Resource Recovery and Reuse (RRR) Project

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

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Contributing Authors (in alphabetical order):

Guéladio Cissé[1, 2]
George Danso[3]
Nguyen Duy Linh[4]
Alexandra Evans[5]
Samuel Fuhrimann[1, 2]
Ganesha Madurangi[3]
Viet-Anh Nguyen
Miriam Otoo[3]
Phuc Pham Duc[6]
Krishna Rao[3]
Lars Schoebitz[7]
Linda Strande[7]
Avinandan Taron[3]
Martin Wafler[8]
Mirko Winkler[1,2]
Chris Zurbrügg[7]

Compiled by:

Miriam Otoo[3]
Krishna Rao[3]
Avinandan Taron[3]

Affiliations:
[1]Swiss Tropical and Public Health Institute, Dept. of Epidemiology and Public Health, Switzerland
[2]University of Basel, Switzerland
[3] International Water Management Institute (IWMI), Sri Lanka
[4]Vietnam National University of Agriculture, Vietnam
[5]Loughborough University, Water Engineering and Development Centre (WEDC), U.K.
[6]Hanoi University of Civil Engineering (HUCE), Institute of Environmental Science and Engineering (IESE), Vietnam
[7]Swiss Federal Institute of Aquatic Science and Technology (Eawag) - Department of Water and Sanitation in Developing Countries (Sandec), Switzerland
[8]International Centre for Water Management Services (CEWAS), Switzerland

Correspondence to Dr. Miriam Otoo:
E-mail: m.otoo@cgiar.org

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Abbreviations

AED	Agency for Enterprise Development
AIW	Agro-Industrial Waste
AM	Animal Manure
BCR	Benefit to Cost Ratio
BMDT	Business Model Development Training
BMs	Business Models
BOD	Biochemical Oxygen Demand
CFU	Coliform Forming Units
CL	Conditional Logit
COD	Chemical Oxygen Demand
DOF	Department of Finance
DONRE	Department of Natural Resources and Environment
DPI	Department of Planning and Investment
EIA	Environmental Impact Assessment
ERAV	Electricity Regulatory Authority of Vietnam
EVN	Electricity Corporation of Vietnam
FECT	Formalin-Ether Concentration Technique
FS	Faecal Sludge
GHG	Green House Gas
HCMC	Ho Chi Minh City
HIA	Health Impact Assessment
HRA	Health Risk Assessment
HRIA	Health Risk And Impact Assessment
IPPs	Independent Power Producers
IRR	Internal Rate of Return
kWh	Kilowatt-Hours
LOC	Law on Construction
LOEP	Law on Environmental Protection
LOWR	Law on Water Resources
LPG	Liquid Petroleum Gas
LPLD	Law on Promulgation of Legal Documents
MARD	Ministry of Agriculture and Rural Development
MCA	Multi-criteria Assessment
MOC	Ministry of Construction
MOF	Ministry of Finance
MOH	Ministry of Health

MOIT	Ministry of Industry and Trade
MONRE	Ministry of Natural Resources and Environment
MPI	Ministry of Planning and Investment
MSW	Municipal Solid Waste
MW	Market Waste
NGOs	Non-governmental Organizations
NPV	Net Present Value
O&M Cost	Operational and maintenance cost
P&L Statement	Profit and Loss Statement
PCs	People's Committees
PPA	Power Purchase Agreement
PPE	Personal Protective Equipment
PPP	Public-private Partnership
RoI	Return on Investments
RR	Relative Risk
RRR	Resource Recovery And Reuse
SADCO	Sanitation and Drainage Company
SEA	Socio-economic Assessment
SMEs	Small and Medium Scale Enterprises
SSP	Sanitation Safety Plan
STEP	Specific Topic Entry Page
SWM	Solid Waste Management
TIA	Technical Infrastructure Agency
UDDTs	Urine Diverting Dry Toilets
URENCO	Urban Environmental Company
VEA	Vietnam Environment Agency
VND	Vietnamese Dong
WHO	World Health Organization
WTP	Willingness-to-Pay
WW	Wastewater
WWF	Wastewater-fed Fish
WWT	Wastewater Treatment
WWTP	Wastewater Treatment Plant

Executive Summary

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

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

Eleven (11) business models were selected for feasibility testing in Hanoi, covering several waste streams (faecal sludge, municipal solid waste (MSW), wastewater, agro-industrial waste) and resulting end-products categorized into energy and nutrient recovery and wastewater use. The business models were selected based information from: a) a pre-feasibility study, b) feedback from stakeholder workshops and c) a no-go analysis based on information from baseline surveys. The selected business models had to have at least triple bottom line targets: high impact from a scalability and replicability perspective and catalyze innovation adoption. The feasibility of each model was then analyzed based on the MCA framework and for its overall potential feasibility based on a 4-level ranking system, i.e. whether it has:

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

The notion behind the ranking of the RRR business models is to provide different stakeholders, in particular, investors with an overview of the potential feasibility for implementation of the business models. Particularly, it provides 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 *'wastewater-fed fish'* and 'large-scale MSW-based composting' models have the highest feasibility potential for implementation in Hanoi. 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).

None of the energy business models were noted to be feasible for implementation in Hanoi. For Model 1a - Dry Fuel Manufacturing (agro-waste to briquettes), although there is a growing and substantial market demand for agro-waste briquettes in Hanoi and the business model is financially viable; it has a low feasibility potential for implementation. This is mainly driven by two factors: a) limited availability and access to waste input and b) restrictive institutional factors. From an institutional perspective, it is noted that although a large number of households and small businesses use charcoal briquettes for cooking it is not a major government focus for the energy sector. The reluctance for support and negative perceptions of the product is mainly driven by agencies worried about access for the poor and indoor air pollution.

Similar to business model 1a, the low feasibility of Model 2a - Energy Service Companies at Scale: Agro-Waste to Energy (Electricity) is attributable to the limited availability of agro-waste in urban and peri-urban Hanoi. And, although there are several supportive policies and legislations, the reality is that there is still a significant amount of work that needs to be done to sufficiently incentivize private sector involvement. Compounding the low feasibility of this model are the market distortions in the energy sector. Generally, there is a significant and growing demand for electricity in Hanoi and Vietnam as a whole and opportunities for waste-to-energy entities to fill this gap based on the anticipated rapid rural electrification program; foreseeable increasing trend in electricity prices; structural and legal feasibility for private sector involvement (some degree of structural unbundling of the Vietnamese power sector, vertically integrated monopoly and privatization of the generation and distribution); a lesser vertically integrated market; and supportive renewable energy policies among others. The increasing number of independent power producers in the energy sector in recent years is also indicative of the fair structural feasibility of the Vietnamese electricity sector. However, electricity producers are currently price takers and restricted to the price ceiling set by the state-owned transmission entity EVN (limited negotiation ability – monopolistic market). Thus, in actuality, the level of market concentration, price setting behavior and potential net profit margins (business performance) will determine the sustainability of a waste-to-energy business, which for the first two factors are significant limiting drivers. The opportunity for waste-generated electricity can only materialize when offered prices in the power purchase agreement (PPA) can substantially cover production costs; as confirmed by the financial analysis which indicates that larger scale plants are very sensitive to the price of electricity for feed-in-tariffs[1].

The low feasibility of Model 4 - Onsite Energy Generation by Sanitation Service Providers (faecal sludge to energy) is driven by the following key factors: a) lack of an enabling institutional environment, b) market distortions in the energy sector and c) waste availability. Although this business model has considerable merit for a city with on-site waste collection (septic tanks) and limited sewerage and centralized wastewater treatment plant, it is not supported by current policies and there are barriers for private sector engagement, primarily as a result of the dominance of the public sector. This could be changed if the government can be convinced of the benefits of onsite treatment and energy generation.

The results showed that Model 6 - Power Capture Model (livestock to energy) has a low feasibility potential for Hanoi and this is mainly driven by the distortions in the energy market. As with model 2, 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

[1]Prices are noted to be currently low in Vietnam (the price of the feed-in-tariff for renewable energy particularly agro-waste is yet to be decided in Vietnam),

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; and thus the opportunity for waste-generated electricity can only materialize when offered prices in the power purchase agreement (PPA) can substantially cover production cost.

Wastewater-fed aquaculture is becoming a major livelihood strategy for many municipalities looking for wastewater treatment and cost-savings options in Hanoi, Vietnam. This business model (Model 8 - Beyond cost recovery (wastewater-fed aquaculture)) has a good potential for implementation given the: a) available wastewater treatment plants and city lakes for integrated aquaculture, b) sound financial viability, c) significant market demand and d) supportive policies. There is legislative support for decentralized wastewater treatment implemented by private sector entities or government departments. There are also existing financial incentives for wastewater reuse but at present these are limited and would need to increase to further incentivize investment. The market analysis results showed that households are willing to pay about 9.20 VND per kg and 25.08VND per kg for wastewater-fed tilapia with information on the sources of water and certification by a trusted government agency respectively. Thus, it will be important for new businesses to consider the provision of a fish product with clear labeling by a third party - a government entity preferred. 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. 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, suggesting that an aggressive marketing strategy is used for the promotion of the fish product. From a financial perspective, while the business model is financially viable, it is highly sensitive to the scale of operations. 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.

There are existing supportive policies for the reuse of wastewater such as the provision of incentives (i.e. tax exemptions and financing for wastewater treatment) in Hanoi. The challenge with the implementation of Model 9 - On Cost Savings and Recovery (wastewater use for irrigation, energy and nutrient recovery) however lies with: 1) the difficulty of private sector entry into the market, 2) market demand as measured by the farmers' willingness-to-pay for treated wastewater and 3) limited financial viability. Most if not all farming households in Hanoi have full subsidization of irrigation fees from the current irrigation system, suggesting that farmers will not be willing to pay for treated wastewater. The key factor however that drives the infeasibility of this business model is its limited financial viability. Although this business model is not financially viable, the option for some cost-recovery and the socio-economic benefits are significant and would justify an investment for the addition of a reuse component to existing or new wastewater treatment plants. The implementation of this model has the potential to significantly reduce surface and groundwater contamination, and GHG emissions.

In regards to the nutrient business models, Model 15 - Large-Scale Composting for Revenue Generation (municipal solid waste to compost) was the only business model noted to be highly feasible in the context of Hanoi. The feasibility is driven mainly by: a) high financial viability, b) supportive institutional and legislative environment, c) significant market demand and d) available technologies. The market analysis results show that there is a demand for MSW-based compost. Consumers' WTP, for compost is significantly higher than the average market price for substitute products ranging between 1000-2000 VND/kg. The results indicated that the farmers were willing to pay more to know the source of the input materials used to produce the compost (i.e. MSW, faecal sludge and/or animal waste) and certification. This suggests that high quality compost product if labelled with information on source of the inputs and has 3rd party certification will command a market price of 2826 VND/kg - which is almost 1 - 2 times higher than the current market price. From an institutional perspective, the use of MSW is well-accepted and supported by policy makers, authorities, private sector players, farmers and communities. The financial assessment was conducted for three different scenarios and it was observed that the 200-ton plant is not feasible without any subsidy or incentives. As per 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 expected to be sold year on year (from 60% to 90%). Previous research from other developing countries show that most compost plants that use municipal solid waste struggle to sell compost (less than 50% sales) and mainly undertake compost production to reduce the overall quantity of waste sent to landfill. The price of compost is one the most sensitive parameter that drives the viability of the business and with higher prices the business can be highly viable at all scales.

Although similar to model 15 - Model 16 - Subsidy-free Community Based Composting (municipal solid waste to compost) has a low feasibility potential and this is mainly driven by the limited space in urban Hanoi for decentralized community level composting activities. From an institutional perspective, there are existing supportive policies and legislation for MSW reuse but support for incentivizing private sector involvement is minimal. The feasibility of this model can however be substantially improved if land can be allocated for operations at the community level. This would result in substantial socio-economic benefits as this business would result in increased waste collection (averted human health risks from decreased exposure to untreated waste) and employment generation at the community level. To further improve its viability, it would be important for the business entity to partner with a larger compost facility or fertilizer companies to sell its compost, 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) 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 demand for Fortifer was noted to be significant with an average WTP value of 6628 VND/kg. The marginal WTP analysis showed that farmers were willing to pay 267.5 VND/kg more for fortification and an even higher premium of 694 VND/kg for certification. The potential market is substantial with the demand for Fortifer estimated at 145,374 tons/year. Whilst the current production level of organic fertilizers is fairly low, it is clear that it is a burgeoning industry with some entry barriers but supportive and existing policies encouraging business development. However, 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 business model will require a capital subsidy and it is unlikely to achieve capital cost recovery with higher compost price.

The remaining 2 nutrient business models (Model 18: Urine reuse and Model 19 - Compost production for sanitation service delivery) were noted to be infeasible for implementation in Hanoi. Their infeasibility was mainly driven by the inexistence of urine diverting dry toilets (UDDTs). As there is almost a 100% sanitation coverage in urban Hanoi, there is very limited opportunity for the consideration of the adoption/use of UDDTs. With significant waste input supply constraint, the business model was deemed infeasible for Hanoi.

Table 1: Overall feasibility ranking of the business models

		Level of feasibility of the business models										
Ranking criteria	**Outputs**	**ENERGY**				**WASTEWATER**		**NUTRIENT**				
		BM1a	**BM2a**	**BM4**	**BM6**	**BM8**	**BM9**	**BM15**	**BM16**	**BM17**	**BM18**	**BM19**
1	Waste supply and availability											
2	Market assessment						N/C				N/C	N/C
1	Institutional analysis										N/C	N/C
3	Technical assessment											
4	Financial assessment			N/C							N/C	N/C
5	Health risk& impact assessment											
	Environmental risk and impact assessment											
6	Socio-economic assessment			N/C							N/C	N/C
	Overall ranking of BM											

Legend:

- **BM 1a:** Dry Fuel Manufacturing: Agro-Waste to Briquettes
- **BM 2a:** Energy Service Companies at Scale: Agro-Waste to Energy (Electricity)
- **BM 4:** Onsite Energy Generation by Sanitation Service Providers (faecal sludge to electricity)
- **BM 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 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 18:** Urine reuse
- **BM 19**: Compost Production for Sanitation Service Delivery (faecal sludge-based compost and urine as a fertilizer).

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.

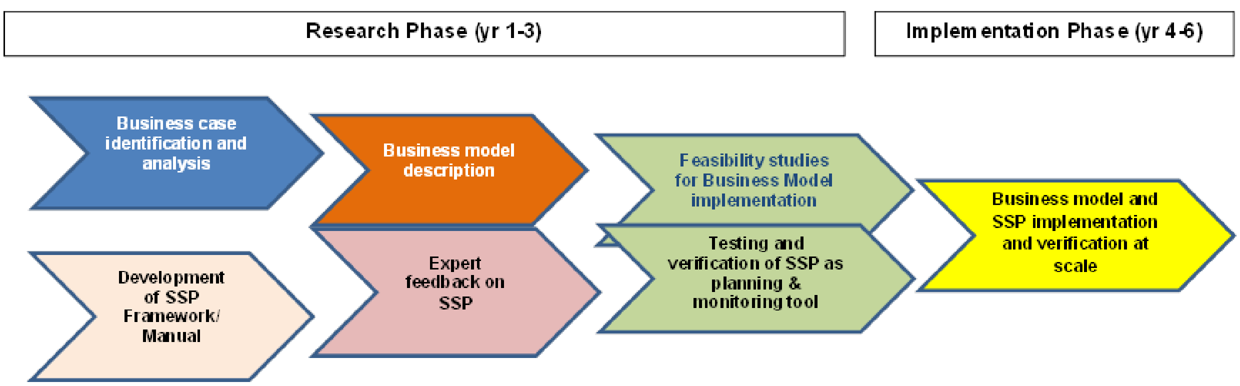

Figure 1: Research Framework for the Project

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)

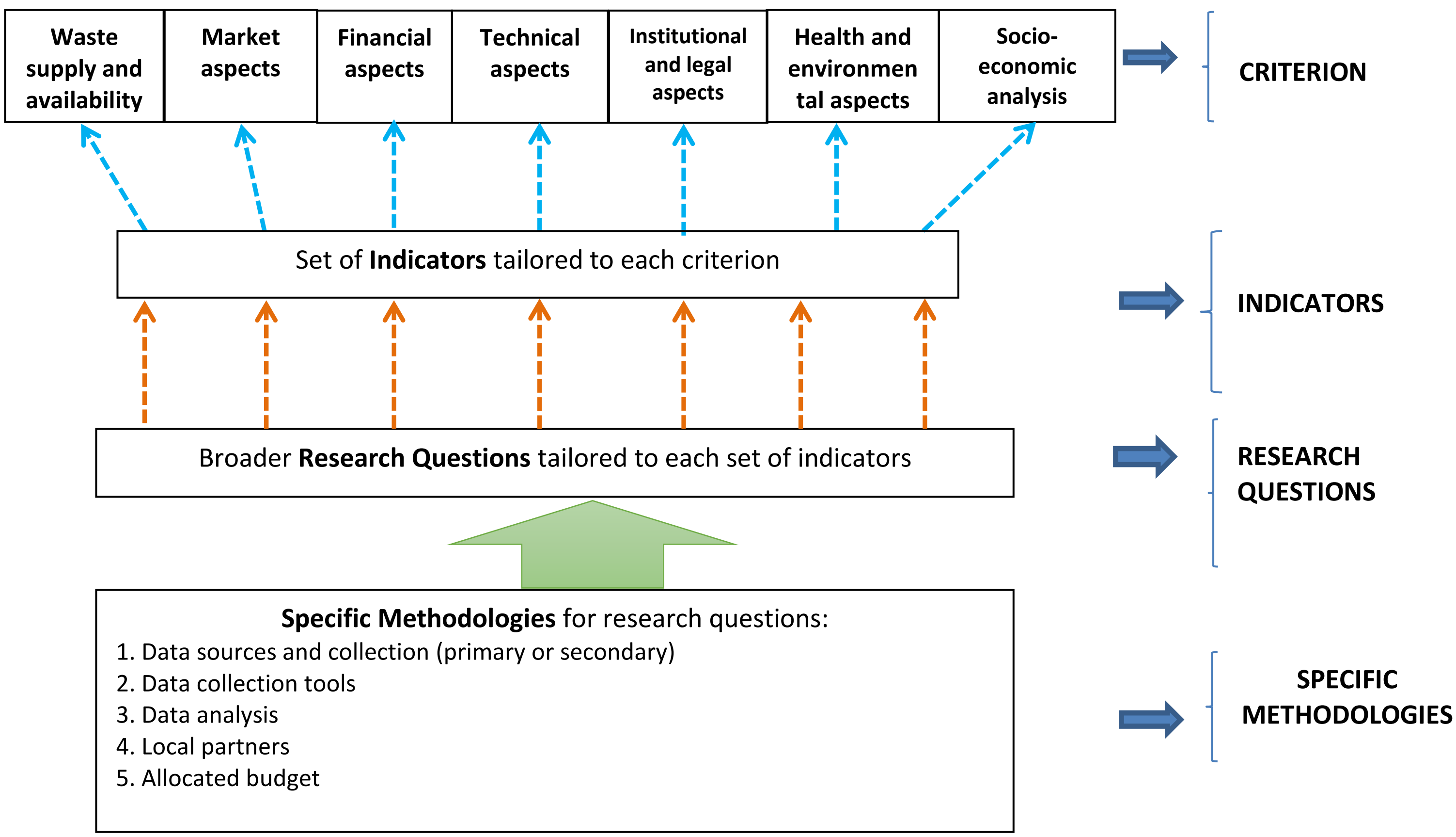

Figure 2: Framework for Feasibility Studies

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 Hanoi, Vietnam. 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. Eleven (11) business models selected for feasibility testing in Hanoi 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.

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 (Synthesis of Feasibility Studies) provides a synthesis of the overall feasibility assessment and ranking of all the selected business models.

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

RRR Business Models	Brief Description
ENERGY	
Model 1a: Dry Fuel Manufacturing: Agro-Waste to Briquettes	The business entity processes crop residues like wheat stalk, rice husk, maize stalk, groundnut shells, coffee husks, saw dust etc. (any agro-based waste) and converts them into briquettes as fuel to be used in households, large institutions and small and medium energy intensive industries.
Model 2a: Energy Service Companies at Scale: Agro-Waste to Energy (Electricity)	The business processes crop residues like wheat stalk, rice husk, maize stalk, groundnut shells, coffee husks, saw dust etc. to generate electricity which is sold to households, businesses or local electricity authority.
Model 4: Onsite Energy Generation by Sanitation Service Providers	The business model is initiated by either enterprises providing a sanitation service such as public toilets or by residential institutions such as hostels, hospitals and prisons with a concentrated source of human waste (i.e. faecal sludge). The business concept is to process and treat human waste in a bio-digester to generate biogas to be used for lighting or cooking.
Model 6: Power capture model: Livestock waste to energy	Similar to model 2a, the business processes animal waste (specifically, livestock) to generate electricity which is sold to households, businesses 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: On Cost Savings and Recovery	The business concept is to treat wastewater for safe reuse in agriculture, forestry, golf courses, plantations, energy crops, and industrial applications such as cooling plant. The sludge from the treatment plant can be used as compost and soil ameliorant and energy generated can be used for internal purpose resulting in energy savings.
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: Decentralized community based MSW Composting	The business concept is similar to that on model 15, with the exception of operations and production of the compost taking place in a decentralized manner.
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 18: Urine for Agricultural Production	The business concept is to generate revenue from the sale of sanitized urine and dry faeces to farmers and nurseries and plantation owners for use in agriculture.
Model 19: Compost Production for Sanitation Service Delivery	The business concept is to provide sanitation service provision and to manage and transform human excreta into safe fertilizer and soil conditioner.

2 Key findings of Waste and Availability Analysis

This section presents the key findings of the "Waste Supply and Availability" analysis that was conducted in Hanoi, Vietnam. 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 3provides 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 Hanoi.
- Accessibility of defined waste streams, and the implications on the potential for implementation of waste-based business models.

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

- Existing reports from research institutes working in the field of waste management and sanitation,
- Reports from the National Government, translated from Vietnamese into English
- Conducting interviews with experts,
- Field data measurements for quantities and characteristics of faecal sludge (Schoebitz et al.,2014)

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: Hanoi, Vietnam. July (2014)",* available for download on www.sandec.ch/rrr

Table 3: Rating of feasibility and recommendations for adaption of business models in Hanoi

Business Model	Waste stream	End-product	Feasibility rating	Recommendations
1 (a, b)	• AIW	• Briquettes	**Medium** Availability of AIW in urban Hanoi is limited. Vegetables are mainly produced in the peri-urban and rural areas south of urban Hanoi and rice, as the main harvested crop, is produced north of urban Hanoi. The use of coal as a cooking fuel is very limited in Hanoi as electricity supply for cooking and heating purposes is sufficient. Therefore, it can be expected that the demand for briquettes as a substitute is limited, but there could be potential market demand for use in industries. From the perspective of technical feasibility, briquetting technologies can be expected to function well, if the operators are trained in operation and maintenance of the equipment. Briquettes are already being produced in Vietnam, mainly from rice husks. They are used to heat industrial boilers for co-firing where it can be combined with coal. Therefore, knowledge on briquetting methods exists and technologies could potentially be implemented if the market demand analysis identifies a demand for the use of briquettes.)	Considering the use of other waste streams for the production of briquettes can increase the feasibility. The calorific value of dried faecal sludge is comparable to other biomass fuels. Other possible adaptations include the production of pellets instead of briquettes, which are often preferred by industries. Targeting industries rather than households as a possible market for the end-product would decrease the social stigma that is created with using briquettes/pellets made of faecal sludge as a fuel.
2 (b)	• AIW	• Gasification -> Electricity	**Low** Availability of AIW in urban Hanoi is limited (as described under business model 1(a)).	Application of gasification in the peri-urban and rural areas where AIW is produced.
4	• Feces • Urine • FS	• Biogas -> Cooking fuel	**Low** The demand for public toilet facilities for sanitation provision is expected to be relatively low in urban Hanoi, as sanitation coverage for households is almost 100%. The high number of public toilets, especially in the districts of Historic Hanoi, shows that toilet facility provision as a public service (e.g. for tourists) is well covered. Upgrading existing facilities ranks low in technical feasibility due to limited availability of space and the combined onsite sanitation and sewer network already in place.	Producing biogas from faecal sludge, especially in co-digestion with other waste streams, is a promising option for the treatment of faecal sludge. A technical adaptation of the business model could include making use of the already collected faecal sludge from public toilets and potentially co-digest it with other waste streams, such as wastewater sludge or the organic fraction of solid waste.
6	• AM	• Biogas -> Electricity	**Medium** Animal manure is not produced within urban Hanoi, while the application of anaerobic digestion in peri-urban and rural areas has been successfully implemented.	Change of location to peri-urban and rural areas where animal manure is produced

8	• WW	• Fish • Treated WW	**Medium** Use of wastewater for aquaculture is a well-established system in Hanoi. It is mainly based on farmer's experience and also utilizes animal manure. However, it can be assumed that these practices are not under safe conditions and that the used wastewater is of mixed domestic and industrial source. To implement a business model, similar to Agriquatics, requires institutional involvement as the city has developed master plans for the expansion of the wastewater treatment infrastructure until 2050. Other limitations include the availability of land for cultivation in urban Hanoi.	
9	• WW • WW sludge	• Electricity • Soil conditioner • Water (for reclamation)	**Medium** Effluent of existing wastewater treatment plants is in line with local water quality standards for discharge, which decreases the feasibility of reclaiming water for the recovery of nutrients. Anaerobic treatment of WW is not implemented at any of the existing treatment plants and no information exists on the current management of WW sludge.	The feasibility of the business model can be increased by starting the communication of resource recovery within the planning of sanitation and wastewater infrastructure until 2050.
15	• MSW • FS	• Soil Conditioner	**Medium-High** This business model ranks highest feasibility, as Hanoi already has an existing and functioning composting facility. The composting facility receives market and restaurant waste from four urban areas. This highly decreases the sorting efforts necessary at the facility. Nevertheless, the facility does not make any profits due to the fact that the treatment costs are higher than the revenues that can be created from the end-product. A functioning business model could increase the profitability of the composting facility. The composting plant also receives faecal sludge from public toilets, of which the liquid part is used to maintain the moisture in the composting piles. Technically, this cannot be considered as co-composting since the solid fraction of the faecal sludge is still disposed of at one of the landfills.	The feasibility can be increased by implementing more source-separation initiatives at the household level to increase the availability of organic solid waste for composting. As faecal sludge is already delivered to the same facility, the solid fraction of the faecal sludge could be utilized for co-composting activities. This would require implementation of faecal sludge drying technologies, such as unplanted drying beds.
16	• MSW	• Soil Conditioner	**Low** Very limited space in urban Hanoi for decentralized community level composting activities. MSW is not source-separated.	No recommendations for adaptations to increase the feasibility.
17	• MSW • FS	• Fertilizer (NPK added)	**Medium-High** Same reasons as for business model 15	Same recommendations as for business model 15.
18	• Urine	• Diluted urine	**Low** No existing urine diverting dry toilets. Agricultural land is far from urban Hanoi. Sanitation coverage is almost 100%.	No recommendations for adaptations to increase the feasibility.
19	• Urine • Feces	• Stored urine • Soil conditioner	**Low** Same reasons as for business model 18	No recommendations for adaptations to increase the feasibility.

3 Key findings of Market Analysis

Introduction

The feasibility studies conducted in Hanoi 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 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. This report thus presents the results of the market assessment as part of the feasibility testing for the implementation of waste reuse (resource recovery and reuse - RRR) business models in Hanoi, Vietnam.

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 11 RRR business models was selected for the feasibility studies in Hanoi. For the purposes of the market assessment, an end-use typology of the business model was employed as although the underlying concept of the business models were different, the end products were the same. Thus for some business models, the related customer segments and relevant actors along the value chain considered would be the same. In that regard, for the selected business models, the following 5 value-added products were considered: 1) briquettes, 2) electricity, 3) wastewater-fed fish, 4) MSW-based compost and 5) faecal sludge-based compost. It was noted from the waste supply analysis that there is very low use and almost inexistent use of urine dry diverting toilets in Hanoi. Thus the urine is not available as a waste input resource. A market assessment was thus not conducted for the resulting product - treated urine.

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 briquette)	Briquettes	Energy
Model 2: Independent power producer (agro-waste to electricity)	Electricity	
Model 4: Onsite energy generation (faecal sludge to electricity		
Model 6: Power capture model: Livestock waste to energy		
Model 8: Beyond cost recovery: the aquaculture example	Wastewater-fed fish	Wastewater-fed fish
Model 9: Treated wastewater for irrigation	Treated wastewater	Wastewater
Model 15: Centralized large-scale compost production (MSW to compost)	Compost	Nutrients
Model 16: Decentralized community based MSW Composting		
Model 17: High quality branded and certified organic fertilizer (faecal sludge to compost)	Faecal sludge-based compost	
Model 18: Urine for Agricultural Production		
Model 19: Sustainable sanitation service delivery via compost production (faecal sludge to compost)		

Methodology

▪ 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) water market and d) fertilizer market.

Study Area and Data

The primary survey covered several key districts in Hanoi (Son Tay, Dong Anh, Choung My, Thanh Tri, Soc Son, Hanoi center and Gia Lam). 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).

Results of the Market Assessment

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

The results indicate that there is a growing and substantial market demand for agro-waste briquettes in Hanoi. The results suggest that a considerable percentage of households, livestock producers and food service businesses are willing to pay for briquettes. On average, 60-80 % of the households, livestock producers as food service businesses surveyed indicated a positive WTP for briquettes. Interestingly, the WTP/ demand measure for households is similar to that of livestock producers, whilst that of food service businesses are comparatively higher. The households' WTP estimate (3,400 VND/kg) was noted to be considerably higher than the current prices of briquettes (about 1.5 thousand VND per kilogram) sold in the South of Vietnam but fairly close in price to that of fossil coal. The same result (3,400 VND/kg) was estimated for the livestock producers. Food service businesses, on the other hand, had a marginally higher WTP, averaging at 3,800 VND/kg. These results suggest that the households, livestock producers and food service businesses are willing to pay a price higher than that of other comparable solid fuels. On average, Hanoi consumes 28,650 tons[2] of honeycomb coal per month, which is equivalent to 71,625 million VND per month (approx. 3.4 million USD[3]), at a price of 2.5 thousand VND/kg. Using the WTP estimates (an average of 3,600 VND/kg), the market for briquettes can be estimated at 4.9 million USD[4]. The quantity of current solid fuels that can be potentially replaced by briquettes was estimated based on the results from the accepted bids of the respondents. On average, between 63 to

[2] Source: Data from investigating charcoal port in Hanoi, 2014.
[3] One USD is about 21,000 VND (exchange rate in 2013)
[4] A 1:1 weight equivalency between honeycomb coal and biomass briquettes was assumed for the estimation.

82% of current fuels been used by the households, livestock producers and food service businesses can be replaced with briquettes.

Whilst the current production level of briquettes is unknown and estimated to be fairly low, it is clear that it is a nascent industry with minimal entry barriers, and inherent distortions in competitors' markets represents opportunities for the development of the briquette industry. Although still in strong effect, the state monopoly of the LPG market has been challenged over the years due to new entrants particularly fully owned private companies and joint stock companies and their high growth rate. Domestic prices are additionally determined mainly by the import price plus transportation cost as nearly 50% of LPG market depends upon the import from other countries. Thus, the domestic market is highly vulnerable to erratic fluctuations in world market prices due to the high level of imports (the limited domestic supply (VPBS, 2014) and limited storage capacity which is insufficient to stabilize the market). These inefficiencies in the LPG market represent opportunities for new briquette businesses to capture part of the related energy market. In terms of the market outlook of the product, the penetration of agro-waste briquettes will be facilitated by prevailing market conditions in competitor sub-sectors. A lower market price than the prevailing price of honeycomb coal and coal briquettes can increase consumers' adoption rate. Strong awareness programs coupled with promotional approaches will be important to eventually increase market demand due to the strong positioning of the honeycomb coal market and further shorten the growth stage which currently is estimated between 6 - 7 years.

- ***Model 2a: Energy service companies at scale (Agro-Waste to Electricity), Model 4: Onsite energy generation by sanitation service providers (Faecal sludge to energy) and Model 6: Power capture model - Livestock waste to energy***

The potential market for waste-generated electricity was assessed as measured by households WTP estimates for public lighting at 12,800 VND/month. This estimate is noted to be considerably higher than the current monthly fees (7,800 VND/month) paid by other households in areas with functioning public lighting systems. Generally, there is a significant and growing demand for electricity in Hanoi and Vietnam as a whole and opportunities for waste-to-energy entities to fill this gap based on the anticipated rapid rural electrification program; foreseeable increasing trend in electricity prices; structural and legal feasibility for private sector involvement (some degree of structural unbundling of the Vietnamese power sector, vertically integrated monopoly and privatization of the generation and distribution); a lesser vertically integrated market; and supportive renewable energy policies among others. The increasing number of independent power producers in the energy sector in recent years is also indicative of the fair structural feasibility of the Vietnamese electricity sector. In an effort to encourage investments in the energy recycling sector, the Ministry of Industry and Trade (MOIT) suggested a price of 6.1 US cents per kwh for electricity made of bagasse instead of 4 cents per kwh, as currently applied[5]. A price level of 7.3 cent per kwh has been suggested for electricity from rice husk (4 cents per kwh currently). Whilst electricity from the burning of garbage would be priced at 10 cents per kwh, and electricity from waste dumping 10 cents per kwh (now 4 cents per kwh). To attract more investments in the waste-to-energy sector, the Vietnamese Prime Minister Decision 31/2014/QĐ-TTg on solid waste-to-energy projects became effective on 20 June 2014. Article 14 of the Decision provided a ground-breaking feed-in tariff for power suppliers of up to "VND 2,114/kWh (equivalent to 10.05 US cents/kWh)". This is a 25 percent higher than the 7.8 cent applicable to wind power projects in Article 14 of Decision 37/2011/QĐ-TTg from 2011[6]. This represents a catalyst to boost investors' interest and the viability of future waste-to-energy businesses.

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[5]http://www.eepmekong.org/main_navigation/EVN%20VIETNAM.pdf
[6]http://www.mondaq.com/x/321970/Energy+Law/GroundBreaking+FeedIn+Tariff+For+WasteToEnergy+Projects+In+Vietnam

Electricity producers are however currently price takers and restricted to the price ceiling set by the state-owned transmission entity EVN (limited negotiation ability – monopolistic market). Thus, in actuality, the level of market concentration, price setting behaviour and potential net profit margins (business performance) will determine the sustainability of a waste-to-energy business, which for the first two factors are significant limiting drivers. The opportunity for waste-generated electricity can only materialize when offered prices in the power purchase agreement (PPA) can substantially cover production costs. Additional limiting factors to business development and sustainability in the sector are: a) continued interest and large hydro-power potential; b) significant interest in small hydro-power projects and c) waste-to-energy projects currently viewed as high-risk ventures by financial investors. While producer prices can be increased, additional market failures inherent in the energy sector can only be rectified with the institution of sound policies.

- ***Model 8: Beyond cost recovery - Wastewater-fed aquaculture***

Wastewater-fed aquaculture is becoming a major livelihood strategy for households and businesses. Using a choice experiment approach, the demand for wastewater-fed fish was assessed in Hanoi, Vietnam. The conditional logit model showed that households are willing to pay about 9.20 VND per kg and 25.08VND per kg for wastewater-fed tilapia with information on the sources of water and certification by a trusted government agency respectively. With common carp fish, households are willing to pay about 11.187 VND and 22.587 VND/kg more for source and certification of fish by a trusted government agency. Overall, the CL model shows that households value fish which is clearly labelled with information on the source of water used to raise the fish and whether it is certified or not. These results were consistent for the results of the analyses for businesses. The demand for wastewater-fed fish are more likely to be affected perception, age and the educational status of households. Thus, it is important for new WWF businesses to consider the provision of a fish product with clear labelling by a third party - a government entity preferred. The freshwater fish market was used as the reference market for the WWF product. The results showed it to be fairly competitive with an easy level of market entry, however, fish farmers are price takers and consumer surplus is mainly captured by the distribution agents and wholesalers who operate at a large scale.

- ***Model 9: Cost recovery - Treated wastewater for irrigation, fertilizer and energy***

The undertaking and sustainability of a business component to wastewater reuse requires an assessment of the market in its entirety to include an evaluation of market demand of wastewater, in particular, for irrigation and multiple uses. Thus, an assessment of market demand and potential size is crucial prior to implementing such an operation and to understand the existing level of demand and driving factors of demand for treated wastewater products. The water market will also need to be evaluated to understand the characteristics of the market structure (i.e. level of competition in the market, characteristics of competitors and factors driving market competitiveness and collusiveness) in order to guide potential investors' decisions. The institutional analysis noted several key factors that point to the fact that farmers in Hanoi do not have to pay for an irrigation fee. Thus, based on this fact, most if not all farming households in Hanoi have fully subsidization of irrigation fees from irrigation system, suggesting that farmers will not be willing to pay for treated wastewater. In that regard, a market assessment was not conducted for this prospective business model and the supportive institutional and legal factors are outlined below. Additionally, the institutional analysis report provides in a detailed discussion on the market structure and outlook.

- ***Model 15: Large-Scale Composting for Revenue Generation (MSW to Compost), Model 16: Decentralized MSW composting, Model 17: High value fertilizer production for profit and Model 19: Compost production for sanitation service Delivery (faecal sludge-based fertilizer)***

The results show that consumers' WTP, for compost is significantly higher than the average market price for substitute products ranging between 1000-2000 VND/kg. The results indicated that the farmers were willing to pay more to know the source of the input materials used to produce the compost (i.e. MSW, faecal sludge and/or animal waste) and certification. This suggests that high quality compost product if labelled with information on source of the inputs and has 3rd party certification will command a market price of 2826 VND/kg - which is almost 1 - 2 times higher than the current market price.The conditional logit model findings confirmed these results and showed that the addition of attributes such as fortification and certification can increase the demand for compost produced from faecal and organic waste. Likewise the demand for Fortifer (faecal sludge-based compost - models 17 and 19) was significant with an average WTP value of 6628 VND/kg. The marginal WTP analysis shows that farmers are willing to pay 267.5 VND/kg more for fortification and an even higher premium of 694 VND/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 noted premiums are slightly lower when socio-economic variables are factored into the choice sets. The potential market for both products are substantial with the demand for Fortifer estimated at 145,374 tons/yearn andMSW-based compost at 181, 897 tons/year.

Whilst the current production level of organic fertilizers is fairly low, it is clear that it is a burgeoning industry with some entry barriers but supportive and existing policies encouraging business development. The organic fertilizer market is less commercialized and the related market structure and business dynamics are very informal. Given data limitations, the inorganic fertilizer market, which is more formal, commercialized and well-researched during past decades was used as the basis to the extent possible for the market structure and outlook assessment. A market condition that would potentially impact the development of organic fertilizer (i.e. compost and Fortifer) businesses is the market power held by chemical fertilizer producers. The fertilizer market in Vietnam is highly concentrated – the top five fertilizer importers (except the commercial farms) account for the largest share of the fertilizer market. This suggests a very high concentration that is characteristic of strong oligopolistic market structures. Whilst the fertilizer industry is highly concentrated, market distortions related to product differentiation, distribution inefficiencies in the supply chain, information flow, foreign exchange rate fluctuations, amongst others, make the fertilizer market imperfectly competitive and represents opportunities for new organic fertilizer businesses.

Additionally, limited and established distribution network, limited infrastructure (storage) and a growing organic agricultural sector has created an even greater opportunity for business development in the organic fertilizer sub-sector. Moreover, there is neither a large-scale government fertilizer program that provides subsidized chemical fertilizer to farmers nor an active private fertilizer sector that supplies fertilizer at competitive prices. With the absence of fertilizer price subsidies, farmers face erratic and significantly high prices for fertilizer. Prices are typically subject to international price changes and exchange rate fluctuations of the economy. Accordingly, the Vietnamese fertilizer market has and continues to experience great price volatility. Fertilizer prices have doubled, and in some cases even tripled, over the past year. The fertilizer price increase has been attributable to the dollar price increase which prompted importers to increase sale prices in VND, which depreciated at an average of 8.27

percent year-on-year as compared to the US dollar. This create significant speculation among local producers and farmers about future price hikes, causing a surge in farmer demand. Whilst, producers benefit from input subsidies, fluctuations in fertilizer prices results in significant uncertainties related to production. These trends however represent a great opportunity for human waste-based organic fertilizer businesses to take advantage of erratic chemical fertilizer prices and the limited number of actors in the respective market and capture a share of the market. On the other hand, the product mix available of chemical fertilizer products is rather extensive, reflecting the grade (nutrient)-specific requirements of the commercial crop growers (estates and horticultural crop farms). This implies that new compost and Fortifer businesses will need at the start-up a highly unique and differentiated product; and innovative marketing strategies to mitigate the effects of the currently limited marketing and distribution channels available in the fertilizer market.

The overall feasibility of the business models was then evaluated based on the different aspects (market demand, market structure and market outlook). Based on this assessment, it is observed in Table 5 below that business models 1a, 8, 15, 16, 17 and 19 have the highest feasibility for successful implementation from a market perspective. In particular for the MSW-based business models, a provision of price subsidies or other subsidies (e.g. agricultural input subsidy, crop price subsidies) for compost businesses will increase their sustainability and create a more conducive environment for entry into the fertilizer market.

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

<table>
<tr><th>Business model</th><th>WTP and Market Demand</th><th>Market Structure</th><th>Market Outlook</th><th>Cumulative feasibility score</th><th>Value-added product/recovered resource</th></tr>
<tr><td>Model 1a – Dry fuel manufacturing: agro-waste to briquettes</td><td>WTP > Current market price of substitute product</td><td>1. Easy market entry
2. Low-to-medium level of concentration
3. Limited to no product differentiation
4. Price setter
5. Potential net profit margins</td><td>6 – 7 years to reach growth stage in business life cycle</td><td>High feasibility</td><td>Briquettes</td></tr>
<tr><td>Model 2a – Energy service companies at scale: agro-waste to electricity</td><td rowspan="3">WTP > Current market price</td><td rowspan="3">1. Difficult market entry
2. High level of concentration (oligopolistic market)
3. No product differentiation
4. Price taker
5. Potential negative profit margins (without subsidies)</td><td rowspan="3">Future demand scenario assessment indicates fair possibility for the government to fulfill supply gap.</td><td rowspan="3">Low feasibility</td><td rowspan="3">Electricity</td></tr>
<tr><td>Model 4 – Onsite energy by sanitation service providers</td></tr>
<tr><td>Model 6: Power capture model - Livestock waste to energy</td></tr>
<tr><td>Model 8: Wastewater-fed fish</td><td>WTP > Current market price</td><td>1. Easy market entry
2. Low-to-medium level of concentration
3. Limited to no product differentiation
4. Price taker - but possible price setter with branding
5. Potential net profit margins</td><td>5 – 7 years to reach growth stage in business life cycle</td><td>Medium feasibility</td><td>Wastewater-fed fish</td></tr>
<tr><td>Model 15& 16 – Large-scale composting for revenue generation (MSW to compost) decentralized composting</td><td>WTP > Current market price of competitive/ substitute products</td><td>1. Medium level of difficulty for market entry
2. Limited level of concentration
3. Limited to no product differentiation in organic fertilizer market
4. Oligopolistic fertilizer market but potential price setter
5. Potential net profit margins –positive</td><td>6 – 7 years to reach growth stage in business life cycle</td><td>Medium feasibility</td><td>MSW compost</td></tr>
<tr><td>Model 17 – High value fertilizer production for profit</td><td rowspan="2">WTP > Current market price of competitive/ substitute products</td><td rowspan="2">1. Medium level of difficulty for market entry
2. Limited level of concentration
3. Limited to no product differentiation in organic fertilizer market
4. Oligopolistic fertilizer market but potential price setter
5. Potential net profit margins –positive</td><td rowspan="2">6 – 7 years to reach growth stage in business life cycle</td><td rowspan="2">Medium feasibility</td><td rowspan="2">Faecal sludge-based organic fertilizer</td></tr>
<tr><td>Model 19 – Compost production for sanitation service delivery</td></tr>
</table>

4 Key findings of the Institutional and Legal Analysis

This report is based on a review of the institutional arrangements around resource recovery and reuse (RRR) in Hanoi and an assessment of the feasibility, in terms of institutional acceptability, of introducing new RRR options or of expanding existing ones. Hanoi'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). Perhaps more excitingly the context is one of rapid economic and governance change, as the country continues to open up and allow private sector engagement, both national and international, in what were government controlled sectors including waste management and energy.

The institutional analysis thus considers a suite of waste streams (wastewater, MSW, FS and sewage sludge) and end-uses (irrigation, aquaculture, energy and compost). A variety of waste stream 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 Hanoi is based on a review of the stakeholders and the institutional arrangements that govern their actions, meaning all the 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. An initial examination of the vast array of concerned stakeholders led to a shorter list of key government organizations that influence policy and legislation at the national and local level; and government organizations that implement or enforce those policies and legislation. To a lesser extent the study considered: 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. This was achieved predominantly through literature review and the knowledge of the project team. The formal institutional arrangements were assessed through an extensive review of national and local laws and policies, and academic literature, as well as some interviews with key stakeholders.

4.1 Institutional Arrangements for Waste Management

Legislation

Vietnam has a very complex system of law making with a whole plethora of legal documents ranging from high level laws through decisions, decrees, ordinances and guidelines, to name but a few. The type of legal document depends on the level at which it has been created (e.g. National Assembly, prime minister, ministry or local government) and the nature of the document, with those generated at local level being designed to offer concrete guidance on the implementation of national level policies and laws (e.g. decisions and resolutions). Recently the system has been streamlined through the Law on Promulgation of Legal Documents (LPLD, 2008) but it is still relatively complex.

The overarching pieces of legislation under which many of the others are formulated are the Law on Environmental Protection No. 52/2005/QH11 (LOEP, 2005)[7] and the Law on Water Resources Order No. 15/2012/L-CTN (LOWR, 2012). Also critical to RRR are Decision No. 04/2008/QD-BXD Vietnam Building Code on Regional and Urban Planning and Rural Residential Planning; and Decree No. 59/2007/ND-CP on management of solid waste (pursuant to LOC and LOEP).

The LOEP (2005) covers management and treatment of: wastewater to prevent pollution of water bodies; solid waste, as well as recycling and reuse; waste from agriculture (including animal waste) and aquaculture. It encourages reduction, collection, recycling and reuse of wastes; development and use of clean and renewable energy; and scientific research, transfer and application of technologies for treating and recycling wastes. It also outlines environmental taxes, including taxes and fees for organizations generating defined wastes, as well as tax exemptions and financial incentives for organizations engaging in waste recycling, treatment and land filling, and in renewable energy, including clean energy from waste. The LOEP provides for State support for products made of recycled material and energy recovered from waste, and investment and incentive policies for organizations and individuals engaging in an environmental industry. According to the LOEP, 2005, the State shall encourage ‘organizations and individuals to establish environmental service enterprises to provide services for environmental sanitation and protection through competitive bidding for the contract’ in fields including ‘waste collection, recycling and treatment’; hence the LOEP, 2005 clearly opens up the environmental sector, including waste management and RRR, to private entities. The amended Environmental Protection Law 2014 adopted by the National Assembly on June 23, 2014 emphasizes the responsibilities of owner of manufacturing and business establishments in reducing, reusing and recycling wastes, and generating energy from wastes in response to climate change (Article 45), being in line with the requirement that all activities relating to environmental protection must be harmoniously connected with the response to climate change (Article 39).

The LOWR, 2012, espouses the principle of increasing the use of recycled water and water reuse and provides for soft loans and tax exemptions for organizations and individuals that invest in such practices. It also prioritizes research, development and application of technologies for using recycled water or reusing water so as to improve efficiency in industry, construction and agriculture. The LOWR, 2012 prohibits pollution of water bodies through the dumping of solid waste and discharge or effluent. The Vietnam Building Code has a chapter on ‘Planning on wastewater drainage and management of solid wastes’ and specifies regulations for this, including such things as the need for all daily life wastewater to be treated by appropriate means and the sewage sludge (mud) to be disposed of in landfill. It specifies that >85% of solid waste collected must be disposed of in ways other than burial, including recycling, reuse and processing into organic fertilizer. It also stipulates safe distances between waste management sites, of all types, and other facilities such as residential areas. Such criteria would be critical for RRR projects. The final element of relevance to RRR is that of electricity supply planning, including such things as specification of power source and electricity ratings.

[7] It should be noted that since writing this report the Law on Environmental Protection, 2014 has been passed.

Decree No. 59/2007/ND-CP on management of solid waste makes stipulations for recycling and disposal facilities making it an offense to place wastes anywhere other than prescribed places; requiring recycling and disposal facilities to be located away from residential areas and other crowded places, and that wastes be conveyed along designated routes; encouraging entrants into the SWM, recycling and reuse business; and advocating technologies for incinerating garbage to generate energy, and processing waste to generate biogas and organic fertilizer.

Electricity LawNo. 28/2004/QH11 is vital for the establishment of waste to energy businesses as it makes provision for an electricity market and provides the legal framework for investment procedures for Independent Power Producers (IPPs).The Law No. 24/2012/QH13 amending and supplementing a number of articles of the Electricity Law which takes effect from July 1, 2013 regulates that electricity retailing prices shall be determined by the electricity retailing unit based on the price framework of average electricity retail price mechanism of price adjustment and the structure of the electricity retail price table.

Stakeholders

The Ministries responsible for formulating guidance on the implementation of these laws and other pieces of legislation are as follows.

- The Ministry of Construction (MOC), under which are the Division of Drainage Management and Wastewater Treatment, and the Division of Solid Waste Management of the Technical Infrastructure Agency (TIA). The MOC is responsible for urban infrastructure and construction standards, rules and regulations, including drainage and wastewater treatment and solid waste management (SWM) infrastructure.
- The Ministry of Natural Resources and Environment (MONRE) has a very broad role as encompassed by the LOEP, 2005, being responsible to the Government for performing the state management of environmental protection.
- The Ministry of Agriculture and Rural Development (MARD) is responsible for state management of agriculture, forestry, irrigation, basin water management and organic fertilizers. Under the LOEP, 2005, it is responsible for compliance with the LOEP and provisions relating to fertilizers and agricultural wastes.
- The Ministry of Health (MOH) does not have such a central role in RRR as the others but is responsible for monitoring and preventing the spread of disease, food safety and environmental health in coordination with MOC and MONRE.
- The role of the Ministry of Planning and Investment (MPI) cuts across almost all the RRR related sectors as the MPI is involved in investment planning, advice to government on foreign direct investment, socio-economic development plans, setting criteria for allocation of development investment capital, and certification of investment projects. The MPI has under its purview the Agency for Enterprise Development (AED) which provides technical advice and regulatory information to small and medium scale enterprises (SMEs).
- The MPI collaborates with the Ministry of Finance (MOF) for many of its tasks. The MOF decides on expenditure on infrastructure such as waste management facilities, collects taxes and fees, and manages state enterprises.
- The Ministry of Industry and Trade (MOIT), is an important national government player, being responsible, with MARD, for many aspects of fertilizer management, and for the energy and electricity sector. The Electricity Department has been created under MOIT, which also houses the Electricity Corporation of Vietnam (EVN), which dominates the power generation market and is currently the only player in distribution and retail (although there is a roadmap to open the market) and the Electricity Regulatory Authority of Vietnam (ERAV).

Below national level responsibility for implementing almost all legislation falls to the People's Committees (PCs) at Provincial, District and Commune level. They are, for example, responsible for State management of environmental protection at the relevant level (LOEP, 2005). They implement their various roles through departments that mirror the ministries, including, the Department of Natural Resources and Environment (DONRE), the Department of Planning and Investment (DPI), and the Department of Finance (DOF). In addition they have established a number of bodies such as Urban Environmental Companies (URENCOs) and Sanitation and Drainage Companies (SADCOs) to manage solid waste, water and sanitation. The role of the People's Committees is extensive and is mentioned in multiple laws and legal documents, for example the LOEP, 2005, which mentions their role in 44 articles including Article 61 on Water Environmental Protection Responsibilities of Provincial PCs in River Basins, Article 69 on Waste Management Responsibilities of PCs at all Levels; and Article 122 on Responsibilities of State Management of Environmental Protection of PCs at All Levels. Elements covered in their remit are environmental protection and urban planning and infrastructure development. Solid waste management is predominantly implemented by URENCO and wastewater management by SADCO.

The private sector is theoretically encouraged to participate in all sectors and there are some companies involved in wastewater and solid waste management. However, the reality is that the state dominates almost all RRR related sectors.

4.2 Institutional Support for RRR

The institutional support for RRR was considered for each waste stream and the following was found.

Wastewater reuse is an important factor in the LOWR, 2012, which offers financial incentives for WWT and recycling. The LOEP, 2005 requires centralized treatment systems, which could benefit RRR or be a hindrance, depending on how likely it is that such infrastructure will be built and its suitability. Hanoi's development plans aim for 100% wastewater collection, 80% treatment and 20-30% reuse by 2025. Sanitation and water supply are the responsibility of MOC and MARD in rural areas, with MPI responsible for investment decisions. MONRE oversees all water quality and pollution issues. There is limited collaboration but some overlap of roles. SADCO is responsible for the infrastructure but is highly stretched and there is a lack of funding and income from fees, which means that facilities are not managed effectively. Capital funding comes from the government but investment has been limited. The result is that most of the wastewater from Hanoi is discharged untreated. There is little if any collaboration with reuse sectors but the Vietnam Environment Agency (VEA) is trying to bring together sector players. Several communities are however already making use of wastewater via pumping from polluted rivers, to grow crops and cultivate fish. There appears to be little objection to this practice and there is ample market for the products.

Sludge (Faecal Sludge-FS and Sewage Sludge-SS) use for nutrient and energy recovery does not appear to be advocated although there are several pieces of legislation on septic tanks, and handling and disposal of sludge. Management comes under the purview of the same agencies as water supply and sanitation but FS management is not a priority. URENCO and the private sector are involved in de-sledging but the latter are likely to dump the waste to avoid disposal fees and because of a lack of incentives for treatment. Due to the lack of explicit regulations and clear mandates, most cities have not made FS/SS management a priority. An exception is HCMC which has passed seepage legislation to address illegal disposal.

RRR from solid waste is covered in tens if not hundreds of pieces of legislation. Cornerstones of this are the LOEP, 2005 and Decree No. 59/2007/ND-CP on management of solid waste. The LOEP, 2005, provides for tax and fee exemptions and reductions for environmental protection activities including waste recycling and clean energy production. The national strategies on environmental protection and SWM set targets for resource recovery of 85% by 2020 and 90% by 2050 respectively. There is a comprehensive structure for SWM led by MONRE with support from MOH, MOC, MPI and MOIT, and implemented by People's Committees, DONRE and URENCOs, however, like wastewater management, the large number of players can reduce efficiency. On the reuse side, nutrient recovery is accepted in various pieces of fertilizer related legislation such as Circular No. 50/2009/TT-BNNPTNT, which lays out types of waste suitable for organic fertilizer production, including MSW and industrial waste processed from agricultural products, food and animal husbandry. The lead agency certifying and regulating the sector is MARD (in collaboration with MOIT). Composting is not yet wide spread but a number of private sectors are involved and vermin-composting is a growing industry. The energy sector is another user, particularly of agro-industrial waste. Decree No. 59/2007/ND-CP advocates technologies for incinerating garbage to generate energy and of processing waste to generate biogas; and a fairly complete legal framework now exists for investment procedures for Independent Power Producers (IPPs) including the Electricity Law. The sector is however dominated by MOIT and its various departments, making it difficult for private entities to engage fairly. More recently, the mechanism supporting the development of electricity generation projects using solid waste (another energy reuse sector) promulgated in the Decision No. 31/2014/QD-TTg regulates that investors will receive support in terms of investment credit, tax incentives (including exemption of import duties of fixed assets, reduction or exemption of corporate income tax, and land rent and land use levy, etc.), and electricity price subsidies. The Decision takes effect since June 20, 2014.

4.3 Business Models

The culmination of the study was the analysis of the feasibility of seven business models of which five were found to be of medium feasibility and two of low feasibility. A brief explanation for these rankings is given in the Table 6below.

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

Business models – title and description	Content	Structure	Culture	Overall institutional feasibility and comments
Model 1a: Dry Fuel Manufacturing	Low	Low	Medium-low	**Low** because: Although a large number of households and small businesses use charcoal briquettes for cooking it is not a major government focus for the energy sector. The drive seems to come mainly from agencies worried about access for the poor and indoor air pollution. These agencies tend to be environmental groups and international organizations. There has been quite a lot of interest in improved cook stoves and environmental issues such as deforestation which may drive changes in the briquette industry. Access to raw material is low.
Model 2a: Energy	Medium-	Low	Medium-	**Low-Medium** because: Several policies and pieces of

Service Companies at Scale - Agro-Waste (or MSW) to Energy (Electricity)	Low		Low	legislation are supportive of such projects but the reality is that there is a long way to go before the sector will open up sufficiently for private sector involvement. This type of project would be viable in the longer term when the rules of engagement in the electricity sector have changed. Access to raw material is low.
Model 4: Onsite Energy Generation by Sanitation Service Providers	Medium	Low	Low	**Low-Medium** because: although this option has considerable merit for a city with on-site waste collection (septic tanks) and limited sewerage and centralized WWT, it is not supported by current policy and there are barriers for private sector engagement, primarily as a result of the dominance of the public sector. This could be changed if the government were to be convinced of the benefits of onsite treatment and energy generation and if the expertise existed in the city, which currently it does not. Some projects have been undertaken to demonstrate the value of onsite WWT and there are examples of community wastewater management but more would need to be done to spread the message and skills. Strong domination by URENCO and SADCO.
Model 6: Manure to Power	Medium	Medium	Medium	**Medium** because: there are a number of related projects in Vietnam. Although most are donor funded and implemented in rural areas they demonstrate the public support for them and the presence of experience within the country. Most are implemented by MARD but the demand from farmers suggests that there is scope for greater private sector involvement.
Model 8: Beyond Cost Recovery: the Aquaculture example	Low Medium	Medium	Low Medium	**Low Medium** because: there is legislative support for decentralized wastewater treatment implemented by the private sector or government departments. There is also financial and other incentives available but at present these are limited and would need to increase to result in sustainable and efficient WWT systems. They are also supported, at least in principle, by international donors. There do not appear to be any WWT systems with planned links to aquaculture (or other forms of income from reuse), but aquaculture is widely practiced using marginal quality water and there is high demand for fish within Hanoi.
Model 9: On Cost Savings and Recovery	Medium	Low	Medium	**Medium** because: policy supports reuse of wastewater and provides incentives such as tax exemptions and funding for wastewater treatment. Furthermore farmers are already using river water that receives large quantities of wastewater and are therefore familiar with some of the problems that they may face when using treated wastewater and have no obvious cultural or agricultural objection. The difficulty with the business model is finding the expertise and capacity, and the difficulty that the private sector have in entering the market, also the lack of collaboration between MARD and those responsible for wastewater management (Hanoi People's Committee, MOC, MONRE). The structure of this business in terms of the role of the various government entities and private

				sector, and the relationship between them will be key to making this model operational and effective.
Model 15: Large-scale Composting for Revenue Generation	High	Medium	Medium	**Medium-High** because: certainly this is supported in terms of policy and legislation content, as there are many policies, laws, decrees etc. making provision for SW recycling and composting, including financial incentives and the involvement of the private sector. In addition fertilizer laws permit the use of waste to generate compost. The limitations to the model lie in the structure and public acceptance. Currently the government structure is complicated with a number of agencies involved. The private sector are gaining ground but SWM is still dominated by the government through departments in the Hanoi People's Committee and URENCO. Public opinion is not easily gauged but is considered generally supportive although more needs to be done to encourage segregation at source and the use of the final compost product.
Model 16: Subsidy Free Community Based Composting	Medium	Low	Low	**Low Medium**, Mostly it is similar to Large scale composting model and has support from law and policy, however on the implementation side, there is poor support for private sector which puts the model at lower feasibility
Model 17: High Value Fertilizer production for profit	Medium High	Medium	Medium	**Medium High** because: Hanoi has experience with co-composting plants with support in terms of policy and legislation content. However due to complicated government structure with number of agencies involved and poor environment for private sector participation and sanitation significantly dominated by URENCO.
Model 18: Urine & Struvite at Scale	Feasibility not undertaken			
Model 19: Compost production from sanitation service delivery	Feasibility not undertaken			

4.4 Conclusion

Institutionally all the business models proposed are feasible predominantly because national legislation strongly supports RRR from waste. The legislation provides for financial support and incentives as well as the entry of the private sector. However the business models are all limited by the reality of implementation. At present many of the necessary government departments do not cooperate well but this could change as most of the sectors are managed at the local level by People's Committees. Implementation by the private sector is also hampered by the dominance of the public sector. There are several pieces of legislation and strategies to open up, for example the energy market, but there is still a long way to go. The final element that supports feasibility is that of public acceptance, along with donor support and the backing of the NGO community, which is not strong in Vietnam but is growing.

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. 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 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 Hanoi

Business Model	**Waste stream**	**End-product**	**Technologies**	**Process**
1 (a, b)	• AIW	• Briquettes	• Carbonized - low pressure • Raw - mechanized high pressure, • Carbonized - mechanized	• Briquetting
2 (a, b)	• AIW • AM	• Gasification -> Electricity • Biogas -> Electricity	• Gasification technologies • Single stage • Multi-stage • Batch • Biogas conversion technologies	• Gasification • Anaerobic digestion • Biogas to electricity conversion
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
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)
18	• Urine	• Diluted urine	• UDDTs	• Urine collection and storage
19	• Urine • Feces	• Stored urine • Soil conditioner	• UDDTs • Co-composting	• Urine application • Co-composting

6 Key findings of the Financial Analysis

6.1 Introduction

The section presents the financial feasibility assessment of the selected RRR business models for Hanoi. The RRR business models assessed for feasibility are classified into Energy, Wastewater and Nutrient based on the resource recovered from the waste generated in the city of Hanoi. The financial analysis of the RRR business models selected for Hanoi considered all the business models described in Table 2 except for Models4, Model 18 and Model 19. Business models 4 and 19 are based on public toilet systems and with high population density and lack of available space around the public toilets, there is no scope for interventions to incorporate reuse to existing public toilets. In the case of model 18, the technology is new and the possibility of technology transfer and technical viability to incorporate the system into an existing wastewater treatment plant in Hanoi is unclear.

6.2 Methodology

The methodology used for the financial assessment of RRR business models 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. Following steps were undertaken to do the financial analysis of the RRR business models:

- **Step 1:** Identification of business cases in Hanoi 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 Central Bank of Vietnam 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 RRR sector is not yet well developed in Vietnam or other regions; data availability and research on financial viability are limited. Also financial assessment had significant challenges in getting data relevant to Hanoi context. As much as possible, input data were collected from business cases identified in Vietnam, 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 which was verified and used; and also supplemented with data from literature and actualized for Hanoi. Data was also validated from the data collected by other components of the feasibility study – market, waste supply and availability, technical, and institutional assessment. Despite these measures, data used for the wastewater business models is noted to be significantly weak.

6.3 Financial Synopsis of the RRR Business Models

The following section presents the key financial highlights of the RRR business models assessed. For detailed assessment 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. As seen from the table, the energy business models show high financial viability for all the models with positive NPV and IRR greater than 12% which is the discount rate in Vietnam. The analysis was conducted at three different scales for Model 2 and as observed for 200 kW of power generation, the business model has negative NPV and IRR below discount rate. Model 4 - onsite energy generation by sanitation service providers was not assessed for Hanoi for reasons mentioned earlier.

Table 8: Energy Business Models

	Model 1: Dry Fuel Manufacturing - Agro-industrial Waste to Briquettes	Model 2: Energy Service Companies at Scale - Agro-Waste to Energy (Electricity)			Model 6: Manure to Power	Model 4: Onsite Energy Generation by Sanitation Service Providers
Scale	4,000 tons of briquette per year	200 kW generation	1.5 MW generation	8 MW generation	1,500 animals, 938 m3 biogas	Financial analysis was not done for this business model
Investment required (in USD)	186,700	394,000	1.9 million	6.5 million	340,000	
Operations Cost (in USD/year)*†	234K to 608K	87K to 220K	496K to 1.25 million	2.1 million to 5.4 million	28K to 71K	
Revenue (in USD/year)*	248K to 768K	117K to 246K	972K to 2.05 million	4.9 million to 10.2 million	95K to 245K	
NPV @ discount rate 12%**	$209,378	($290,417)	$583,042	$8, 437,961	$154,938	
IRR**	25%	-6%	17%	32%	19%	

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

6.3.2 *Wastewater Reuse Business Models*

Table 9presents the key highlights of the wastewater reuse business models. The scale was based on the new large wastewater treatment plants which are planned and under construction in Hanoi and it treats 200,000 cubic meter of wastewater on a daily basis.

Table 9: Wastewater Reuse Business Models

	Model 9: On Cost Savings and Recovery			Model 8: Beyond cost recovery: the Aquaculture example
Scale	200,000 m3 for irrigation	2000 tons of sludge per day	200,000 m3 per day & 1400 kW generated	144,000 m2 area for 85 tons of fish
Investment required (in	2.5 million	1.5 million	5.3 million	96,000

USD)				
Operations Cost (in USD/year)*†	2 to 3.8 million	312K to 645K	717K to 1.3 million	106K to 289K
Revenue (in USD/year)*	3 to 3.2 million	318K to 820K	536K to 1.4 million	127K to 660K
NPV @ discount rate 12%**	$2,690,037	(210,670)	($3,233,201)	$378,453
IRR**	43%	10%	-2%	39%

* 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

In the financial analysis of model 9, the assessment assumed an investment for the reuse infrastructure in an existing treatment plant. The financial assessment takes into consideration additional investment required to incorporate recovery of energy (including carbon credits), nutrient and treated wastewater for irrigation and related operation cost and revenue for the treatment plant. Treated wastewater used of irrigation show positive NPV and IRR greater than discount rate while sludge for compost and electricity generation show negative NPV and IRR less than discount rate. In the case of model 8, it was assumed the aquaculture would be initiated in a pond system for treating wastewater by harvesting duckweed that would be used as fish feed.

6.3.3 Nutrient Business Models

Table 10presents the key highlights of the nutrient business models. As seen from the table, for Model 15- large scale composting plants shows positive NPV and IRR greater than discount rate for 70 tons and 600 tons plant. All the plants under large scale composting is assumed to have 25% equity. The community based composting model shows positive NPV and IRR greater than discount rate. In the case of high value fertilizer production NPV is negative and IRR less than discount rate. Financial assessment for model 18 and 19 was not done for reasons mentioned earlier.

Table 10: Nutrient Business Models

	Model 8: Large-Scale Composting for Revenue Generation			**Model 16: Subsidy free Community based composting**	**Model 17: High value Fertilizer Production for Profit**	**Model 18& 19**
Scale	70 tons of MSW per day	200 tons of MSW per day	600 tons of MSW per day	3 tons of MSW per day serving 2000 households	1000 tons of compost	Financial analysis was not done for this business model
Investment required (in USD)	474K	1.3 million	3.7 million	21K	327K	
Operations Cost	73K to	230K to	600K to 1.5	22K to 56K	68K to 176K	

(in USD/year)*†	187K	596K	million			
Revenue (in USD/year)*	149K to 430K	284K to 1.06 million	904K to 3.1 million	29K to 68K	53K to 211K	
NPV @ discount rate 12%**	$228,599	($115,709)	$784,233	$23,051	($225,776)	
IRR**	18%	11%	15%	29%	-2%	

* 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 12outlines the summary on the feasibility of RRR business models for Hanoi. As mentioned earlier in the methodology, Monte Carlo risk analysis was done on the financial models for variables with high 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 in providing 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 simulation exercise formed our key indicators to assess the feasibility of the RRR business model. The indicators used to assess feasibility of RRR business models were based on – P (NPV<0), Mean NPV is positive or negative and Mean IRR is greater than or less than the discount rate in Peru (4%). The methodology used to define the feasibility is as described in Table 11.

Table 11: Feasibility Methodology

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

Using the methodology defined in Table 11, the RRR business models were assessed for their viability to Hanoi context. As seen from the Table **12**, Model 11 – High Value Fertilizer Production for Profit and Model 16 – On Cost Savings and Recovery is not feasible. Under Model 16, treated wastewater used for irrigation shows high feasibility, however it is assumed that the farmers will be willing to pay for treated water. Model 2 – Energy Service companies at scale and Model 8 – large scale composting for revenue generation, financial assessment was done for different scales and as observed 200 kW plant and 200 tons plant are not feasible. As for other scales, the model either had high or medium to high viability. The models which show high feasibility are Model 1 – Dry fuel manufacturing, Model 3 – Manure to Power, Model 17: Beyond Cost recovery – Aquaculture example and Model 9: Subsidy Free community based composting. Energy models are solely private entity driven models while remaining models analyzed are public-private partnership (PPP) models where it's assumed that land and sometimes capital is provided by the municipality.

Table 12: RRR Business Models Feasibility

RRR Business Models	P (NPV< 0)	Mean NPV	Mean IRR	Feasibility
ENERGY				
Model 1: Dry Fuel Manufacturing – Agro-industrial Waste to Briquettes	24%	$166,952	22.06%	High
Model 2: Energy Service Companies at Scale – Agro-Waste to Energy (Electricity) – 200kW plant	99.8%	($271,114)	-3.63%	Not Feasible
Model 2: Energy Service Companies at Scale – Agro-Waste to Energy (Electricity) – 1.5 MW plant	12.8%	$742,732	18.07%	High
Model 2: Energy Service Companies at Scale – Agro-Waste to Energy (Electricity) – 8 MW plant	0%	$9,219,940	33.41%	High
Model 6: Manure to Power	0.5%	$154,496	18.65%	High
Model 4: Onsite Energy Generation by Sanitation Service Providers	*Financial Feasibility not undertaken*			
WASTEWATER REUSE				
Model 9: On Cost Savings and Recovery – Irrigation reuse	8.7%	$2,680,079	44.12%	High
Model 9: On Cost Savings and Recovery – sludge recovery as soil conditioner	69.3%	($148,388)	10.38%	Not Feasible
Model 9: On Cost Savings and Recovery – electricity for onsite use	99.5%	-$2,691,011	-2%	Not Feasible
Model 9: On Cost Savings and Recovery – combined energy, water and nutrient	57.1%	($366,483)	10.66%	Not Feasible

recovery				
Model 8: Beyond Cost Recovery: the Aquaculture example	1.7%	$384,526	38.59%	High
NUTRIENTS				
Model 15: Large-Scale Composting for Revenue Generation - 70 tons	34.9%	$59,524	13.83%	Medium to High
Model 15: Large-Scale Composting for Revenue Generation - 200 tons	56.7%	($38,768)	11.12%	Not feasible
Model 15: Large-Scale Composting for Revenue Generation - 600 tons	18.4%	$992,608	15.62%	High
Model 16: Subsidy-free community based composting	27%	$22,177	32.76%	High
Model 17: High value Fertilizer Production for Profit	100%	(229,140)	-2.4%	Not Feasible
Model 19: Compost Production for sanitation service	*Financial Feasibility not undertaken*			
Model 18: Urine and Struvite Use at Scale	*Financial Feasibility not undertaken*			

While the Table 12 attempts to give a snapshot on the RRR business model viable for Hanoi context, however it needs to be noted that all the business models under a specific conditions, the models show high feasibility and similarly unviable. For example, Model 2 – Energy Service Company, becomes increasingly viable when per unit price of electricity is increased by 0.01 USD and similarly as it is reduced the viability drastically reduces. In addition, the debt to equity ratio has a significant impact on the viability with greater equity ratio improving the viability and higher debt decreasing the viability. Other than interest rates, percentage of sale of product plays a significant role in the viability. Below is brief on key aspects that determine the feasibility of each of the business models in Hanoi:

Model 1 – Dry fuel Manufacturing: Charcoal briquettes are widely used across Vietnam by households and small businesses. These businesses have performed consistently for a number of years resulting in a relatively stable market environment but a strong competition for new briquette products in the market. The business model's biggest risk is from the price of inputs (agro-waste) that highly fluctuates and the input also determines the quality of briquette which in turn dictates the price of briquette in the market. It is critical for the enterprise to build a strong partnership to procure the input raw material at relatively fixed and stable price point.

Model 2 – Energy Service Companies: Private energy-based business models are mostly seen in the hydro energy generation in Vietnam. The private sector entry to energy sector has been limited largely due to regulations and feed-in-tariffs. In the past the observed feed-in-tariff rates have been at USD 0.04/kWh and at this price it is not possible for the business model to be feasible. However recently the people's committee in Vietnam have recommended new tariffs with floor price of USD 0.11/kWh and ceiling price of 0.18/kWh. The financial assessments were carried out for the newly introduced tariff. The financial assessments show that these plants are highly price sensitive to electricity sale price. And with increased equity contribution, even the 200 kW plant can yield positive NPV. The business shows increasing viability when the equity portion of the investment is increased.

Model 6–Manure to Power: This business model is specific to private ownership and the model is based 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 faced is in the case of a lack of availability of land to construct anaerobic digester. The agro-waste generated from any medium or large agro-industry is high and enough to cover internal energy requirement. In the case the business generates excess energy, it can sell it to neighboring households and businesses. The investment shows high viability and assuming the markets for sale of excess energy is nearby or there is possibility of feeding excess electricity to grid the viability can be significantly improved. The business hardly has any variables that dictate its viability, however plant operation days and electricity price dictate the extent of profitability.

Model 8 – Beyond cost recovery the aquaculture example: The financial analysis of the model assumed a construction of a pond based system to cultivate duckweed to treat the water. Fish is raised in a separate pond with treated water and duckweed is used as fish feed. The business would require partnership with municipality to source wastewater. The business is highly sensitive to the scale of operations. At a lower fish production, it is not viable to undertake it as the cost of labor to manage aquaculture makes the investment unviable. In addition the price of inputs (fingerlings) and the price of fish also determine the business viability. The concern of market acceptability is minimal as rarely are consumers aware of source of water used for aquaculture.

Model 9 – On Cost savings and recovery: The financial analysis of this model focused on the reuse component and does not take into consideration the setting up of a new wastewater treatment plant. Three scenarios were developed based on the type of resource recovered (energy, water and nutrient). The key assumption in the case of water and nutrient recovery is sale of treated wastewater for irrigation (or industry) or sale of sludge as soil conditioner. We acknowledge that these assumptions of sale is the riskiest aspect of this business model as farmers rarely pay for freshwater in developing countries and to assume that they would pay for treated water is questionable. In the event of drought or water scarcity, there is possibility of increased willingness to pay for treated wastewater. Alternatively, the treatment plant could target sale of treated water to industries. The feasibility of supplying treated wastewater also depends on the length of the canal or pipeline and pumping costs to deliver the water to its customer segment. Similar is the case for sale of sludge as soil conditioner where farmers are willing to pay for sludge from treatment plant. In the case of electricity generated, financial assessment shows that about 35% of energy required for the treatment plant is covered and viability is significant, however high investment cost and lower electricity price are key aspects for non-feasibility of the scenario. A treatment plant incorporating all these reuse investments does not yield a positive NPV.

Model 15 – Large scale composting for revenue generation: The financial assessment was conducted for three different scenarios and it was observed that the 200-ton plant does not show feasibility without any subsidy or incentives. 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 60% to 90%). In this study, it has been observed that in developing countries, most compost plants from 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. The price of compost is one the most sensitive parameters that drives viability of the business and with higher prices the business can be highly viable at all scales.

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 for the assessment only the revenue from household fees and sale of compost were considered. While the business shows high viability, it could improve the viability, if the business partners with larger compost facility or fertilizer companies to sell the compost else the business is focusing on too many aspects – collection of MSW, production of compost and sale of compost. The business has higher potential to capture urban customers who have higher willingness to pay for the compost in comparison to farmers. With increased compost price, the business can show higher feasibility.

7 Key findings of the Health Risk and Impact Assessment

7.1 Introduction and methodology

For the 4 targeted feasibility cities of the RRR project, the health components around the selected business models (BM) employed two methodologies, with two different foci: Health Risk Assessment (HRA) and the Health Impact Assessment (HIA). The HRA aimed at identifying health risks associated with the input resources (e.g. faecal sludge, waste water) of proposed BMs and defining what control measures are needed for safeguarding occupational health and producing outputs (e.g. treated waste water, soil conditioner) that are compliant with national and international quality requirements. The HIA aimed at identifying potential health impacts (positive or negative) at community level under the scenario that the proposed BMs are implemented at scale in Hanoi. The magnitude of potential impacts was determined by means of a semi-quantitative impact assessment. The feasibility studies in Hanoi were oriented towards 11 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 2a: Energy service companies at scale: agro-waste to energy (electricity)
- 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 recovery
- Model 15: Large-scale composting for revenue generation
- Model 16: Subsidy-free community based composting
- Model 17: High value fertilizer production for profit
- Model 18: Urine and struvite use at scale
- Model 19: Compost production for sanitation service Delivery

7.2 Evidence-base of the HRIA

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

- Case 1: Nam Son landfill

- Case 2: CauDien composting plant
- Case 3: Co Dong livestock service cooperative Son Tay town, Hanoi
- Case 4: KieuKy waste treatment plant (landfill)
- Case 5: Wastewater treatment and management by the Hanoi Sewerage and Drainage Limited Company (HSDC)
- Case 6: Wastewater reuse in the peri-urban area of Hanoi (Thanh Tri district)

The cases were studied considering the given context and by following a similar methodology in all 4 feasibility study cities. An additional important component of the case studies were an assessment of the use and acceptability of personal protective (PPE) among the workforce. In addition to the standardised methodology of the health component around these six existing RRR cases, the city of Hanoi benefited from a complementary in-depth survey in the frame of a PhD study project, which focused on environmental and health risks related to the reuse of wastewater for agriculture. The in-depth study focused on the To Lich River (one of the city's main open drainage channels which was also selected as a SSP testing site). With the aim to generate evidence on the exposure risk along the wastewater chains in Hanoi, a cross-sectional survey was carried out to assess and map the existing exposure risks due to wastewater. A total of 675 individuals participated in the study, representing different exposure groups: Workers at HSDC (n=128); farmer (n=278); community members (n=269). The cross-sectional survey comprised two components: (i) a questionnaire study to obtain self-reported data on health risks and health outcomes (e.g. diarrhoeal episodes and skin and eye disease) related to the exposure to wastewater and faecal sludge; and (ii) the collection of stool samples to determine the prevalence and the intensity of parasitic infections. The stool samples were analysed for helminth infections by means of the Kato-Katz technique. As a quality control measure, one stool sample was subjected to duplicate Kato-Katz thick smear. Protozoa infections were assessed with the formalin-ether concentration technique (FECT). In the environmental sampling component of the in-depth study, a total of 230 water samples were collected over a period of 8 weeks (April to June 2014). Samples were tested for the following indicators: coliform forming units (CFU) of (i) faecal coliform bacteria and (ii) E. coli; Salmonella spp.; and (iv) helminth eggs.

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 Hanoi, specific diarrhoea diseases, flu, shigellosis, dengue fever and varicella (chickenpox), all of which are communicable diseases, were the leading causes of morbidity at health facilities in urban, peri-urban and rural settings of Hanoi in 2007 and 2011. The most striking difference between different environments is the high number of dengue fever cases reported at the urban health facilities when compared to the peri-urban and rural health facilities. With regard to access to sanitation facilities, the 2009 Vietnam population and housing census found that 46% use non-improved toilet facilities (61% in rural areas and 12.2% in urban areas), while 10.2% of the households in rural Vietnam have no toilet facilities. In Hanoi water supply is managed by Hanoi Water Work Authority under the Hanoi Party Comity. In general the public water supply is characterised by low pressure, frequent interruptions and occasional contamination.

Against this background, it is not surprising that all major STH species are endemic and of public health importance in Hanoi. In our own in-depth study, the most common STH infection was hookworm with a prevalence of 15.5% in local farmers. Prevalence of intestinal protozoa was found to be very low, i.e.

≤1.0% and differences between exposure groups were not at statistically significant levels. In Vietnam, both fish-borne zoonotic trematodes that infect the liver and the intestines are common, with prevalences up to 50%. Skin disease among farmers using wastewater is a common reported health outcome in Vietnam. A study in Nam Dinh, northern Vietnam could show that exposure to wastewater was a major risk factor for skin disease with a relative risk (RR) of 1.89.

Acute respiratory diseases, particularly flu, are a major public health concern in Hanoi (second leading cause of consultations at health facilities). This clearly shows that a lot of transmission is taking place, with poor personal hygiene and weak sanitation system as important determinants. Also the burden of chronic respiratory diseases and cardiovascular diseases is high, accounting for 7% and 33% of total mortality (all ages, both sexes), respectively, in Vietnam. Various vector-borne diseases are endemic and of major public health relevance in Vietnam (e.g. malaria, dengue and Japanese encephalitis). There is, however, great geographical variation in the frequency of transmission in vector-borne diseases. Due to climatic and environmental factors, Hanoi city is not considered a risk area for Malaria transmission, with rare cases being reported by Hanoi's health system. In contrast, annual reported cases of Dengue fever varied between 500 and 16,000 in Hanoi in 2009-2011.

With regard to environmental parameters, the water quality monitoring data in the four main rivers and lakes in Hanoi have clearly shown that the water quality of rivers, lakes and ponds is worsening due to the discharge of untreated industrial wastewater, which contains toxic substances, inorganic substances and high organic content. Averagely, concentrations of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), heavy metals and coliform in To Lich, Lu, Set and Nhue rivers are 3–4 times higher than target values. In our in-depth study, bacteria concentration was found highest in Nhue and Red River with up to 6.5 log CFU total faecal coliform. Helminth egg concentration where all below 1 egg/L and hence below WHO thresholds for wastewater reuse in agriculture. Only 5 and 7 samples were found positive for *A. lumbricoides* and *T. Trichiura*, respectively.

7.4 Key findings of the HRA

All of the identified occupational health risk – such as exposure to pathogens, skin cuts or inhalation of toxic gases – can be managed by providing appropriate PPE, health and safety education to workers and appropriate design of the operation and technical elements. Biological hazards mostly derive from human and/or animal wastes that serve as inputs *per se* for the proposed BM (e.g. animal 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.

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

In terms of physical hazards, sharp objects deriving from contaminated inputs (e.g. faecal sludge or MSW) ending-up in soil conditioner are a risk that has been identified for a number of BM. This will require careful pre-processing of inputs and sieving of End-products. Moreover, users need to be 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. Concerns about heavy metals and other chemical contaminants remain for all the wastewater-fed BM. From a health perspective, wastewater fed agriculture (Model 8) in Hanoi needs to be promoted with care , also since the concentration of heavy metals is likely to further increase over time due to accumulation in the soils. Model 15 and 17, both of which use municipal solid waste (MSW) as an input, are only an option if no medical waste from health facilities is mixed with common MSW.

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 Hanoi 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 major positive health impact. Under the given scenarios, Model 8 (beyond cost recovery: the aquaculture example) has the greatest potential for having a positive impact since it will result in a reduction in exposure to pathogens at community level. It has, however, to be noted that this only applies if the wastewater that is used for aquaculture is compliant with national and international quality requirements regarding toxic chemicals. Also Model 9 (treated wastewater for irrigation/fertilizer/energy: on cost savings and recovery) has considerable potential for resulting in positive health impacts 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.

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 Hanoi will use briquettes from the BM as cooking fuel	Impact 1: increase in chronic respiratory disease and cancer	**Moderate negative impact (-560)**
Model 2a – Energy service companies at scale: agro-waste to energy (electricity)	50 villages in rural and peri-urban areas of Hanoi will implement the BM	Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases	**Moderate positive impact (75)**
		Impact 2: changes in health status due to access to electricity	**Insignificant (0)**
Model 4 – Onsite energy generation in enterprises providing sanitation services	30 villages in rural and peri-urban areas of Hanoi will implement the BM	Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases	**Moderate positive impact (90)**
		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 Hanoi 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 and 10'000 community members benefitting from the treated wastewater	Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases	**Moderate positive impact (545)**
		Impact 2: reduction in exposure to toxic chemicals (e.g. heavy metals)	**Minor positive impact (325)**
		Impact 3: access to electricity	**Insignificant (0)**
Model 15 – Large-scale composting for revenue generation	Two centralised co-composting plants are installed in Hanoi, serving 2'000 households each	Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases	**Moderate positive impact (90)**
		Impact 2: indirect health benefits due	**Minor positive**

		to reduced MSW loads on landfills	**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 Hanoi, 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 18 – Urine and struvite use at scale	No health impacts at community, farmer or consumer level are anticipated for this model		**Insignificant (0)**
Model 19 – Compost production for sanitation service Delivery	30 villages in rural and peri-urban areas of Hanoi will implement the BM	Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases	**Moderate positive impact (90)**

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 Hanoi

Business Model	Waste stream	End-product	Technologies	Process	Pot. Env. Hazard	Mitigation measures
1 (a, b)	• AIW	• 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
2 (a, b)	• AIW • AM	• Gasification -> Electricity • Biogas -> Electricity	• Gasification technologies • Single stage • Multi-stage • Batch • Biogas conversion technologies	• Gasification • Anaerobic digestion • Biogas to electricity conversion •	• Hazardous air emissions • Residuals (tar, char, oil) • Solid residue (digestate) • Liquid effluent	• Air emission control technologies • Collection/Storage/Disposal at appropriate location • Solid/liquid residue post-treatment
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

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
18	• Urine	• Diluted urine	• UDDTs	• Urine collection and storage	• Ammonia intoxication • Ammonia oxidization	• Urine dilution with water
19	• Urine • Feces	• Stored urine • Soil conditioner	• UDDTs • Co-composting	• Urine application • Co-composting	• Ammonia intoxication • Ammonia oxidization • Insufficient pathogen inactivation • Leachate from co-composting	• Urine dilution with water • Moisture control • Leachate treatment • Temperature control (compost heap)

9 Key findings of the Socio-Economic Assessment

9.1 Introduction

The section presents the socioeconomic assessment of the selected RRR business models. The socioeconomic assessment acts as a decision making tool for determining the feasibility of the business model from a 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 of the system boundary. This is an integration of two aspects –

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

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

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

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

- **Step 5:** The socioeconomic viability of an RRR business model was 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 evaluate 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 noted in the synopsis of the financial assessment since the RRR sector is nascent in Vietnam, data access and availability were limited. This was even more critical for the socio-economic assessment which relied heavily on the secondary databases and the financial models. The financial models developed for the business cases served as the data source for the economic data used in the socioeconomic assessment. The data for the environmental and health costs and benefits were obtained from secondary sources and the literature survey contextualized for Vietnam. However, in certain cases where data was not available, data from certain reports showing global figures or assessments were utilized and actualized for the context of Hanoi. Since the financial model is the base for the economic model, it needs to be mentioned here that economic data not available for the businesses were mined from the different business sources operating in Asia, Africa and Latin America and were verified before their use. However, as explained before in the financial assessment, data sources for wastewater is weak and this produces a cascading effect in the socioeconomic assessment as well.

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 adjusted such that the entire waste can be utilized by the particular business. The socioeconomic assessment of the business models is performed taking into consideration two contrasting situations where the baseline condition refers to the present situation in Hanoi and the alternative scenario proposes the introduction of the business. The scale of operation for each of the businesses is based on two aspects –

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

The following table (Table 15) indicates the baseline and alternative scenarios and also describes the scale of operation for the different business models in Hanoi.

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			
Dry-fuel manufacturing (Agro-waste to briquettes)	3819 tons of organic waste accumulates daily in the peri-urban areas which includes wastes from rice husk and straw, corn, sweet potato, cassava waste, sugarcane waste, soya bean and peanut	The alternative scenario assumes that briquette plants targets the wastes from rice husk. Thus this assumption leads us to the fact that 15 large scale plants as had been considered in the financial analysis (consumption on 2222 tons of agro-waste per year) would be needed to consume the whole of the waste.	
Independent power producer/private power developer (Agro-waste to electricity)	3819 tons of organic waste accumulates daily in the peri-urban areas which includes wastes from rice husk and straw, corn, sweet potato, cassava waste, sugarcane waste, soya bean and peanut	Financial analysis considers 8 MW plant utilizing 250 tons/ day. The alternative scenario assumes that electricity generating plant targets 75% of the wastes from rice husk. This implies that 10 plants have to be considered in SEA which takes up all of the organic waste generated.	
Power capture model – Livestock to energy	The 3 major livestock companies do not produce power from animal manure	The alternate scenario considers all the 3 major livestock companies produce electricity each with a capacity of 218 kW	
System Boundary for the Wastewater models			

Business Models	Base case	Alternative	Remarks
Wastewater treatment and fish production	Out of 651,400 m^3 of wastewater generated per day, 248,100 m^3/d is being treated. It has been planned that the remaining wastewater is to be treated in two WWTP of treatment capacity about 200,000 m^3/d. No wastewater aquaculture is being practiced	In the alternate scenario, the socio-economic study models three different pond sizes – 14.4 ha. 4.5 ha. and 1 ha. Based on the capacity of the existing WWTP and the planned WWTPs, number of ponds required with their estimated size has been calculated. In each of these cases, while calculating the pond size (area) it has been assumed that aerobic maturation pond is used for the final level of treatment.	
Treated wastewater for irrigation/electricity/fertilizer – cost recovery	Treated wastewater of volume 248,100 m^3/d is being discharged into water bodies. The amount of wastewater treated and planned to be treated is 651,400 m^3/d.	In the financial analysis two scales of WWTP is being modeled – 42,000 m^3/d and 200,000 m^3/d. The alternate scenario considers 2 large size and 3 medium sized treatment plant (following the financial analysis), treating 596,100 m^3/d.	In the financial analysis no investments costs for setting up the WWTP is considered. It is being assumed that the WWTP already exists and additional investments for electricity generation, water treatment and compost recovery is analyzed. Similarly in the socioeconomic assessment, the same assumption of existence of WWTP is maintained. In the socio-economic assessment the existing smaller plants of 13,000 m^3/d, 2,300 m^3/d & 3,700 m^3/d are not being considered since it is not technically feasible to produce electricity from these pilot small plants.
System Boundary for the Nutrient Models			
Centralized large-scale compost production for carbon emission reduction (MSW to compost)	The municipal waste that is being collected is open-dumped and landfilled. In Hanoi, The total waste generated per day is 6500 tons of which 55-60% of the total generated amount of MSW (about 3600 tons) is actually collected and transported to landfill. The rest is open-dumped along banks and embankments of the rivers.	6 Compost plants of 600 tons is assume which would handle all the MSW generated.	In the financial analysis compost plants of 600 tons has been assessed. The data from these models will be incorporated in the Socio-economic Assessment (SEA)
Decentralized community based MSW composting	The municipal waste that is being collected is open-dumped and landfilled. In	The amount of waste targeted to be collected and composted through de-centralized operation is about	It is assumed that decentralized system of waste collection is more efficient and

Business Models	Base case	Alternative	Remarks
	Hanoi, The total waste generated per day is 6500 tons of which 55-60% of the total generated amount of MSW (about 3600 tons) is actually collected and transported to landfill. The rest is open-dumped along banks and embankments of the rivers.	4500 tons per day. The alternate scenario assumes formation of 104 co-operatives at the ward levels and 7 such co-operatives are linked with a business entity responsible for collection of waste.	hence a greater amount of waste is being targeted.
High Quality branded/certified organic fertilizer from faecal sludge and MSW	Fecal sludge is dumped or being partially treated	The scale of operation for the fortifier is 9 plants which generates 1000 tons of fortifier yearly. This can accommodate 16 tons of fecal sludge per day since each of the plant will handle around 2 tons of dewatered fecal sludge per day.	

9.4 Synopsis of the socioeconomic assessment of the RRR business models

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

9.4.1 Energy Business Models

Table 16provides 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 2: Energy Service Companies at Scale - Agro-Waste to Energy (Electricity)**	**Model 6: Power capture model – Livestock to energy**
Scale of operation	15 plants, each having a production capacity of 2000 tons per year	10 plants each with a production capacity of 8 MW	8 plants each with a generating capacity of 218 kW

NPV Financial (in USD)**	3,125,002	(32,898,502)	1,004,009
NPV Financial & Environmental (in USD)**	4,971,054	27,976,857	727,503
NPV Financial, Environmental & Social (in USD)**	14,025,925	179,098,933	10,709,636
B:C Ratio	10.17	3.58	6.58
ROI	100%	53%	464%

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

9.4.2 *Wastewater Reuse Business Models*

In the context of Hanoi, two different scenarios are considered – (i) Treated wastewater for irrigation, fertilizer and energy, and (ii) Wastewater for irrigation and ground water recharge. Table 17provides key highlights of wastewater reuse business models. The scale was based on the input wastewater quantity in Hanoi which was from the waste supply and availability data based on sewer network in Hanoi. Both of these models exhibits higher environmental and societal benefits in terms of reduction of pollution and health benefits. Using WSPs has a lower cost which is also being reflected in the NPV of the financial benefits from the introduction of wastewater for recharge and utilization in agriculture.

Table 17: Wastewater Reuse Business Models

	Model 8: Wastewater-fed aquaculture	**Model 9: Treated wastewater for irrigation/fertilizer/energy – cost recovery**
Scale of operation	An estimated 63 aerobic ponds of 14.4 ha.; 4 ponds of 4.5 ha and 3 ponds of 1 ha. is being used for aquaculture within the existing and planned WWTPs.	The capacity of the wastewater treatment plant is considered to be 42,000 m^3 and 200,000 m^3. 2 large size plants and 3 medium sized plants are used for evaluation
NPV Financial (in USD)**	6,088,209	(14,848,445)
NPV Financial & Environmental (in USD)**	8,486,791	491,047,520
NPV Financial, Environmental & Social (in USD)**	53,232,036	679,337,423
B:C Ratio	8.8	27.63
ROI	155%	443%

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

9.4.3 *Nutrient Business Models*

The nutrient business models have been compared in 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	6 plants each with a handling capacity of 600 tons of MSW is assumed. Total compost production capacity in each plant is 96 tons per day	104 co-operatives with 15 business entities is said to serve about 70% of the population in Hanoi	9 plants are assumed to consume the entire faecal sludge produced and each with a production capacity of 1000 tons in a year
NPV Financial (in USD)**	(43,45,607)	(783,795)	(2,75,9413)
NPV Financial & Environmental (in USD)**	9,815,107	14,010,280	2,533,644
NPV Financial, Environmental & Social (in USD)**	60,789,713	74,502,891	21,770,187
B:C Ratio	4.81	14	7.77
ROI	31%	200%	74%

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

9.5 Summary assessment of financial feasibility of RRR Business Models

Table 19provides a summary overview of the criteria used for feasibility of RRR business models for Hanoi based on the socioeconomic assessment. Three main criteria were used to assess the feasibility of the business model - (i) Benefit-Cost Ratio (BCR), (ii) Rate of Investment; and (iii) Probability distribution of the Net Present Value (NPV). The BCR was derived as a ratio of economic, social, health and environmental benefits to the costs in monetary terms. Any project or business with a BCR greater than 1 is termed to be generating more societal benefits compared to the costs for implementing the project and therefore the BCR was used as the governing criterion for the feasibility assessment. The Rate of Investment (RoI) was determined based on all the benefits that accumulated from the business with respect to the initial investments made for the business. Along with these criteria, the probability distribution of the NPV based on the uncertainty of different parameters used in the model was used.

As mentioned earlier in the methodology, a Monte Carlo risk analysis was performed on the Net Present Value (NPV) derived from the costs and benefits from the different parameters of the socioeconomic models. These parameters which were considered as stochastic in the model were defined by a suitable probability distribution to represent uncertainty in the values used for the models. For the Monte Carlo analysis a large number of iterations were performed to obtain empirical estimates of the NPV and also derive a probability distribution of the NPV. The probability distribution obtained for the NPV was used as one of the criterion for assessing the feasibility of the business model. The mean value obtained from the probability distribution of the NPV was taken as a benchmark for determining the feasibility. The probability distribution thus generated was utilized to find out the probability of the NPV value below the benchmark (mean). The methodology used to define the feasibility is as described in Table 19below.

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

Using the methodology defined in Table 19, the RRR business models were assessed for their viability in the context of the Hanoi city. Based on the criteria of assessment, it is found that the energy models have a lower feasibility compared to that of the wastewater and the nutrient models. All the energy models have a BCR greater than 1 however, the ROI is lower than 100% indicating that the business model would not be able to reap benefits larger than the investments. Along with these observations, it was also estimated that the probability of NPV dipping down from the mean value is more than 50% or close to it. In comparison to these scenario, although the models for wastewater and nutrients had probability values close to 50%, the other criteria of BCR to be greater than 1 and RoI of more than 100% make the business models to be feasible at a medium range. It has been mentioned previously that economic costs and benefits utilize the database from the financial analysis. At the same time the financial models had been scaled up linearly to meet the waste resources from different waste streams produced in Hanoi. Therefore, it becomes imperative to check the convergent validity of the financial and socioeconomic model in which further we assess the social, environmental and health aspects. The results of the socioeconomic assessment for the wastewater and nutrient models conforms to that of the financial analysis while that of the energy models (excepting the Energy Service Companies) differ in the results.

Table 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	49.4%	10.17	100%	High

Model 2: Energy Service Companies at Scale - Agro-Waste to Energy (Electricity) – *8MW Profit Maximization Model*	55.1%	3.58	53%	**Low**
Model 6: Power capture model – livestock waste to energy	53.9%	6.58	464%	**Medium**
WASTEWATER REUSE				
Model 8: Wastewater-fed aquaculture	52.27%	8.8	155%	**Medium**
Model 9: On Cost Savings and Recovery – combined energy, water and nutrient recovery	48.8%	27.63	443%	**High**
NUTRIENTS				
Model 15: Large-Scale Composting for Revenue Generation - 600 tons	50.1%	4.81	31%	**Low**
Model 16: Decentralized community based composting	53.8%	14	200%	**Medium**
Model 17: High value Fertilizer Production for Profit	48.4%	7.77	74%	**Low**

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

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

Model 2 – Energy Service Companies: This business model has a lot of potential when we consider electricity generation which Vietnam imports from China. The total potential for all agro-waste being utilized for electricity generation in Hanoi is about 32 MW. Associated with this there is net GHG emissions saved per kWh of electricity generated is 2.724 kg CO2eq. The highest savings in GHG emissions are mainly from avoided burning of agro-waste while the highest emissions from the business model is from the gasifier. In the present situation most of the agro-waste finds its way to the landfills and open dumpsites. However, as the financial analysis indicates that larger scale plants are very sensitive to price of electricity for feed-in-tariffs which are currently on the lower side in Vietnam (the price of the feed-in-tariff for renewable energy particularly agro-waste is yet to be decided in Vietnam), this model faces a stiff challenge financially. The next challenge for the business model is the accessibility of the agro-waste as mentioned previously.

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 import of electricity from China and also reduction in the wastewater run-off with a high BOD content from the farms.

Model 8– Wastewater-fed aquaculture (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 Hanoi with the newly planned WWTPs coming up there is a lot of potential for electricity generation. Consideration of the health and environmental aspects shows that there is substantial amount of reduction in surface and groundwater which has indirect costs associated inter-temporally. In addition there is also a potential of earning benefits due to reduced GHG emissions and savings incurred in using compost as a soil ameliorant which reduced the fiscal burden. The socioeconomic feasibility shows that health issues among farmers which might arise due to use of wastewater is overweighed by the benefits incurred. However, application of the business model should be subjected to the research on health effects both on consumers and farmers consuming food irrigated by wastewater and producing food irrigated by wastewater respectively.

Model 15 – Large scale composting for revenue generation: The financial analysis shows that large sized compost plants of 600 tons/day is not feasible. The socioeconomic assessment considered the 6 plants of same scale for absorbing the waste of the city. The economic feasibility of the model is similarly low in spite of the fact that there are savings in terms of GHG emissions. In fact the amount of GHG emissions are quite low to ensure the feasibility of the business.

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

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

10 Synthesis of Feasibility Studies

This section presents the overall synthesis and ranking of the potential feasibility of the selected business models for Hanoi. 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 21below.

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 22below. It is noted that the *'wastewater-fed fish' and* 'large-scale MSW-based composting' models have the highest feasibility potential for implementation in Hanoi. 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)

The market analysis results suggest that a considerable percentage of households, livestock producers and food service businesses are willing to pay for briquettes. On average, 60-80 % of the households, livestock producers as food service businesses surveyed indicated a positive WTP for briquettes. Interestingly, the WTP measure for households is similar to that of livestock producers, whilst that of food service businesses are comparatively higher. The households' WTP estimate (3,400 VND/kg) was noted to be considerably higher than the current prices of briquettes (about 1.5 thousand VND per kilogram) sold in the South of Vietnam but fairly close in price to that of fossil coal. The same result (3,400 VND/kg) was estimated for the livestock producers. Food service businesses, on the other hand, had a marginally higher WTP, averaging at 3,800 VND/kg. Whilst the current production level of briquettes is unknown and estimated to be fairly low, it is clear that it is a nascent industry with minimal entry barriers, and inherent distortions in competitors' markets represents opportunities for the development of the briquette industry. Although still in strong effect, the state monopoly of the LPG market has been challenged over the years due to new entrants particularly fully owned private companies and joint stock companies and their high growth rate. Domestic prices are additionally determined mainly by the import price plus transportation cost as nearly 50% of LPG market depends upon the import from other countries. Thus, the domestic market is highly vulnerable to erratic fluctuations in world market prices due to the high level of imports and limited storage capacity which is insufficient to stabilize the market. These inefficiencies in the LPG market represent opportunities for new briquette businesses to capture part of the related energy market.

Furthermore, this model is economically and financially viable. There is a significant increase in the economic feasibility of the business due to social and environmental benefits associated with the business. However, price of the inputs highly fluctuate which pose a significant threat to the business. Although there is a growing and substantial market demand for agro-waste briquettes in Hanoi and the business model is financially viable, it has a low feasibility potential for implementation. This is mainly driven by two factors: a) limited availability and access to waste input and b) restrictive institutional factors. From an institutional perspective, it is noted that although a large number of households and small businesses use charcoal briquettes for cooking it is not a major government focus for the energy sector. The reluctance for support and negative perceptions of the product is mainly driven by agencies worried about access for the poor and indoor air pollution.

Model 2a - Energy Service Companies at Scale: Agro-Waste to Energy (Electricity)

Similar to business model 1a, the low feasibility of this business model is related to the limited availability of agro-waste in urban and peri-urban Hanoi. Additionally, although there are several supportive policies and legislations, the reality is that there is still a significant amount of work that needs to be done to sufficiently incentivize private sector involvement. Compounding the low feasibility of this model are the market distortions in the energy sector.Generally, there is a significant and growing demand for electricity in Hanoi and Vietnam as a whole and opportunities for waste-to-energy entities to fill this gap based on the anticipated rapid rural electrification program; foreseeable increasing trend in electricity prices; structural and legal feasibility for private sector involvement (some degree of structural unbundling of the Vietnamese power sector, vertically integrated monopoly and privatization of the generation and distribution); a lesser vertically integrated market; and supportive renewable energy policies among others. The increasing number of independent power producers in the energy sector in recent years is also indicative of the fair structural feasibility of the Vietnamese electricity sector. However, electricity producers are currently price takers and restricted to the price ceiling set by the state-owned transmission entity EVN (limited negotiation ability – monopolistic market). Thus, in actuality, the level of market concentration, price setting behavior and potential net profit margins (business performance) will determine the sustainability of a waste-to-energy business, which for the first two factors are significant limiting drivers. The opportunity for waste-generated electricity can only materialize when offered prices in the power purchase agreement (PPA) can substantially cover production costs; as confirmed by the financial analysis which indicates that larger scale plants are very sensitive to the price of electricity for feed-in-tariffs[8].Additional limiting factors to business development and sustainability in the sector are: a) continued interest and large hydro-power potential; b) significant interest in small hydro-power projects and c) waste-to-energy projects currently viewed as high-risk ventures by financial investors. While producer prices can be increased, additional market failures inherent in the energy sector can only be rectified with the institution of sound policies.

Model 4 - Onsite Energy Generation by Sanitation Service Providers (faecal sludge to energy)

The low feasibility of this business model is driven by the following key factors: a) lack of an enabling institutional environment, b) market distortions in the energy sector and c) waste availability. Although this business model has considerable merit for a city with on-site waste collection (septic tanks) and limited sewerage and centralized WWT, it is not supported by current policy and there are barriers for private sector engagement, primarily as a result of the dominance of the public sector. This could be changed if the government were to be convinced of the benefits of onsite treatment and energy generation and if the expertise existed in the city, which currently does not. Some projects have been undertaken to demonstrate the value of onsite WWT and there are examples of community wastewater management but more would need to be done to spread the message and skills.

Model 6 - Power Capture Model (livestock to energy)

The results showed that the proposed business model has a low feasibility potential for Hanoi and this is mainly driven by the distortions in the energy market. As with model 2, 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; and thus the opportunity for waste-generated electricity can only materialize when offered prices in the power purchase agreement (PPA) can substantially cover production cost.

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 Hanoi, Vietnam. This business model has a potential

[8]Prices are noted to be currently low in Vietnam (the price of the feed-in-tariff for renewable energy particularly agro-waste is yet to be decided in Vietnam),

for implementation with: a) available wastewater treatment plants and city lakes for integrated aquaculture, b) financial viability, c) significant market demand and d) supportive policies. There is legislative support for decentralized wastewater treatment implemented by the private sector or government departments. There are also existing financial incentives for wastewater reuse but at present these are limited and would need to increase to further incentivize investment. The market analysis results showed that households are willing to pay about 9.20 VND per kg and 25.08VND per kg for wastewater-fed tilapia with information on the sources of water and certification by a trusted government agency respectively. Thus, it is important for new businesses to consider the provision of a fish product with clear labeling by a third party - a government entity preferred. 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.

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 labour 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[9].

Model 9 - On Cost Savings and Recovery (wastewater use for irrigation, energy and nutrient recovery)
There are existing supportive policies for the reuse of wastewater such as the provision of incentives (i.e. tax exemptions and financing for wastewater treatment) in Hanoi that are essential for the feasibility of this business model. Furthermore, considering the key customer segments - i.e. farmers they are already using river water that receives large quantities of wastewater and are therefore familiar with the use of treated wastewater and have no obvious cultural or agricultural objection. The challenge with the implementation of this business model however is two-fold: 1) the difficulty of private sector entry into the market and b) market demand as measured by the farmers' willingness-to-pay for treated wastewater. Farmers in Hanoi do not have to pay for an irrigation fee. Most if not all farming households in Hanoi have full subsidization of irrigation fees from the current irrigation system, suggesting that farmers will not be willing to pay for treated wastewater. The key factor however that drives the infeasibility of this business model is its limited financial viability. The financial analysis of this model focused on the reuse component and did not take into account the setting up of a new wastewater

[9]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.

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 drought or water scarcity, there is possibility of increased willingness to pay for treated wastewater. The feasibility supplying treated wastewater will also depends on the length of the canal or pipeline and pumping costs to deliver the water the different customer segments. The inference from this result also applies to the sale 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, however high investment cost and lower electricity price are key drivers of the infeasibility of the business model. A treatment plant incorporating all these reuse investments does not yield a positive NPV. Although this business model is not financially viable, the option for some cost-recovery and the socio-economic benefits are significant and would justify an investment for the addition of a reuse component to existing or new wastewater treatment plants. The implementation of this model has the potential to significantly reduce surface and groundwater contamination. Additionally, there is the potential for reducing GHG emissions. Whilst there might be some potential health risks associated with wastewater use, it is assumed that this business model requires the wastewater to be treated to a level safe for use. Additionally, any health risks will be mitigated with a reasonable set of control measures.

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 Hanoi. The feasibility is driven mainly by: a) high financial viability, b) supportive institutional and legislative environment, c) significant market demand and d) available technologies. The market analysis results show that there is a demand for MSW-based compost. Consumers' WTP, for compost is significantly higher than the average market price for substitute products ranging between 1000-2000 VND/kg. The results indicated that the farmers were willing to pay more to know the source of the input materials used to produce the compost (i.e. MSW, faecal sludge and/or animal waste) and certification. This suggests that high quality compost product if labelled with information on source of the inputs and has 3rd party certification will command a market price of 2826 VND/kg - which is almost 1 - 2 times higher than the current market price. From an institutional perspective, the use of MSW is well-accepted and supported by policy makers, authorities, private sector players, farmers and communities. The financial assessment was conducted for three different scenarios and it was observed that the 200-ton plant is not feasible without any subsidy or incentives. As per 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 expected to be sold year on year (from 60% to 90%). Previous research from other developing countries show that most compost plants that use municipal solid waste struggle to sell compost (less than 50% sales) and mainly undertake compost production to reduce the overall quantity of waste sent to landfill. The price of compost is one the most sensitive parameter that drives the viability of the business and with higher prices the business can be highly viable at all scales.

Model 16 - Subsidy-free Community Based Composting (municipal solid waste to compost)
Although similar to model 15 - this business model has a low feasibility potential and this is mainly driven by the limited space in urban Hanoi for decentralized community level composting activities.

Additionally, MSW is not source-separated and this may represent additional operational costs. From the institutional perspective, the influencing factors to the development of these types of businesses is similar to that of model 15. There are existing supportive policies and legislation for MSW reuse but support for incentivizing private sector involvement is minimal. From the financial perspective, it would be important 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. The feasibility of this model can be further substantially improved if land can be allocated for operations at the community level. This would result in substantial socio-economic benefits as this business would result in increased waste collection (averted human health risks from decreased exposure to untreated waste) and employment generation at the community level.

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 demand for Fortifer was noted to be significant with an average WTP value of 6628 VND/kg. The marginal WTP analysis shows that farmers are willing to pay 267.5 VND/kg more for fortification and an even higher premium of 694 VND/kg for certification. Nutrient content and quality which have direct positive effects on farm yields and profits are preferred attributes. The potential market is substantial with the demand for Fortifer estimated at 145,374 tons/year. Whilst the current production level of organic fertilizers is fairly low, it is clear that it is a burgeoning industry with some entry barriers but supportive and existing policies encouraging business development. The organic fertilizer market is less commercialized and the related market structure and business dynamics are very informal. A market condition that would potentially impact the development of organic fertilizer (i.e. compost and Fortifer) businesses is the market power held by chemical fertilizer producers. The fertilizer market in Vietnam is highly concentrated – the top five fertilizer importers (except the commercial farms) account for the largest share of the fertilizer market. This suggests a very high concentration that is characteristic of strong oligopolistic market structures. Whilst the fertilizer industry is highly concentrated, market distortions related to product differentiation, distribution inefficiencies in the supply chain, information flow, foreign exchange rate fluctuations, amongst others, make the fertilizer market imperfectly competitive and represents opportunities for new organic fertilizer businesses. However, 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 business model will require a capital subsidy and it is unlikely to achieve capital cost recovery with higher compost price.

Model 18: Urine reuse

The infeasibility of this business model is mainly driven by the inexistence of urine diverting dry toilets (UDDTs). As there is almost a 100% sanitation coverage in urban Hanoi, there is very limited opportunity for consideration the adoption/use of UDDTs. In that regard, given the waste input supply constraint, the feasibility of this business model was not assessed for any of the remaining criteria.

Model 19 - Compost production for sanitation service delivery

The infeasibility of this business model is also mainly driven by the inexistence of urine diverting dry toilets (UDDTs); and the arguments presented for business model 18 are also applicable here.

Table 22: Overall feasibility ranking of the business models

		Level of feasibility of the business models										
Ranking criteria	Outputs	ENERGY				WASTEWATER		NUTRIENT				
		BM1a	BM2a	BM4	BM6	BM8	BM9	BM15	BM16	BM17	BM18	BM19
1	Waste supply and availability											
2	Market assessment						N/C				N/C	N/C
1	Institutional analysis										N/C	N/C
3	Technical assessment											
4	Financial assessment			N/C							N/C	N/C
5	Health risk & impact assessment											
	Environmental risk and impact assessment											
6	Socio-economic assessment			N/C							N/C	N/C
	Overall ranking of BM											

Legend:

- **BM 1a:** Dry Fuel Manufacturing: Agro-Waste to Briquettes
- **BM 2a:** Energy Service Companies at Scale: Agro-Waste to Energy (Electricity)
- **BM 4:** Onsite Energy Generation by Sanitation Service Providers (faecal sludge to electricity)
- **BM 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 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 18:** Urine reuse
- **BM 19**: Compost Production for Sanitation Service Delivery (faecal sludge-based compost and urine as a fertilizer).

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 Hanoi 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 8th to 12thDecember 2014.The BMDT was completed by 13 participants (Table 2) representing a total number of 8 business ideas and BMs:

- Infrastructure Construction and Environmental Technologies Company (NUCE-TECH) is a consulting and constructor services company that offers customized wastewater treatment solutions (construction, delivery, O&M) to public and private companies. The business model is inspired by the generic business model "Compost Production for Sustainable Sanitation Service Delivery".
- Van Bien Nguyen is an entrepreneur that owns a pig farm that produces electricity from the pigs dung with a biogas plant. He plans to sell generators and liquefied biogas to nearby farmers in Phuc Tho district. The business model is inspired by the generic business model "Manure to Power".
- Duc Minh Co., Ltd. is a company producing municipal and industrial solid waste incinerators for public and private companies in the pulp & paper sector. The waste heat can be used for heating boilers. The business model is inspired by the generic business model "Energy Service Companies at Scale: Agro-industrial Waste to Electricity".
- Khac Hanh Nguyen is an entrepreneur that wants to collect and treat solid waste in rural areas. His clients are municipalities and small industrial clusters as well as buyers of compost. The business model is inspired by the generic business model "Subsidy-free Community Based Composting".
- Van Thuong Dinh is an entrepreneur that wants to collect and treat solid waste in rural areas. His clients are public buildings, small-scale industries and households. The business model is inspired by the generic business model "Subsidy-free Community Based Composting".
- Do Ngoc Hai Dinh is an entrepreneur that wants to collect and treat cow dung from TH Milk Company to produce biogas and fertilizer. His clients are TH Milk Company (onsite faeces treatment) as well as agricultural associations and farmers (biogas and fertilizer). The business model is inspired by the generic business model "Manure to Power".

12 Annex 2: MCA Framework

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

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

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

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

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

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

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

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

4. Institutional and Legal Settings and Public Support

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

5. Financial feasibility/viability assessment

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

6. Health and Environmental risks and risk mitigation

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

7. Socio-economic impact assessment

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

13 References

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