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Resource Recovery and Reuse as an Incentive for a More Viable Sanitation Service Chain

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ABSTRACT: Recovering nutrients, water and energy from domestic waste streams, including wastewater and faecal sludge, is slowly gaining momentum in low-income countries. Resource recovery and reuse (RRR) offers value beyond environmental benefits through cost recovery. An expected game changer in sanitation service provision is a business model where benefits accrued via RRR can support upstream sanitation services despite the multitude of private and public stakeholders involved from waste collection to treatment. This paper shows options of how resource recovery and reuse can be an incentive for the sustainable sanitation service chain, by recovering costs where revenue can feed back internally or using generated revenues from reuse to fill financial gaps across the service chain to complement other supporting mechanisms for making waste management more attractive.

KEYWORDS: Faecal sludge, resource recovery, business models, cost recovery, waste treatment

INTRODUCTION

On-site sanitation systems (OSSs) are a key component of sanitation services to safeguard human health and prevent environmental pollution, and this is not limited to low- and middle-income countries. OSSs such as septic tanks and pit latrines, currently serve globally more than 2.7 billion people and this population is expected to be as high as 4.9 billion by 2030 (Cairns-Smith et al., 2014). Despite significant progress under the Millennium Development Goals (MDGs) to increase access to improved sanitation, investments in the subsequent steps, such as the safe collection, disposal and treatment of faecal sludge (FS) from on-site sanitation systems, remain a significant challenge (Kone, 2010; Blackett et al., 2014). The lack of treatment services often results in unsafe disposal of FS, which poses health and environmental risks from toilets to rivers that may undermine improvements in drinking water supply and thus water security and sustainable growth. It is in this regard that the

Sustainable Development Goals (SDGs) under target 6.2 emphasises the importance of "safely managed sanitation services", i.e. faecal sludge management (FSM) beyond the provision of toilets.

Sanitation services around sewerage systems are mostly provided by government agencies which also regulate or operate wastewater treatment plants, and establish policies on environmental sanitation (BMGF, 2012). In contrast, on-site sanitation systems and FSM are in many locations handled by the informal and private sectors or a mix of public and private operators. In many settings, the service falls outside regulatory frameworks, policies or utility jurisdictions.

An interesting aspect of FS from domestic on-site sanitation systems is the potential for safe resource recovery from septage compared to sewage sludge generated in conventional sewer and wastewater treatment systems, since the latter has mixed sources of waste (i.e. domestic, industrial and urban runoff). Resource recovery allows for possibilities to apply market-based principles at least on parts of the service delivery chain where waste (particularly, faecal sludge in this instance) can offer incentives for business development and cost recovery (Murray and Buckley, 2010). Although sanitation is and remains foremost a 'social business model', and is seldom considered as a business, resource recovery and reuse (RRR) help to shift the focus away from waste that needs disposal toward creating a valuable resource that can benefit farmers, create jobs and generate energy and funds to improve the sanitation service chain.

With an increasing interest in a green and circular economy, and new technical innovations available for energy and biofertiliser generation, an emerging set of entrepreneurs are recognising the opportunities in human waste management (Drechsel and Hanjra, 2016; Selvaratnam et al., 2016; Sadef et al., 2016; Otoo and Drechsel,2017; Carey et al., 2016) and are gradually playing an important role in leveraging private capital to help realise the commercial value of waste and wastewater (Murray and Buckley, 2010; EAI, 2011; Murray et al., 2011a; ADB, 2014; Balasubramanian and Tyagi, 2017). This paper reflects on RRR as an incentive for a more viable sanitation service chain as a key component of public health and water quality management. This paper aims to increase the knowledge on locally appropriate FSM models for low- and middle-income countries and draws from FSM business cases from settings across Asia and Africa, including Ghana, India, Peru and Sri Lanka.

'Business modelling' is used as a tool to articulate different FSM solutions – their costs, potential for revenue generation and interaction between diverse stakeholders in FSM (municipalities, governments, donors, policy-makers, entrepreneurs, community-based organisations [CBOs] and non-governmental organisations [NGOs]). The business models highlight the common barriers to be overcome by FSM stakeholders, and also potential opportunities and scope for increased private-sector participation in sanitation service delivery. The generic business model for FSM is described based on using an adapted business model canvas framework by Osterwalder and Pigneur (2010), which allows to highlight multiple-value propositions as they occur across the sanitation service chain. At the core, the business model canvas describes how a business creates, delivers and captures value, and hence it helps the business to develop an operational process of delivering a product or service to a target customer. However, as mentioned above, the canvas only addresses parts of a business case, and requires additional information. The presented business models draw strongly on the analysed business cases, supported by additional information from related cases in the literature and interviews. The business models presented in this report were developed and analysed based on a review of FSM cases from Asia and Africa, taking into consideration the key challenges faced by the FSM stakeholders. Several business models are presented to bundle services together and deliver at different scales the "safely managed sanitation services" and functions that can be mutualised with other services like waste management, energy, and compost.

The paper is organised as follows. First, we review selected literature on the subject and then outline the sanitation service chain and the related typologies of business models for faecal sludge management. We then provide an overview of the institutional and regulatory environment within which possible FSM business models operate. Case studies to highlight cost recovery potential and three prominent FSM business models centred on the concept of resource recovery to promote sustainable sanitation service delivery[1] are subsequently presented.

LITERATURE REVIEW

Amid population growth, urbanisation and widening gap in safely managed sanitation services, policy-makers, international donors and sanitation investors are constantly exploring a holistic approach in generating multiple benefits from waste reuse businesses, and as a pathway to scaling up local resource recovery and reuse initiatives (Hanjra et al., 2015b). Improved wastewater and faecal waste management has the potential to significantly reduce risks related to public health given the current and widespread practice of direct disposal of untreated waste into the environment (ADB, 2014). For example, new microbial source-tracking tools link faecal bacteria in rivers to diffuse human sources at the basin scale and show that pollution arising from on-site septic system discharges seems to be the primary driver of faecal bacterial levels (Verhougstraete et al., 2015).

In Africa and South Asia, a larger proportion of faecal waste is handled by non-sewerage systems. Indeed, on-site sanitation systems handle around 80% of the faecal waste and are highly problematic. In many cases such as Dhaka City, Bangladesh, the overall system fails such that only a small proportion is safely managed (2%), while almost all faecal sludge (98%) in on-site sanitation systems remains unsafely managed (WSP, 2014) and enters the environment and waterways untreated. A review of faecal sludge management in 12 cities across Africa and South Asia shows that faecal sludge is poorly managed, while two-third of households depend on on-site sanitation, and only 22% of faecal sludge is safely managed on average (WSP, 2014). This is supported by another study in 30 cities across 10 countries in Asia and Africa (BMGF, 2012) which highlights that social businesses lack the necessary information to make faecal sludge management a functional component of the sanitation value chain. This withholds progress towards sustainable sanitation programmes (Trémolet, 2011). There is a huge and unmet demand for toilets and other on-site sanitation systems from households in low-income settings across Asia and Africa (Ramani et al., 2012; World Bank, 2014; Gonsalves et al., 2015; Nallari, 2015).

The development of companies for waste-to-energy or compost for market sale is a more recent phenomenon. New waste-based businesses are emerging such as vacuum trucks to pump up and transport faecal sludge for composting and/or resale to farmers around metropolitan cities including Accra, Ghana and Delhi, India (Otoo et al., 2015), Dhaka, Bangladesh (Balasubramanya et al., 2016) and Lahore, Pakistan (Masood et al., 2014). Yet, commercial production of energy and compost from organic municipal waste has only recently been incentivised by some city councils (Sadef et al., 2016).

In networked sewerage systems, incentives for a more viable sanitation service chain could come from recovery of agricultural nutrients and maximising recovery of energy and nutrients from urban waste streams (Carey et al., 2016; Selvaratnam et al., 2016), to address the trade-offs in environmental quality and public health. But even such systems face significant economic and financial barriers against resource recovery and reuse (Hanjra et al., 2015a). For instance, reuse of sludge for agriculture and effluent for internal use are the most common options, while more than 60% of Italian plants do not perform any kind of recovery action (Papa et al., 2017). Data from principal actors in USA show that the cost of doing something different is the principal consideration in resource recovery actions (Coats and Wilson, 2017). "Economics drive decisions and 95% of the bottom line is money – if government is not

[1] We refer to the sustainability of the entire sanitation service chain – to include consistency of service provision (e.g. waste collection), financial sustainability of waste collection businesses, waste treatment facilities and related RRR entities (if applicable). It is important to note that the main objectives may differ across different stakeholders and financial sustainability (profit-generation, particularly for waste-treatment facilities) may not be the goal of some actors and it may or may not be guaranteed.

going to pay or give grants and utilities cannot raise rates then 'show return on investment' will get peoples' attention". Therefore, applying business case evaluations and a business model approach seems a pathway to actualising resource recovery and reuse amid institutional and financial barriers.

On-site systems and FSM are handled by informal and private-sector organisations, allowing additional autonomy for tariff setting and investment planning as incentives, as well as greater user and provider inclusivity and financial sustainability. As on-site sanitation and waste management services fall outside the utility service area in many settings, poor households often depend on such localised solutions as pit latrines due to their low cost. Local solutions for emptying pit latrines in low-income urban settlements are lacking and in some cases business models for faecal sludge management are slowly evolving, for instance in capital city Lilongwe in Malawi (Chipeta et al., 2017) and Maputo in Mozambique (Hawkins and Muxímpua, 2016) and other African and Asian settings (Murray et al., 2011b; WSP, 2014). Once the pit fills up, users often abandon old pits and resort to new ones where possible. Vast amounts of nutrients thus become locked up in on-site sanitation systems. Financial and economic benefits from resource recovery and reuse can provide incentives towards a more viable sanitation service value chain, as the business models and case examples discussed below show.

Sanitation service chain for on-site sanitation systems

The functioning and process flow of an OSS is characterised by access to toilets, emptying, transport, treatment and disposal or reuse as highlighted in Figure 1, and this is referred to as the 'sanitation service (delivery) chain'. The chain has been widely used for analysing the physical flow of FS through the system (Trémolet, 2011; WSP, 2014; Blackett et al., 2014), and this paper uses the chain to describe stakeholders and related business interactions along the chain.

Figure 1. Sanitation service chain for on-site sanitation systems.

Source: Rao et al., 2016

The different parts of the chain are briefly described below:

1. *Access to toilet (containment):* Practices of open defecation or lack of adequate sanitation facilities are dealt with through the provision of sanitation technologies, such as pit latrines and septic tanks, which safely contain and store human excreta.
2. *Emptying and transport:* Septic tanks and pit latrines contain human excreta and gradually fill up over time. Once they are full, the sludge collected needs to be emptied and transported to a designated treatment site.
3. *Treatment:* The sludge collected from on-site sanitation facilities is treated such that its solid and liquid fractions do not harm public health and the environment.
4. *Disposal:* Safe disposal of treated sludge, especially the part which does not provide value for resource recovery for reuse, is critical to ensure isolation of the waste from human and environmental contact.
5. *Reuse:* FS contains resources such as nutrients, energy and water, all of which have intrinsic value and can offer monetary gain for the treatment plant.

OVERVIEW OF BUSINESS MODELS FOR FSM

Based on the analysis of the business of FSM cases from Africa and Asia (Rao et al., 2016), several value propositions can be differentiated according to different business models such as given below (see also Figure 2):

- Models for toilet access and in-situ energy recovery (I)
- Models for emptying and transporting of faecal sludge (II)
- Models linking emptying, transporting and treatment (III)
- Models emphasising reuse at the end of the service chain (IV)
- Models covering the entire sanitation service chain from toilet access to reuse (V).

It is noted that the next best alternative to 'treatment for disposal' is 'treatment for reuse'. Resource recovery and reuse (RRR) from faecal sludge offers social and economic value beyond environmental benefits through cost recovery; and key transformative levers for sustainable sanitation service provision are business models where benefits accrued via RRR can support upstream sanitation services (Hanjra et al., 2015b; Selvaratnem et al., 2016; Sadef et al., 2016; Balasubramanian and Tyagi, 2017). Resources can be recovered from FS to produce a variety of value-added by-products to generate energy (biogas, biochar, fuel briquettes, syngas, and liquid fuel), produce nutrients (soil ameliorant for crop production, fish feed, livestock fodder, and protein feedstock production), and reclaim water for irrigation and environmental flow (Otoo et al., 2015; Balasubramanian and Tyagi, 2017). Other than these resources, FS can also be used to make building materials.

In this paper, the business models and related case examples discussed will focus on resource recovery solutions (i.e. energy and nutrient recovery from faecal sludge – models I, IV and V) and related mechanisms for cost recovery to ensure sustainable service delivery. For nutrient recovery, it is well noted that FS contains organic matter that can improve the biophysical characteristics of poor soils such as water-retention capacity and FS contains macro- and micro-nutrients, which are required to aid plant growth (Kengne et al., 2014; Drechsel and Hanjra, 2016; Carey et al., 2016; Sadef et al., 2016). Historically, composting is well recorded as a well-known practice to recover organic matter and nutrients from FS in a safe way, especially where FS-producing households and farms are in close proximity (Cofie et al., 2016). With rapid urbanisation, this is not a business-as-usual norm anymore due to the disconnection between excreta-generating centres and food production areas. In this paper, examples of nutrient recovery demonstrate involvement of new stakeholders and incentives required to close the loop. The paper reports only on common nutrient and energy recovery examples. There is potential, however, for leapfrogging in nutrient extraction through production of protein feedstock, which is of higher value and can be marketed at a higher price in comparison to substitute feedstock for poultry or fish production, instead of nutrient use for products such as fodder crops (Otoo and Drechsel, 2017).

For energy recovery, FS contains organic carbon that can be used to generate energy in the form of heat or electricity. The recovery of energy from FS can be done through various biological, mechanical and thermal process. For example, anaerobic digestion to produce biogas, gasification to produce syngas, pyrolysis to yield biochar, etc. In this paper, the focus on energy recovery is restricted to biogas production (Sadef et al., 2016; Selvaratnam et al., 2016). However, it is important to note that there are upcoming commercial solutions to covert FS to briquettes for cooking and pellets for industrial use.

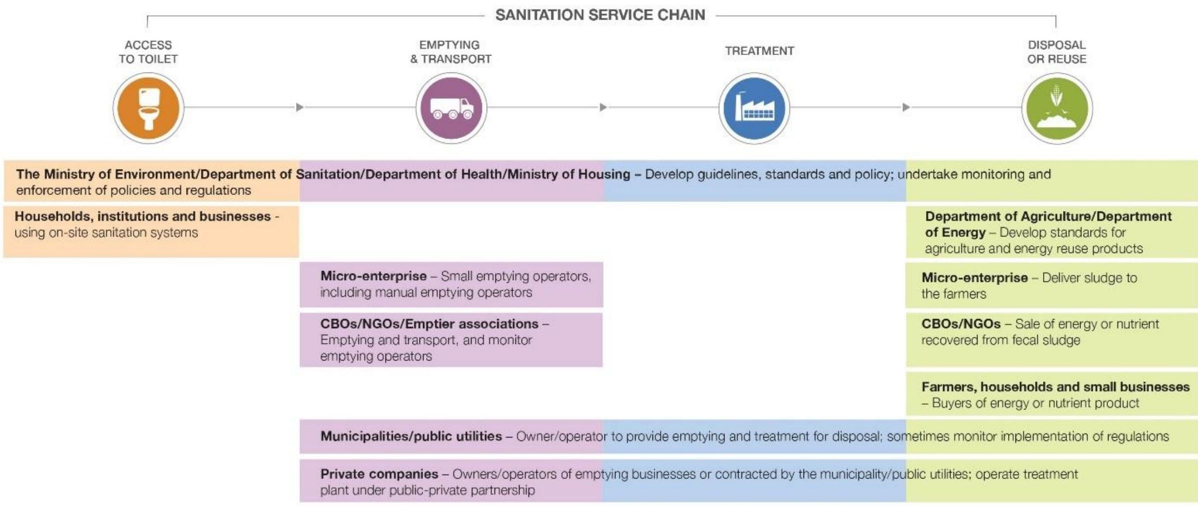
Figure 2. Proposed typology of FSM business models.

Source: Rao et al., 2016.

Stakeholders and institutions

Based on the FSM business cases analysed and corresponding business models developed, the key stakeholders engaged in FSM can be categorised across the components of the sanitation service chain as presented in Figure 3. Households, businesses and institutions are the key stakeholders in the *Access to Toilet* component of the chain. In the *Emptying and transportation* component, the type of stakeholders engaged varies according to region, population, regulations and institutional arrangements, accessibility to toilets and market demand (including affordability). In most regions, municipality/public utilities are responsible for the provision of sanitation services. Private companies are sometimes contracted by municipalities/public utilities for desludging activities. In addition, private companies operate independently in regions where public entities are unable to provide reliable timely services. Where households are difficult to access by trucks, the sludge is disposed of manually by operators, i.e. manual emptying. Community Based Organisations (CBOs) or Non-governmental organisations (NGOs) with social mandates may play a key role in emptying and transportation in underserved communities. In certain regions, private truck operators have formed associations primarily to lobby their business.

Figure 3. Stakeholders and their functions in FSM



Source: Rao et al., 2016.

The *Treatment* component of the chain is dominated by either the municipality or public utility. In a very few cases, the municipality/public utility contract operations to a private company. There are examples of private companies in Benin, Mali and Gabon (BMGF, 2012; Bassan, 2014; World Bank, 2014; WSP, 2014; Drechsel and Hanjra, 2016) that own and operate treatment plants. In the *Reuse* component, stakeholders engaged under this component depend on the type of resource recovered (energy or nutrient) from FS. Private truck operators are one of the key stakeholders that deliver sludge to farmers who directly use FS on farms. NGOs and community-based organisations (CBOs) can play a key role in marketing (through awareness creation) and sale of reuse-based products.

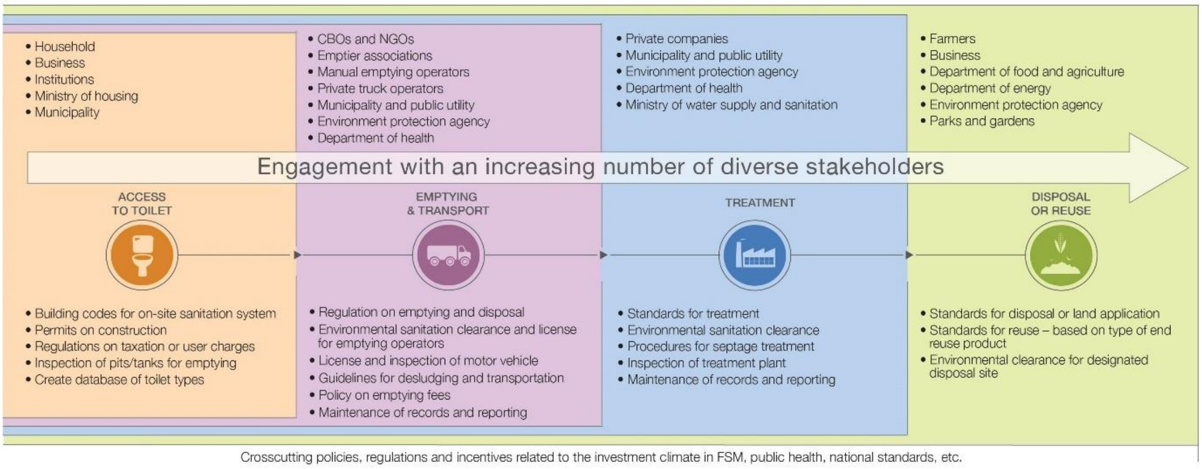
There are additional stakeholders in FSM such as financial institutions, central and state governments that finance different parts of the sanitation chain, and institutions and ministries that are in charge of building codes and water resource protection. Stakeholders involved in the implementation and monitoring of regulation and policy cut across more than one component of the sanitation value chain. Different institutions are involved in the formulation of regulatory standards and guidelines, and it is typically the responsibility of a regional equivalent of the Ministry of Environment and Health. The regulatory and monitoring agency at the local level is highly contextual. It can be the responsibility of the municipality, environment department and/or health authority monitoring the public or private service provider.

Figure 4 provides a snapshot of stakeholders, and relevant policies, regulations and guidelines across the sanitation service chain. As observed from the figure, in FSM, as we engage with more components of the service delivery chain, engagement with different stakeholders with varying interests increases. The diverse actors may make on-site sanitation service delivery, especially concerning resource recovery, more difficult to implement and regulate.

Cost recovery from reuse

The next best alternative to 'treatment for disposal' is, as noted, 'treatment for reuse', whereby resources in FS, such as nutrients or energy, are recovered and used internally for cost savings and/or sold to generate revenue. There are different RRR alternatives for the management of faecal sludge. The technological process applied varies significantly depending on the type of resource recovered (energy or nutrient), and the value proposition (cost recovery or sale revenue) and target customer segment (farmers, shops or grid).

Figure 4. Increasing complexity of regulations and stakeholders along the service chain.

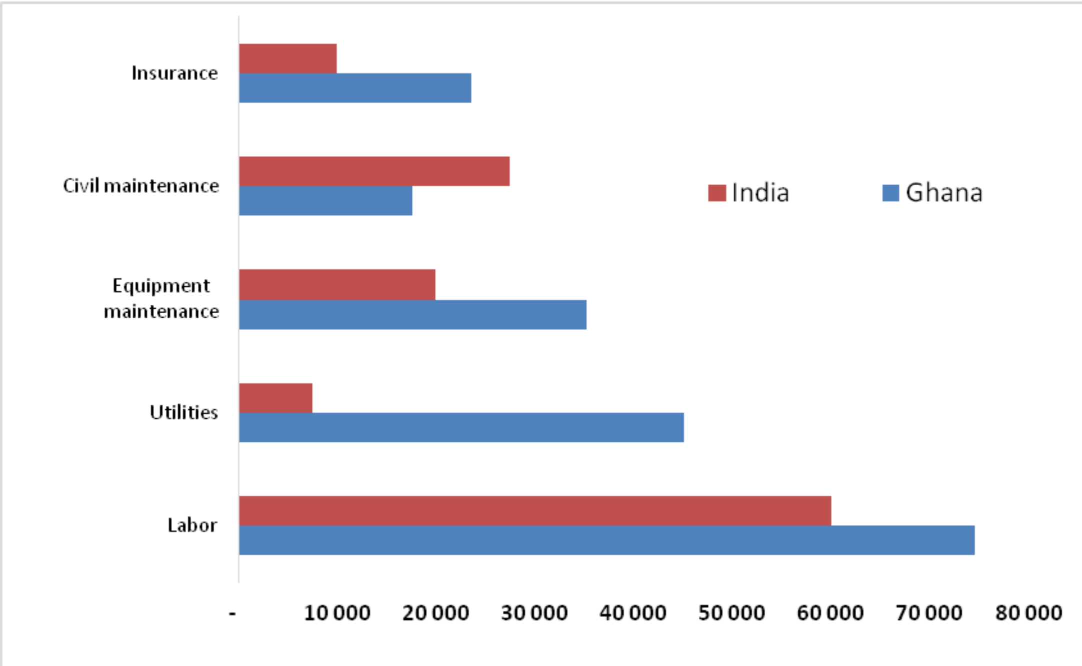


Source: Rao et al., 2016

To illustrate the potential *cost recovery at the end of the service chain (IV)* from reuse for FSM management, we consider two cases from India and Ghana. Cost data were derived from an internal report by the International Water Management Institute (IWMI, 2014b; IWMI, 2014a) on the construction and operation of an FS treatment and co-composting[2] plant in India and Ghana. The indicators were informed by scientific works (Dodane et al., 2012; Nikiema et al., 2014) based on existing treatment plants and for the evaluation of cost and financial performance (Steiner et al., 2002). The capital cost for co-composting (Cofie et al., 2016) was estimated as slightly higher in Ghana (USD1.17 million) than in India (USD832,000) to serve a population equivalent of 100,000. The higher cost in Ghana is largely attributable to larger quantities of sludge generated, lower population density and latrine access (and shared use). This result in greater geographic spread of services and therefore larger volume processed, and in a larger civil engineering requirement (e.g. bigger trucks requiring larger waste receiving station, co-composting platform, co-compost storage room, larger rooftop area) and higher machine costs for compost sieving, packing or if considered, compost pelletisation. Due to higher unit cost, O&M costs of co-composting are also higher in Ghana (USD196,000) than in India (USD125,000). In both Ghana and India, co-composting has a higher O&M cost than treatment for disposal due to additional processes involved and higher labour requirements. Figure 5 provides a breakdown of the O&M costs of the co-composting plant. As shown in the figures below, labour (manpower) and civil works maintenance cover the bulk of O&M costs in India, whilst in Ghana it is labour and utilities.

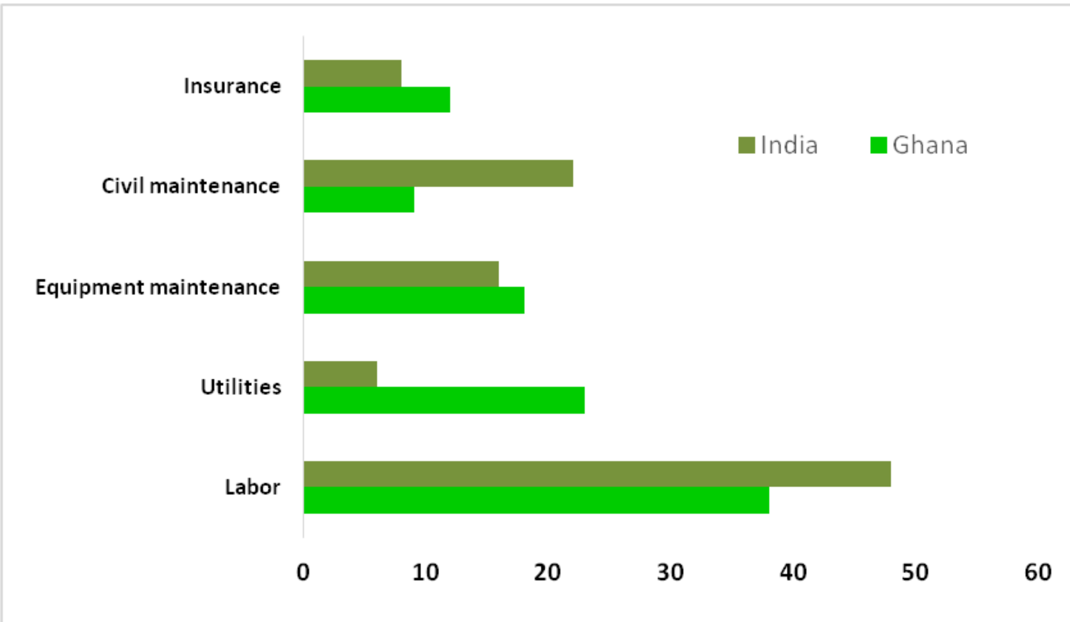
[2] Co-composting here refers to the simultaneous composting of at least two organic sources. In this case, FS from on-site sanitation systems rich in nitrogen is combined with the organic portion of MSW, sawdust or agro-waste rich in carbon to produce the optimal carbon-nitrogen ratio for composting (Cofie et al., 2016). The resulting high-nutrient compost can be sold to agricultural producers as an alternative fertilizer to generate revenue.

Figure 5. Breakdown of O&M costs (in USD) of the co-composting plants in the Indian and Ghana scenarios.



Source: Rao et al., 2016.

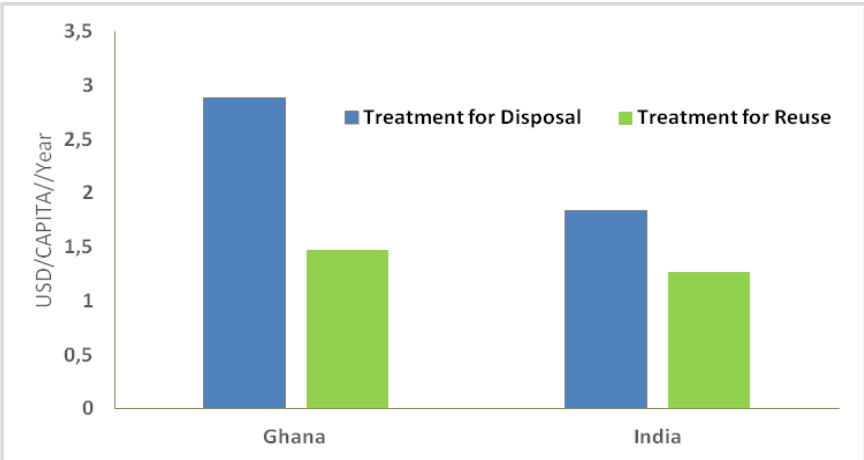
Figure 6. Breakdown of O&M costs (in percentages) of the co-composting plants in the Indian and Ghana scenarios.



Source: Rao et al., 2016.

To assess the cost recovery potential from reuse, the operating costs of two treatment scenarios, namely treatment for disposal and treatment for reuse were compared (Figure 7) for the scenarios assumed for Ghana and India to achieve operational cost recovery based on user charges for sanitation service. The total operational cost per capita per year (including transportation) for *treatment for disposal* is about USD1.84 to 2.88 per capita in both countries. The net operation cost per capita per year for *treatment for reuse* could decrease to USD1.27 to 1.47 due to revenue earned from the sale of compost, based on common local prices of composts. These earnings, if fed into the same budget, could theoretically be used to reduce household waste management charges for using the sanitation service by 1/3 to 1/2. The operational costs could be recovered from household charges or revenue generation to improve service delivery (if these are the only revenue sources for a waste management service provider to obtain cost recovery). While there is almost unlimited supply of feedstock for composting, uncertainties in the estimate arise due to slack market demand and policy issues. These numbers are, however, only indicative figures as the level of revenue generated/cost recovery varies within the regional context depending among other factors on the competitive compost market, transport cost, local willingness-to-pay, acceptance and quality of the product, competition and subsidy on fertiliser and/or compost (Box 1).

Figure 7. Operational cost per capita per year comparing treatment for disposal and treatment for reuse



Source: Rao et al., 2016.

Box 1. Cost recovery from reuse: Case study from India.

IWMI carried out a feasibility assessment to set up a co-composting treatment plant serving three neighbouring towns (Budhni, Shahganj and six wards of Hoshangabad closer to Budhni) with a total population of 7,784 households in the state of Madhya Pradesh, India (IWMI, 2014a). The population produced about 40 m^3 of FS per day from scheduled desludging of septic tanks once every two years, and two towns (Budhni and Shahganj) produced 12.8 tons of MSW per day. This waste can produce 4.4 tons of compost on a daily basis. An assessment was carried out to evaluate the monthly usage fee needed to be charged per household to cover the operation cost of the treatment plant.

To recover the operational cost of collection and transportation of FS, and the O&M cost of the treatment plant, the monthly fee that needs to be charged per household ranges between INR84 (USD1.3) and INR122 (USD1.88). The selling price of normal compost varies between INR1,400 (USD21) and INR4,000 (USD62) per ton in India, and depending on the selling price of compost, the monthly fee that needs to be charged per household reduces by INR20 (USD0.31) and INR57 (USD0.9) if reuse is factored into the overall business model and the compost revenues feed into the same budget.

Business models for sustainable service delivery

This section provides practical illustrations of business models highlighting the relevant stakeholders at play and the related financial setup.

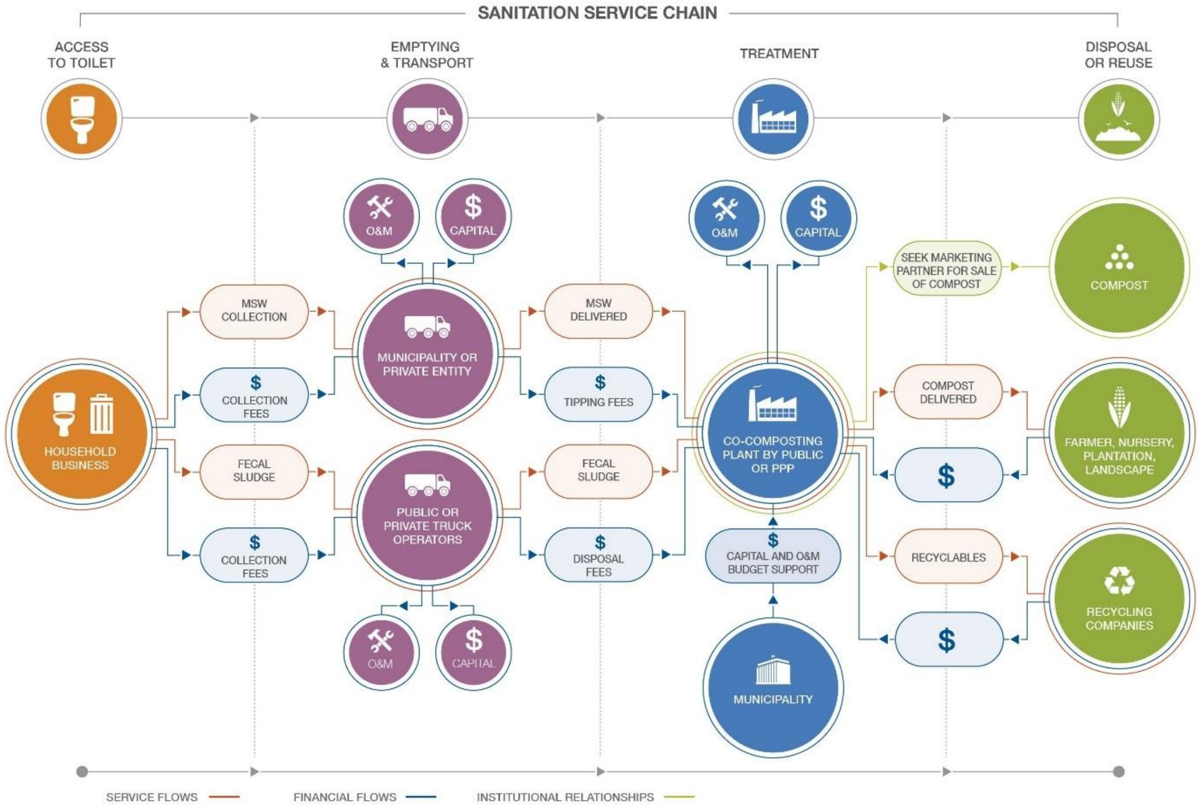
Business model of reuse at the end of the service chain

The business model of reuse at the end of the service chain presented here focuses on the value proposition pertaining to the reuse product, and it depends on the type of resource recovered (nutrients/organic matter/energy) from the FS and target customer segment. Figure 8 provides a diagrammatic overview of the institutional and financial set-up of the business model. This model is demonstrated by two case examples (a. case of Balangoda in Sri Lanka and b. Safi Sana in Ghana). The case example in Balangoda, Sri Lanka, has shown significant potential for supporting a sustainable service chain. With a population of about 35,000, a successful co-composting business model is run by the Balangoda compost plant, a public entity owned and managed by the local municipal council. The council is responsible for delivering MSW and FS collected from the municipal region to the plant. Desludging of FS from OSSs is carried out on an on-demand basis and households pay about USD30 for the service. The local urban council undertakes door-to-door MSW collection from households on a daily basis and twice a day from commercial entities. The council encourages waste segregation at source, and unsegregated waste is collected from commercial entities for a fee (USD0.75 to USD9 depending on the quantity of waste) while segregated waste is collected for free, which results in most commercial entities segregating the waste at the source. Currently, households do not pay for the MSW collection service. The council has set up recycling centres in different parts of the town, and the key role of these centres is to collect recyclable material and deliver it to the plant. To incentivise these centres, the council awards points to recycling centres (with 1 point = 1 Sri Lankan Rupee, USD 1 = 130 Sri Lankan Rupees) and points are awarded based on the type of recyclable material and quantity.

The Government of Sri Lanka provided the required capital under its 'Pilisaru' project for construction of the compost plant. In addition, the plant has partnered with different local universities and received training via LIRNEasia (www.lirneasia.net). The capital cost of the co-compost treatment plant was USD352,000, with operation costs of USD1,340 per month and a demand-based production capacity of up to 14 tonnes of compost per day; however, they produce around 420 tonnes of compost annually. The compost is sold to smallholder farmers (at USD77 to 120 per tonne) in the Eastern Province of Sri Lanka, where soils are sandy and chemical fertiliser has proved less effective. Revenues generated from the sale of compost and recyclables, waste collection fees from private markets, and waste tax charged to entities that do not segregate their waste, are able to sufficiently cover all the related waste management costs, ensuring a functioning and sustainable service delivery chain. It is important to note that although operating below the optimal production capacity, the plant is still able to sufficiently cover the O&M costs from compost sales but the primary driver for achieving cost recovery is derived from the waste tax and collection fees.

An additional case example illustrating the co-composting business model is Safi Sana, in Ghana (Safi Sana, 2015). Safi Sana is a social enterprise in Accra, Ghana, which started in 2009 to provide a public toilet service and treatment of waste generated in these toilets. The enterprise collects toilet and organic waste from slums in Accra, which is then used to produce organic compost and generate renewable energy. Since 2011, the enterprise has established three communal service blocks (public toilets) franchised to local entrepreneurs for management. The waste from public toilets is collected on an on-demand basis, and organic waste from local food markets and small enterprises are collected and transported on a daily basis to its factory in Ashaiman, where the waste is treated to generate electricity and produce fertiliser. As of 2015, the factory had received 1 tonne of waste per day and there are plans to scale the operations to process 25 tonnes per day from late 2016 onwards. The factory has, as of 2015, constructed a digester 2,500 m^3 in size for stabilising waste, and producing bio-

Figure 8. Institutional and financial set-up of a co-composting business model.



Source: Rao et al., 2016.

gas to generate heat and electricity of around 100 kW. The plan is to sell the electricity to the local power grid at a pre-fixed, feed-in-tariff. Information on the capital and operation cost and revenue sources is not available. The co-composting model is observed in many low- and middle-income countries, for example, Vietnam, Bangladesh, Ghana, etc. In Accra, Ghana, IWMI, under a project funded by the Bill & Melinda Gates Foundation, has initiated a PPP (between Accra Metropolitan Assembly [AMA] and Jekora Ventures Private Ltd.) to commission a treatment plant to produce 1,000 tonnes of compost per year from organic waste and FS collected from OSSs in Accra. The plant started its operations in May 2017.

In-situ resource (energy or nutrient) recovery business model

An effective and sustainable sanitation service delivery is one that provides products and services across the entire sanitation value chain, interlinks with other economic sectors (e.g. energy, agricultural) to generate benefits to all economic actors in the respective value chains, and creates connectivity of resources among socioeconomic and biophysical systems (Figure 1). To that end and scale, a model for important consideration is one that links both ends of the sanitation service chain, i.e. the provision/access to toilets with resource recovery and reuse, thus providing in-built financial and provider-user incentives for a more viable sanitation service chain. In this case, we consider the *in-situ resource (energy or nutrient) recovery business model* that generates the triple value proposition of:

- Provision of sanitation facilities (such as urine diversion dry toilets (UDDTs)) to unserved public.
- Provision of reliable waste management (collection and treatment) services to poorer segments of society in greatest need of these services.
- Provision of affordable and high quality organic fertiliser for agricultural production and/or biogas/electricity generation.

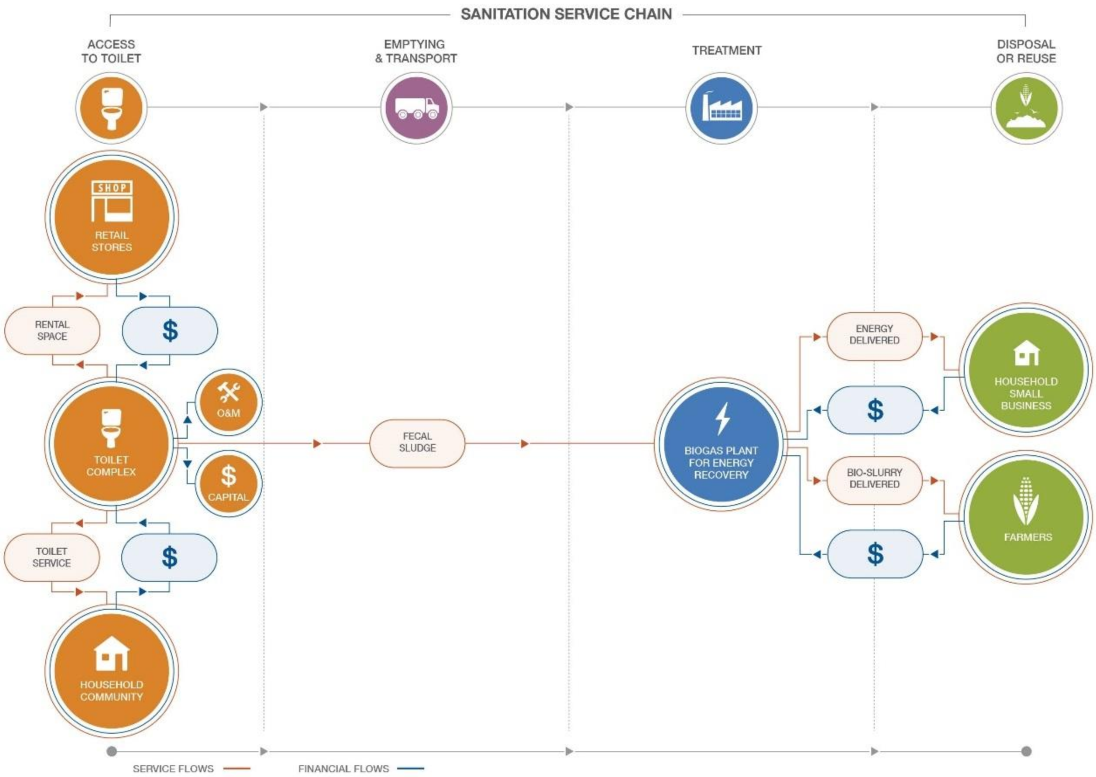
This business model focuses on the direct link of the two ends of the sanitation service chain – access to toilets and resource recovery. Access to toilets is through the public toilets and treatment allows energy recovery from the FS. The business model considered here does not engage in the emptying and transportation component of the service chain, as waste generation, treatment and reuse take place in close proximity. A variation to the business model is where the focus is on the treatment for reuse component of the chain, for example, in the case of hotels and residential institutions where large quantities of FS are generated and there is no space for on-site treatment. Figure 9 provides a diagrammatic overview of the institutional and financial set-up of the business model.

This business model hinges on the desirable social impact of providing hygienic sanitary facilities to society, particularly masses at public places; whilst also providing an effective way to meet agricultural input needs of farming communities via compost production from human excreta and/or enterprise energy needs (via biogas or electricity generation for internal use resulting in energy cost savings). This business approach works because it is built around harnessing economic value from human waste whilst providing sanitation services to the poorer segments of society, which represents the greatest percentage of population in low- and middle-income countries in need of such services.

Biogas production for thermal and electricity generation from different waste streams, particularly excreta is showing great promise in many developing regions, including South Asia. Faecal sludge is being reused to generate energy to meet the internal thermal and electric power requirements for institutions and with future plans of selling the excess to local electric grids (EAI, 2011). An example of an enterprise that has successfully implemented this model is Sulabh International in India.

Sulabh is a private NGO engaged in the provision of sanitation services to the poorest population of the society through its pay-and-use public toilet model which has shown that people are willing to pay for use of toilet facilities that are clean and hygienic. In addition, Sulabh is involved in the collection, treatment and conversion of human excreta into energy. Sulabh’s business approach involves a partnership with the public sector, with the latter providing the land and 20% of the funds for construction of public toilets. Sulabh (India) commits to maintain the toilet facilities for 30 years, free of cost, and charges 1 Indian rupee (about UD 2 cents) from each person who uses the community toilets. The success of the 'Sulabh model' rests on a multiple-revenue stream approach. Revenue is generated from two major streams: biogas sales and toilet user fees. Not only does the operation of public toilets ensure a stable source of waste resource supply for biogas production, but revenues from toilet user fees provide capital investment for the start-up of the biogas plants. The diversification of revenue to dual streams helps mitigate risks associated with fluctuations in the demand for energy. The integration of the biogas plant with community toilets increases the viability of the business due to capital subsidies available from the government-sponsored biogas promotion programmes and revenues from the sales of energy (Otoo and Drechsel, 2017). Biogas production from human waste is particularly exciting as the revenue generated in that market might offset the costs of recovering nutrients from sludge. Examples of such septage utilising businesses are few and far between. Thus, more research is needed to explore such opportunities for developing not only viable but also safe business models for private and public entities to consider.

Figure 9. Institutional and financial set-up of a toilet access and in-situ energy recovery business model.



Source: Rao et al., 2016.

Whilst there is great potential to support sustainable sanitation service delivery from RRR, it is important to note however, that reuse is not a panacea for the viability of FSM given that more often than not different actors work across the service chain and financial gains at one end do not automatically support the other end. Although a well-designed and conceived reuse plan presents a good opportunity to decrease the overall cost of the FSM chain, it has to be supported by the contractual agreements of the involved actors. Rao et al. (2016) provide theoretical and empirical examples of institutional options in this regard. These also show that where one entity tries to manage the whole chain from toilet to farm, revenues generated from waste management fees charged to households remain the backbone of the business plan.

Business model covering the entire sanitation service chain from toilet access to reuse

A business model that covers the entire sanitation service chain from toilet access to reuse is the container-based sanitation (CBS) system. Figure 10 provides a diagrammatic overview of the institutional and financial set-up of the business model. This model, in which human waste is captured in sealable containers, and then transported to treatment facilities – is a sanitation option in urban areas where permanent on-site sanitation and sewerage systems are infeasible such as hilly and remote areas, slums, emergency camps and floods. Typically, on a scheduled basis (weekly or twice every week), the containers are collected and transported to a central processing facility where the waste is processed. Some of the CBS providers take the additional step to produce compost, which reduces the waste volume, allows to sanitise also the most recent (fresh) faecal matter and to produce a soil ameliorant for farming. The extra efforts to engage in compost production and marketing are of not only ecological value (circular economy) but also help the operator to minimise the otherwise costly waste accumulation and disposal. For example, six months after the 2010 earthquake in the Haiti emergency camps, relief agency incurred a monthly expenditure of about USD500,000 to empty the toilets and dispose of FS (Bastable and Lamb, 2012). Thus, the investment in composting should not only be compared with its possible revenues, but include the costs of the next best alternative for safe faecal sludge disposal. This could be the transport costs to a landfill (with designated area for human waste) and the local tipping costs. In this case, travel distance and the nature of the tipping fee (subsidised or cost recovery) will matter. Toilet facilities in highly dense areas such as slums and emergency camps fill up rapidly, requiring frequent emptying of big quantities of fresh faecal sludge containing large amounts of active pathogens, for instance the toilets managed by the social enterprise Sanergy in the slums of Nairobi, Kenya.

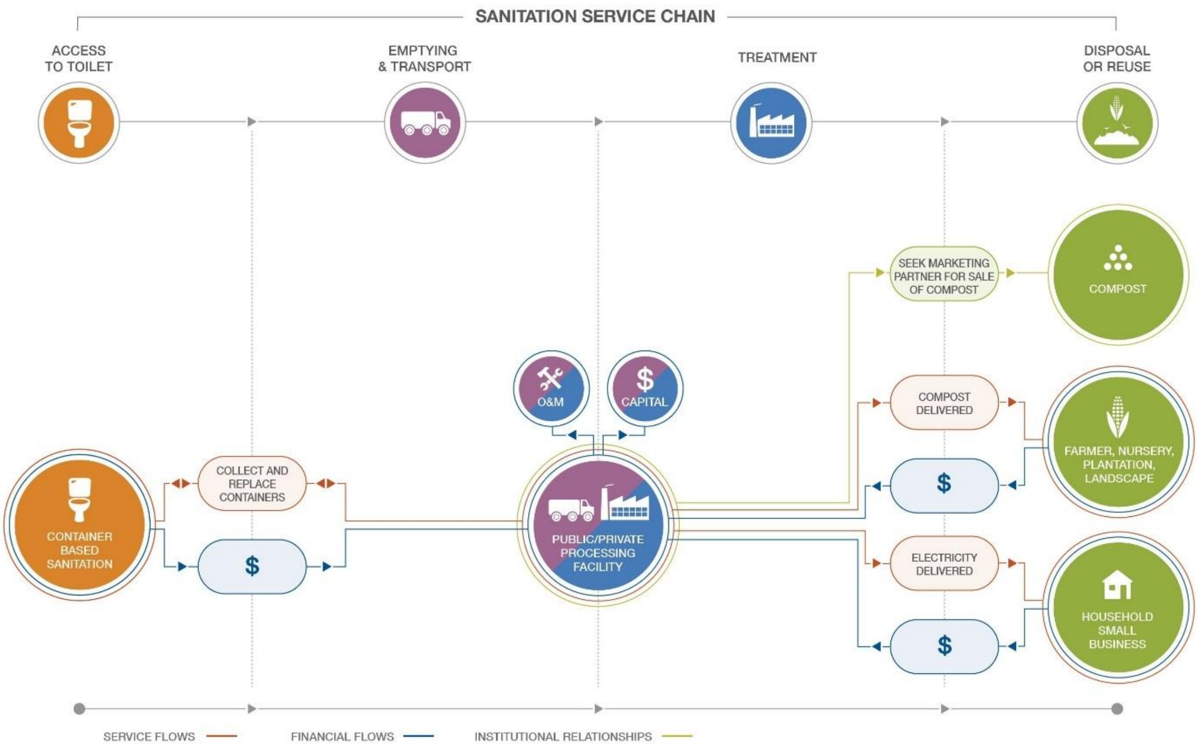
Fast and efficient technologies such as microwave technology are required for sludge and pathogen reduction (Mawioo et al., 2016) but the energy consumption and economic analysis compared with other technologies might provide additional incentives to use dried faecal matter for composting, to expand the social business model by helping poor farmers use the compost.

The triple value proposition of composting to (a) turn a potentially harmful waste product safer, (b) reduce its volume by half, and (c) to make it easily 'disposable' through sales, should be key considerations. An alternative is energy generation, which could take place at a centralised processing facility for the faecal matter. The business model has high applicability in underserved communities, such as remote areas or slums. The key revenue for the business is from the rental of toilets (and emptying service), complemented by the sale of reuse products. There are several cases that run related business models, such as SOIL in Haiti, X-Runner in Peru, Clean team in Ghana, and Sanergy in Kenya. This is also supported by other studies on container-based sanitation assessing cost recovery and effectiveness of excreta management in Haiti (Russel et al., 2015; Tilmans et al., 2015).

SOIL offers UDDTs, and provides collection, transport and treatment of mainly faeces to produce compost in two locations in Haiti (Port-au-Prince and Cap-Haïtien) using the container-based sanitation. The compost is, in part, sold to farmers, and also used in tree nurseries, reforestation, and large-scale agricultural use through other NGOs and companies. SOIL works mainly with household toilets and to some extent, with public toilets. This is an interesting example as so far SOIL serves the entire sanitation service chain. Compared to its local management cost (about USD140,000), direct cost recovery is still modest, with about USD83,000 in service fees and programme revenues, including from compost sales (SOIL, 2016). To support its social business model, SOIL is, however, serving those who need compost and not those who might pay what is needed to break even. However, SOIL is very successful in attracting grants to buffer any gap. To increase financial viability in the long run, SOIL plans to outsource parts of its activities to private entrepreneurs, such as local bucket collection, with the ultimate goal of eventually having the entire sanitation service managed by private-sector entities, possibly with the compost sites being managed by the government or through a public-private partnership (PPP).

Another case example illustrating this model is X-runner in Peru. X-runner is a social enterprise in Peru providing sanitation solutions to low-income urban households, with the target of providing sanitation services to 550 households in three districts of Lima. X-runner has established an alliance with Separett, one of the world's leading urine separating toilet manufacturers. Their products are well designed to satisfy customers' high demands on appearance, environmental impact, function and quality. The toilets are rented out to households. X-runner's portable dry toilets separate urine and faeces, and the latter is collected in a bin lined with a compostable bag. The customers pay an initial fee of USD35.00 plus a monthly fee of about USD13.00 for waste collection services. The business aims to collect 20 tonnes of human waste on a monthly basis to produce 11 tonnes of compost per month. Gradually, it hopes to achieve scale and reduce the waste collection cost to its customers. As of December 2014, X-runner had tested its compost product, which met the standards prescribed by Austria and Chile. Based on these results, the social enterprise is in the process of establishing a partnership with landscapers for maintaining green zones in the water-scarce regions of Lima, where soils are very poor and lack organic matter (SuSanA 2013a; Pires, 2014; Swiss Re Foundation 2015; X-runner 2015).

Figure 10. Institutional and financial set up of a container-based sanitation business model.



Source: Rao et al., 2016.

CONCLUSIONS

The overarching priorities to undertake improved sanitation service delivery from containment through to treatment are to safeguard public health and the environment. The shift in focus from access to sanitation (under the MDGs) to the entire sanitation service chain (under the SDGs) entails massive investments into the sanitation sector. The global cost of inadequate water supply and sanitation was estimated at USD260 billion annually (WHO, 2012). The total annual capital costs of meeting SDG target 6.2 have been estimated at USD19.5 billion for achieving basic sanitation and USD49 billion for safe faecal waste management (Hutton and Varughese, 2016). Given that 2.7 billion people worldwide currently use onsite sanitation systems, and since this is also the preferred system in many regions (based on logistical reasons, costs or water scarcity), the challenge is extremely ambitious and stepwise solutions are needed (Hutton, 2016). A city or town that aims to meet the SDGs should carefully and strategically look into the most suitable approach between improved on-site sanitation systems for FSM and expansion of networked sewerage solutions to maximise service delivery at affordable costs. Both systems have advantages and disadvantages, and can largely complement each other; thus onsite sanitation systems are definitely not an interim solution and require our full attention.

In view of RRR, onsite sanitation systems offer an easier and much safer entry point for nutrient and organic matter recovery for agriculture and landscaping, than sewage treatment. This paper shows that whilst resource recovery comes with costs, it also offers an additional revenue stream to partially offset costs along the sanitation service chain beyond the extra treatment and marketing costs for RRR. But even where the direct revenues do not allow to break even, many enterprises engage in composting as it allows to save costs compared to any alternative (and unavoidable) waste disposal option. It is important to note that the implementation and potential scaling-up of business models for FSM may generate benefits (have an impact) beyond the direct key stakeholders involved. Thus, an impact assessment to capture potential externalities from implementation of business models for FSM should be considered for future study. Internalising the significant social and environmental benefits of safe FSM for reuse into corporate accounting can, in addition, easily justify financial support and public policy instruments for the set-up and operations of enterprises in this sector (Hanjra et al., 2015b).

However, resource recovery from on-site as well as off-site systems implies challenges, such as the involvement of new stakeholder groups (e.g. in the agricultural sector), understanding and stimulating secondary markets, and giving attention to social and cultural issues of product acceptance. The earlier the sectors involved get together to jointly address the opportunities that FSM (including RRR) can offer them, the higher the probability of success. It is important to note, however, that where multiple governmental institutions are responsible for designing policies and implementing interventions, unclear and complex coordination issues can make it difficult to capture economic value and plug it back into the value chains, posing challenges for both pure public-sector models and public-private partnerships. Changing the 'business-as-usual' scenario in the conservative sector of waste and sanitation will also require significant investments in capacity development.

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