing countries and to assume that they would pay for treated water is questionable. In the event of a drought or water scarcity, there is a possibility of increased willingness to pay for treated wastewater. Additionally, Bangalore has observed cases of farmers demanding wastewater to revive a dried lake and with increased water scarcity there is potential for peri-urban agriculture to significantly benefit from 365 days of water and hence increased willingness to pay for treated water. Alternatively, the treatment plant could target the sale of treated water to industries. The feasibility of supplying treated wastewater also depends on the length of the canal or pipeline and pumping costs to deliver the water to its customer segment. The inference from this result also applies to the case of sale of sludge as soil conditioner where farmers are willing to pay for sludge from treatment plant. In the case of electricity generation, the financial assessment shows that about 35% of energy required for the treatment plant can be covered and its viability is significant from the sale of carbon. However, given the fluctuation in carbon price which is currently less than a dollar for ton of CO_2, the impact on the viability of the investment will be significant. A treatment plant incorporating all these reuse investments yields a positive NPV and in the long-run, once the reuse component of the investment is paid back, the generated revenues will significantly improve the operational cost recovery of the wastewater treatment plant.

Model 15 – Large scale composting for revenue generation: The model is highly dependent on the scale of operations and the financial assessment was carried out for a scale of 200 tons of MSW processed on a daily basis. As per the sensitivity analysis, as the scale of waste processed is increased, the feasibility of the compost production plant improves. The debt to equity ratio plays a significant role for positive NPV. A critical assumption in the business model is the significant quantity of compost sold year on year (from 50% to 80%). In the study, it was observed that in developing countries, most compost plants that use municipal solid waste, struggle to sell compost (less than 50% sales) and they undertake compost production to reduce the overall quantity of waste sent to landfill. Additionally, the compost price in India is significantly lower as it competes with subsidized fertilizer. The price of compost was found to be one the most sensitive parameter that drives the viability of the business and with higher prices the business can be highly viable even at a lower scale.

Model 16 – *Subsidy-free community based composting:* The model requires the entity to undertake MSW collection from households and make compost from organic portion of the waste. In the financial assessment recyclables were not taken into consideration and the likelihood of capturing high value recyclables is high. However as observed in the Bangalore context, high value recyclables are captured by rag pickers and hence a worst case scenario of no access to the high value recyclables was assumed. In addition to improve the viability of the business, the business would have to partner with larger compost facility or fertilizer company to sell the compost as it has a competitive advantage in other activities (such as the collection of MSW, production of compost and sale of compost). The business has a higher potential to capture urban customers who have a higher willingness to pay for the compost in comparison to farmers. With an increased compost price, the business may show a higher feasibility potential.

Model 17 – High value fertilizer production for profit: Under this business model, one of the products is co-compost (mix of fecal sludge and solid waste). The product is relatively unknown and due to the nature of raw material used (fecal sludge), it has a significant risk related to consumer acceptability. The business model shows a limited feasibility because of a low price of the product and quantity of product sold. The stochastic simulations indicate that the product price and percentage of sales from year 3 onwards is the most sensitive variable. The business model will require a capital subsidy and it is unlikely to achieve capital cost recovery with higher compost price.

Model 20 – *Outsourcing fecal sludge treatment to the farm:* The model is applicable to regions that has high onsite sanitation system. The challenge with this model is related to the incomplete regulatory framework on which entities can be the operator of such trucks and how permits/licenses are issued to private businesses. Currently most of these operations are done on an informal basis and based on a market-driven response to the demand for emptying septic tanks. The business is completely viable from emptying fees and it currently faces challenges of disposing waste which is typically done in an unhygienic manner through indiscriminate disposal. Farmers who are knowledgeable of the nutrient rich waste want this sludge to be delivered to their farm, however during rainy season the demand from farmers is limited due to challenges with drying. The business model does pose health risks but if regulated in the right manner including following WHO 2006 guidelines and sanitation safety practice, these risks can be mitigated.

7 Key findings of the Health Risk and Impact Assessment

7.1 Introduction and methodology

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

- Model 1a: Dry fuel manufacturing: agro-industrial waste to briquettes
- Model 4: Onsite energy generation by sanitation service providers
- Model 6: Manure to power
- Model 8: Beyond cost recovery: the aquaculture example
- Model 9: On cost savings and recover
- Model 10: Informal to formal trajectory in wastewater irrigation: incentivizing safe reuse of untreated wastewater
- Model 11: Inter-sectoral water exchange
- Model 15: Large-scale composting for revenue generation
- Model 16: Subsidy-free community based composting
- Model 17: High value fertilizer production for profit

7.2 Evidence-base of the HRIA

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

- Case 1: Jakkur Lake
- Case 2: Jakkur Sewage Treatment Plant
- Case 3: Waste Water Management Devanahalli Town
- Case 4: Solid Waste Management – Devanahalli Town

- Case 5: Faecal Sludge Management – Devanahalli Town
- Case 6: Karnataka Composting Development Corporation – Bangalore
- Case 7: Decentralised Waste and Composting Center (DWCC) operated by SAAHAS

The cases were studied considering the given context and by following a similar methodology in all 4 feasibility study cities. An additional important component of the case studies was an assessment of the use and acceptability of personal protective equipment (PPE) among the workforce. In addition to the data collection activities at the level of existing RRR cases, an in-depth study was carried out in the frame of the pre-testing of the Sanitation Safety Planning (SSP) manual in Bangalore. The in-depth study aimed at filling important data gaps in the knowledge on the acceptability and practicability of health protection measures in wastewater reuse systems in Bangalore. The context of Devanahalli served as study site. A questionnaire survey and structured observations were undertaken to generate a preliminary understanding of situations or activities in which sanitary workers, farmers and consumers are exposed to various biological, physical, ergonomic and chemical hazards related to wastewater and sanitation in Devanahalli. Based on the information gathered, a semi-quantitative health risk assessment (HRA) was conducted with the aim to identify Critical Control Points (CCPs), i.e. situations/activities that bear high risks for the exposure groups. Subsequently, control measures for the hazards prevention and health protection were outlined which aimed at reducing health risks at CCPs. Finally, in focus group discussions (FGDs) the exposure groups' perceptions towards the health protection measures were assessed.

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

According to health statistics from rural, peri-urban and urban areas of Karnataka, dog bites, tuberculosis, gastroenteritis, malaria and typhoid are the most important causes for consultations at health facilities. These are followed by Dengue fever, snake bites and viral hepatitis. Taken together, the vector-related diseases malaria, dengue, filariasis and Chikungunya are a leading cause of morbidity in Karnataka with similar case numbers as Gastroenteritis. With regard to access to sanitation facilities, the 2005-06 National Family Health Survey (NFHS) found that 57.1% of urban households in Karnataka use some type of improved, not shared sanitation facility and 42.3% use non-improved sanitation facilities. In contrast, 82.5% of households in rural areas had a non-improved sanitation facility. Half of the households in urban Karnataka were connected to the sewer system in 2005-06, whereas this only applied to one in eight households in rural areas. In both rural and rural areas of Karnataka, more than 80% of households had access to an improved source of drinking water in 2005-06.

Soil-transmitted helminthic (STH) infections, as well as intestinal protozoa infections, are closely associated with sanitation practices. The STH surveys that have been carried out in Karnataka State found prevalence rates of >20-50%. No information could be identified on the incidence or prevalence of intestinal protozoa infections in India. Also, little information is available on the burden of acute respiratory diseases. The burden of chronic respiratory diseases and cardiovascular diseases is high, accounting for 13% and 26% of total mortality (all ages, both sexes) in India.

Various vector-borne diseases are endemic and of major public health relevance (e.g. malaria, Dengue fever, lymphatic filariasis, Chikungunya fever and Japanese encephalitis). Clearly, malaria is the most important vector-borne disease. It is a leading cause of morbidity, accounting for more than 12'000 cases in Karnataka in 2013. For the same year, 6,408 cases of Dengue fever were reported for Karnataka, including 12 fatalities.

Exposure to noise, air pollution, contaminated drinking water, contaminated surfaces and contaminated food products are important environmental determinants of health. In Karnataka State a number of studies have been carried out investigating chemical pollution (e.g. heavy metal concentration) of surface waters. For example, pronounced levels of pollution of the heavy metals copper (Cu), nickel (Ni), led (Pb) and cadmium (Cd) were found in sediments of urban lakes in Bangalore by different studies. Further environmental health concerns that have been identified for Bangalore area are elevated levels of chromium in groundwater and increased levels of particulate matter (PM) in ambient air.
Selected findings of the in-depth studies in Devanahalli are as follows:

- **Results from questionnaire survey with farmers (n=19) sanitary workers (n=7) and households (n=10)**
    - 53% farmers in Devanahalli area use open drain water to irrigate their field
    - All farmers practice furrow irrigation during which skin always gets exposed to the irrigation water
    - Farmers use hands, feet and picks to form earth heaps to stop the water flow in the furrows or to dig a furrow to start water flow
    - During work in the drainages, the wastewater is commonly touching the skin of sanitary workers
    - Neither the farmers nor the sanitary workers use PPE to protect irrigation water touching their skin
    - The majority of households (86%) in the study area has access to an own pit latrine. Pit latrine sharing is not common
    - While working the majority of workers (77%) do not have access to a toilet facility
    - Good hand-washing behaviour was reported: hand washing occurs after eating (92%), before eating (100%), after eating (94.4%) and after going to toilet (72%)
    - A majority (71.4%) uses soap when washing hands at home. At work, soap is used by 32% only
    - Washing of vegetables before cooking or before raw consumption is very common
    - Drinking water from bore wells or tap is common while water treatment is not common
    - The most frequently reported health problems were muscle pain, back pain or joint pain. Diarrhoea was not reported by the participants
- **Results from focus group discussions with farmers, community members, consumers and sanitary workers**
    - The use of gloves and boots is not practiced due to two different reasons. Farmers are not using, as it is not a custom to use rubber boots and gloves when working in their fields: "since ages we are working without boots and gloves. The land is like god for us. We are not comfortable with using boots"
    - While for all farmers (N=6) gloves and boots are not acceptable, sanitary workers told that these measures are not affordable for them. The SSP team, on the contrary, experienced that when gloves and boots are provided, their workforce does not feel comfortable due to sweating and itching while wearing
    - Farmers are conscious that using toilets instead of open defecation while working, would keep the surrounding near their fields clean. But they clearly told that they couldn't afford to spend money on something they feel is not necessary
    - Produce restriction was very much doubted by farmers and the SSP team. The choice of products depends on the economic revenues of the produce

- Drip irrigation is practiced less frequently than furrow irrigation in Devanahalli. Farmers told that drip irrigation only works with bore well water because the “water force of the wastewater is not enough” for drip irrigation (not acceptable as not practicable)
- Farmers and the SSP team told likewise that cessation of irrigation is only acceptable for some crops. The farmers stated their main interest is growing crops and not health issues: “we put water based on the requirement and we do not bother about health reasons to stop water”
- Most farmers stated that if available they would like to use treated water for farming practices

Overall, the in-depth studies indicates that the WHO 2006 guidelines’ for health protection measures regarding occupational and consumption related risk mitigation would not be easily adopted among farmers and workers. This is primarily explained by a low level of risk awareness and the unsuitability of rubber gloves and boots under hot conditions. Also affordability of PPE is a key factor. The adoption of pre-harvest intervention measures (i.e. safer irrigation, cessation of irrigation, crop restriction) lacks a financial incentive for farmers to change their current behaviour. As consequence, a close collaboration with farmers will be important to jointly discuss and find mutually acceptable solutions of risk intervention strategies at farm level and to raise awareness concerning wastewater related health risks. On the contrary, post-harvest intervention measures like safe food preparation practices and hand washing with soap were generally well received.

7.4 Key findings of the HRA

All of the identified occupational health risk – such as exposure to pathogens, skin cuts or inhalation of toxic gases – can be managed by providing appropriate PPE and appropriate design of the operation and technical elements. Since the application of PPE is not easily accepted in Bangalore area as illustrated by the in-depth study in Devanahalli Town, any PPE-based intervention needs to be complemented with an ongoing health education programme.

Biological hazards mostly derive from human and/or animal wastes that serve as inputs per se for the proposed BM (e.g. animal manure or human faeces) or are a component thereof (e.g. human waste in wastewater). For meeting pathogen reduction rates as proposed by the World Health Organization’s ‘Guidelines for the Safe Use of Wastewater, Excreta and Greywater’ and other standards, a series of treatment options are at disposal. The HRA provides guidance on which treatment options are required for what reuse option. When it comes to the implementation of the BM, the challenge will be to respect indicated retention times and temperatures for achieving the required pathogen reduction rates. Since the proposed retention times may also have financial implications, it is important that these are taken up by the financial analysis. Also vector-related diseases are an important concern in Bangalore area and therefore vector-control measures are indicated for many processes of the BMs.

Chemical hazards primarily concern wastewater fed BMs. Pollution of surface and ground water with heavy metal and other toxic chemicals are an important environmental health concern in Bangalore area, though high local variation might apply. This needs to be taken into account for the planning of any wastewater fed BM, i.e. environmental sampling is indicated for identifying suitable locations. Where threshold values of toxic chemicals exceed national and WHO guideline values, physiochemical treatment for removing chemicals are required. Also co-composting with wastewater sludge is only an option if the sludge is compliant with heavy metal thresholds. In addition, for both irrigation with treated wastewater and the use of sludge-based soil conditioner, chemical parameters of receiving soils need to be taken into account.

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

Overall, the health risks associated with most of the proposed BM can be mitigated with a reasonable set of control measures. Model 10 – untreated wastewater for irrigation and groundwater recharge – is not recommended in Bangalore area. Model 15, 16 and 17, all of which use municipal solid waste (MSW) as an input, are only an option if no medical waste from health facilities is mixed with common MSW.

7.5 Key findings of the HIA

The objective of the HIA was to assess potential health impacts at community level of proposed BMs for Bangalore under the assumption that the control measures proposed by the HRA are deployed. This included consideration of both potential health benefits (e.g. business is resulting in reduced exposure to pathogens as it entails treatment of wastewater) and adverse health impacts (e.g. exposure to toxic gases by using briquettes as cooking fuels). Since the HIA aimed at making a prediction of potential health impacts of a given BM under the assumption that it was implemented at scale, a scenario was defined for each BM as an initial step. The scenario was then translated into the impact level, the number of people affected and the likelihood/frequency of the impact to occur. By means of a semi-quantitative impact assessment, the magnitude of the potential impacts was calculated. A summary of the nature and magnitude of anticipated health impacts for each of the proposed BM is presented in Table 13. Most of the proposed BMs have the potential for resulting in a minor to moderate positive health impact.

Under the given scenarios, Model 8 (the aquaculture example) and Model 9 (treated wastewater for irrigation/fertilizer/energy: cost recovery) have the greatest potential for having a positive impact since they will result in a reduction in exposure to pathogens at community level. Model 1a – Dry fuel manufacturing: agro-waste to briquettes – bears the risk to result in a moderate negative impact by replacing more clean cooking fuels such as gas and electricity with briquettes. Also Model 11 – Intersectoral water exchange –, which aims at replacing drinking water for irrigation with treated wastewater for irrigation, has the potential for negatively impacting on the health of farmers, consumers and community members by increasing exposure to pathogens and toxic chemicals. As already highlighted under the HRA, from a health perspective it is not recommended to promote the reuse of untreated wastewater for irrigation purposes in Bangalore (Model 10).

Table 13: Summary table of anticipated health impacts and their respective magnitude

Business model	Scale of the BM: applied scenario	Anticipated health impact	Magnitude (score)
Model 1a – Dry fuel manufacturing: agro-waste to briquettes	One percent of the population in Bangalore will use briquettes from the BM as cooking fuel	Impact 1: increase in chronic respiratory disease and cancer	**Moderate negative impact (-490)**
Model 4 – Onsite energy generation in enterprises providing sanitation services	30 villages in rural and peri-urban areas of Bangalore will implement the BM	Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases	**Moderate positive impact (432)**
		Impact 2: changes in health status due to access to electricity	**Insignificant (0)**
Model 6 – Manure to power	10 villages in rural and peri-urban areas of Bangalore will implement the BM	Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases	**Moderate positive impact (27)**
		Impact 2: changes in health status due to access to electricity	**Insignificant (0)**
Model 8 – Beyond cost recovery: the aquaculture example	3 operations serving 500 farmers. Products irrigated with safe irrigation water and safe fish from the aquaculture will be consumed by 150'000 consumers	Impact 1: reduction in respiratory, diarrhoeal, intestinal and skin diseases	**Major positive impact (4,535)**
Model 9 – On cost savings and recovery	Wastewater treatment plant with 500 farmers, 10'000 community members and 70'000 farmers benefitting from the treated wastewater	Impact 1: reduction in respiratory, diarrhoeal, intestinal and skin diseases	**Moderate positive impact (2,185)**
		Impact 2: reduction in exposure to toxic chemicals and heavy metals	**Moderate positive impact (402.5)**
		Impact 3: changes in health status due to access to electricity	**Insignificant (0)**
Model 10 – Informal to formal trajectory in wastewater irrigation: incentivizing safe reuse of untreated wastewater	Not defined	Impact 1: increase in exposure to pathogens and chemicals such as heavy metals	**Not recommended**
Model 11 – Intersectoral water exchange	5 small-scale waste water treatment plants. One plant will serve 100 farmers who supply products to10, 000 consumers each. 1,000 households would gain access to fresh water	Impact 1: increase in respiratory, diarrhoeal, intestinal and skin diseases at farmer level	**Moderate negative impact (-265)**
		Impact 2: decrease in diarrhoeal, respiratory and intestinal diseases linked to	**Moderate positive impact (875)**

		access to safe drinking water	
		Impact 3: reduction in respiratory, diarrhoeal, intestinal and skin diseases due to the promotion of waste water treatment	**Moderate positive impact (525)**
Model 15 – Large-scale composting for revenue generation	Two centralised co-composting plants are installed in Bangalore, serving 2'000 households each	Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases	**Moderate positive impact (90)**
		Impact 2: indirect health benefits due to reduced MSW loads on landfills	**Minor positive impact (12.5)**
Model 16 – Subsidy-free community based composting	The waste volume of 10,000 households will be collected by the business	Impact 2: indirect health benefits due to reduced MSW loads on landfills	**Minor positive impact (12.5)**
Model 17 – High value fertilizer production for profit	Two centralised co-composting plants are installed in Bangalore, serving 2'000 households each	Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases	**Moderate positive impact (90)**
		Impact 2: indirect health benefits due to reduced MSW loads on landfills	**Minor positive impact (12.5)**

8 Key findings of the Environmental Assessment

For the Environmental Impact Assessment (EIA), business model flow diagrams are used as a tool to visualize both impact assessments. The EIA takes into consideration the “Technology Assessment”, which comprises an extensive literature review on technologies for resource recovery also identifying potential environmental hazards and measures of mitigation. Within the scope of this assessment, the environmental impact of the business models are not assessed in detail, as information on facility scale and specific location in the city was not available. Rather, with the level of technical detail currently available, the EIA shows potential environmental hazards, which should be recognized and mitigated during implementation.

More detailed analysis of specific environmental impacts can follow at a later stage if treatment infrastructure has been clearly defined based of an analysis of market demand for end-products and the respective determination of treatment goals. Such an evaluation would have to include detailed laboratory analyses of the waste streams to be utilized, so that treatment technologies can be selected and designed in detail. Currently, and based on the EIA as a stand-alone component, the feasibility of business models cannot be ranked, which is the reason for all business models resulting in “medium feasibility”. Ultimately, the implementing business has to mitigate the identified potential environmental hazards, which will results in little, or no environmental impact.

Table 14 provides a summary for all business models, the respective waste streams, end-products technologies, processes and potential environmental hazards, including proposed mitigation measures.
Detailed information is available in: Resource, Recovery and Reuse Project. From Research to Implementation. Component 4 – Technology Assessment: Bangalore, India; Hanoi, Vietnam; Kampala/Uganda; Lima, Peru. February (2015). *Download on www.sandec.ch/rrr*

Table 14: Summary of business models under consideration for Bangalore

Business Model	Waste stream	End-product	Technologies	Process	Pot. Env. Hazard	Mitigation measures
1 (a, b)	• AIW • MSW	• Briquettes	• Carbonized - low pressure • Raw - mechanized high pressure, • Carbonized - mechanized	• Briquetting	• Hazardous air emissions • Accumulated inorganic waste • Process water	• Air emission control technologies (e.g. activated carbon, scrubbers) • Proximate and ultimate analyses • Post-treatment of process water
4	• Feces • Urine • FS	• Biogas -> Cooking fuel	• Single stage • Multi-stage • Batch	• Anaerobic digestion	• Air emissions • Solid residue (digestate) • Liquid effluent	• Maintenance of anaerobic digester • Solid/liquid residue post-treatment
6	• AM	• Biogas -> Electricity	• Single stage • Multi-stage • Batch • Biogas conversion technologies	• Anaerobic digestion • Biogas to electricity conversion	• Hazardous air emissions • Solid residue (digestate) • Liquid effluent	• Maintenance of anaerobic digester • Air emission control technologies • Solid/liquid residue post-treatment
8	• WW	• Fish • Treated WW	• Duckweed • Aquaculture	• Pond treatment	• Heavy metals in effluent and/or sludge from WW treatment • Solid residue (sludge from WW treatment)	• Upstream monitoring of heavy metal concentration • Monitoring of effluent and solids • Solid residue (sludge from WW treatment) post-treatment
9	• WW • WW sludge	• Electricity • Soil conditioner • Water (for reclamation)	• Conventional wastewater treatment technologies • Biogas conversion technologies	• Conventional WW treatment • Biogas to electricity conversion	• Heavy metals in effluent and/or WW sludge • Solid residue (sludge from WW treatment) • Air emissions	• Upstream monitoring of heavy metal concentration • Monitoring of effluent and solids • Solid residue (sludge from WW treatment) post-treatment • Maintenance of anaerobic digester
10	• WW	• Water (for reclamation) • Water for groundwater recharge	• Slow rate infiltration • Rapid infiltration • Overland flow • Wetland application	• Land treatment	• Groundwater contamination (heavy metals/pathogens) • Contamination of irrigated crops with heavy metals and/or pathogens	• Upstream monitoring of heavy metal concentration • Monitoring of effluent and solids • Crop selection • 2006 WHO guidelines

11	• Treated WW	• Water (for reclamation)	• Slow rate infiltration • Rapid infiltration • Overland flow • Wetland application	• Land application through irrigation	• Groundwater contamination (heavy metals/pathogens) • Contamination of irrigated crops	• Crop selection • Upstream monitoring of heavy metal concentration • Monitoring of effluent and solids • 2006 WHO guidelines
12	• WW • WW sludge	• Biogas -> Electricity	• Conventional WW treatment including anaerobic digestion technologies	• Conventional WW treatment	• Heavy metals in effluent and/or WW sludge • Air emissions • Solid residue (digestate) • Liquid effluent	• Influent free of heavy metals • Monitoring of influent • Air emission control technologies • Solid/liquid residue post-treatment
15	• MSW • FS	• Soil Conditioner	• Solid/liquid separation • Drying beds • Co-composting	• Co-composting (MSW + FS)	• Accumulated inorganic waste • Leachate from composting • Insufficient pathogen inactivation • Liquid effluent (from FS treatment)	• Storage/transport/disposal (sanitary landfill) • Moisture control • Leachate treatment • Temperature control (compost heap) • Post-treatment of liquid effluent
16	• MSW	• Soil Conditioner	• Windrow (static/turned) • In-Vessel • Inclined step grades • Vermi-composting	• Composting	• Accumulated inorganic waste • Leachate from composting	• Storage/transport/disposal (sanitary landfill) • Moisture control • Leachate treatment
17	• MSW • FS	• Fertilizer (NPK added)	• Solid/liquid separation • Drying beds • Co-composting	• Co-composting (MSW + FS)	• Accumulated inorganic waste • Leachate from composting • Insufficient pathogen inactivation • Liquid effluent (from FS treatment)	• Storage/transport/disposal (sanitary landfill) • Moisture control • Leachate treatment • Temperature control (compost heap) • Post-treatment of liquid effluent
20	• NA	• NA	• NA	• NA	• NA	• NA

9 Key findings of the Socio-Economic Assessment

9.1 Introduction

The section presents the socioeconomic assessment of the selected RRR business models. The socioeconomic assessment acts as a decision making tool for determining the feasibility of the business model from a 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.

9.2 Methodology

The first important footstep towards a socioeconomic assessment is defining 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 analysed based on the NPV of the benefits and costs, Benefit to Cost Ratio (BCR) and the Rate of return on Investments (RoI). For each of the economic, social, health and environmental aspects, the benefits and costs were measured (in monetary terms) separately, and the cumulative figure was used to 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.

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

The following matrix defines the system boundary of the socioeconomic models used in the assessment for the RRR business models. In all of these cases, the scale of the business model is so adjusted such that the entire waste can be utilized by the particular business. The socioeconomic assessment of the business models is performed taking into consideration two contrasting situations where the baseline condition refers to the present situation in 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 15) indicates the baseline and alternative scenarios and also describes the scale of operation for the different business models in Bangalore.

Table 15: 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 1: Dry Fuel Manufacturing - Agro-industrial Waste to Briquettes	Baseline considers burning of the agro-waste 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			

Business Models	Base case	Alternative	Remarks
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 of the WWTP and the electricity generation unit is an addition.	The feasibility of electricity generation from WWTPs requires a capacity to treat more than 5 MGD. 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	

Business Models	Base case	Alternative	Remarks
		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	
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.		

9.4 Synopsis of the socioeconomic assessment of the RRR business models

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

9.4.1 Energy Business Models

Table 16 provides key highlights of the 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 16: Energy Business Models

	Model 1: 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 production capacity of 325 KW	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
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

9.4.2 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 17) 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 17: Wastewater Reuse Business Models

	Model 8: Wastewater-fed Aquaculture (phyto-remediative wastewater treatment and fish production)	Model 9: Treated wastewater for irrigation/fertilizer/energy – cost 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

9.4.3 Nutrient Business Models

The nutrient business models have been compared in the following Table 18. This table provides key highlights of the 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 18: Nutrient Business Models

	Model 15: Large-Scale Composting for Revenue Generation	**Model 16: Decentralized 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

9.5 Summary assessment of financial feasibility of RRR Business Models

Table 19 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 19 below.

Table 19: Feasibility Ranking Methodology

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

Using the methodology defined in Table 19, the RRR business models were assessed for their viability in the context of the Bangalore city (shown in Table 20). 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 20: Synopsis of Socioeconomic Feasibility RRR Business Models

RRR Business Models	P (NPV< NPV_{mean})	B:C Ratio	Rate of Investment (ROI)	Feasibility
ENERGY				
Model 1: Dry Fuel Manufacturing - Agro-industrial Waste to Briquettes	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**
Model 16: 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 6 – 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 4 – 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 8 – 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 9 – On Cost savings and recovery: It is being assumed that the wastewater treatment plant exists and additional investments are made to retrieve water for irrigation, sludge for compost and electricity for use in the plant. The feasibility of the business model is governed by the fact that there is lower initial investments compared and practically no operation costs, while the benefits like irrigation and groundwater recharge are more favorable. In 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 15 – 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 16 – 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 17 – High value fertilizer production for profit: This product is relatively unknown and due to the nature of raw material used (faecal sludge), there is inherent risks of acceptability among farmers. The economic viability of the business model closely follows that of the compost obtained from municipal solid wastes in 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.

10 Synthesis of Feasibility Studies

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

10.1 Methodology for the Ranking of the Business Models

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

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

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

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

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

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

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

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

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

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

BM = HF

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

It is assumed that for the Health & Environmental assessment criterion, irrespective of its results as LF, MF and HF, it will not dictate the final RRR business model viability for implementation as risks and associated mitigation measures are incorporated/ captured in both the technical and financial feasibility; as is for the socio-economic assessment. The methodology rules described above is captured as a snapshot in Table 21 below.

Table 21: Methodology for the Ranking of the Feasibility of the Business Models

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

Medium and/or High feasibility	High	High	Medium	L, M, H	L, M, H	High feasibility
Medium and/or High feasibility	High	Medium	High	L, M, H	L, M, H	
Medium and/or High feasibility	High	High	Medium	L, M, H	L, M, H	
Medium and/or High feasibility	Medium	High	High	L, M, H	L, M, H	
Medium and/or High feasibility	High	High	High	L, M, H	L, M, H	

10.2 Synthesis of feasibility ranking of business models

The overall feasibility of the selected business models are presented in

Table **22: Level of feasibility of the business models** below. It is noted that the **dry fuel manufacturing (agro-waste to briquettes)**, **wastewater use for irrigation, energy and nutrient recovery**, and **MSW-based compost** (models 15 and 16) have the highest feasibility potential for implementation in Bangalore. It is important to note however that some of the feasibility of some of the business models can be improved with some adaptation (e.g. use of strategic partnerships, consideration of alternative waste streams and institution of supportive policies).

Model 1a - Dry Fuel Manufacturing (agro-waste to briquettes)
This business model has a good potential for implementation in Bangalore. This is attributable to several factors including: a) availability of waste input; b) growing market demand among households and industries; c) supportive institutional environment; and d) high financial viability. In Bangalore, there are many agro-processing industries that provide the waste input material to the briquette businesses and it is noted that although access may not be a challenge, there is growing competition for agro-waste. From a market's perspective, the results indicate that there is a fair market demand for agro-waste briquettes in Bangalore, although not substantial. Among the surveyed households (both urban and rural), none were currently noted to be using briquettes. Appropriate planning and marketing strategy will be required for new briquette businesses to gain a share of the market, especially given that there is no significant demand supply gap for briquettes, although the estimated demand exceeds estimated supply. New briquette businesses also will need to accommodate customer expectations in terms of credit, delivery, and near nil expenditure for marketing by the current market players. Differential pricing can be instrumental in gaining market share, although its implementation needs to be studied in greater detail. Across all the studied markets product promotion and marketing is close to nil. New briquette businesses would need to invest in R&D in order to mitigate the effects of high social barriers. This would place them at a competitive disadvantage compared to their competitors. There are also both policy induced factors and environmental factors that are representative of entry barriers for briquettes to penetrate the household sector. Government subsidies for existing competing products in the energy market (LPG and Kerosene) can pose a challenge to new briquette businesses, and thus appropriate product positioning and customer targeting would be very essential to overcome the challenges posed by the subsidy. Additionally, the extensive established network of LPG has improved the product's accessibility not only in urban areas but also in rural areas - thus a significant competitor for briquettes. Similarly, the steady

improvement of electrification has resulted in households relying on electricity. In addition, urban low income households have the access to kerosene both through public distribution system and open markets; and in the rural areas, households have the luxury of collecting firewood free of cost. From an institutional perspective, there are supportive legislation and incentives for private sector engagement in the sector. The briquette business has been operational in India for some time now and these businesses have performed consistently well over a number of years resulting in a relatively stable market environment for the business model. The biggest challenge faced by these businesses has been the price of raw material (agro-waste) and a key necessity will be for future briquette businesses to build strong partnerships with farmers to supply agro-waste at a set price to reduce high input supply volatility.

Model 4 - Onsite Energy Generation by Sanitation Service Providers (faecal sludge to electricity)
The low feasibility of this business model is mainly driven by a constraining market and institutional environment. Although, there is a significant amount of faecal sludge available in the city (between 300-700 m^3/d is collected per day), only a small percentage is safely treated for reuse. Whilst the legislation permits the reuse of faecal sludge and also provides financial incentives for biogas plants from human waste, a key challenge primarily lies in the capacity of BBMP to actually manage the public toilets. In regards to the energy sector, the electricity market is heavily regulated and monopolized by state agencies. Private participation although present is very limited and permitted only for certain aspects of power generation. Pricing of electricity is negotiated between the private entrepreneurs and the respective electricity reforms commission. As private electricity suppliers do not supply directly supply to households but rather to the national grid, the only direct market/ consumer is with the latter. Thus, any potential for sale of excess electricity to the national grid will be limited by a price setting environment. Additionally, the financial assessment indicates that the primary revenue of the business will come from toilet user fees and revenues solely from reuse are significantly low. The business will not be able to survive from only the sale of biogas as the biogas yield from faecal sludge alone is noted to be comparatively low. The financial viability is also highly dependent upon the location of the public toilet, and places such as bus stands and market areas where there could be significant customers' demand of public toilets are necessary.

Model 6 - Power Capture Model (livestock to energy)
The results showed that the proposed business model has a low feasibility potential for Bangalore and this is driven by a number of factors. Although, there is a substantial amount of livestock waste generated in and around the city, the majority is already reused in agriculture. From a financial perspective, this business model is based on a private ownership structure, on energy savings and sale of energy only in the case of excess energy produced. The model is viable based on the internal energy requirements met and has a complete win-win proposition. The only challenge the business may face is related to limited land availability for the construction of the anaerobic digester. As with model 4, any new waste-to-energy business will face an electricity market that is heavily regulated and monopolized by state agencies. Private participation although present is very limited and permitted only for certain aspects of power generation. Pricing of electricity is negotiated between the private entrepreneurs and the respective electricity reforms commission. As private electricity suppliers do not supply directly supply to households but rather to the national grid, the only direct market/ consumer is with the latter. Thus, any potential for sale of excess electricity to the national grid will be limited by a price setting environment. From an institutional perspective, there are existing supportive policies for waste-to-energy initiatives although mainly for MSW-based and does not specify scales of operation or offer detailed guidance for on-site technologies. There is a general positive consensus for this business model across the board from communities to NGOs and government officials but it is noted that there needs to be more support,

particularly provision of financial incentives to potential businesses. An improved enabling environment from an institutional perspective will generally improve the feasibility of this model.

Model 8 - Beyond cost recovery (wastewater-fed aquaculture)
Wastewater-fed aquaculture is becoming a major livelihood strategy for many municipalities looking for wastewater treatment and cost-savings options in Bangalore, India. This business model has a potential for implementation with: a) available wastewater treatment plants and city lakes for integrated aquaculture, b) financial viability but is largely limited by the market demand. The results show that consumers derive a negative utility from wastewater-fed fish. The results show the WTP for wastewater-fed fish among consumers to be estimated at Rs 63.97/Kg which is lower than the current market price of non-certified fish with no source information. Consumers are willing to pay Rs.37.25/kg to know the source of the fish (i.e. which medium the fish was reared in) and Rs. 136.36/kg for certification. The market prospect for wastewater-fed fish has some promise but will face social barriers and consumer perceptions in the initial stages. Innovative marketing strategies including pricing and product promotion strategies will be required to facilitate the entry of new businesses into the market. It is suggested that food products made from fish harvested in treated wastewater must be priced differentially lower than that of food products of freshwater fish, in order to capture a share of the market. An aggressive marketing strategy for the promotion of treated wastewater fish is also recommended. Overall, wastewater-fed fish has a good market outlook but will have to compete aggressively with their alternative products to sustain in the market eventually. Freshwater fish is a very a close substitute for fish from treated wastewater. Therefore, this product will offer a high degree of competition to the RRR product. With an ever-expanding cultivation of freshwater fish and with an ever increasing level of income and population, the demand for freshwater fish will grow steadily. However, if proper labeling is done by appropriate regulatory authorities to educate the prospective consumers that the consumption of fish reared from treated wastewater will not pose any health risks, and if it is sold at a competitive price, it will find its way into the market, though gradually and steadily.

The financial analysis of the model assumed that there is no additional investment and the cultivation of the fish occurs in an existing treatment plant that has a waste stabilization pond system, with production activities occurring in the tertiary treatment pond. From a financial perspective, the business of wastewater-fed fish is highly sensitive to the scale of operations. At lower fish production levels, the business model is not viable as the cost of labor to manage the production activities is high and drives the investment to be unviable. Although the financial indicators suggest potential feasibility of this model, the overall feasibility of the model may also be limited by the institutional environment. The implementation of this business model may also face some institutional hurdles as such initiatives are not fully supported by the law, institutional arrangements or public perceptions. Given the importance of the institutional and legal environment for the implementation of this model, there will be the need for a revision of the policies and regulations to incentive the implementation in such initiatives, especially given that this model has the greatest potential for having a positive impact from a reduction in exposure to pathogens at community level[4].

Model 9 & 12 - On Cost Savings and Recovery (wastewater use for irrigation, energy and nutrient recovery)
The high feasibility for implementation of this business model is driven key factors related to: a) high financial viability, b) supportive institutional environment and c) wastewater availability and access. There is significant wastewater generated and treated in Bangalore (at approx. 457 Million Litres per Day (MLD)

[4]It has, however, to be noted that this only applies if the wastewater (untreated or treated) used is compliant with national and international quality requirements regarding toxic chemicals.

of treated wastewater from 14 WWTPs and 1000 m^3 of wet sludge per day) that can be reused at some level. The results from the WTP assessment show that the majority of farming households are willing to use and pay for treated wastewater for irrigation purposes, especially during the drier seasons. A lower percentage (63%) was however noted to be willing to pay for treated wastewater during the monsoon season. On average, 89% of these farmers were willing to pay for using treated wastewater for irrigation. The farmers were willing to pay Rs.482/- per 10000 litres (10 m^3) of treated/partially treated wastewater. The results also showed that the farmers placed a higher value on treated wastewater under a scenario of 'increased water scarcity' compared to any increment in cost of water supply. The bids offered by the farmers for an increase in cost of water at the initial levels (10% to 25%) are similar in terms of the average value (Rs.315.38). This increases marginally by Rs 66 when an option of 100% cost increment is faced by the farmers. In comparison, the marginal change in the bid offered when scarcity of water increases from 25% to 50% is about Rs. 210 per 100m^3 which is 3 times the increase in the bid offered for cost changes. Additionally, farmers dependent on rainwater for irrigation were willing to pay a higher fee for wastewater for irrigation than farmers utilizing groundwater. This might be due to the fact that farmers practising rain-fed farming are willing to hedge the risk of vagaries of rainfall and hence have a higher willingness to pay. The farmers dependent on groundwater pay a relatively higher price for water compared to the other group of farmers and may not consider treated wastewater a substitute with the assured water supply they presently receive. For the surveyed businesses, the results showed that on average of 84% of the surveyed enterprises were willing to pay for treated wastewater. The average WTP value was Rs.455/- per tanker of treated/partially treated wastewater. However, among the larger enterprise respondents, they were willing to pay on an average of Rs.1160/- per 8000 litre tanker. The results also indicated that the enterprises value treated wastewater relatively higher under the scenarios of 'increment in cost of water supply' than that of 'water. Under the water scarcity scenario, it was found that the payments offered by the enterprises were relatively lower. The enterprises included in the survey comprised of institutional houses (*Kalynmantapas*), hotels, car services, washer-man and industries (like brick manufactures, chemicals and garments). Demand for treated wastewater among businesses was found to be specific to the enterprise type and use. From an institutional perspective, there are supportive policies for the use of treated wastewater and there are quite number of existing reuse cases. It is however noted that the initiatives occur as single-activity entities and not in combination yet (wastewater reuse, energy generation and sludge treatment and reuse). For example, BWSSB currently supplies treated wastewater to industries; individuals/private operators collect sewage sludge and supply/sell it to farmers; energy generation has been tried unsuccessfully. There are opportunities for these initiatives to combined and explored together as whole as in this model, however considerable institutional changes would be required.

The financial analysis of this model focused on the reuse component and did not take into account the setting up of a new wastewater treatment plant. Three scenarios were developed based on the type of resource recovered (energy including carbon credits, water and nutrient). The key assumption in the case of water and nutrient recovery is the sale of treated wastewater for irrigation (or industry) or sale of sludge as soil conditioner[5].In the event of a drought or water scarcity, there is a possibility of increased willingness to pay for treated wastewater. Bangalore has observed cases of farmers demanding wastewater to revive a dried lake and with increased water scarcity there is potential for peri-urban agriculture to significantly benefit from 365 days of water and hence increased willingness to pay for treated water. Alternatively, the treatment plant can target the sale of treated water to industries. The feasibility of supplying treated wastewater will depend on the length of the canal or pipeline and pumping costs to deliver the water to its customer segment. The inference from this result also applies to the sale

[5]We acknowledge that these assumptions of sale is the riskiest aspect of this business model as farmers rarely pay for freshwater in developing countries and to assume that they would pay for treated water is questionable.

of sludge as a soil conditioner where farmers are willing to pay for sludge from treatment plant. In the case of the electricity generated, the financial assessment shows that about 35% of energy required for the treatment plant is covered and viability is significant from the sale of carbon. However, given the fluctuation in carbon prices (which is currently less than a dollar for ton of CO_2), the impact on the viability of the investment will be significant. A higher electricity price in Bangalore will make the investment viable. A treatment plant incorporating all these reuse investments yields a positive NPV and in the longer run, after the reuse component of the investment is paid back, it will help significantly improve the operation cost recovery of wastewater treatment plant.

Model 10 - Informal to Formal Trajectory in Wastewater Irrigation - Incentivizing safe reuse of untreated wastewater

The infeasibility of this model in Bangalore is driven mainly by the institutional regulations which note that the use of untreated wastewater for irrigation is not permissible under the city and national policies on wastewater and irrigation. The key challenge with this model is the lack of treatment - which is confirmed by the results from the health risk and impact assessment which notes that it is not recommended to promote the reuse of untreated wastewater for irrigation purposes in Bangalore.

Model 11 - Wastewater and drinking water exchange

The feasibility assessment of this business model was difficult to undertake both from the market and financial perspective. Thus, whilst the institutional analysis noted a potential for implementation, it was difficult to assess the benefits to the key economic actors and the dynamics in the market environment. This business model has potential to be feasible but would require significant negotiation and contractual arrangements to make it possible. BWSSB and MID will need a capacity strengthening of staff to undertake the operations as well as contracting and negotiation. Funding will be needed/required for infrastructure (water pipes). There is potential for the private sector to enter the market by agreement with BWSSB or through groundwater sales. Given the importance of the institutional and legal environment for the implementation of this model, there will be the need for some revision of the policies and regulations to incentive the implementation of such initiatives, especially the negotiation of water rights.

Model 15 - Large-Scale Composting for Revenue Generation (municipal solid waste to compost)

This business model based on compost production from municipal solid waste is noted to be highly feasible in the context of Bangalore. The feasibility is driven mainly by: a) high financial viability, b) supportive institutional and legislative environment, c) significant market demand and d) available technologies. There is a significant quantity of waste generated however this is collected in an unsorted form from households and markets (total MSW amount to ~4500 t/d and roughly 70% of which is organic).Food market waste may be an alternative sub-waste stream to target, which is easier to segregate at a centralized level given the high concentration of organic waste.

The overall market assessment suggests that there is a significant demand for MSW-based compost.The potential market for MSW-compost is noted to be substantial with the demand estimated at 578,400 tons/year, with an adoption rate of 20% and application rate of 12.5 tons/ha/year. The total cultivated area is 231,377 ha[6]. The results indicate that farmers are willing to pay 1.458 INR/kg more to know the source of the waste input used to produce the compost; and an even higher premium of 5.359 INR/kg for pelletization and 14.397 INR/kg for certification. Nutrient content and quality which have direct positive effects on farm yields and profits are preferred attributes. Given these marginal estimates, the full analysis shows the estimated WTP for compost to be 61.214 INR/kg, which is significantly higher than the current

[6]http://agcensus.dacnet.nic.in/districtT1table1.aspx

market of competitive products. The results suggest that the demand for compost could increase if the abovementioned attributes are factored into the final product for the market. From a business perspective, it is pertinent to evaluate the costs of introducing any of these attributes as against the benefits, which are measured through the WTP estimates. In the instance where such product differentiation is not cost-effective, it is important to explore the opportunities that partnerships can offer and also those related to some form of government subsidization.

From an institutional perspective, the use of MSW is well-accepted and supported by policy makers, authorities, private sector players, farmers and communities. This is indicative of the different types of businesses currently being established in this sector and the increasing private sector participation. From a financial perspective, the model is highly dependent on the scale of operations. The financial assessment was conducted for a scale of 200 tons. It was noted that as the scale of the waste processed increases, the feasibility of the compost production plant improves. The debt to equity ratio plays a significant role in the viability of the business. A critical assumption in the business model is the significant quantity of compost sold from year to year (from 50% to 80%). In the study, it was observed that in developing countries, most compost plants that use municipal solid waste, struggle to sell compost (less than 50% sales) and they undertake compost production to reduce the overall quantity of waste sent to landfill. Additionally, the compost price in India is significantly lower as it competes with subsidized fertilizer. The price of compost was found to be one the most sensitive parameter that drives the viability of the business and with higher prices the business can be highly viable even at a lower scale.It is important to note that the decision of a business to operate at a certain scale will be determined by several factors: a) demand, b) price of the compost, c) economies of scale, among others. Whilst the current production level of compost is unknown, it is clear that the compost sector is a burgeoning industry with some entry barriers but supportive and existing policies encouraging business development.

Model 16 - Subsidy-free Community Based Composting (municipal solid waste to compost)
This model also showed a high feasibility and the driving factors are similar to that of model 15 above.
This model requires the business entity to undertake the collection of MSW from households and produce the compost from the organic fraction of the waste. In the financial assessment, recyclables were not taken into consideration and the likelihood of capturing high value recyclables is high. However as observed in the Bangalore context, high value recyclables are captured by rag pickers and hence a worst case scenario of no access to the high value recyclables was assumed. For this model, in particular, it would be important from a financial perspective that the business entity partner with a larger compost facility or fertilizer companies to sell its compost in order to improve its viability, especially if it has a competitive advantage in other activities such as the collection of MSW, production of compost and sale of compost.

Model 17 - High value Fertilizer Production for Profit (combination of municipal solid waste and faecal sludge to organic fertilizer)
This model is similar to model 15 in concept but in addition to MSW, the business entity uses fecal sludge as a waste input from onsite sanitation which is rich in nutrients. There are opportunities for pelletization and blending of faecal sludge-based compost with rock-phosphate, urea/struvite or NPK which is an additional value proposition that can be explored under this business model, allowing the product to have nutrient levels specific for target crops and soils, and a product structure improvement (pellets) to improve its competitive advantage, marketability and field use. Although there is a substantial market demand for Fortifer, supportive policies and availability of the waste input, this model has no feasibility for implementation and this mainly driven by the limited financial viability.

The potential market for Fortifer is noted to be substantial with the demand estimated at 54,249 tons/year, assuming an adoption of 40% and application rate of 0.59 tons/ha/year. The results indicate that farmers are willing to pay 10.63 INR/kg more for fortification and an even higher premium of 14.97/kg for pelletization. Interestingly, the farmers were however noted to have a lower valuation for the certification attribute and would need a compensation of 0.77 INR/kg for certification[7]. Nutrient content and quality which have direct positive effects on farm yields and profits are preferred attributes. Given these marginal estimates, the full analysis shows the estimated WTP for fortified and certified Fortifer to be 67.06 INR/kg, which is significantly higher than the current market of competitive products. The market structure assessment suggests an oligopolistic fertilizer market, plagued by market distortions attributable to limited infrastructure (installed capacity); high energy requirements for production and a growing organic agricultural sector which has created an opportunity for business development in the organic fertilizer sub-sector. The chemical fertilizer sector is also a capital-intensive industry. Thus, limited access to financing at a large scale further exacerbates supply-related constraints (IFDC and CHEMONICS, 2007). There is however a large-scale government fertilizer program that provides subsidized fertilizer to farmers and a fairly active private fertilizer sector that supplies fertilizer at competitive prices; this represents a potential limitation for market entry of organic fertilizer businesses. It is important to note that there could be a potential revision to the current subsidy regime in the instance that the national budget deficit continues to grow. On the other hand, the growing organic foods market will increase the demand for organic fertilizers and the respective producers certainly have an opportunity to play a key role in filling this gap in the fertilizer market. From an institutional perspective, there are supportive legislations for co-compost production but there are limited guidelines on enrichment.

The financial viability is the key limiting factor to the feasibility of this model. The business model shows a limited feasibility because of a low price of the product and quantity of product expected to be sold. The stochastic simulations indicate that the product price and percentage of sales from year 3 onwards is the most sensitive variable. The business model will require a capital subsidy and it is unlikely to achieve capital cost recovery with higher compost price.

Model 20 - Outsourcing Faecal Sludge Treatment to the Farm:

This model although applicable to regions with high onsite sanitation system coverage (applicable to many developing countries) has a low feasibility potential. The challenge with this model is related to the incomplete regulatory framework for truck operators, permits/licenses issuing processes for private businesses, amongst others. Currently most of the on-going operations are done on an informal basis and based on a market-driven response to the demand for emptying septic tanks. This type of business is completely viable from emptying fees but currently faces the challenge of accessing waste disposal sites. From an institutional perspective, this model has a low ranking given that it operates legally in a grey area although it is being very effectively practiced by the private sector and the number of people involved appears to be growing. In terms of legality, faecal sludge collection by non-manual means is very much supported but disposal to farm land is illegal. Changes to the institutional arrangements in the system could possibly result in a workable, legal model, but care would need to be taken to ensure that legitimizing the practice does make it unviable in the process. This business model does pose health risks but if regulated in the right manner including following WHO 2006 guidelines and sanitation safety practice, these risks can be mitigated.

[7]Chemical fertilizer application rates were used as a basis for the calculation of the application rates of Fortifer (IFPRI, 2012). The average chemical fertilizer applications were estimated at 117 kg/ha and Fortifer at 5 times this estimate as Fortifer is considered a close competitive substitute product.

Table 22: Level of feasibility of the business models

Ranking criteria	Outputs	ENERGY			WASTEWATER				NUTRIENT			
		BM1a	BM4	BM6	BM8	BM9 and 12	BM10	BM11	BM15	BM16	BM17	BM20
1	Waste supply and availability											N/C
2	Market assessment							N/C				
1	Institutional analysis											
3	Technical assessment											
4	Financial assessment						N/C	N/C				
5	Health risk& impact assessment											N/C
	Environmental risk and impact assessment											
6	Socio-economic assessment											
	Overall ranking of BM											

Legend:

- **BM 1a:** Dry Fuel Manufacturing: Agro-Waste to Briquettes
- **BM 4:** Onsite Energy Generation by Sanitation Service Providers (faecal sludge to electricity)
- **BM 6:**Power Capture Model (livestock to energy)
- **BM 8:** Beyond cost recovery: wastewater-fed aquaculture
- **BM 9:** On Cost Savings and Recovery (wastewater use for irrigation, energy and nutrient recovery)
- **BM 10:** Incentivizing safe reuse of untreated wastewater
- **BM 11:** Wastewater and drinking water exchange
- **BM 12:** Wastewater treatment for carbon emissions reduction
- **BM 15:** Large-Scale Composting for Revenue Generation (municipal solid waste to compost)
- **BM 16:** Subsidy-free Community Based Composting (municipal solid waste to compost)
- **BM17:** High value Fertilizer Production for Profit (combination of municipal solid waste and faecal sludge to organic fertilizer)
- **BM 20:** Outsourcing Faecal Sludge Treatment to the Farm

Legend

High feasibility
Medium feasibility

Low feasibility
No feasibility

N/C = Assessment not conducted

11 Annex 1: Linking Research and Business Development

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

To help empower the private and public sector in Bangalore a 5-day Business Model Development Training (BMDT) focusing on the translation of RRR business ideas into promising business models for the safe resource recovery from liquid and solid waste businesses models was held from 22nd to 29th January 2015.

The BMDT was attended by 12 entrepreneurs/intrapreneurs and trainers representing 5 institutions and companies:

- The Consortium for DEWATS Dissemination (CDD) Society is an organization working in the field of decentralised waste water management systems. Their BM is centred around providing de-centralized faecal sludge management products and services to entrepreneurs that want to establish their own sludge treatment plant.
- Ms. Chakraborthy and Mr. Kale developed a Corporate Social Responsibility (CSR) centred BM that matches the needs of the un-served rural population and the desire of national and international companies to support social development through CSR activities.
- Representatives from VISHWA and IHP jointly focused upon manufacturing, popularizing and marketing of pipes and allied products for large-scale infrastructure projects.
- Energy and Environment Resource Group Inc. (eERG) works in the field of water management, specializing in domestic wastewater treatment plant. During the training Mr. Kalkai developed a BM for producing and selling briquettes made from agro-waste.
- Ms. Satish and Ms. Weber developed designed a BM for a RRR Business Development Hub that will provide services such as training, coaching, mentoring, office space to RRR Start-Ups in Bangalore and beyond.

12 Annex 2: MCA Framework

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

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

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

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

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

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

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

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

4. Institutional and Legal Settings and Public Support

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

5. Financial feasibility/viability assessment

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

6. Health and Environmental risks and risk mitigation

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

7. Socio-economic impact assessment

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

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