Resource Recovery and Reuse (RRR) Project

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

July, 2015

Contributing Authors (in alphabetical order):

Marcos Alegre[1]
Cecilia Castro[2]
Guéladio Cissé[3, 4]
George Danso[5]
Maria del Pilar Céspedes[1]
Luca Di Mario[6]
Oscar Espinoza[7]
Lourdes Fernández Felipe-Morales[1]
Samuel Fuhrimann[3, 4]
Stella Hartinger[8]
Ganesha Madurangi[5]
Rosa Maria Miglio Toledo[7, 9]
Miriam Otoo[5]
Flor Paredes[7]
Krishna Rao[5]
Lars Schoebitz[7]
Avinandan Taron[5]
Gonzalo Urbina[1]
Martin Wafler[10]
Mirko Winkler[3, 4]

Compiled by:

Miriam Otoo[5]
Krishna Rao[5]
Avinandan Taron[5]

Affiliations:
[1]Grupo GEA, Peru
[2]El Centro de Ecoeficiencia y Responsabilidad Social (CER), Peru
[3]Swiss Tropical and Public Health Institute, Dept. of Epidemiology and Public Health, Switzerland
[4]University of Basel, Switzerland
[5]International Water Management Institute (IWMI), Sri Lanka
[6] Swiss Federal Institute of Aquatic Science and Technology (Eawag) - Department of Water and Sanitation in Developing Countries (Sandec), Switzerland
[7]IPES - Promocion del Desarrollo Sostenible, Peru
[8]Unidad de Desarrollo Integral Ambiente y Salud, Universidad Peruana Cayetano Heredia, Peru
[9]Universidad la Molina, Peru
[10]International Centre for Water Management Services (CEWAS), Switzerland

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

This report is an output as part of the research project on *Resource Recovery and Reuse: From Research to Implementation* funded by the Swiss Agency for Development and Cooperation.

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

Table of Contents

List of Figures

List of Tables

Abbreviations

ANA	National Water Authority
AIW	Agro-Industrial Waste
AM	Animal Manure
ANA	National Water Authority
BCR	Benefit to Cost Ratio
BMDT	Business Model Development Training
BMs	Business Models
BOD	Biological Oxygen Demand
CCL	Lima Chamber of Commerce
CDM	Clean Development Mechanism
DALYs	Disability Adjusted Life Years
DGAA	General Directorate of Environmental Affairs
DIGESA	General Environmental Health Directorate
ECOSAN	Ecological sanitation
EIA	Environmental Impact Assessment
ESCO Model	Energy Services Company Model
FS	Faecal Sludge
GHG	Green House Gas
GWh	Gigawatt Hour
HIA	Health Impact Assessment
HRA	Health Risk Assessment
HRIA	Health Risk and Impact Assessment
IRR	Internal Rate of Return
MC	Market Concentration
MCA	Multi-criteria Assessment
MEF	Ministry of Economy and Finance
MINAG	Ministry of Agriculture
MINAM	Ministry of the Environment
MINEM	Ministry of Energy and Mines
MLD	Million Liters per Day
MML	Metropolitan Municipality of Lima
MSW	Municipal Solid Waste
MVCS	Ministry of Housing, Construction and Sanitation
MW	Market Waste
NAMA	Nationally Appropriate Mitigation Action
NGOs	Non-governmental Organizations
NPV	Net Present Value
OEFA	Environmental Assessment and Control Agency
OFMSW	Organic Fraction Municipal Solid Waste
OSINERGMIN	Supervisory Body for Investments in Energy and Mining
P&L	Profit and Loss
PETRAMAS	Peruvian solid waste management company
PIGARS	Integral Plan of Solid Waste Environmental Management
PPE	Personal protective equipment

PPP	Public-private Partnership
PRODUCE	Ministry of Production
PROINVERSION	Private Investment Promotion Agency
RER	Renewable Energy Resources
RoI	Return on Investments
RRR	Resource Recovery and Reuse
SCP	Structure–Conduct–Performance
SEDAPAL	Water and Sanitation Service Utility of Lima
SEIN	National Integrated Electricity System
SENASA	National Agrarian Health Service
SERNANP	National Service of Protected Natural Areas
SERPAR	Park Service of the Municipality of Lima
SMEs	Small and Medium Sized Enterprises
Sol	Currency of Peru / Peruvian Nuevo Sol
SSP	Sanitation Safety Planning
STEP	Specific Topic Entry Page
SUNASS	National Agency of Water and Sanitation Services
SUNAT	National Tax Management agency
SWM	Solid Waste Management
ToR	Terms of Reference
TTC	Thermotolerant Coliform
UNALM	National Agrarian University
WHO	World Health Organization
WTP	Willingness-to-Pay
WW	Wastewater
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 Lima, Peru. The feasibility studies conducted in Lima 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).

Ten (10) business models were selected for feasibility testing in Lima, covering several waste streams (faecal sludge, municipal solid waste (MSW), wastewater, agro-industrial waste) and resulting end-products categorized into energy and nutrient recovery and wastewater use. The business models were selected based on information from: a) a pre-feasibility study, b) feedback from stakeholder workshops and c) a no-go analysis based on information from baseline surveys. The selected business models had to have at least triple bottom line targets: high impact from a scalability and replicability perspective and catalyze innovation adoption. The feasibility of each model was then analyzed based on the MCA framework and for its overall potential feasibility based on a 4-level ranking system, i.e. whether it has:

(red)	**No feasibility**	(grey)	**Low feasibility**	(light green)	**Medium feasibility**	(green)	**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 use for irrigation, energy and nutrient recovery*' business model (BM 9) has the highest feasibility for Lima; the nutrient business model (MSW-based compost) and energy business model (MSW for electricity generation) have a medium level of feasibility. It is important to note however that 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).

The high feasibility potential for implementation of the '*wastewater use for irrigation, energy and nutrient recovery*' business model (BM 9)[1] is driven by key factors related to: a) high financial viability, b) supportive institutional environment and c) wastewater availability and access. There is significant wastewater generated and treated in Lima (at approx. 900 Million Litres per Day (MLD) of

[1]Business models 9, 12 and 13 were initially considered as separate models. However based on the concept behind the business models and the multi-criteria framework used for the analyses, they were combined into one business model with different scenarios.

treated WW) that can be reused at some level. Although treated wastewater is already in use in the city (in almost 12 of the 26 WWTPs, concentrated in the southern part of the city), the majority of the treated wastewater is discharged into the sea. This is similar for treated agro-industrial wastewater (~12 MLD mainly from dairy and beer production), which is discharged into the city rivers (Huaycloro and Rimac) and could be diverted for reuse. Business model 9 is noted to be the most feasible, particularly for projects of medium and small scale associated to irrigation in the districts of Lima. However, depending on who demands the treated wastewater, one must take into account the aims and objectives of the project/initiative, some of which are justifiable in the grounds of public interest.

- SEDAPAL has clearly signaled its priority of reducing pollution and damage to health through treatment of wastewater —a public good component. While the price structure suggests a bias towards offering cheaper rates for agricultural purposes, it is possible to increase awareness towards the public need to invest in wastewater treatment plants (WWTP) to clean the Rimac River. Then, a combination of adjusting reference prices in coordination with ANA and other users plus use of enforcing mechanisms to reduce contamination of the Rimac River, could promote investments in wastewater treatment. Through PPPs, where Peru shows a friendly environment, some of these projects could become viable.
- The Metropolitan Municipality of Lima, including SERPAR is one key potential user of treated wastewater to irrigate the parks they administer in the city. However, these plans must be aligned with the new administration' priorities. It should take into account the political risk of these projects, since previous commitments with the previous administration have been cancelled.
- District municipalities are another potential area for their parks and gardens, but they will only invest if a high price of commercial water justifies the investment. The country clubs, schools and other private entities with large green areas are also potential users of treated wastewater for irrigation, although with similar cautions[2]. However, the feasibility of supplying treated wastewater will depend on the length of the canal or pipeline and pumping costs to deliver the water to its customer segment.
- The component of creating compost and organic fertilizer adds a possibility of a future cash flow, but has potential limitations.

In regards to the *wastewater-fed fish* business model, although the market and financial indicators suggest potential feasibility of this model, the overall feasibility of the model is limited by the institutional environment. There are existing regulations for providing authorizations for reusing treated wastewater for irrigation but not for aquaculture. Additionally, there are no existing technical rules or standards nor policies or incentives that support wastewater-fed aquaculture. 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 incentivize the implementation of 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[3].

Only one of the energy business models was noted to be feasible for implementation in Lima - Model 2a - energy service companies at scale (agro-waste to electricity), in the context of the energy market of Peru where hydroelectric and thermoelectric plants predominate. From the market perspective, it is important to note that waste-to-energy entities will have to compete in the market of non-conventional renewable energies (relevant market), where wind and solar energy are prevalent. Whilst these are critical factors to be considered, Lima has several particular advantages in place such as the availability of inputs to produce energy, low-cost technologies, a high potential to produce technological change and a high probability of replacement when energy sources such as diesel, wood,

[2]It is important to note that any health risks associated with this business model can be mitigated with a reasonable set of control measures.

[3]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.

batteries (usually more expensive) are prevalent. It is also important to note that whilst only a small percentage of the population in Lima still lacks power or still live in remote rural areas, their sources for electricity are based on non-conventional sources, in the order of: 1) solar, 2) mini-hydro or 3) biogas at a domestic scale. This thus represents an opportunity that waste-to-energy entities can capture. Additionally, the electricity market in Peru has favorable conditions and an abundance of energy sources, reflected in an energy matrix with high potential and high presence of energy production from renewable sources (mainly hydropower). An orderly and competitive energy market offers several options for the business model proposed, which should focus on preparing to participate as investment projects in the auction market. While the costs of entering the National Integrated Electricity System (SEIN) may be prohibitive for small projects, the stability of the regime (a third auction will happen in 2015:III) allows long-term investors to compete and reduce costs, while promoting technological change and innovation in order to help make these technologies more profitable. From a financial perspective, the analyses indicated that larger-scale plants are feasible but highly sensitive to the sale price of electricity. Additionally, the business model showed increasing viability with increases in the equity component of the investment.

Although there is a significant availability and easy access to inputs (agro-waste, in particular pig manure) and the model showed a high financial viability, Model 3 has a low level of feasibility for implementation. This is mainly driven by a weak legal framework which is limited to energy generation from agro-waste in general and bio-fuels, without a focus on animal waste. There is thus no direct policy framework and standards or technical regulations in place that support the implementation of this model. This may be due to the novelty of waste reuse (gap in legislation) and the city's priorities as on the other hand, there are no laws/regulations that would represent a threat to the business either. There is a general notion that public institutions may not be interested to promote the model but there is a general interest from manure generators for on-site reuse. Thus, an improved enabling environment from an institutional perspective will generally improve the feasibility of this model[4].

The infeasibility of Model 4 - Onsite Energy Generation by Sanitation Service Providers (faecal sludge to energy) is mainly driven by the fact that Lima is predominately covered with sewer systems (90% coverage) and has very limited onsite sanitation coverage (6%) - thus a limited availability of waste input for energy generation. Additionally, there are no regulations, laws or any governmental policies that directly or indirectly promote and/or support this model. The main limiting factor is that the law establishes that sludge from WWTPs is considered a hazardous waste. Thus, by law, sanitation service providers are required to stabilize the sludge on-site and then, transport it to the sanitary landfills for proper disposal. Given these institutional constraints and limited onsite sanitation systems, this business model is noted to not be well-suited for the context of Lima.

The nutrient business model - MSW-based compost (BM 15)[5] is noted to be highly feasible in the Limean context. The feasibility is driven mainly by: a) high financial viability, b) supportive institutional and legislative environment, c) significant market demand and d) available technologies. There is a significant quantity of waste generated however this is collected in an unsorted form from households and markets. Food market waste may be an alternative sub-waste stream to target, which is easier to segregate at a centralized level given the high concentration of organic waste. The overall market assessment suggests that there is a fair demand for MSW-based compost in Lima. It is expected that 44% of all households with plants/green areas will be willing to pay for compost (126,236 households); with a willingness-to-pay ranging between 2-2.5 Sol/Kg. The estimated demand from households for compost is 25,163 tons/year. On the other hand, about 14% of farmers are already using compost as

[4] From a market perspective, given that the end-product is electricity the conclusions elaborated under Model 2 are also applicable to model 4.

[5] Business models 15 and 21 were initially considered as separate models. However based on the concept[5] behind the business models and the multi-criteria framework used for the analyses, they were combined into one business model with different scenarios.

a soil input and hence a conservative demand estimate would be 7,280 tons/year if we assume that only this group of farmers are willing to use compost. If we assume that farmers are provided with adequate training on compost use and its advantages the remaining 86% of the farmers can possibly be included as part of the potential market demand and thus the total estimated demand for compost will be 52,000 tons/productive cycle in a year. The market structure assessment revealed that the organic fertilizer market is small but a growing part of a concentrated fertilizer market led by imported chemical fertilizers. Currently, the organic fertilizer market is small and scattered (70 percent in the Andes), but strongly following the trend of organic food demand (currently mostly related to the external market demand). A premium for organic fertilizers is found in some niche markets, but the fertilizer market is generally a price-taker and also very volatile. Lima as a main potential market for organic fertilizers is moderately valid, mainly because of its potential as a distribution market (domestic and external) and less because of a growing domestic organic farming market. Other actors are planning to enter the latter market, mainly for organic agriculture for exports, and they are expecting future growth of urban farming demand, suggesting an expected increase in organic fertilizer demand. The financial assessment was conducted for three different scenarios and it was observed that at a lower scale of 70 tons and 200 tons, the viability of the business without any subsidy or incentives was marginal but as the scale of the waste processed increases, the feasibility of the compost production plant improves.It is important to note however that the decision of a business to operate at a certain scale will be determined by several factors: a) demand, b) price of the compost, c) economies of scale, among others. Whilst the current production levels of compost is unknown, it is clear that the compost sector is a burgeoning industry with some entry barriers but supportive and existing policies encouraging business development.

Similar to business model 4, the infeasibility of Model 17 - High value fertilizer production for profit (faecal sludge-based compost) is mainly driven by the fact that Lima is predominately covered with sewer systems (90% coverage) and has very limited onsite sanitation coverage (6%). With no regulations, laws or any governmental policies that directly or indirectly promote and/or support this model and limited onsite sanitation systems, this business model is not well-suited for the context of Lima.

Table 1: Overall feasibility ranking of the business models

		Level of feasibility of the business models						
Ranking criteria	Outputs	ENERGY			WASTEWATER		NUTRIENT	
		BM2a	BM3	BM4	BM8	BM9, 12, 13	BM15& 21	BM17
1	Waste supply and availability							
2	Market assessment							
1	Institutional analysis							
3	Technical assessment							
4	Financial assessment							
5	Health risk& impact assessment							
	Environmental risk and impact assessment							
6	Socio-economic assessment			N/C				N/C
	Overall ranking of BM							

Legend:

- **BM 2a:** Energy Service Companies at Scale (MSW to energy)
- **BM 3:** Energy Generation from own Agro-industrial waste (agro-waste to energy)
- **BM 4:** Onsite Energy Generation by Sanitation Service Providers (faecal sludge to electricity)
- **BM 8:** Beyond cost recovery: wastewater-fed aquaculture
- **BM 9:** On Cost Savings and Recovery (wastewater use for irrigation, energy and nutrient recovery)
- **BM 12:** Wastewater treatment for carbon emissions reduction
- **BM 13:** Wastewater treatment for irrigation
- **BM 15:** Large-Scale Composting for Revenue Generation (municipal solid waste to compost)
- **BM17:** High value Fertilizer Production for Profit (combination of municipal solid waste and faecal sludge to organic fertilizer)
- **BM 21:** Partially subsidized Composting at District Level

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.

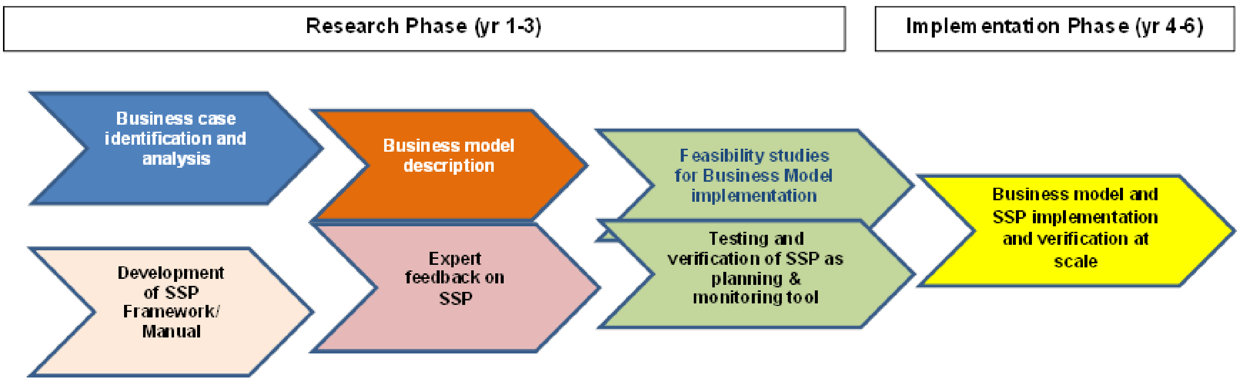

Figure 1: Research Framework for the Project

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 assessment
4. Institutional and legal settings and public support assessment
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)

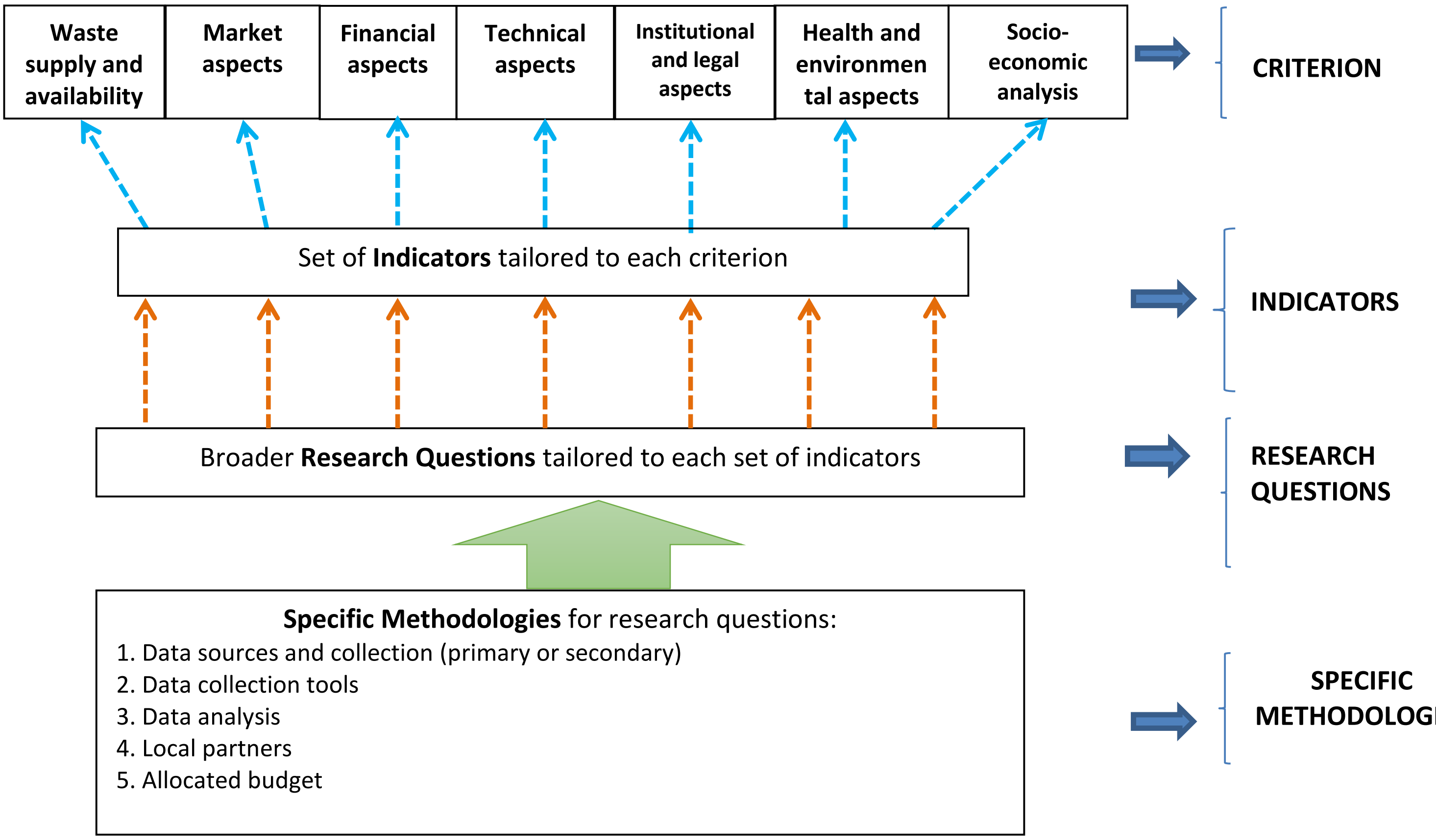

Figure 2: Framework for Feasibility Studies

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 in 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 basis 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 Lima, Peru. 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. Ten (10) business models selected for feasibility testing in Lima are presented in Table 2. The selection process of the business models was based on three components: a) a pre-feasibility study, b) feedback from stakeholder workshops and c) a no-go analysis based on information from the baseline survey.

Table 2: Selected RRR Business Models for Feasibility Testing in Lima[6]

RR Business Models	Brief Description
ENERGY	
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 3: Energy Generation from own Agro-industrial waste (Agro-waste to energy)	The business processes agro-waste to generate electricity which use for internal purposes and any excess 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.
WASTEWATER REUSE	
Model 8: Beyond cost recovery: the aquaculture example	The business concept is to treat wastewater to an advanced tertiary state and during that process produce fish for human consumption. The concept offers business opportunities at medium scale, where existing in-use treatment plants can be used to raise fish for sale into the market, providing avenues for cost recovery to municipal wastewater management entities.
Model 9, 12 & 13: On Cost Savings and Recovery - Wastewater treatment for irrigation/ fertilizer	The business concept is to treat wastewater for safe reuse in agriculture, forestry, golf courses, plantations, energy crops, and industrial applications such as cooling plant. The sludge from the treatment plant can be used as compost and soil ameliorant and energy generated can be used for internal purpose resulting in energy savings.
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 21: Partially subsidized Composting at District Level	
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

[6]The business model on incineration of municipal solid waste (MSW) for energy production was not considered for Lima for the following reasons:

a) Waste in developing countries has high water content and hence has a significantly lower calorific value;
b) There are noted concerns of significant potential negative health and environmental impact associated with the model;
c) Among the empirical business cases reviewed for the study on MSW to energy, MSW to landfill gas to energy was not analyzed;
d) Different stakeholders strongly opposed MSW incineration energy generation.

	for target crops and soils, and a product structure improvement (pellets) to improve its competitive advantage, marketability and field use.

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:

(red)	**No feasibility**	(grey)	**Low feasibility**	(light green)	**Medium feasibility**	(green)	**High feasibility**

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

2 Key findings of Waste and Availability Analysis

This section presents the key findings of the “Waste Supply and Availability” analysis that was conducted in Lima, Peru. 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 Lima, including cost for collection and disposal.
- Accessibility of defined waste streams, and the implications on the potential for implementation of waste-based business models.

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

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

Business Model	Waste stream	End-product	Feasibility	Recommendations
2 (a)	• MSW	• Biogas -> Electricity	**Medium-High** (Households): a total of ~1Million t/yr (~2700 t/d) of organic waste is generated in the city from household waste. The majority of this (~70%) is currently collected in a mixed form and disposed in sanitary landfills. High (Market – high concentration of organic waste (84%) OFMSW): it is estimated that 214,000 t/yr (~550 t/d) of waste is produced by the 1200 foodmarketsofLima.About84% of market waste is organic (~460 t/d) and the majority of which (~70%) is currently collected in a mixed form and disposed to sanitary landfills.	To receive high-quality OFMSW (organic fraction of municipal solid waste), it is recommended to stress on source-segregation of organic waste at food market and household (the latter having the greatest potential). Alternatively, food market waste may be targeted, which may be easier to segregate at centralized level given the high concentration of organic waste. Pig manure may be a good stream to focus on, given its nutrient and energy contents and lack of reuse in the city.
3	• AIW • AM	• Ethanol • Electricity	**Medium (AIW) – High** (Pig Manure): Although a substantial generation of manure (e.g. Lima is the largest broiler producer in the country) and agro-industrial waste, the majority of this is already reused in agriculture (medium confidence). However, pig manure (~100t/d, fresh weight) represents an exception given the lack of market for it (due to unpleasant odors). Other waste streams total generation consist of (medium confidence): • 680 t/d of poultry litter; 900 t/d of cattle manure; • Agro-industrial waste was estimated at 191 t/d • ~150,000 t/yr (410 t/d) from slaughterhouse, mostly reused for animal feeds	Pig manure (via biogas) may be a good manure stream to focus on, given its nutrient and energy contents and the lack of reuse in the city.
4	• Feces • Urine • FS	• Biogas -> Cooking fuel	**Medium:** There are very few experiences covered by ECOSAN toilets and FS generation and collection is low (see model 17). However, access to toilets services may be required particularly in the cities slums (low confidence).Similar businesses (e.g. x-runner) are already operating in similar contexts.	This model may focus on slums areas by providing integrated sanitation services (e.g. toilets/showers).
8	• WW	• Fish • Treated WW	**High** (Partially Treated and Treated WW): There is enough wastewater and margin for duckweed cultivation or direct aquaculture. Aquaculture is already happening in Lima.	8 WWTPs have pond-based technologies (mostly in the south) and may be adapted (or retrofitted) for duckweed or aquaculture production.
9	• WW • WW sludge	• Electricity • Soil conditioner • Water (for reclamation)	**High** (Treated WW): ~900 Million litres per Day (MLD) of treated WW are produced in the city (high confidence).Although treated WW reuse is already happening in the city (in almost 12 of the 26 WWTPs, concentrated in the southern part of the city), yet the majority of the treated WW is discharged into the sea. High (WW sludge): the city generates ~24,000 m^3 of WWTP sludge per year (medium-high confidence), which is currently disposed in the city landfills.	The WWTP sludge can be recovered for energy or nutrient recovery (via compost) either on-site or offsite. If the compost from WW sludge is considered, a more detailed assessment on heavy metals concentration in

			High (Treated Industrial WW) – Most of treated agro-industrial wastewater (~12 MLD mainly from dairy and beer production) is discharged into the city rivers (Huaycloro and Rimac) and could diverted to reuse.	the sludge of targeted WWTPs may be required.
15	• MSW	• Soil conditioner	**Medium-High** (Households): a total of ~1M t/yr (~2700 t/d) of organic waste is generated in the city from household waste. The majority of this (~70%) is currently collected in a mixed form and disposed in sanitary landfills High (Market – high concentration of organic waste (84%) OFMSW): it is estimated that 214,000 t/yr (~550 t/d) of waste is produced by the 1200 food markets of Lima. About 84% of market waste is organic (~460 t/d) and the majority of which (~70%) is currently collected in a mixed form and disposed to sanitary landfills.	For high quality compost, it is recommended to stress on source-segregation of waste at household or market level. Alternatively, food market waste may be targeted (high fraction of organic waste and may be easier to separate).
17	• MSW • FS	• Fertilizer (NPK added)	**Medium** (Households): a total of ~1M t/yr (~2700 t/d) of organic waste is generated in the city from household waste. The majority of this (~70%) is currently collected in a mixed form and disposed in sanitary landfills. It may be hard to receive OFMSW from this waste stream given that very little source segregation is happening at the moment. High (Market – high concentration of organic waste (84%) OFMSW): it is estimated that 214,000 t/yr (~550 t/d) of waste is produced by the 1200 food markets of Lima. About 84% of market waste is organic (~460 t/d) and the majority of which (~70%) is currently collected in a mixed form and disposed to sanitary landfills. **Low (FS):** low FS production and collection was estimated in the city. Most of the onsite systems are uphill and latrines, when full, are buried and not emptied. Animal manure may be used for the enrichment process (see BM2 and 3). The availability of this waste stream is Medium to High.	For high quality compost, it is recommended to stress on source-segregation of waste at household or market level. Alternatively, food market waste may be targeted (high fraction of organic waste and may be easier to separate). Agreement with market associations or owners to segregate OFMSW at generation may facilitate the sourcing of OFMSW. If this is not possible, segregation at treatment plant level can be easily done given the high percentage of organic waste in market waste.
21	• MSW	• Soil conditioner	**Medium-High** (Households): a total of ~1M t/yr (~2700 t/d) of organic waste is generated in the city from household waste. The majority of this (~70%) is currently collected in a mixed form and disposed in sanitary landfills. High (Market – high concentration of organic waste (84%) OFMSW): it is estimated that 214,000 t/yr (~550 t/d) of waste is produced by the 1200 food markets of Lima. About 84% of market waste is organic (~460 t/d) and the majority of which (~70%) is currently collected in a mixed form and disposed to sanitary landfills.	For high quality compost, it is recommended to stress on source-segregation of waste at household or market level. Alternatively, food market waste may be targeted (high fraction of organic waste and may be easier to separate).

3 Key findings of Market Assessment

3.1 Introduction

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

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

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

As noted earlier, a total of 10 RRR business models were selected for the feasibility studies in Lima. For the purposes of the market assessment, an end-use typology of the business models was employed as although the underlying concept of the business models were different, a number of the end-products were the same across different business models. Thus for some business models, the related customer segments and relevant actors along the value chain considered would be the same. In that regard, for the selected business models, the following 5 value-added products were considered: 1) electricity, 2) wastewater-fed fish, 3) treated wastewater, 4) MSW-based compost and 5) faecal sludge-based compost.

Table 4: List of RRR business models and related products

Business Model	Value-added product	Recovered resource
Model 2: Independent power producer (agro-waste to electricity)	Electricity	Energy
Model 3: Energy Generation from own Agro-industrial waste (Agro-waste to energy)		
Model 4: Onsite energy generation (faecal sludge to electricity		
Model 8: Beyond cost recovery: the aquaculture example	Wastewater-fed fish	Wastewater-fed fish
Model 9, 12 & 13: On Cost Savings and Recovery - Wastewater treatment for irrigation/ fertilizer and energy production	Treated wastewater	Wastewater
Model 15: Large-Scale Composting for Revenue Generation (MSW to compost)	Compost	Nutrients
Model 21: Partially subsidized Composting at District Level		
Model 17: High value Fertilizer Production for Profit(faecal sludge to compost)	Faecal sludge-based compost	

3.2 Methodology

3.2.1 Overview of Methodology

The successful development of any RRR business depends on the effective workings of different facets of the respective value chain including: (a) market linkages between related subsector markets; (b) business dynamics between relevant economic actors and (c) consumers' responsiveness to newly developed and available products. When introducing a new product into the market or simply entering a new industry, 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 subsequent sections will outline in detail the data collection tools and estimation approaches. 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) electricity market, b) fish market, c) water market and d) fertilizer market).

3.2.1.1 Willingness-to-pay and Market size estimation

Stated and revealed preference methodologies have gained immense popularity in eliciting consumers' valuation of new products (Lusk and Hudson, 2004; Kimenju and Groote, 2008). The choice between the uses of stated or revealed preference methods is dependent on the RRR product under consideration. Stated preference methods such as contingent valuation methods are typically used for assessing consumer WTP of products with an inexistent market price (Adamowicz and Deshazo, 2006; Freeman, 2004). An example would be that of faecal sludge-based organic fertilizer, a new product in the fertilizer market. Alternatively, revealed preference methods such as hedonic pricing can be used to obtain the price of a good via real market purchasing mechanisms. These methods are grounded in economic theory of welfare analysis and can also be used for the valuation of goods and services without market prices or shadow prices. Contingent valuation approaches has been successfully applied in the estimation of the demand for compost in Ghana (Danso et al., 2006); Tanzania (Valerian et al., 2011), and Ethiopia (Hagos et al., 2012). For the purpose of this study, contingent valuation methods were applied for the WTP assessment of the energy business models (i.e. electricity) and nutrient and wastewater business models. Based on the WTP measures, the potential market size of the RRR products was estimated.

3.2.1.2 Market structure assessment

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

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

3.2.1.3 Market outlook assessment

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

3.2.2 Study Area and Data

The primary survey covered several districts of Lima as shown in Figure **3** below. For the WTP and market size assessment, primary data on price offers from market experiments, participants' demographics and socio-economic factors were collected from different groups of respondents depending on the RRR product. Additionally, data on price of substitute products, macro-economic factors, etc. 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. For example, supply chain analyses have been conducted on the fertilizer market in many agricultural dependent countries. If applicable to the city, these served as key sources for secondary data. Data on the number and size of key players, the characteristics of these players (e.g. economies of scale, access to financing, marketing and distribution costs, and level of integration and nature of contractual agreements) was collected from primary sources. For the market outlook, 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 (e.g. quantity of fertilizer sold per year, time series data of fertilizer, etc.) was collected from relevant institutions (e.g. marketing boards and departments). Revenues and cost data were collected from existing business as well as alternative input and output products markets. The sampling strategy for the different research aspects and models are outlined in Table 5below.

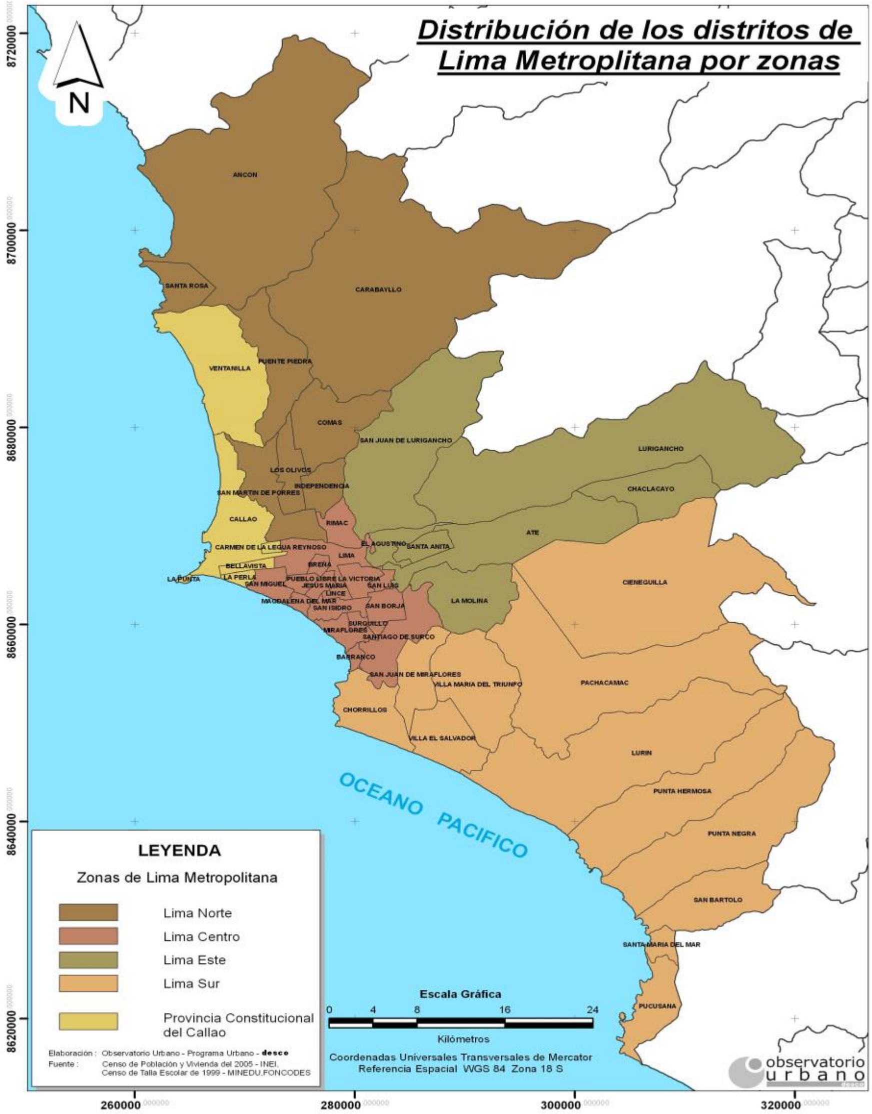

Figure 3: Map of the city of Lima

Table 5: Sampling Strategy for Market Assessment

Sub-research components	**Business Models**				
	Model 2b, 3&4 [Electricity]	**Model 8: [Wastewater fed fish]**	**Model 9, 12, 13 [Wastewater]**	**Model 15 &21 [MSW-based compost]**	**Model 17 [Faecal sludge-based fertilizer]**
WTP and Market size	Electricity market - secondary data	H = 443	Water sector - secondary data	H = 300 F = 115	H = 288
Market structure	Electricity market - secondary data	Fish market - secondary data	Water sector - secondary data	Fertilizer market - secondary data	
Market Outlook	Time series 2º data; 1º data from WTP assessment				
Pricing & Marketing strategy	Electricity market - secondary data		Water sector - secondary data	Fertilizer market - secondary data	
Optimal location or distribution strategy		Fish market - secondary data	Water sector - secondary data	Fertilizer market - secondary data	

3.3 Results of the Market Assessment

Model 2a: Energy service companies at scale (Agro-Waste to Electricity), Model 3: Energy Generation from own Agro-industrial waste (agro-waste to electricity) and Model 4: Onsite energy generation by sanitation service providers (Faecal sludge to energy)

The analysis showed that the proposed business models could work in the context of the energy market of Peru (general market) where hydroelectric and thermoelectric plants predominate; yet it will need to compete in the market of non-conventional renewable energies (relevant market), where wind and solar energy are prevalent. Thus, the proposed business models will be the best options if particular advantages are in place such as the availability of inputs to produce energy, low-cost technologies or with a high potential to produce technological change, or with a high probability of replacement when energy sources such as diesel, wood, batteries (usually more expensive) are prevalent. In addition, only a small percentage of the population in Lima still lacks power or still live in remote rural areas, but in any case their main options to obtain electricity rely on non-conventional sources (in this order) solar, mini-hydro or biogas at a domestic scale.

Free users (*usuarios libres* in Spanish) who generate their own power, are more likely to switch to other sources of energy, included entering to the national network—this works by assuring that the new options could generate savings. Of companies reporting to MINEM in 2013, there were 73 companies generating their own power, concentrated in manufacturing activities, mining, agribusiness, and fisheries, among others. Of all hydropower plants, 79% buys energy from the electricity market and 21% use their own. This latter group of companies may be willing to generate savings, and technological changes may allow them to save resources in electricity, or they could seek using clean energy as a matter of reputation. Based on the data for production of electrical energy (hydro, thermal, solar, wind) for the SEIN and others (in 2013), it can be seen that only a few large users generate their own power—that is justified by their scale of operation and possibly their remote location. For this reason, it seems the use of renewable energies in the case of free users is marginal. Nevertheless, it is noted that there are several individual cases promoted by some NGOs and obtaining resources from international cooperation. Similarly, low energy prices could be signaling a trend where more and more users decide to move to the national grid. In Peru power plants generate energy for both the national grid (SEIN) and *usuarios libres*. In 2013 the members of the SEIN power plants had generated 40,284GWh, i.e. 93% of the total and the latter had an output of 2,848GWh (7% of the total). In this sense, the production SEIN increased 6.1% and production of isolates decreased by 0.1% over the previous year.

The electricity market in Peru has favorable conditions and abundance of energy sources, reflected in an energy matrix with high potential and high presence of energy production from renewable sources (mainly hydropower). In the course of several decades, and enabled by the Camisea gas and power plants, it has managed to do most of the work to replace polluting energy sources to generate electricity, such as diesel oil or coal. The Peruvian government is making an effort to promote renewable energy technologies through an auction mechanism that ensures competition between several alternatives. Thus, it is not engaged in promoting a particular kind of alternative energy source, but seeks investors' own capacities to innovate and produce technological changes between each auction. The goal is that, by 2021, Peru will be producing 5% of its energy from non-conventional sources —it is currently at 2.5%. It is here where the main chances of financing the proposed technologies are. In conclusion, an orderly and competitive energy market offers several options for the business models proposed, which should focus on preparing to participate as investment projects in the auction market. While the costs of entering to the National Integrated Electricity System (SEIN) may be prohibitive for small projects, the stability of the regime (a third auction will happen in 2015:III) allows long-term investors to compete and reduce costs, while promoting technological change and innovation in order to help making these technologies more profitable.

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

Wastewater-fed aquaculture is becoming a major livelihood strategy for many municipalities looking for wastewater treatment and cost-savings options in Lima, Peru. To assess the market feasibility of such an initiative, a choice experiment approach was used to estimate the WTP and market demand of wastewater-fed fish in Lima, Peru. The results from the conditional logit model showed that households are willing to pay S. 0.64/kg more for information on source of water used to raise the fish they consume and S. 0.84/kg to know if additives had been used to raise the fish. Under the random parameter model (RPL) however, households were noted willing to pay S. 0.2/kg for information on source and S. 0.3/kg for information on whether additives had been used in rearing the fish. In both models, households were willing to pay S. 2.475/kg and S. 0.221/kg compensations for certification. Given these marginal estimates, the WTP for wastewater-fed fish with product information on the source of water used and additives was estimated at S. 3.99/kg; which was noted to be comparatively higher than the current market prices of other competitive products. This difference in prices is mainly driven by the respondents' marginal WTP for information on product quality. Additionally, the RPL model results showed that the demand for wastewater-fed fish is likely to be affected by factors such as perceptions, age, gender, and households' income level. Thus, it is important for new wastewater-fed fish businesses to consider the provision of a fish product with clear labelling on source and additive information. Results from the market structure assessment showed that whilst entry into the fish market is not free, it is clear that there are no barriers to entry, rather bureaucratic procedures which must be conducted prior to obtaining permission. The high level of concentration of the market (with two very large operations followed by a myriad of smaller ones) is more an indication of a growing market rather than a stabilized equilibrium enforced by market power or inefficiencies.

Model 9, 12 and 13: Cost recovery - Treated wastewater for irrigation, fertilizer and energy

Business model 9 is noted to be the most feasible, particularly for projects of medium and small scale associated to irrigation in the districts of Lima. However, depending on who demands the WWTP, one must take into account the aims and objectives of the project, some of them justifiable in the grounds of public interest.

- SEDAPAL has clearly signaled its priority of reducing pollution and damage to health through treatment of wastewater —a public good component. While the price structure suggests a bias towards offering cheaper rates for agricultural purposes, it is possible to increase awareness towards the public need to invest in WWTP to clean the Rimac River. Then, a combination of adjusting reference prices in coordination with ANA and other users plus use of enforcing mechanisms to reduce contamination of the Rimac River, could promote investments in this area. Through PPPs, where Peru shows a friendly environment, some of these projects could become viable.
- The Metropolitan Municipality of Lima, including SERPAR is one key potential user of treated wastewater to irrigate the parks they administer in the city. However, these plans must be aligned with the new administration' priorities. It should take into account the political risk of these projects, since previous commitments with the previous administration have been canceled.
- District municipalities are another potential area for their parks and gardens, but they will only invest if a high price of commercial water justifies the investment. However, associated costs

beyond technology make these hardly profitable projects, land costs, for example. The country clubs, schools and other private entities with large green areas are also potential users of treated wastewater for irrigation, although with similar cautions.
- The component of creating compost and organic fertilizer adds a possibility of a future cash flow, but has its own problems as discussed in the previous sector.

The other models are impractical from the market perspective for the following reasons:
- Model 13 has low likelihood in the coming years. Current megaprojects cover much of the wastewater treatment according to the objectives of SEDAPAL. Nevertheless, it cannot be ruled out that a previous megaproject to maintain and expand the existing public WWTP could be part of the Proinversión portfolio.
- The participation of farmers and buyers of treated water is not viable for model 13, due to the low price of water they access and the lack of value of wastewater in legislation. For farmers, it is likely that treated water is considered as a public good rather than having market value.
- Finally, model 12 of sewage treatment through carbon credits is less viable. For Latin America, these projects have not obtained CERs. Moreover, most WWTP projects produce a positive financial value for irrigation, which would not justify issuing carbon credits for financing these types of projects.

Model 15: Large-Scale Composting for Revenue Generation (MSW to Compost), Model 21: MSW collection service and low-cost organic fertilizer and Model 17: High value fertilizer production for profit (faecal sludge-based fertilizer)

The overall market assessment suggests that there is a fair demand for both MSW-based compost and Fortifer in Lima. In regards to MSW-based compost, it is expected that 44 % of all households with plants to be willing to pay for compost (126,236 households) since this is the percentage of the sampled respondents who are at least willing to pay between 2-2.5 Sol/Kg which is inclusive of the average price of 2.29-2.47. The estimated demand from households for compost is 25,163 tons/year. The estimated total number of farms for the two main peri-urban agrarian areas around Lima (i.e. Pachacamac and Carabayllo) is 5,200. The results suggest that on average each farm uses about 10 tons of manure (9.5-13.5 tons) per hectare. About 14% of the farmers are already using compost for soil enhancement and hence a conservative estimate of the demand would be 7,280 tons/year if we assume that only this group of farmers are willing to use compost. If we assume that farmers are provided with adequate training on compost use and its advantages the remaining 86% of the farmers can possibly be included as part of the potential market demand and thus the total estimated demand for compost will be 52,000 tons/productive cycle in a year. However, assuming the product makes a new entry and is priced at 2.40 S/. per 10 Kg, the demand curve estimated from the open bids show that about 25% of the farmers are ready to pay the mean price and hence the market size estimate will be 13,000 tons/year.

For the assessment of the Fortifer business model, it was noted that whilst farmers are considered a key customer segment, data was not collected from this group as the scoping study and follow-up interviews indicated that the farmers were uninterested in using the product and were unwilling to participate in the interviews. The resulting sample size and data provided were insufficient to conduct a meaningful WTP analysis. Thus, the analysis conducted here is based on data collected solely from households. In that regard, the results revealed that 52% of all households with plants would be willing to use Fortifer (i.e. 149,188households) since this is the percentage of the sampled respondents who preferred fortification of the product. The average expenditure revealed by the households that is spent on soil inputs was S/. 18.80. Assuming a price of S/. 6/10Kg for Fortifer, any household would be able to purchase about 30 Kg of Fortifer. However, if we consider a downward sloping demand curve we find that about 15% and 30% of the sampled respondents have stated their WTP to be over 6 S/. per Kg for powdered and pelletized Fortifer respectively. Thus a conservative estimate of the market size for powdered and pelletized Fortifer can be derived using these results and the total demand for

Fortifer derived. The estimates of the potential market size is therefore 2,228 tons/year and 4,457 tons/year for powdered and pelletized Fortifer, respectively. It is important to note that these conservative estimates are based on the mean WTP derived from the contingent valuation which might have biases in terms of the respondents' choice of bids.

The market structure assessment revealed that the organic fertilizer market is a small but a growing part of a concentrated fertilizer market led by imported chemical fertilizers. Currently, the organic fertilizer market is small and scattered (70 percent in the Andes), but strongly following the trend of organic food demand (currently mostly related to external market demand). A premium for organic fertilizers is found in some niche markets, but the fertilizer market is generally a price-taker and also very volatile. Lima as a main potential market for organic fertilizers is partially valid, mainly because of its potential as a distribution market (domestic and external) and less because of a growing domestic organic farming market. Other actors are planning to enter the latter market, mainly to address organic agriculture for exports, and they are expecting future growth of urban farming demand. Moreover, they expect growth in organic certification. New private investments are trying to increase the local production of chemical fertilizers.

The distribution strategy assessment revealed that a recent important benchmark for the organic fertilizer market is Mallki, a collateral business of the "San Fernando" corporation, which transforms pre-treated chicken manure into organic fertilizers, using its own distribution network. Having invested US$1.5 million, they expect US$2 million in sales in 2016 —40 percent of which will go to the external markets that currently pay US$13 per 25 kilo. In the domestic market, they are offering US$2.5 Mallki bags for the growing organic market. One big advantage of this project is the access to inputs, which significantly lowers costs compared to collecting and segregating MSW. Moreover, their distribution network and the commoditization of the organic fertilizer are probably market barriers to other actors, unless they compete with lower prices or subsidies to their operations in a market that tends to concentrate. In summary, whilst there is potential in the fertilizer sector for organic fertilizer businesses in Lima, there are some challenges that the latter may face. Future demand for organic fertilizer has already created interest from a big corporation working on a scale of 100ton per year, and the case for subsidies to production (in the form of public funding) is expected to decline. As an overall conclusion, the analysis suggests a shift from the original model to focus on demand segments with high growth potential. These could be export markets for certified crops, small-scale urban agriculture or urban gardens, and foreign markets. Thus, Lima should become a distribution center rather than the main target for organic fertilizers.

Table 6: Summary of the feasibility of the selected RRR business models from a market perspective

Business models	WTP and Market Demand	Market Structure	Market Outlook	Cumulative feasibility score	Value-added product/recovered resource
Model 2a – Energy service companies at scale: agro-waste to electricity **Model 3 – Energy Generation from own Agro-industrial waste (agro-waste to energy)** **Model 4 – Onsite energy by sanitation service providers**	There is an already existing market for electricity - thus a WTP estimate not relevant. Additionally, any new businesses will be price takers given the regulations.	1. Fair ease of entry into market 2. High level of concentration (oligopolistic market) 3. No product differentiation 4. Price taker 5. Potential negative profit margins (without subsidies)	Expected growth in demand from households and industrial sector	**Medium feasibility**	**Electricity**
Model 8: Wastewater-fed fish	WTP > Current market price	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	5 – 7 years to reach growth stage in business life cycle	**High feasibility**	**Wastewater-fed fish**
Model 9, 12 &13 - Treated wastewater for irrigation, fertilizer and energy	WTP < Current market price *(current price structure suggests a bias towards offering lower rates for agricultural purposes)*	1. Highly institutionalized 2. High level of concentration 3. Limited to no product differentiation 4. Price taker	Significant and growing demand from private entities with green areas.	**Low feasibility**	**Treated wastewater**
Model 15– Large-scale composting for revenue generation (MSW to compost) & Model 21 - Partially subsidized composting at district level	WTP > Current market price of competitive/ substitute products	1. Medium level of ease of market entry 2. Limited level of concentration in organic fertilizer market 3. Limited to no product differentiation 4. Price taker but potential price setter 5. Potential net profit margins –positive	Significant and growing demand.	**Medium feasibility**	**MSW-based compost**
Model 17 – High value fertilizer production for profit	WTP ≥ Current market price of competitive products (but limited to households). Key customer segment - farmers are unwilling to use the product	1. Medium level of ease of market entry 2. Limited level of concentration in organic fertilizer market 3. Limited to no product differentiation 4. Price taker but potential price setter 5. Potential net profit margins –positive	Significant and growing demand (*demand limited to households per the assessment).*	**Medium feasibility**	**Faecal sludge-based organic fertilizer**

4 Key findings of the Institutional and Legal Analysis

Lima is the capital city of Peru, and is situated on one of the driest deserts in the world, at sea level, along the Pacific coast of South America. Lima city has an area of 2,670 km2 and a population of almost 9 million people (one-third of the country's population), with an annual growth rate of 1.42%. Lima is mostly urban and its remaining rural zones (peri-urban) feature some agricultural and livestock raising activities that continue to progressively disappear as urbanization relentlessly advances. The urban growth of the latest 50 years has been disordered and unplanned, and this has resulted in serious problems for the planning and implementation of urban services (water, sanitation, waste collection, etc.). Lima is subdivided territorially and politically into 43 districts, which together are called the Province of Lima (this is equivalent to the whole city). Every territory has a District Municipality with elected District Mayors and the Provincial Municipality of Lima manages the whole territory. This situation generates some problems for the municipal coordination of service provision, and a disparity of coverage depending on the municipal budgets available. In addition, although there is a city master plan and provincial environmental policies developed in accordance to what is set forth in the national legal framework, each Municipality develops its own regulations for implementation within their territories.

There are five main categories into which RRR stakeholders in Lima can be organized.

- Under the first category are the governmental agencies with national authority for developing environmental policies and standards. They are responsible for formulating environmental policy and establishing rules and incentives for the functioning of RRR businesses. These are the Ministry of the Environment (MINAM), the Ministry of Housing, Construction and Sanitation (MVCS), the Ministry of Energy and Mines (MINEM), the Ministry of Economy and Finance (MEF) and the Ministry of Production (PRODUCE). MINAM was created only recently in 2008 and is the leading governing entity of the environmental sector; it formulates national environmental policy and is also responsible for overseeing the formulation of sectoral environmental policies and monitoring policy enforcement and implementation.
- The second category is for the central government public entities or agencies that have monitoring and oversight functions, who are involved in developing technologies, standards and specific policies, granting permits and licenses, setting service tariffs related to solid waste, wastewater or energy or that enable business creation. They are the Environmental Assessment and Control Agency (OEFA), the National Water Authority (ANA), the National Agrarian Health Service (SENASA), the General Environmental Direction of the MVCS (DGAA), the National Agency of Water and Sanitation Services (SUNASS), the General Environmental Health Directorate (DIGESA), the Supervisory Body for Investments in Energy and Mining (OSINERGMIN), the National Service of Protected Natural areas (SERNANP) and the Water and Sanitation Service Utility of Lima (SEDAPAL).
- The third category includes local authorities, and the main functions and roles of the Province and the 42 District Municipalities regarding environmental aspects and establishment of businesses are presented. The role that Municipalities have in issuing operating licenses is also explained.
- The fourth category consists of stakeholders of the private sector. This includes main generators of waste (municipal solid waste, wastewater, agro-industrial waste), the companies formally dealing with the provision of solid waste services (EPS-RS) and their commercialization (EC-RS), the formal and informal waste pickers, the producers and users of compost and other organic fertilizers, users of

treated wastewater for irrigating green areas (private institutions such as golf clubs, cemeteries, schools, and real estate enterprises; Municipalities; farmers, etc.).

- The fifth and last category of stakeholders includes the main stakeholders related to business start-up and operation, in which we have the National Tax Management agency (SUNAT) and the Lima Chamber of Commerce (CCL). The procedure for establishing a formal enterprise in Peru is also presented, showing how difficult it is to start-up a formal business (although there are more simple procedures for SMEs), but that formality implies paying taxes and registration fees used to enforce compliance with the different regulations ruling the sector the SME belongs to. Also mentioned is the fact that there is no special tax regime, incentives or exemptions for businesses or enterprises engaged in waste reuse and/or recycling. Furthermore, the Chamber of Commerce does not yet have, among its members, any company related to waste reuse. Other stakeholders mentioned as support organizations are NGOs, local media, universities and research institutions and international cooperation agencies. It was not possible to identify actors with funds available for direct implementation of RRR business models, but there was mention of the existing environmental and investment funds (public and private) that could be applied for by Municipalities or interested entrepreneurs.

This chapter also presents the analysis of national and local regulations that promote or relate to resource recovery and recycling. All the current regulations - which define the general and the specific institutional-legal framework - are presented for the different waste streams (treated wastewater, nutrients, solid waste and energy). One of the main conclusions in this chapter is that there is a comprehensive legal framework for environmental matters that establishes the environmental management system of the country, which is sector-based and decentralized. The legal system confers functions and powers related to environmental issues to several stakeholders (and sectors) in a dispersed manner. Then, upon analysis, in several cases there are loopholes that prevent the effective application of the existing technical and legal rules that assign overlapping functions, a framework that becomes difficult to understand for ordinary citizens.

In the case of the laws and regulations related to the reuse of treated wastewater, upon reviewing the regulatory framework, it was found that there are several laws and technical rules that promote treatment and reuse. In general, the regulatory framework promotes the application of different wastewater treatment systems and oversees the effluents of domestic wastewater treatment plants. In addition, the ANA authorizes the reuse of treated wastewater though the basin councils, and depending on the end use, also in coordination with sectoral agencies and the competent authority, i.e. the Ministry of Environment. There are several formal arrangements established along these lines regarding reuse for irrigation purposes, and potentially interested users can obtain reuse permissions from ANA. Nevertheless, there are still gaps to improve quality for reuse with different purposes since the standards set are only for release into water bodies (intended to reduce pollution). This situation has forced users of treated wastewater to invest in small in-site plants for secondary treatment that can provide treated wastewater suitable to reuse for irrigation purposes. Furthermore, it was found that at the moment, aquaculture using treated wastewater is not an activity that is encouraged by Law and is in fact not being done at all. In relation to the sludge from wastewater treatment plants, this material is considered by law a hazardous solid waste and therefore, there are no specific laws or policies that promote its reuse, for example for producing fertilizer or generating energy or any other product. Nonetheless, there are some technical rules (non-mandatory at the moment) for the construction of wastewater treatment plants that - if followed during plant design and construction - could enable reuse in agricultural activities.

In relation to the legal framework for solid waste recovery and reuse, there are several regulations that promote them, and the main one is the Solid Waste Act. There are national policies and targets in national plans which require municipalities and stakeholders engaged in waste management to achieve 100% of appropriate management (reuse, recycling, final disposal). However, in practice, regulations and policies are more aimed at promoting the achievement of targets for inorganic waste recycling and reuse, while there are very few laws or decrees issued to promote recycling, segregation at source, selective collection or to regulate the stakeholders of the recycling chain. Besides, there is no law or rule that directly promotes composting or which enables specific regulations and public funds or support for that activity. At the local level there are some statutes enacted by the Municipal Government of Lima province and district municipalities that promote separation at source, selective collection, and other similar activities. However, there are very few laws or decrees in place to encourage recycling, segregation at source, or selective collection at the local level, or to regulate the stakeholders of the recycling chain.

There are some national laws and regulations that indirectly encourage the reuse of waste for energy generation, but they are still limited. The legal framework promotes energy generation from non-conventional renewable energy on a large scale (on-grid and off-grid) considering biomass (and municipal solid waste) as a source. It also promotes electricity sales through auctions and the use of agricultural waste for biofuel production. There are arrangements already established under this framework, carried out through auctions, which provide energy to the national integrated energy system.

The institutional assessment of some of the RRR business were undertaken that mirror the business models assessed for feasibility in Lima. The assessment included understanding how business was developed (its origin, how it was funded, etc.), agreements and critical relationships with various stakeholders, supportive or barriers in regulatory framework, advantages and difficulties business owners identified and their perceptions including policy gaps, which formed one of the basis in defining the feasibility of the RRR business models. The following are the business cases that were assessed:

- Wastewater reuse:
  - Tilapia breeding for research purposes (Park 26 Bio-Technological complex) implemented by the Ministry of Housing, Construction and Sanitation in agreement with the La Molina National University
  - Tilapia breeding in reservoirs containing treated irrigation water contaminated by sewage (the case of Reymundo Jauliz in Carapongo), this is a small-scale private initiative that was initially supported by CGIAR; and
  - Reuse of treated wastewater from SEDAPAL's WWTP for irrigating crops and green areas.
- Nutrient (compost production) recovery:
  - Implemented by the private enterprise INGEMEDIOS (from municipal solid waste) and
  - A community-based experience that produces vermi-compost (La Lombriz Feliz Ecological Centre) (among other activities related to waste management: separation at source, collection, etc.). The vermi-compost is branded and sold in small plant/flower markets. This experience started with the support of the Catholic Church around 18 years ago.
- Energy recovery:
  - PETRAMAS SAC, which generates energy from municipal solid waste through biogas captured in the final disposal cells of a sanitary landfill; the experience has been implemented with private funds, obtained support from the World Bank and the National Government pays for the electricity generated (the company is one of the companies that bid in the first RER auction that supplies energy to the national electric grid.
  - A small-scale enterprise using guinea pig manure to generate power, implemented by the farmers of Casablanca farm for self-consumption (electricity, cooking and animal heating)

- Energy from pig manure, implemented by a pig-breeder also for self-consumption (electricity and animal heating).

Key lessons learnt on existing frameworks, supportive policy and gaps from various stakeholder interviews for RRR business models are as follows:

- *Treated wastewater*: The regulations in place are more oriented toward reducing the pollution load of treated wastewater discharged into bodies of water, and also toward improving the quality of wastewater treatment intended (to a limited extent) for reuse in the irrigation of high stem crops. Regulations also establish the need for each sector (Ministry) to develop maximum allowable limits and environmental quality standards for reuse purposes. Since specific standards are necessary to complement existing standards meant for human consumption however it currently limits reuse for irrigation. MINAM has to address this pending task in coordination with the other Ministries (MVCS, MINAG, and others) considering the different possibilities for reuse.

  Although the standards are not defined yet, the Government promotes reuse by authorizations provided by the National Water Authority (ANA) and the Ministry of Housing, Construction and Sanitation (MVCS) has also issued policy guidelines for promoting the inclusion of municipal and domestic treated wastewater reuse for irrigating urban and peri-urban green areas into the National Water and Sanitation Policy, plans and strategies. A law which states that sanitation service providers (such as SEDAPAL) are authorized to sell treated wastewater from wastewater treatment plants; however, although the law has been regulated, there are no sanitation service providers making use of it yet at the national level. One task still pending is the formulation of a National Strategy for promoting the reuse of domestic and municipal wastewater for irrigation and greening in urban and peri-urban areas (particularly in coastal regions) and the development of complementary regulations and standards. It would also be necessary to enhance the monitoring of wastewater treatment and reuse in order to guarantee compliance with technical, social and environmental standards for reuse.

- *Aquaculture:* The existing law for aquaculture promotion and development does not include the possibility of performing aquaculture activities using treated wastewater and therefore, there is no legal framework that supports this potential reuse, but neither are there any laws prohibiting it or limiting its development. This framework needs to be developed, and should take into consideration the lessons learned from existing experiences, pending areas of research, and the implementation of pilot projects which can help to develop a suitable legal framework for these types of businesses or activities.
- *Nutrient recovery:* The legal framework for nutrients (compost, organic fertilizers, etc.), has several laws and regulations that promote reuse and recycling, with composting and vermi-composting mentioned as potential reuse purposes, among others. Nevertheless, there are no regulations that specifically encourage or directly promote the recycling of organic waste or regulates the production of organic fertilizers (i.e. compost, worm humus). Existing programs promoted by government agencies and municipalities are more focused on inorganic recycling and reuse. Neither are there any rules or regulations enacted to authorize or quality control standards for composting. The existing legal framework does not prohibit the recycling of organic waste, as long as proper and sanitary conditions for waste treatment and reuse in general are observed. Besides, concerning agricultural waste, MINAG has recently established a set of waste management regulations for the agriculture sector, covering activities from generation to final disposal, which considers composting as an alternative.

Since there are no promotion policies or regulations to follow, composting is done informally by farmers and municipalities at a very small scale, mainly for self-consumption using primarily aerobic methods. Municipalities and farmers seem to be interested in acquiring compost made from municipal solid waste only if it is cheap and meets technical requirements that guarantee good results for green areas or crops, and health conditions, rather than demanding that there be formal standards established that need to be mandatory for producing entities or companies.

- *Energy recovery:* Energy recovery from waste is a recent development in Peru. The national policy framework currently includes producing electricity from renewable energy sources, but at the moment there are only national laws and regulations that indirectly encourage the reuse of solid waste for generating electricity. The composition of Peru's energy matrix shows that governmental entities are gradually incorporating (or planning to incorporate) a major contribution from renewable energy (biomass among others) and it opens a good opportunity for generating electricity from municipal solid waste, but limited possibilities for using animal manure (which due to the scale is more oriented toward self-consumption). The calls for bids for renewable energy resources (RER) that supply electricity to the SEIN (National Electric Interconnected System), have already included energy from municipal waste (among other sources). Experiences have to be supported by private investment, but could also apply for international cooperation funds or governmental funds (carbon credits).

The legal-institutional feasibility analysis for each of the ten business models identified for Lima was conducted using a ten-evaluation criteria, which include analyzing the content of written laws and policies, the funds available, the norms and rules of game, the existing structure or mechanisms for laws and policies and the informal institutional arrangements. They also analyze the existing culture in terms of values and behavior that shape how people deal with and understand the RRR issue, unofficial attitudes and community perceptions. A summary of the results of the feasibility study is presented in the following Table 7.

Table 7: Summary of institutional feasibility of selected business models for Lima

Business models	Content	Structure	Culture	Overall	Overall institutional feasibility and comments
Model 2: Energy Service Companies at Scale: (b) Municipal Solid Waste to Energy (Electricity)	Medium	Low to Medium	Medium	Medium	The laws and regulations are not well established (specifically for power generation from municipal waste), they are oriented toward promoting renewable energy resources (waste is one of them). Existing laws do not threaten the business model. PIGARS of Lima proposes to include the recovery of biogas from their sanitary landfills in the ToR of the new concession service for Lima Province. There is indirect financial support given by the public sector (MINEM, OSINGERMIN) through RER auctions. There are also CDM projects that EPS-RS could develop and apply for co-investment funds. Public Institutions are active and proactive in promoting this business model (MINAM, MINEM). Not directly but there are RER auctions (promoted by MINEM) that include the topic, and projects/programs interested in reducing carbon emissions (i.e. NAMA of MINAM).There is one landfill producing energy and selling carbon credits (Huaycoloro Private Landfill). There is no data or technical information available regarding the technological adaptations made. This case is not exactly a PPP, but can be used as a good reference for private participation. There is donor support from World Bank for the model. Improving waste management is one of the environmental priorities, and with the latest COP 20 in Lima, people are becoming aware of the importance of reducing greenhouse gases. This topic has not attracted much attention among civil society, nor has it garnered media coverage.
Model 3: Energy Generation from own Agro-industrial waste	Low	Low	Low	Low	There is a weak legal framework limited to generating power from agro-waste but nothing mentioned about manure. There is no policy framework to support the model and it is limited to RER and energy generation from biofuels. There are no standards or technical regulations in place to develop the business models, nor any laws/regulations that represent a threat. No budget or financial support from public entities and only covered by private investment (on a very small scale and generally for self-consumption).MINEM indirectly incentives by considering energy generation from animal waste (and industrial waste) as raw material for power production (RER) but there is not any explicit (policy or budget) support.Public Institutions seem not interested to promote the model and leave the possibility to interested manure generators for on-site reuse.There is not enough technical professionals to develop this business model.
Model 4: Onsite Energy Generation by Sanitation Service Providers	Not feasible	Low	Low	Low to infeasible	There are no regulations, laws or any governmental policies that directly or indirectly promote and/or support this model. The main problem found is that the law establishes that sludge from WWTPs is considered a hazardous waste. Therefore, by law, sanitation service providers are required to stabilize the sludge on-site and then, transport it to the sanitary landfills for proper disposal. There are no existing experiences of onsite energy generation.

Model 8: Beyond Cost Recovery: the aquaculture example	Low	Low	Low	Low	There are regulations for providing authorizations for reusing treated wastewater for irrigation but not for aquaculture. There are no technical rules or standards associated with this business model. There are no policies or incentives for aquaculture using treated wastewater. There is one experimental center of the MVCS that combines wastewater treatment (tertiary) and aquaculture (tilapia). Research is carried out with students of the UNALM. Currently, there are not enough qualified professionals to develop this business model. There was donor support for the Urban Harvest initiative in Carapongo, but not available anymore.
Model 9: On Cost Savings and Recovery - Wastewater for Irrigation, Energy and Nutrient Recovery	Medium to high	Medium to high	Medium to high	Medium to high	There are several legal instruments that promote the reuse of treated wastewater for irrigation and enable reuse authorizations. Wastewater related problems are increasingly becoming a priority for the government. There are policies that seek to promote reuse for greening and landscaping, or other uses related to irrigation. Also, the Ministry of Environment is promoting carbon emissions reduction from wastewater treatment and other sources and is developing a national strategy for reducing carbon emissions. Limited budget available to treat wastewater but not necessarily oriented to reuse. MVCS is providing some financial support to install small WWTPs for reuse. No financial incentives are provided by public institutions to projects or initiatives related to this business model. Regulations issued by MVCS promote the sale of treated wastewater and organic waste generated in WWTP for reuse. SEDAPAL plans to conduct research in reuse of sludge (biogas capture) for energy production. Treatment is done by WWTPs. They are obliged to treat wastewater as part of their mandate, but most WWTPs only comply with the low standards required to deliver treated wastewater into the sea. Farmers and Municipalities interested in reuse have to implement secondary and tertiary treatment to obtain the proper quality for reuse. There are not enough technical professionals in WWTPs that treat for reuse purposes. Legally forming the business is easy but the problem to overcome is the location of the treatment plants for reuse (secondary) and other operational aspects (distance, pumping, delivery to users, etc.)However, there is no evidence of any PPP under development. There is much interest in this topic among civil society and media but it is increasing.
Model 15: Centralized Large-scale Compost Production for Revenue Generation	Medium	Medium	Medium	Medium	There is a regulatory framework for waste reuse able to be used to support the business although composting or carbon emissions reduction is not explicit. At the moment, no financial support is given by the public sector. It is expected that there would be public budget available in Lima (funds raised by the MMML) as part of the implementation of the PIGARS proposed activities. Public Institutions' roles are active and proactive in developing this business model (MINAM, MML, district municipalities). MINAM is promoting carbon emissions reductions coming from organic municipal waste and other sources. There are some enterprises interested in investing in this model but in Peru there are not enough technical professionals with practical experience in composting from municipal solid waste. No donors identified that could provide support. Farmers and municipalities need to have technical evidence of the quality of the compost produced from MSW for greening or to be used on different

					crops. Since this compost comes from waste they feel it has to be cheaper than the compost they buy.
Model 17: High value Fertilizer Production for Profit from Fecal Sludge	Low	Low to Medium	Low	Low	There is a regulatory framework for waste reuse that can be used to support the business although composting is not explicit. There are no technical standards in place that could be used either to develop or threaten the business model. At the moment, no budget or financial support is provided by the public sector. MINAM and MML support recycle and reuse (in general) but it is not clear if they have progressively increased their interest in reusing organic waste (fertilizers from organic matter).No public actors identified but there are small plants run by communities and/or organized by the church or NGOs. Depending on the source and/or raw material and/or process for making the fertilizer, the acceptance could be good.
Model 21: Partially subsidized composting at district level	Medium	Medium	Medium	Medium	There is a regulatory framework for waste reuse that could be used to support the business, although composting is not explicit at district and/or province level. At the moment, no financial support is given by the public sector but some municipalities implement composting with their operational budget. Public Institutions' roles are active and proactive in developing this business model (MINAM, MML, district municipalities).There are some district municipalities already producing compost from their green wastes and other inputs. There are some few enterprises interested in investing in this model in public-private partnerships with District Municipalities. No significant interest amongst civil society and media support for the topic

Considering the above criteria set mentioned for evaluating institutional-legal feasibility, there is only one model in Lima with medium-high feasibility: on wastewater reuse (model 9: On Cost Savings and Recovery: Treated wastewater for irrigation/fertilizer/energy and carbon). There are three models with medium feasibility – energy generated from municipal solid waste (Model 2b: energy generation from waste) and the other two are related to nutrients and production of compost from municipal solid waste (Model 15: Large scale composting for revenue generation, and Model 21: Partially subsidized composting at district level). Compost from SWM and organic fertilizers seem to have an undeveloped market niche, in which institutions interested in transforming open public spaces into green spaces and for the development and maintenance of public green areas. Furthermore, the development of energy models are able to apply for funding from CDM project funds and others related to climate change (reduction of methane emissions and contribution to mitigate global warming) or public investment projects with social impact, either by applying for public funding from PROINVERSION or participating as bidders in renewable energy resources auctions. The other four business models selected for analysis in Lima, have institutional limitations that prevent them from being feasible from an institutional-legal perspective, but also considering the current culture and level of interest among citizens and the civil society.

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". 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 8 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 8: Summary of business models under consideration for Lima

Business Model	**Waste stream**	**End-product**	**Technologies**	**Process**
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
3	• AIW • AM	• Ethanol • Electricity	• Fermentation, Distillation Technologies • Single stage • Multi-stage • Batch • Biogas conversion technologies	• Fermentation, • Distillation • Biogas to electricity conversion
4	• Feces • Urine • FS	• Biogas -> Cooking fuel	• Single stage • Multi-stage • Batch	• Anaerobic digestion
8	• WW	• Fish • Treated WW	• Duckweed • Aquaculture	• Pond treatment
9	• WW • WW sludge	• Electricity • Soil conditioner • Water (for reclamation)	• Conventional WW treatment technologies • Biogas conversion technologies	• Conventional WW treatment • Biogas to electricity conversion
12	• WW • WW sludge	• Biogas -> Electricity	• Conventional WW treatment including anaerobic digestion technologies • Biogas conversion technologies	• Conventional WW treatment • Biogas to electricity conversion
13	• WW	• Water (for reclamation)	• Conventional WW treatment with limited nutrient removal • Slow rate infiltration • Rapid infiltration • Overland flow • Wetland application	• Conventional WW treatment • Land application
15	• MSW • FS	• Soil Conditioner	• Solid/liquid separation • Drying beds • Co-composting	• Co-composting (MSW + FS)
17	• MSW • FS	• Fertilizer (NPK added)	• Solid/liquid separation • Drying beds • Co-composting	• Co-composting (MSW + FS)
21	• MSW • FS	• Soil Conditioner	• Solid/liquid separation • Drying beds • Co-composting	• Co-composting (MSW + FS)

6 Key findings of the Financial Analysis

6.1 Introduction

This section presents the financial feasibility assessment of the selected RRR business models for Lima. The RRR business models assessed for feasibility are classified into Energy, Wastewater and Nutrient based on the resource recovered from the waste generated by the city of Lima. The financial analysis of the RRR business models selected for Lima considered all the business models except for models 4 and 17. This is because these business models are based on onsite sanitation systems and in Lima, the majority of the city has sewerage coverage and has less than 6% through onsite sanitation systems.

6.2 Methodology

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

- **Step 1:** Identification of business cases in Lima 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 scales 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 waste supply, demand, technical 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 did not 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 the Central Bank of Peru 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 RRR business models, 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 significantly affect the economic performance of the RRR business model and which are 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 generates 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. RRR sector development is not yet well developed in Peru and sectors such as making compost from waste is hardly known. This limited data availability from the local context in assessing the financial viability of the business models. Additionally, significant challenges were encountered in obtaining data relevant to the Limean context. As much as was possible, input data were collected from business cases identified in Lima, however when data was not available or not provided by the businesses, data collected from similar business cases operating in Asia, Africa and Latin America was verified and used; and also supplemented with data from literature and actualized for Lima. Data was also validated from the data collected by other components of the feasibility study – market, waste supply and availability, technical, and institutional assessment.

6.3 Financial Synopsis of the RRR Business Models

The following section presents the key financial highlights of the RRR business models assessed. For the detailed assessment, 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 9 presents the key highlights of the energy business models. As seen from the Table 9, the energy business models show a high financial viability with both the models: Model 2 – Energy service companies at scale and Model 3: Energy from own agro-industrial waste with positive NPV and IRR greater than 4% which is the discount rate in Peru. Model 4 - onsite energy generation by sanitation service providers was not assessed for Lima for reasons mentioned earlier.

Table 9: Energy Business Models

	Model 2: Energy Service Companies at Scale - Agro-Waste to Energy (Electricity)	Model 3: Energy from own Agro-industrial waste	Model 4: Onsite Energy Generation by Sanitation Service Providers
Scale	Process 200 tons of MSW per day	Piggery rearing 4,000 pigs	Financial analysis was not done for this business model
Investment required (in USD)	3.36 million	382K	
Operations Cost (in USD/year)*†	0.94 million to 1.7 million	55K to 94K	
Revenue (in USD/year)*	1.27 million to 2.31 million	137K to 239K	
NPV @ discount rate 4%**	$470,238	389,714	
IRR**	5.35%	13.16 %	

* 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 10 provides key highlights of the wastewater reuse business models. The scale was based on serving population of 300,000 which would result in 52,800 m^3 of wastewater on a daily basis.

In the financial analysis of models 9, 12 and 13, the assessment assumed investment of reuse infrastructure in an existing treatment plant. The financials assessment takes into consideration the 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. All three recovery options shows positive NPV and IRR greater than discount rate. In the case of model 8, the reuse activity - cultivation of wastewater-fed fish is assumed to occur in an existing wastewater treatment plant using a waste stabilization pond system for treatment and the fish is cultivated in the tertiary pond.

Table 10: Wastewater Reuse Business Models[$]

	Model 9, 12 & 13: On Cost Savings and Recovery			Model 8: Beyond cost recovery: the Aquaculture example
Scale	52,800 m3 for irrigation	932 tons of sludge per day	5,250 m3 of biogas + carbon benefits	5,000 kg of annual harvest of tilapia fish
Investment required (in USD)	660K	224K	1.5 million	11,200
Operations Cost (in USD/year)*†	554K to 936K	48K to 84K	0.96 million to 1.7 million	6K to 10K
Revenue (in USD/year)*	634K to 1 million	84K to 166K	1.24 million to 2.2 million	8K to 14K
NPV @ discount rate 4%**	$917,252	$741,247	$4.1 million	$8,970
IRR**	19%	25%	29.87%	12%

[$]Business models 9, 12 and 13 were initially considered as separate models. However based on the concept[7] behind the business models and the multi-criteria framework used for the analyses, they were combined into one business model with different scenarios.

* 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

6.3.3 Nutrient Business Models

Table 11 presents the key highlights of the nutrient business models[8]. As seen from the Table 11below, for Model 15 - large scale composting plants as the scale increases the NPV and IRR also increases. For all three scenarios, the NPV is positive and IRR is equal to above discount rate. However it is to be noted that for the 70-ton and 200-ton plant it is assumed to have capital subsidy of at least 75% from the municipality and in addition there is an incentive in the form of tipping fees for private sector participation. For the 600 ton plant, such an incentive and subsidy is not required. In the case of high value fertilizer production and compost production for sanitation service delivery, they both have positive NPVs and IRR greater than discount rate.

[7]The concept behind business models 9, 12 and 13 was to assess the operational cost recovery and related viability of the BM from the reuse components which are: a) Energy recovery - energy generation for internal use to reduce electricity related costs which are the primary operation costs for WWTP, b) Carbon sales - carbon reductions which is mainly captured when treatment plant generates energy by capturing methane, c) Nutrient recovery – Sale of sludge as fertilizer and, d) Treated water – Sale towards irrigation. BM 9 focuses on recovery of energy, nutrient and treated water, while BM 12 is for carbon emission (read as energy recovery) and BM 13 is for irrigation.

[8]Business models 15 and 21 were combined into 1 business model with different scales (70 and 200 tons for model 21 & 70, 200 and 600 tons for model 15).

Table 11: Nutrient Business Models

	Model 15: Large-Scale Composting for Revenue Generation			Model 17: High value Fertilizer Production for Profit	Model 21: Partially subsidized composting at District level
Scale	70 tons of MSW per day	200 tons of MSW per day	600 tons of MSW per day		
Investment required (in USD)	628K	1.22 million	3.3 million		
Operations Cost (in USD/year)*†	73K to 217K	284K to 488K	549K to 992K	Financial analysis was not done for this business model	Financial assessment as under Model 15
Revenue (in USD/year)*	150K to 354K	385K to 719K	809K to 2.45 million		
NPV @ discount rate 12%**	$14,965	$64,807	$2,847,902		
IRR**	4%	5%	12%		

* 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 13 provides a summary overview of the feasibility of RRR business models for Lima. As mentioned earlier in the methodology, a Monte Carlo risk analysis was done for the financial models for variable parameters with a high level of uncertainty. A stochastic simulation model was run for a large number of iterations to generate empirical estimates of probability distributions for NPV and IRR, to guide investors, donors and entrepreneurs to evaluate the probability of success for an RRR business model. This simulation results evaluated several aspects: a) a probability of NPV < 0, mean NPV and IRR, pessimistic and optimistic NPV and IRR values. The mean NPV and IRR is the net average of the lowest and highest NPV and IRR value for various iterations. The results from the simulation exercise formed the basis for the selection of key indicators to assess the feasibility of the RRR business model. The indicators used to assess the feasibility of the RRR business models were based on: P (NPV<0), *Mean NPV* been positive or negative and a *Mean IRR* greater than or less than the discount rate in Peru (4%). The methodology used to define the feasibility is as described in Table 12 below.

Table 12: 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	

50% and above	+	Less than discount rate	**Low**
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 12 above, the RRR business models were assessed for their viability to Lima context. Model 15 – large scale composting for revenue generation (200 tons) as seen from the Table 13 is the only model that is not feasible while the remaining models show either medium or high feasibility. The models with high feasibility are Model 3 – Energy Generation from own Agro-Industrial waste, Model 9 – On Cost Savings and Recovery: Sludge recovery as nutrient and electricity generation including carbon credits and Model 15 – large scale composting for revenue generation @ 600 tons per day of waste processed. Except for Model 3 – Energy generation from own Agro-industrial waste, the remaining models are public-private partnership (PPP) models where it is assumed that land and oftentimes capital is provided by the municipality. Model 9 – On cost savings and recovery (sludge recovery and electricity generation) when all three components are combined in a treatment plant, has a medium to high feasibility potential.

Table 13: RRR Business Models Feasibility

RRR Business Models	**P (NPV< 0)**	**Mean NPV**	**Mean IRR**	**Feasibility**
ENERGY				
Model 2: Energy Service Companies at Scale –MSW to Energy	32.1%	$369,445	4.94%	Medium to High
Model 3: Energy Generation from own Agro-industrial waste	0.2%	$389,714	15.04%	High
Model 4: Onsite Energy Generation by Sanitation Service Providers	*Financial Feasibility not undertaken*			
WASTEWATER REUSE				
Model 8: Beyond Cost Recovery: the Aquaculture example	35%	$3,116	12.37%	Medium to High
Model 9: On Cost Savings and Recovery – Irrigation reuse	43%	$333,510	22.82%	Medium to High
Model 9: On Cost Savings and Recovery – sludge recovery as soil conditioner	8.6%	$972,011	30.65%	High
Model 12: On Cost Savings and Recovery – electricity for onsite use + carbon credits	0%	$3,333,526	25.72%	High
Model 13: On Cost Savings and Recovery – combined energy, water and nutrient recovery	8.4%	$969,649	30.45%	High
NUTRIENTS				
Model 15: Large-Scale Composting for Revenue Generation - 70 tons	48%	$16,381	4.06%	Medium
Model 15: Large-Scale Composting for Revenue Generation - 200 tons	56.9%	($80,739)	2.78%	Not feasible
Model 15: Large-Scale Composting for Revenue Generation - 600 tons	0%	$3,004,169	12%	High

Model 17: High value Fertilizer Production for Profit	*Financial Feasibility not undertaken*
Model 21: Partially subsidized composting at district level	*Financial Feasibility as part of Model 8 – 70 tons and 200 tons*

While Table 13 above attempts to give a snapshot of the RRR business models viable for the Lima context, it however needs to be noted that all the business models under different conditions other than that in Lima may have high feasibility potential or 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 reducing the viability due to high debt rates at 15% (as per the Central Bank of Peru). Other than the interest rates, the percentage of sale of product plays a significant role in the viability.

Below is a brief overview of the key aspects that will influence the feasibility of each of the business models in Lima:

Model 2 – Energy Service Companies-MSW to Energy: This business model is observed at a large scale in Lima where a landfill in Huaycoloro is used to generate power by tapping landfill gas. The financial assessments show that larger scale plants is feasible but highly sensitive to the sale price of electricity. In addition as mentioned earlier, the business shows increasing viability when the equity component of the investment is increased.

Model 3: Energy generation from own agro-industrial waste: This is the only business model with complete private ownership. The model is based on energy savings and in the case of excess energy, it is sold to neighboring households and businesses. The agro-waste generated from any medium or large agro-industry is high and enough to cover internal energy requirement. The investment shows a very strong viability assuming the markets for the sale of excess energy is nearby or there is possibility of feeding the excess electricity to grid. 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 that there is no additional investment and the cultivation of the fish occurs in an existing treatment plant that has a waste stabilization pond system, with production activities occurring in the tertiary treatment pond. Another approach that can be considered is the investment in a pond system which is fed with secondary treated water to cultivate duckweed for tertiary treatment, which is fed to the fish. The business is highly sensitive to the scale of operations. At lower fish production levels, the business model is not viable as the cost of labor to manage the production activities is high and drives the investment to be unviable. Additionally, the price of inputs (fingerlings) and the price of fish also determine the business viability. The concern of market acceptability is minimal as consumers are rarely aware of the source of water used for aquaculture.

Model 9, 12 and 13 – On cost savings and recovery: The financial analysis of this model focused on the reuse component and does not take into account the setting up of a new wastewater treatment plant. Three scenarios were developed based on the type of resource recovered (energy including carbon credits, water and nutrient). The key assumption in the case of water and nutrient recovery is the sale of treated wastewater for irrigation (or industry) or sale of sludge as soil conditioner. We acknowledge that these assumptions of sale is the riskiest aspect of this business model as farmers rarely pay for freshwater in developing countries and to assume that they would pay for treated water is questionable. In the event of a drought or water scarcity, there is the possibility of increased willingness to pay for treated wastewater and in the case of Lima which is one of the driest regions in the world, peri-urban agriculture could significantly benefit from 365 days of water. Alternatively, the treatment plant could target the sale of treated water to industries. The feasibility of supplying treated wastewater also depends on the length of the canal or pipeline and pumping costs to deliver the water to its customer segment. In the case of the electricity generated, the financial assessment shows that about 35% of energy required for the treatment plant is covered and viability is significant from the sale of carbon. However, given the fluctuation in carbon prices (which is currently less than a dollar for ton of CO_2), the impact on the viability of the investment will be significant. A higher electricity price in Lima will make the investment viable. A treatment plant incorporating all these reuse investments yields a positive NPV and in the longer run, after the reuse component of the investment is paid back, it will help significantly improve the operation cost recovery of wastewater treatment plant.

Model 15– Large scale composting for revenue generation and Model 21 - Partially-subsidized composting (MSW-based compost): As noted above, the financial assessment was conducted for three different scenarios and it was observed that at a lower scale of 70 tons and 200 tons, the viability of the business without any subsidy or incentives was marginal and as the scale of waste processed increases, the feasibility of the compost production plant improves. Similar to Model 2, the debt to equity ratio plays a significant role for a positive NPV especially for the 70-ton and 200-ton plant. A critical assumption in the business model is the significant quantity of compost sold per year (from 50% to 80%). In the study, it was 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. In addition, the compost price in Peru is significantly high in comparison to countries in Asia and Africa. The price of compost is one the most sensitive parameters that drives viability of the business.

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 Lima. The magnitude of potential impacts was determined by means of a semi-quantitative impact assessment. The feasibility studies in Lima were oriented towards nine BMs that were selected due to their potential in the given context. These BMs are:

- Model 2b: Energy service companies at scale: MSW to energy (electricity)
- Model 3: Energy generation from own agro-industrial waste
- Model 4: Onsite energy generation by sanitation service providers
- Model 8: Beyond cost recovery: the aquaculture example
- Model 9: On cost savings and recovery
- Model 13: Informal to formal trajectory in wastewater Irrigation: sale/auctioning wastewater for irrigation
- Model 15: Large-scale composting for revenue generation
- Model 17: High value fertilizer production for profit
- Model 21: Partially subsidized composting at district level

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 seven existing RRR cases were investigated in Lima area:

- Case 1: Wastewater treatment for irrigation: Fundo Palo Alto
- Case 2: MSW collection service- San Luis Municipality-Recyclers
- Case 3: Treated wastewater for irrigation/fertilizer/energy: ParqueZonal Huascar
- Case 4: High quality branded/certified organic fertilizer form faecal sludge and municipal solid waste (MSW) & onsite energy generation: ECO Granja “Camila” (pig farm)

- Case 5: Phyto-remediative water treatment and fish production (Tilapia ponds): urban agricultural family business, Carapongo, Lurigancho
- Case 6: High Quality Branded/Certified Organic Fertilizer from Faecal Sludge X-runners - Dry toilets- Sanitation Solution in urban Areas
- Case 7: Phyto-remediative water treatment and fish production (Tilapia ponds): Union University

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 seven existing RRR cases, the city of Lima benefited from a complementary in-depth study on the concentration of heavy metals, protozoa and helminth eggs were carried out in the frame of the pre-testing of the Sanitation Safety Planning (SSP) manual in Lima. For the pre-testing of the SSP manual in Lima, two study sites were selected: the agricultural area in Cono Este (peri-urban area of Lima) and the ParqueHusacar in Lima city. In the frame of those two case studies, the team led by Dr Julio Moscoso collected a large number of environmental samples (water, soil and plant) for determining the presence and/or concentration of heavy metals, bacteria, protozoa and helminth eggs. Hence, the data generated by the SSP manual trials make an important contribution to the evidence-base of the HRIA.

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

According to health statistics from the districts where the data collection activities at the level of existing RRR cases took place (i.e. Lurigancho, Villa el Salvador and Lurin districts, and San Luis municipality), respiratory diseases, diseases of the digestive system and different infectious and parasitic diseases were the leading causes of morbidity at the represented health facilities in 2009, 2010 and 2011. A closer look at the statistics reveals that upper respiratory tract infections and intestinal infections are the principal cause for consulting a health facility, with most patients being under the age of 5 years.
With regard to access to sanitation facilities, the 2012 Peru Demographic and Health Survey (PDHS) found that three in four households in urban areas have access to piped drinking water inside their house and are connected to the sewerage system [15]. In Lima, the percentage of houses that are connected to the sewerage system is 90.3%, which is clearly above the national average. In 2012, 6.3% of the households in Lima collected their drinking water from a pipe or fountain outside their house or apartment.

Against this background, it is not surprising that helminthic infections are not a major health concern in urban and peri-urban areas of Lima. Intestinal protozoa infections are of greater public health concern, particularly in children. The burden of chronic respiratory diseases and cardiovascular diseases is relatively high in Peru, accounting for 4% and 22% of total mortality (all ages, both sexes), respectively.
Depending on the season, a broad range of mosquito vectors such as *Anopheles spp*., *Aedes spp*. and *Culex spp*. are present in Peru. Therefore, various vector-borne diseases are endemic in the country, particularly in the jungle areas in the north. The most important vector-borne disease in Peru is Dengue, but also malaria, leishmaniasis and Chagas disease are important public health concerns. However, none of those vector-borne diseases is of public health relevance in Lima.

Exposure to noise, air pollution, contaminated drinking water, contaminated surfaces and contaminated food products are important environmental determinants of health. The findings of the environmental sampling at the Cono Este study can be summarised as follows:

- Water samples: none of the average values for heavy metals exceeded the national threshold. Protozoa concentrations above the national limit of 0 protozoa per 1 L were detected in water samples from each sampling site. Also helminth eggs were detected in most samples, though the average concentration did not exceed the national limit of ≤1 helminth egg per 1 L.
- Soil samples: concentrations of arsenic and led exceeded national limits at two of the three sampling sites. Cadmium was above the national threshold at one study site.
- Grass samples at UPeU: helminth eggs (A. *Lumbricoides* and *Strongyloides* sp.) were detected on grass surfaces irrigated with wastewater.
- Vegetable samples collected at Carapongo: all the vegetable samples showed contamination with protozoa eggs. Helminth eggs were less of an issue.
- Fish: fish cultivated at the Nievería site showed concentrations of TTC exceeding the national limit of 100 TTC/g (maximum). The maximum concentration of TTC of fish cultivated at the Carapongo site was 3.3 TTC/g.

Findings of the environmental sampling at the Parque Huascar study site are as follows:

- Water samples: none of the average values for heavy metals exceeded the national threshold. The crude water from the waste water treatment plant (WWTP) showed protozoa concentrations above the national limit of 0 protozoa per 1 L and also high concentrations in TTC (up to $7x10^7$ TTC/100mL). Also helminth eggs were detected in all crude water samples.
- Soil samples: concentrations of chrome exceeded national limits in soil of the green areas and agricultural surfaces of Parque Huascar. Larvae of *Ascaris* spp. and *Strongyloides* spp. were detected in soil samples of the green areas.
- Grass samples: as for the soil samples, helminth larvae (*Ascaris* spp. and *Strongyloides* spp.) were detected on grass surfaces irrigated with wastewater. No protozoa were found in grass samples. Interestingly, very high concentrations of TTC were measured on grass samples (up to $2x10^5$ TTC/g).

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, 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 Lima area showed variation in heavy metal concentration, often exceeding national and international thresholds. This clearly indicates that irrigation with wastewater is of concern in Lima 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. Of note, reuse of sludge is currently prohibited in Peru.

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 Lima 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. Models 2b, 15, 17 and 21, all of which use municipal solid waste (MSW) as an input, are only an option if no medical waste from health facilities is mixed with common MSW.

7.5 Key findings of the HIA

The objective of the HIA was to assess potential health impacts at community level of proposed BMs for Lima 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 14. Most of the proposed BMs have the potential for resulting in a minor to major positive health impact. Under the given scenarios, Model 9 (treated wastewater for irrigation/fertilizer/energy: on cost savings and recovery), 13 (informal to formal trajectory in wastewater irrigation: sale/auctioning wastewater for irrigation) and Model 8 (the aquaculture example) have 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 (untreated or treated) used is compliant with national and international quality requirements regarding toxic chemicals. The other BMs are anticipated to only have a minor positive or insignificant impact on community health.

Table 14: Summary table of anticipated health impacts and their respective magnitude

Business model	Scale of the BM: applied scenario	Anticipated health impact	Magnitude (score)
Model 2b – Energy service companies at scale: MSW to energy (electricity)	Two plants as proposed by the business will be implemented in Lima.	Impact 1: changes in health status due to access to electricity	**Insignificant (0)**
Model 3 – Energy generation from own agro-industrial waste	Two plants as proposed by the business will be implemented in Lima, resulting in 500 people that will have a reduce exposure to manure	Impact 1: changes in health status due to access to electricity	**Insignificant (0)**
		Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases	**Minor positive impact (15)**
Model 4 – Onsite energy generation in enterprises providing sanitation services	10 villages in rural and peri-urban areas of Lima will implement the BM with a population of 1,000 each	Impact 1: reduction in respiratory, diarrhoeal and intestinal diseases	**Moderate positive impact (30)**
		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	Scenario of Cono Este: 5,600 farmers, 700,000 consumers and 22,000 people downstream will be impacted	Impact 1: reduction in respiratory, diarrhoeal, intestinal and skin diseases	**Major positive impact (25,030)**
		Impact 2: reduction in exposure to chemicals and heavy metals	**Moderate positive impact (28)**
		Impact 3: changes in health status due to access to electricity	**Insignificant (0)**
Model 13 – Informal to formal trajectory in wastewater Irrigation: sale/auctioning wastewater for irrigation	Scenario of Cono Este: 5,600 farmers, 700,000 consumers and 22,000 people downstream will be impacted	Impact 1: reduction in respiratory, diarrhoeal, intestinal and skin diseases	**Major positive impact (25,030)**
		Impact 2: reduction in exposure to toxic chemicals (e.g. heavy metals)	**Moderate positive impact (28)**
Model 15 – Large-scale composting for revenue generation	Two centralised co-composting plants are installed in Lima, serving 2'000 households each	Impact 1: reduction in respiratory, diarrhoeal, intestinal and skin diseases	**Minor positive impact (4)**
Model 17 – High value fertilizer production for profit	Two centralised co-composting plants are installed in Lima, serving 2'000 households each	Impact 1: reduction in respiratory, diarrhoeal, intestinal and skin diseases	**Minor positive impact (4)**
Model 21 – Partially subsidized composting at district level	No health impacts anticipated		**Insignificant (0)**

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 15 provides a summary for all the business models, the respective waste streams, end-products technologies, processes and potential environmental hazards, including proposed mitigation measures.

Detailed information is available in the reports on: Resource, Recovery and Reuse Project. From Research to Implementation. Component 4 – Technology Assessment: Bangalore, India; Hanoi, Vietnam; Kampala/Uganda; Lima, Peru. February (2015)and Component 7 – Health and environmental risk and impact assessments of waste reuse business models: Lima, Peru.

Table 15: Summary of business models under consideration for Lima

Business Model	Waste stream	End-product	Technologies	Process	Potential Environmental Hazard	Mitigation measures
2 (a)	• MSW	• Gasification -> Electricity • Biogas -> Electricity	• Gasification technologies • Single stage • Multi-stage • Batch • Biogas conversion tech.	• 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
3	• AIW • AM	• Ethanol • Electricity	• Fermentation, Distillation Technologies • Single stage • Multi-stage • Batch • Biogas conversion technologies	• Fermentation, • Distillation • Biogas to electricity conversion	• Hazardous air emissions • Solid residue (digestate) • Liquid effluent	• Air emission control technologies • Solid/liquid residue post-treatment
4	• Faeces • 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
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 WW 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

12	• WW • WW sludge	• Biogas -> Electricity	• Conventional WW treatment including anaerobic digestion technologies • Biogas conversion technologies	• Conventional WW treatment • Biogas to electricity conversion	• Heavy metals in effluent and/or WW sludge • Air emissions • Solid residue (sludge from WW treatment) • Liquid effluent	• Upstream monitoring of heavy metal concentration • Monitoring of effluent and solids • Solid residue (sludge from WW treatment) post-treatment • Maintenance of anaerobic digester
13	• WW	• Water (for reclamation)	• Conventional WW treatment with limited nutrient removal • Slow rate infiltration • Rapid infiltration • Overland flow • Wetland application	• Conventional WW treatment • Land application	• Groundwater contamination (heavy metals/pathogens) • Contamination of irrigated crops • Solid residue (sludge from WW treatment)	• Crop selection • Upstream monitoring of heavy metal concentration • Monitoring of effluent and solids • 2006 WHO guidelines • Solid residue (sludge from WW treatment) post-treatment
15	• MSW • FS	• Soil Conditioner	• Solid/liquid separation • Drying beds • Co-composting	• Co-composting (MSW + FS)	• Accumulated inorganic waste • Leachate from composting • Insufficient pathogen inactivation • Liquid effluent (from FS treatment)	• Storage/transport/disposal (sanitary landfill) • Moisture control • Leachate treatment • Temperature control (compost heap) • Post-treatment of liquid effluent
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
21	• 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

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 Lima
- 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, annual write off, insurance, depreciation and debt-equity ratios were obtained from published data reports by Bank of Peru 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 Peru. 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 Peru, 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 Peru. 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 Lima. Since the financial model is the base for the economic model, it needs to be mentioned here that economic data not available for the businesses were mined from the different business sources operating in Asia, Africa and Latin America and were verified before their use. However, as explained before in the financial assessment, data sources for wastewater is weak and this produces a cascading effect in the socioeconomic assessment as well.

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

The following matrix defines the system boundary of the socioeconomic models used in the assessment for the RRR business models. In all of these cases, the scale of the business model is so adjusted such that the entire waste can be utilized by the particular business. The socioeconomic assessment of the business models is performed taking into consideration two contrasting situations where the baseline condition refers to the present situation in Lima 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 Lima 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 16) indicates the baseline and alternative scenarios and also describes the scale of operation for the different business models in Lima.

Table 16: Baseline and Alternative Scenarios used for the Socioeconomic Assessment for the different Business Models

<table>
<tr><th>Business Models</th><th>Base case</th><th>Alternative</th><th>Remarks</th></tr>
<tr><td colspan="4">System Boundary of the Energy Models</td></tr>
<tr><td>Model 2: Energy Service Companies at Scale – MSW to Energy</td><td>Landfill gas is not being utilized for generation of electricity</td><td>The alternative scenario assumes the utilization of the entire landfill gas for electricity production. The scale considered for the socio-economic assessment includes the entire MSW generated in Lima.</td><td></td></tr>
<tr><td>Model 3: Energy Generation from own Agro-industrial waste</td><td>The baseline scenario does not consider any generation of electricity from livestock wastes.</td><td>The alternate situation assumes 10 pig farms with a herd size of 4,000 that generates electricity from livestock waste.</td><td>In absence of the data about the number of pig farms existing in Lima it is considered that establishment of 10 big farms would be representative scale for the city.</td></tr>
<tr><td>Model 4: Onsite Energy Generation by Sanitation Service Providers</td><td colspan="3">Feasibility study was not undertaken.</td></tr>
<tr><td colspan="4">System Boundary for the Wastewater models</td></tr>
<tr><td>Model 9: On Cost Savings and Recovery – combined energy, water and nutrient recovery</td><td>The WWTPs existing does not have electricity production</td><td>9 WWTPs treating wastewater of more than 5000 MGD is considered for the analysis</td><td rowspan="2">There exists 26 WWTPs in Lima which is not being used either for aquaculture or electricity, fertilizer and irrigation. The socioeconomic study assumes that the smaller plants with than 5000 MGD is used for aquaculture</td></tr>
<tr><td>Model 8: Beyond Cost Recovery: the Aquaculture example</td><td>The WWTPs are not linked with ponds</td><td>16 WWTPs which are smaller in capacity is assumed to be linked with ponds for aquaculture.</td></tr>
</table>

Business Models	Base case	Alternative	Remarks
	where aquaculture is practiced		and the rest plants are used for electricity, irrigation and fertilizer production (since plants with capacity less than 5000 MGD is economically not feasible for electricity generation)
System Boundary for the Nutrient Models			
Model 15: Large-Scale Composting for Revenue Generation	No Large scale composting in Lima	The alternate scenario assume 8 large scale compost plants which can take up 600 tons of organic waste to exhaust the entire organic fraction of MSW of the city.	
Model 17: High value Fertilizer Production for Profit	Feasibility study was not undertaken		
Model 21: Partially subsidized composting at district level	Feasibility study was not undertaken		

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

Table 17: Energy Business Models

	Model 2: Energy Service Companies at Scale – MSW to Energy	Model 3: Energy Generation from own Agro-industrial waste
Scale of operation	***Power generation from the landfills at the city level***	***10 Plants generating electricity from livestock waste targeted for farm size with 4000 pigs***
NPV** Financial (in USD)	***3,761,904***	***3,147,990***
NPV** Financial & Environmental (in USD)	***15,297,902***	***18,718,720***
NPV** Financial, Environmental & Social (in USD)	***50,646,571***	***48,795,286***
B:C Ratio	***9.28***	***6.87***
ROI	***321%***	***126%***

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

10 plants assumed since actual number of the pig farms existing in Lima were not available

K = 1,000

9.4.2 Wastewater Reuse Business Models

In the context of Lima, two different scenarios are considered – (i) Treated wastewater for irrigation, fertilizer and energy, and (ii) Wastewater for irrigation and ground water recharge. Table 18provides key highlights of wastewater reuse business models. The scale was based on the input wastewater quantity in Lima which was from the waste supply and availability data based on sewer network in Lima. 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 18: Wastewater Reuse Business Models

	Model 8: Wastewater-fed aquaculture	Model 9: Treated wastewater for irrigation/fertilizer/energy – cost recovery
Scale of operation	***17 small scale ponds are considered for aquaculture. These ponds are linked to the WWTPs from which there is no electricity generation***	***9 WWTPs which have a treatment capacity of more than 5000 MGD per day is being considered for the socio-economic assessment***
NPV** Financial (in USD)	***152,490***	***(1,437,849)***
NPV** Financial & Environmental (in USD)	***311,988***	***83,747,518***
NPV** Financial, Environmental & Social (in USD)	***2,700,704***	***110,880,671***
B:C Ratio	***14.18***	***7.33***
ROI	***122%***	***146%***

** 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 19. This table provides key highlights of Nutrient business models in terms of the NPVs for the financial, environmental and societal net benefits. It can be seen from the table that High value Fertilizer production and compost derived from Sanitation Service Delivery have higher increase in societal benefits compared to the compost production from MSW. This is primarily due to the fact that sanitation infrastructure either in terms of better service delivery or treatment of faecal sludge have pertinent health benefits as well as positive environmental impacts for the society.

Table 19: Nutrient Business Models

	Model 15: Large-Scale Composting for Revenue Generation & Model 21: Partially subsidized composting at the district level
Scale of operation	***8 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***
NPV** Financial (in USD)	***25,258,365***
NPV** Financial & Environmental (in USD)	***143,483,439***
NPV** Financial, Environmental & Social (in USD)	***238,801,928***
B:C Ratio	***11.62***
ROI	***104%***

** 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 20 provides a summary overview of the criteria used for feasibility of RRR business models for Lima 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 20below.

Table 20: 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 20, the RRR business models were assessed for their viability in the context of the Lima city (shown in Table 21). Based on the criteria of assessment, it is found that the energy models have a lower feasibility compared to that of the wastewater and the nutrient models. All the energy models have a BCR greater than 1 however, the ROI is lower than 100% indicating that the business model would not be able to reap benefits larger than the investments. Along with these observations, it was also estimated that the probability of NVP dipping down from the mean value is more than 50% or close to it. In comparison to these scenario, although the models for wastewater and nutrients had probability values close to 50%, the other criteria of BCR to be greater than 1 and RoI of more than 100% make the business models to be feasible at a medium range. It has been mentioned previously that economic costs and benefits utilize the database from the financial analysis. At the same time the financial models had been scaled up linearly to meet the waste resources from different waste streams produced in Lima. 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 21: Synopsis of Socioeconomic Feasibility RRR Business Models

RRR Business Models	P ($NPV<NPV_{mean}$)	B:C Ratio	Rate of Investment (ROI)	Feasibility
ENERGY				
Model 2: Energy Service Companies at Scale - Agro-Waste to Energy (Electricity) – 8MW Profit Maximization Model	50.5%	9.2	321.6%	Medium
Model 3: Energy Generation from own Agro-industrial waste	50.2%	6.87	126%	Medium
Model 8: Phyto-remediate wastewater treatment and fish production	49%	14.18	122%	High
Model 9: On Cost Savings and Recovery – combined energy, water and nutrient recovery	49.3%	7.33	146%	High
Model 15: Large-Scale Composting for Revenue Generation - 600 tons	50.6%	8.18	104%	Medium
Model 21: Partially subsidized composting at district level				

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

Model 2 – Energy Service Companies: This business model has a lot of potential when we consider electricity generation for rural Peru where electricity is a basic need. Associated with this there is net GHG emissions saved per kWh of electricity generated is 2.724 kg CO_2eq. The highest savings in GHG emissions are mainly from avoided from the MSW which is practically untapped while the highest emissions from the business model is from the leakages from gasifier. In the present situation most of the MSW 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 when coupled with the societal benefits provides impetus for the feasibility of the model.

Model 3 – Energy generation from own agro-industrial waste – 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 self-sufficiency in electricity 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 Lima 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 highly feasible. The socioeconomic assessment considered the 8 plants of same scale for absorbing the waste of the city. The economic feasibility of the model is similarly high mainly due to the fact that there are savings in terms of GHG emissions. This model also has societal impacts through soil amelioration and increasing the farm income in future years with higher yields when used in conjunction with chemical fertilizers and ultimately also reduces the use of the fertilizers helping the soil to retain nutrients for a longer period of time.

10 Synthesis of Feasibility Studies

This section presents the overall synthesis and ranking of the potential feasibility of the selected business models for Lima. 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 provides insights on the 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: 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 a potential of:

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 > 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:* The 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, the Waste Supply &Availability and Institutional criteria has to be of either medium or high feasibility and then the 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 22 below.

Table 22: 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 23 below. It is noted that the '*wastewater use for irrigation, energy and nutrient recovery*' business model has the highest feasibility for Lima'; the nutrient business model (MSW-based compost) and energy business model (MSW for electricity generation) have a medium level of feasibility. 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 2a - Energy Service Companies at Scale (MSW to electricity):
The results showed that the proposed business model has potential for implementation in Lima and could work in the context of the energy market of Peru where hydroelectric and thermoelectric plants predominate. From the market perspective, it is important to note that waste-to-energy entities will have to compete in the market of non-conventional renewable energies (relevant market), where wind and solar energy are prevalent. Whilst these are critical factors to be considered, Lima has several particular advantages in place such as the availability of inputs to produce energy, low-cost technologies, a high potential to produce technological change and a high probability of replacement when energy sources such as diesel, wood, batteries (usually more expensive) are prevalent. It is also important to note that whilst only a small percentage of the population in Lima still lacks power or still live in remote rural areas, their sources for electricity are based on non-conventional sources, in the order of: 1) solar, 2) mini-hydro or 3) biogas at a domestic scale. This thus represents an opportunity that waste-to-energy entities can capture.

The electricity market in Peru has favorable conditions and abundance of energy sources, reflected in an energy matrix with high potential and high presence of energy production from renewable sources (mainly hydropower). In the course of several decades, and enabled by the Camisea gas and power plants, it has managed to do most of the work to replace polluting energy sources to generate electricity, such as diesel oil or coal. The Peruvian government is making an effort to promote renewable energy technologies through an auction mechanism that ensures competition between several alternatives. Thus, it is not engaged in promoting a particular kind of alternative energy source, but seeks investors' own capacities to innovate and produce technological changes between each auction. The goal is that, by 2021, Peru will be producing 5% of its energy from non-conventional sources —it is currently at 2.5%. It is here where the main chances of financing the business model is. In conclusion, an orderly and competitive energy market offers several options for the business model proposed, which should focus on preparing to participate as investment projects in the auction market. While the costs of entering the National Integrated Electricity

System (SEIN) may be prohibitive for small projects, the stability of the regime (a third auction will happen in 2015:III) allows long-term investors to compete and reduce costs, while promoting technological change and innovation in order to help making these technologies more profitable. From a financial perspective, the analyses indicated that larger-scale plants are feasible but highly sensitive to the sale price of electricity. Additionally, the business model showed increasing viability with increases in the equity component of the investment.

Model 3 - Energy Generation from own Agro-industrial Waste (agro-waste to electricity):
From a financial perspective, this is the only business model with complete private ownership. The model is based on energy savings and any excess energy generated is sold to neighboring households and businesses. The agro-waste generated from any medium or large agro-industry is typically sufficient to cover any internal energy requirements. The analysis shows the business to have a very strong viability assuming the markets for the sale of excess energy is nearby or there is possibility of feeding the excess electricity to grid. The business hardly has any variables that dictate its viability, however plant operation days and electricity price may dictate the extent of profitability.

Although there is significant availability and easy access to inputs (agro-waste, in particular pig manure), and the model shows a high financial viability, the results show that this business model as a low level of feasibility for implementation. This is mainly driven by a weak legal framework which is limited to energy generation from agro-waste, in general and bio-fuels, without a focus on animal waste. There is thus no direct policy framework and standards or technical regulations in place that support the implementation of this model. This may be due to the novelty of waste reuse (gap in legislation) and the city's priorities as on the other hand, there are no laws/regulations that would represent a threat to the business either. There is currently no known budget or financial support from public entities and all existing initiatives are covered by private investment (on a very small scale and generally for self-consumption). There is a general notion that public institutions may not be interested to promote the model but there is a general interest from manure generators for on-site reuse. Thus, an improved enabling environment from an institutional perspective will generally improve the feasibility of this model[9].

Model 4 - Onsite Energy Generation by Sanitation Service Providers (faecal sludge to energy):
The infeasibility of this business model is mainly driven by the fact that Lima is predominately covered with sewer systems (90% coverage) and has very limited onsite sanitation coverage (6%). The public toilets in Lima are mostly connected to the central sewer system. The onsite energy generation by sanitation service provider business model can be initiated by either an enterprise running a toilet complex or residential institution. In both cases the toilets are not connected to the sewers, thus limiting the availability of the sludge. There are however very few experiences covered by ECOSAN toilets and FS generation and collection is generally low[10]. Additionally, there are no regulations, laws or any governmental policies that directly or indirectly promote and/or support this model. The main limiting factor is that the law establishes that sludge from WWTPs is considered a hazardous waste. Thus, by law, sanitation service providers are required to stabilize the sludge on-site and then, transport it to the sanitary landfills for proper disposal. Given these institutional constraints and limited onsite sanitation systems, this business model is not well-suited for the context of Lima.

---

[9]From a market perspective, given that the end-product is electricity the conclusions elaborated under Model 2 are also applicable to model 4.
[10]However, access to toilets services may be required particularly in the slum areas. There are some businesses such as X-Runner that have implemented this business model.

Model 8 - Beyond Cost Recovery: Wastewater-fed Aquaculture

Wastewater-fed aquaculture is becoming a major livelihood strategy for many municipalities looking for wastewater treatment and cost-savings options in Lima, Peru. The results show that generally consumers are willing to pay for wastewater-fed fish however, it is important for new wastewater-fed fish businesses to consider the provision of a fish product with clear labelling on source and additive information. The concern of market acceptability is minimal as consumers are rarely aware of the source of water used for aquaculture. It is noted that whilst entry into the fish market is not free, it is clear that there are no barriers to entry, rather bureaucratic procedures which must be conducted prior to obtaining permission. The high level of concentration of the market (with two very large operations followed by a myriad of smaller ones) is more an indication of a growing market rather than a stabilized equilibrium enforced by market power or inefficiencies.

The financial analysis of the model assumed that there is no additional investment and the cultivation of the fish occurs in an existing treatment plant that has a waste stabilization pond system, with production activities occurring in the tertiary treatment pond. From a financial perspective, the business of wastewater-fed fish is highly sensitive to the scale of operations. At lower fish production levels, the business model is not viable as the cost of labor to manage the production activities is high and drives the investment to be unviable. Although the market and financial indicators suggest potential feasibility of this model, the overall feasibility of the model is limited by the institutional environment. There are existing regulations for providing authorizations for reusing treated wastewater for irrigation but not for aquaculture. Additionally, there are no existing technical rules or standards nor policies or incentives that support this wastewater-fed aquaculture. 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[11].

Model 9, 12 and 13 - On Cost Savings and Recovery (Wastewater use for irrigation, nutrient recovery and electricity generation)[12]

The high feasibility for implementation of this business model is driven key factors related to: a) high financial viability, b) supportive institutional environment and c) wastewater availability and access. There is significant wastewater generated and treated in Lima (at approx. 900 Million Litres per Day (MLD) of treated WW) that can be reused at some level. Although treated wastewater is already in use in the city (in almost 12 of the 26 WWTPs, concentrated in the southern part of the city), the majority of the treated wastewater is discharged into the sea. This is similar for treated agro-industrial wastewater (~12 MLD mainly from dairy and beer production), which is discharged into the city rivers (Huaycloro and Rimac) and could be diverted for reuse.

Business model 9 is noted to be the most feasible, particularly for projects of medium and small scale associated to irrigation in the districts of Lima. However, depending on who demands the treated wastewater, one must take into account the aims and objectives of the project/initiative, some of which are justifiable in the grounds of public interest.

---

[11]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.

[12]Business models 9, 12 and 13 were initially considered as separate models. However based on the concept behind the business models and the multi-criteria framework used for the analyses, they were combined into one business model with different scenarios. The concept underlying these business models is to treat wastewater for safe reuse in agriculture and industrial applications, convert the sludge from the treatment plant to compost and soil ameliorant for sale and generate energy for internal purposes resulting in energy savings or sale to the national grid. The premise is that these activities will generate revenue to curb maintenance costs of the wastewater treatment plant and ensure its sustainability.

- SEDAPAL has clearly signaled its priority of reducing pollution and damage to health through treatment of wastewater —a public good component. While the price structure suggests a bias towards offering cheaper rates for agricultural purposes, it is possible to increase awareness towards the public need to invest in WWTP to clean the Rimac River. Then, a combination of adjusting reference prices in coordination with ANA and other users plus use of enforcing mechanisms to reduce contamination of the Rimac River, could promote investments in wastewater treatment. Through PPPs, where Peru shows a friendly environment, some of these projects could become viable.
- The Metropolitan Municipality of Lima, including SERPAR is one key potential user of treated wastewater to irrigate the parks they administer in the city. However, these plans must be aligned with the new administration' priorities. It should take into account the political risk of these projects, since previous commitments with the previous administration have been canceled.
- District municipalities are another potential area for their parks and gardens, but they will only invest if a high price of commercial water justifies the investment. The country clubs, schools and other private entities with large green areas are also potential users of treated wastewater for irrigation, although with similar cautions[13].However, the feasibility of supplying treated wastewater will depend on the length of the canal or pipeline and pumping costs to deliver the water to its customer segment.
- The component of creating compost and organic fertilizer adds a possibility of a future cash flow, but has potential limitations.

The financial analysis of this model focused on the reuse component and did not take into account the setting up of a new wastewater treatment plant. Three scenarios were developed based on the type of resource recovered (energy including carbon credits, water and nutrient). The key assumption in the case of water and nutrient recovery is the sale of treated wastewater for irrigation (or industry) or sale of sludge as soil conditioner[14]. In the event of a drought or water scarcity, there is the possibility of increased willingness to pay for treated wastewater and in the case of Lima which is one of the driest regions in the world, peri-urban agriculture could significantly benefit from 365 days of water. Alternatively, the treatment plant can target the sale of treated water to industries. In the case of the electricity generated, the financial assessment shows that about 35% of energy required for the treatment plant is covered and viability is significant from the sale of carbon. However, given the fluctuation in carbon prices (which is currently less than a dollar for ton of CO_2), the impact on the viability of the investment will be significant. A higher electricity price in Lima will make the investment viable. A treatment plant incorporating all these reuse investments yields a positive NPV and in the longer run, after the reuse component of the investment is paid back, it will help significantly improve the operation cost recovery of wastewater treatment plant.

Model 15 - Large scale composting for revenue generation and Model 21 - Partially subsidized Composting at District Level (MSW-based compost)[15]

[13]It is important to note that any health risks associated with this business model can be mitigated with a reasonable set of control measures.

[14]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.

[15]Business models 15 and 21 were initially considered as separate models. However based on the concept behind the business models and the multi-criteria framework used for the analyses, they were combined into one business model with different scenarios. BM 15 and 21 are similar in concept in terms of the end-product (MSW-based compost) and waste stream (MSW). In that regard, the waste supply and market assessment was conducted for one waste stream (MSW) and one end-product (compost). Similarly, the technology used is the same for both models given the same waste stream and end-product. For the institutional analysis, the results for the model-specific assessment resulted in the same findings across the different sub-components for the 2 models as the actors, policy support, local acceptance, etc. are the same. The financial analysis was

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

The overall market assessment suggests that there is a fair demand for MSW-based compost in Lima. It is expected that 44% of all households with plants/green areas will be willing to pay for compost (126,236 households); with a willing-to-pay between 2-2.5 Sol/Kg. The estimated demand from households for compost is 25,163 tons/year. On the other hand, about 14% of farmers are already using compost as a soil input and hence a conservative demand estimate would be 7,280 tons/year if we assume that only this group of farmers are willing to use compost. If we assume that farmers are provided with adequate training on compost use and its advantages the remaining 86% of the farmers can possibly be included as part of the potential market demand and thus the total estimated demand for compost will be 52,000 tons/productive cycle in a year. The market structure assessment revealed that the organic fertilizer market is a small but a growing part of a concentrated fertilizer market led by imported chemical fertilizers. Currently, the organic fertilizer market is small and scattered (70 percent in the Andes), but strongly following the trend of organic food demand (currently mostly related to the external market demand). A premium for organic fertilizers is found in some niche markets, but the fertilizer market is generally a price-taker and also very volatile. Lima as a main potential market for organic fertilizers is moderately valid, mainly because of its potential as a distribution market (domestic and external) and less because of a growing domestic organic farming market. Other actors are planning to enter the latter market, mainly for organic agriculture for exports, and they are expecting future growth of urban farming demand, suggesting an expected increase in organic fertilizer demand.

The financial assessment was conducted for three different scenarios and it was observed that at a lower scale of 70 tons and 200 tons, the viability of the business without any subsidy or incentives was marginal but as the scale of the waste processed increases, the feasibility of the compost production plant improves. The debt to equity ratio plays a significant role in the viability of the business.It is important to note however that the decision of a business to operate at a certain scale will be determined by several factors: a) demand, b) price of the compost, c) economies of scale, among others. Whilst the current production levels of compost is unknown, it is clear that the compost sector is a burgeoning industry with some entry barriers but supportive and existing policies encouraging business development.

Model 17 - High value fertilizer production for profit (faecal sludge-based compost)

Similar to business model 4, the infeasibility of this business model is mainly driven by the fact that Lima is predominately covered with sewer systems (90% coverage) and has very limited onsite sanitation coverage (6%). The public toilets in Lima are mostly connected to the central sewer system. The onsite energy generation by sanitation service provider business model can be initiated by either an enterprise running a toilet complex or residential institution. In both cases the toilets are not connected to the sewers, thus limiting the availability of the sludge. There are however very few experiences covered by ECOSAN toilets and FS generation and collection is generally low[16]. Additionally, there are no regulations, laws or any governmental policies that directly or indirectly promote and/or support this model. The main

---

conducted for 1 model (MSW - compost) with different scales (70 and 200 tons for model 21 & 70, 200 and 600 tons for model 15). Given the above, the overall feasibility was combined for both models 15 and 21.

[16]However, access to toilets services may be required particularly in the slum areas. There are some businesses such as X-Runner that have implemented this business model.

limiting factor is that the law establishes that sludge from WWTPs is considered a hazardous waste. Thus, by law, sanitation service providers are required to stabilize the sludge on-site and then, transport it to the sanitary landfills for proper disposal. Given these institutional constraints and limited onsite sanitation systems, this business model is not well-suited for the context of Lima.

Table 23: Overall feasibility ranking of the business models

		Level of feasibility of the business models						
Ranking criteria		ENERGY			WASTEWATER		NUTRIENT	
	Outputs	BM2a	BM3	BM4	BM8	BM9, 12, 13[17]	BM15 & 21	BM17
1	Waste supply and availability							
2	Market assessment							
1	Institutional analysis							
3	Technical assessment							
4	Financial assessment							
5	Health risk& impact assessment							
	Environmental risk and impact assessment							
6	Socio-economic assessment			N/C				N/C
	Overall ranking of BM							

Legend:

- **BM 2a:** Energy Service Companies at Scale (MSW to energy)
- **BM 3:** Energy Generation from own Agro-industrial waste (agro-waste to energy)
- **BM 4:** Onsite Energy Generation by Sanitation Service Providers (faecal sludge to electricity)
- **BM 8:** Beyond cost recovery: wastewater-fed aquaculture
- **BM 9:** On Cost Savings and Recovery (wastewater use for irrigation, energy and nutrient recovery)
- **BM 12:** Wastewater treatment for carbon emissions reduction
- **BM 13:** Wastewater treatment for irrigation
- **BM 15:** Large-Scale Composting for Revenue Generation (municipal solid waste to compost)
- **BM17:** High value Fertilizer Production for Profit (combination of municipal solid waste and faecal sludge to organic fertilizer)
- **BM 21:** Partially subsidized Composting at District Level

[17] Based on the described methodology for ranking the feasibility of the business models, BM9 should be ranked low given that the market feasibility is low. It was difficult to obtain data from the main users of treated wastewater which are farmers and directly estimate their willingness-to-pay and thus the notion of a low willingness-to-pay was based on the fact that some farmers access water at a low tariff and there is currently no "price" for wastewater because there is no developed market and current regulators have not placed a reference value of reutilizing wastewater. Given the data limitations with the market assessment, it was important not to limit the final feasibility assessment based on a possibly biased market assessment, especially given the growing demand for wastewater for irrigation of green areas in Lima. Municipalities and private clubs need water to irrigate their landscaping and save money after legislations changed—resulting in them now paying commercial rates for water. Their willingness to pay is expected to increase if accessing treated wastewater implies savings in the long term. In this situation, it would also be key to analyze the case of SERPAR which is responsible for zonal parks. Another opportunity exists with the implementation of the Urban Development Plan for Lima and Callao 2035 (PLAM) —prepared in the previous municipal administration.

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 Lima a 6-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 30thOctober to 6th November 2014. The BMDT was completed by 10 intrapreneurs representing 6 companies/institutions, 5 entrepreneurs and 6 future trainers (21 participants in total). A total number of 10 BMs were prepared during the training:

Luisiana Vega, San Fernando

ProteinPLUS
INSUMOS PROTEICOS DE CALIDAD PARA LA ADECUADA NUTRICIÓN ANIMAL

Production of flour PROTEIN PLUS for animal food from hatchery waste with a high content of protein, Ca and P and high digestibility.

VilmaVilca, Fertipez

Fertipez

Production of organic fertilizer from fish waste FERTIPEZ, rich in nutrients for agricultural production (avocados and olives)

Jesusa Palomino, Agua Ecosan Peru

Production of liquid fertilizer FLOR PNK, which is rich in NPK and micronutrients, that ensures organic certification and the wellbeing of the coffee ecosystem.

Cecilia Vasquez, X-Runner

Programs for the recovery of impoverished soils by the application of BIOGREEN, an organic soil conditioner with high nutrient availability and water retention.

Paul Pucuhuaranga, Selvandina

Production of Fertilize-2, a biological fertilizer from bio-digestion of sheep and guinea pigs excreta, that provides micro and macro nutrients.

Gustavo Huamani, Green Garden

ME fortified compost production from organic waste generated in the markets located in Lima.

Roger Pérez, Muyuy

Cubipapel

Paper recycling company, segregating and packing paper in Andahuaylas.

Diana Palomino y FlorParedes, Municipalidad de Miraflores

RECICLAJE ARSEMIM

Integral solid waste management service, with an emphasis on collection, segregation, processing and marketing of 10 kinds of paper for export.

Yovanna Orihuela, Municipalidad de Villa el Salvador

*RECICLEVES

Collecting solid waste and transforming into souvenirs and decorative articles for Corporate Events.

Hugo Gurrionero, CER

CER

Consulting company in RRR, specialized in the design and implementation of match-making community-industry development projects.

12 Annex 2: MCA Framework

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

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

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

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

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

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

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

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

4. Institutional and Legal Settings and Public Support

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

5. Financial feasibility/viability assessment

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

6. Health and Environmental risks and risk mitigation

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

7. Socio-economic impact assessment

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

13 References

1. Adamowicz W. and J.R. Deshazo. 2006. Frontiers in stated Preferences Methods: An introduction. Environmental and Resource Economics.34 (1): 1-6.
2. Danso G., Drechsel P., Fialor S. and M. Giordano. 2006. Estimating the demand for municipal waste compost via farmers' willingness-to-pay in Ghana. Waste management.26:1400-1409.
3. Freeman A.M. 2004.Economic valuation: What and why. In: A primer on nonmarket valuation. The Netherlands: Kluwer Academic Publishers.
4. Holtzman S. 2002. Using Subsector Analysis to Assess the Impact of Policy Reform on Commodity Subsectors. Impact Assessment Report No. 27.
5. Hagos D., Konnen A.M. and Z. Gebreegziabher. 2012. Environment for Development Discussion Paper Series: Households' Willingness to Pay for Improved Urban Waste Management in Mekelle City, Ethiopia.
6. Lusk J.L. and D. Hudson. 2004. Willingness-to-Pay Estimates and Their Relevance to Agribusiness Decision Making. Review of Agricultural Economics. 26(2):152-169.
7. Kimenju S.C. and H.D. Groote. 2008. Consumer Willingness to Pay for Genetically Modified Food In Kenya. Agricultural Economics.38: 35-46.
8. Valerian J., Domonko E., Mwita S. and A. Shirima.2011. Assessment of the Willingness to Pay for Organic Products amongst Households in Morogoro Municipal, Sustainable Agriculture, Tanzania.
9. Wanzala M.M., Bumb B. and R. Groot. 2009. Fertilizer Markets in Africa: Challenges and Policy Responses. Prepared for presentation at the Conference towards Priority Actions for Market Development for African Farmers. Nairobi, Kenya.