PAPER 17

TECHNO-ECONOMIC EVALUATION OF INNOVATIVE SANITATION TECHNOLOGIES: COST MODELLING FOR NON-SEWERED SANITATION SYSTEMS (NSSS) TO ASSESS INDUSTRY DEVELOPMENT OPPORTUNITY IN SANITATION

By Mishqah Hussain[1], Rajiv Paladh[2], Jason Holder[1]
[1]Bosch Projects
[2]Bosch Capital

1. ABSTRACT

Bosch Capital, in partnership with Bosch Projects, was appointed by the South African Sanitation Technology Enterprise Programme (SASTEP) to conduct a techno-economic evaluation of innovative sanitation solutions, specifically Non-Sewered Sanitation Systems (NSSS). The study aimed to assess the industry development opportunity in sanitation and provide high-level findings and recommendations for future generations of NSSS. The project included a cost modelling exercise for three emerging Non-Sewered Sanitation Solutions (NSSS) against four conventional sanitation solutions in three potential markets. Markets assessed included domestic users, schools, and informal settlements.

Of the fourteen sanitation systems considered in the study, six were membrane treatment technologies, one used activated sludge for wastewater treatment and included sludge disposal, four systems utilised bio-media for treatment purposes and consisted of a back-end system and sludge disposal, and three of the options offered no treatment of the wastewater generated but included a front-end, back-end, and sludge disposal system.

The use of Discounted Cash Flow (DCF) assisted in the comparison of the NSSS and conventional solutions through the use of costs expected to be incurred over 15 years, as well as the quantification of savings that may be realised through the End User not being required to purchase water for flushing, as well as not being required to pay a sanitation charge for disposal of effluent. The outputs of the study suggest that there may be potential to invest in the NSSS solutions given the potential benefits that may accrue particularly in schools and informal settlement markets. However, the current lifecycle costs to the End User may be higher than conventional solutions.

Despite the higher lifecycle costs, there are other strategic benefits to NSSS that should be considered. These systems can be used to provide flushing toilets in areas without a bulk water and sewer connection. Bulk sewer upgrades typically require higher capital costs than specific development requirements, whereas NSSS could be specified to meet specific development or property requirements and deployed as a more modular solution. NSSS also offers the option for Users to progress on the sanitation level of the service ladder as they would be able to use water to flush toilets. NSSS therefore does not require extensive time and cost to extend the bulk water and sewer networks to allow flushing toilets.

2. INTRODUCTION

SANS 30500 defines Non-Sewered Sanitation Systems (NSSS) as a system that collects, conveys, and fully treats the specific input to allow for the safe reuse or disposal of generated solid output and/or effluent. In this work, it is therefore assumed that NSSS will refer to a Wastewater Treatment Works (WWTW) solution that does not have a connection to a bulk wastewater network. It is also important to note that these solutions are localised and have the potential to:

1. Generate effluent that could be used for reuse (irrigation or flushing of toilets);
2. Biogas that could be used for cooking; and
3. Biosolids that could be used for agricultural purposes.

2.1 The Scenarios

Three scenarios were conceptualized to assess the viability of NSSS against conventional wastewater treatment systems and are summarised in Table 1.

TABLE 1: *Scenario Specifications*

	Scenario 1 - Household	Scenario 2 – Informal Settlements	Scenario 3 – Schools
Treated Wastewater (kl/day)	0.6	8	18.24
Total Users (No.)	4	315	493

A brief description of each scenario is provided below.

Scenario 1 - Household: An average single household is expected to produce around 0.6kl/day (600l/day) of wastewater (Still et al., 2009). This aligns with real discharge data and standard wastewater discharges in various sources.

Scenario 2 - Informal Settlements: Historically, informal settlements in eThekwini Municipality have been served by containerised ablution blocks (CAB) or Modular Ablution Blocks (MAB), with a recorded daily wastewater volume of approximately 8kl (Bosch Projects, 2013).

Scenario 3 - Schools: This scenario is based on a typical informal/rural school with approximately 500 pupils. Based on literature reviews, a waste generation rate of 37 l/day was applied for pit latrines (Bosch Stemele, 2015).

2.2 The Baseline Technologies

The conventional sanitation solutions used and their associated cost elements that were included in the study are presented in Table 2.

The estimated capital costs for the technologies are intended to serve as a conceptual reference rather than an exact figure. Various factors, such as site-specific conditions and urban versus rural location, contribute to the variability of capital costs. Nevertheless, these cost estimates inform NSSS innovators of the typical expenses associated with conventional technologies in different scenarios. They can also serve as targets for improving the cost structure of their offering through successive iterations.

TABLE 2: *Baseline Technology Specifications*

Technology	Description	Capital Cost elements included	Source of capital cost information
Centralised WWTW	Connected to a bulk sewer network with a treatment capacity greater than 5ML/d.	Bulk sewer network (including pipe crossings) Pump Station Treatment Facility	As built treatment works costs were undertaken in 2015 and escalated to 2023 prices.
Decentralised WWTW	Connected to a bulk sewer network with a treatment capacity of 200kl/d that is relatively close to the End User.	Bulk sewer network Treatment Facility	As built treatment works costs were undertaken in 2019 and escalated to 2023 prices.
VIP	Collection and storage of human excreta in a pit.	Top structure Pit excavation and lining	As built treatment works costs were undertaken in 2015 and escalated to 2023 prices.
Chemical Toilets	Portable units that contain a holding tank to store human excreta that can be broken down and deodorised using Ammonia compounds	These units are typically rented and are emptied relatively often.	Sanitech Solutions provided a quotation to supply chemical toilets.

2.3 Front-End Systems

The front-end systems considered in each of the scenarios investigated are summarised in Table 3 below.

TABLE 3: *Front-End Specification*

	Scenario 1 – Household	Scenario 2 – Informal Settlements	Scenario 3 - Schools
Description	A single cubical that is 1.5 square meters in size contains 1 flush toilet.	Modified shipping container consisting of 2 showers, 2 flush toilets, 2 hand basins, and 4 outside basins.	15 cubicles each containing a single flush toilet.
Number of Seats	1	2	15

3. KEY FINDINGS

3.1 Front-End Capital Cost

Table 4 below presents the capital cost for the front-end systems in each of the scenarios considered. In the household scenario, the value in parenthesis depicts the front-end system cost with the inclusion of a low-flush cistern. It is noted that these systems have a higher upfront cost due to their efficient design however, these systems may offer a saving to the End-User as less water will have to be bought from the municipality for toilet flushing.

TABLE 4: *Capital Cost of Front-End Systems*

	Scenario 1 – Household	Scenario 2 – Informal Settlements	Scenario 3 - Schools
Total Capital Cost (R)	12 399 (13 149)	412 072	800 357
Unit Capital Cost (R/kl)	20 665 (21 915)	51 509	43 877
Unit Capital Cost (R/ user)	3 100 (3 287)	1 308	1 623

3.2 Capital Cost for NSSS

Figure 1 shows the unit capital cost for providing sanitation treatment solutions to a household through the various technologies. Options one to nine (1 – 9) depict the various NSSS technologies investigated. The costs for informal settlements and schools are estimated by scaling up the costs for households.

The unit capital cost for providing NSSS to households varies significantly, ranging from around R120,000/kl to just under R 1.1 million/kl. This variation is due to the scale at which the technology operates, with larger units expected to have lower unit capital costs compared to the smaller units, following the 'economies of scale' principle.

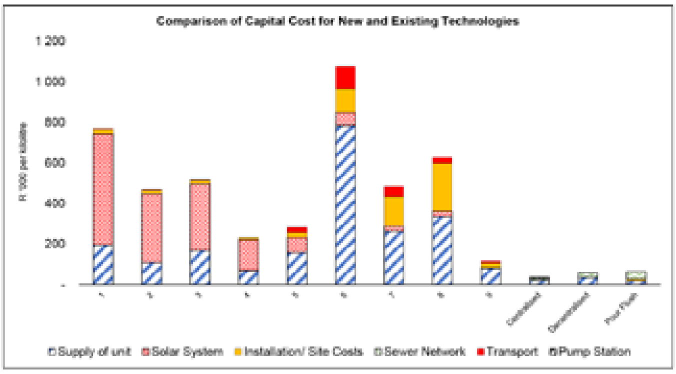

FIGURE 1: *Unit Capital Cost (R/kl) for NSSS for Households.*

The costs linked to providing solar systems with NSSS should be further investigated, as they represent a relatively substantial cost for some of the options. There might be potential in optimizing the design of the solar solutions across several NSSS.

There is potential to reduce site and installation costs, as well as the actual production and supply of the unit, to ensure that the technologies can be more competitive against centralized (R36,000/kl) and decentralized (R59,000/kl) sanitation solutions.

3.3 Operating Costs for NSSS

Figure 2 below shows the unit operating cost (R/kl) for providing a NSSS to a household for the various technologies.

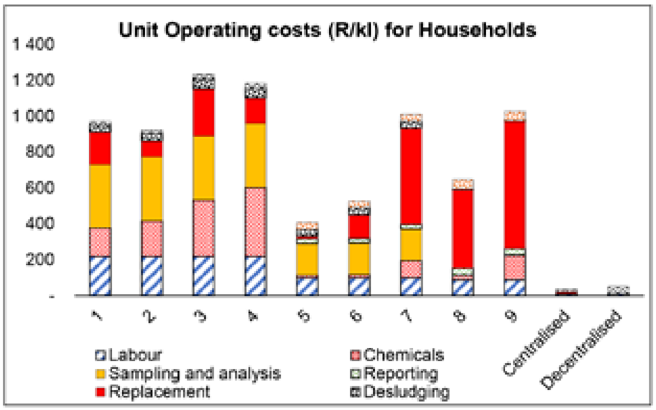

FIGURE 2: *Unit Operating Costs (R/kl) for Households.*

The analysis revealed that sampling and analysis constituted a significant portion of the operating costs of the NSSS under consideration. In the

Household scenario, sampling and analysis represented 37% of Option 1 and 43% of Option 5 annual operating costs. Overall, in the Household scenario, sampling and analysis accounted for 25% of the total annual operating costs of the NSSS.

However, it is important to note that in the informal settlement scenario, sampling and analysis accounted for only 7% of the overall annual operating cost, and in the school's scenario, it accounted for a mere 3%. This is due to the fixed nature of the sampling and analysis component, which remains unchanged across different scenarios. The operating costs that are influenced by flow rates saw a significant increase in the schools and informal settlements scenarios, resulting in sampling and analysis representing a smaller portion of the overall annual operating costs.

Capital costs were factored in to determine the annual replacement cost of the asset, ensuring its continued operation over 15 years. Consequently, a reduction in the replacement cost of the asset is expected as the capital cost decreases. While a generalized approach was used in the modeling exercise, the replacement cost for an NSSS should be evaluated independently, as some solutions are more resilient and require fewer replacements over the operational period.

3.4 A Discounted Cash Flow Approach

A Discounted Cash Flow (DCF) approach was used to assess the value proposition to the End User in various scenarios over 15 years. This approach factored in upfront capital costs, escalated operating costs, replacement costs, and potential savings for the End User from not purchasing water and paying sewerage charges. Conventional technologies would result in a net cash output from the End User, requiring payment of water and sanitation tariffs to the Municipality.

Assumptions in the DCF model included the following;

1. Operating costs increased by 6%;
2. Municipal tariffs increased by 10%;
3. Weighted Average Cost of Capital was 10%;
4. Water Tariff for Households – R15/kl; and
5. Sanitation Tariff for Households – R12/kl.

During the study, it was assumed that all solar PV solutions would be able to supply the full electricity needed to operate the backend treatment facility. The study did not consider any preferential rates for the decentralized and centralized solutions.

The study did not account for the land procurement costs necessary for implementing upgrades at the WWTW. Additionally, the potential externalized pollution costs resulting from the inefficient operation of the WWTW and the corresponding rehabilitation expenses, along with asset depreciation, were also excluded from the study.

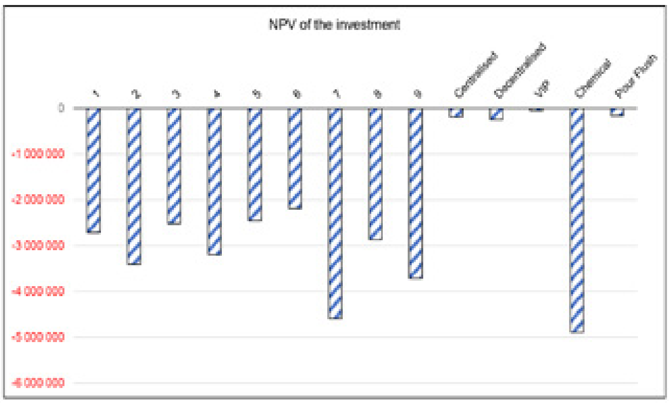

FIGURE 3: *NPV for a Household.*

3.5 The Outcomes of the Modelling Exercise

Figure 3 indicates the Net Present Value (NPV) that a household would incur should an NSSS be employed as compared to a conventional sanitation solution.

The cost of using NSSS over 15 years is much higher than conventional sanitation solutions for households. Chemical toilets are a relatively high life-cycle cost to the household for an asset that is perpetually rented by the Household and is not owned by the End User. The presented scenario considers one household connected to the NSSS, but some technologies can handle higher flows.

Figure 4 provides an indication of the NPV for a household but with each solution serving the maximum number of households being served and operating at full capacity.

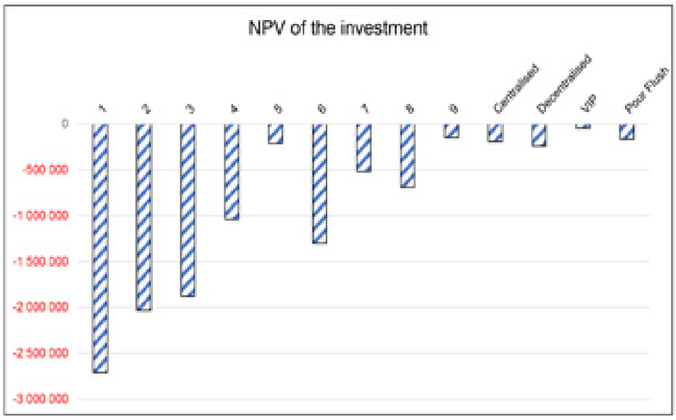

FIGURE 4: *NPV per Household at full capacity.*

Figure 4 indicates that the NPV to a household is comparable to conventional solutions for Option 5 and Option 9. This is due to these solutions having a higher capacity and being able to connect to several households. This highlights the benefit that economies of scale can provide. This is highlighted further in Figure 5 which indicates the benefit of implementing an NSSS at a school.

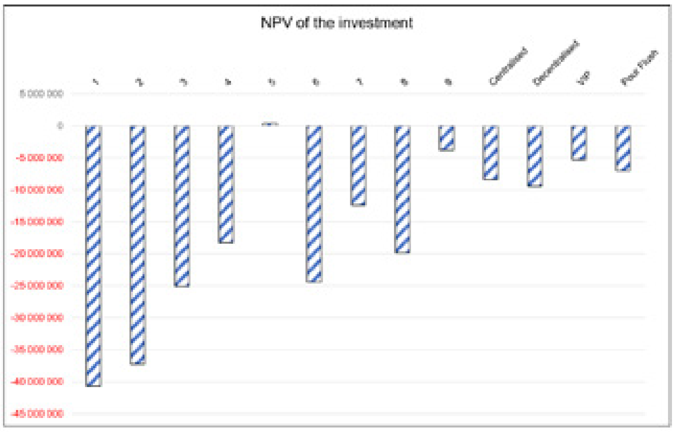

FIGURE 5: *NPV at a school.*

Figure 5 presented is based on the linear scaling up of the NSSS in relation to their wastewater treatment capacity. There may be other benefits that accrue based on providing a solution that can treat a higher volume of wastewater, but the linear approach was considered adequate to provide an understanding of the potential benefits of these technologies when implemented in a school setting. Upon examination of Figure 5, it is evident that Options 5 and 9 yield a lower NPV in comparison to traditional solutions.

This outcome is attributed to the cost savings realized from not needing water to flush toilets and the avoidance of expenses associated with wastewater disposal into the sewerage network.

Furthermore, the diagram emphasizes the significance of the tariff in determining the financial feasibility of the solution. It is important to note that a commercial tariff of R43.22/kl of potable water was employed to calculate the savings that would accrue to the school. Figure 6 illustrates the impact of utilizing a tariff of R59.48/kl of potable water at a school.

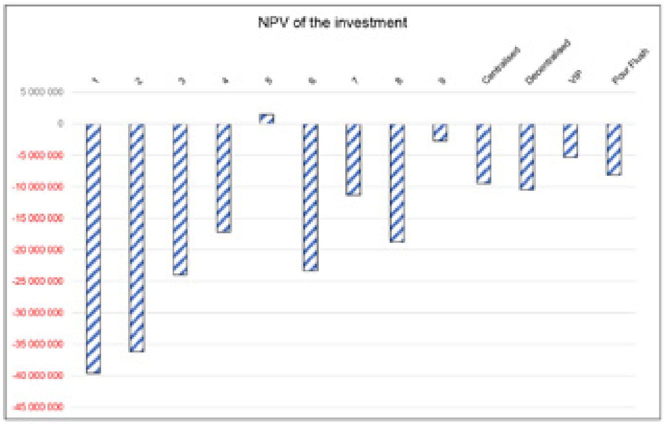

FIGURE 6: *NPV at a school with a tariff of R59.48 per kl.*

Figure 6 illustrates that Option 5 offers a cumulative cash saving for the school over 15 years. This suggests that under certain circumstances, NSSS has the potential to generate financial savings for the End User based on the volume of treated wastewater and the relevant tariff structure.

3.6 Sensitivity Analysis

A Sensitivity Analysis was conducted to assess the impact of reducing capital and operating costs by 30% and increasing the tariff by 30%. It was found that reducing operating costs had the most significant impact across all scenarios due to these costs being incurred and escalated annually over fifteen years. Increasing the tariff by 30% had little impact on households but affected schools with higher base tariffs, indicating that higher-income households would benefit more from the system.

4. OTHER STRATEGIC BENEFITS

4.1 The Strategic Benefits

The NSSS solutions can be completed within a much shorter timeframe than centralised and decentralised solutions and do not require a bulk water and sewer connection. This is particularly important when considering the time required to institute a municipal bulk sewer connection in a rural area.

It should also be noted that whilst the analysis was conducted on a user or kilolitre basis, it is unlikely that centralised wastewater treatment works will be upgraded on a relatively small basis. This total cost of the upgrade of centralised wastewater treatment works would require a significantly larger investment from a municipality as compared to a smaller modular investment in NSSS.

4.2 Reduction in Capital Cost

The capital expenses for each of the NSSS decreased from the initial engagement to the final information-sharing session with the innovators. This reduction was due to the developers' increased familiarity with the technologies and their understanding of areas where changes could be made without negatively impacting the performance of their respective technologies.

The decrease in capital costs should be viewed as a successful outcome of SASTEP's pilot initiatives. It is anticipated that further reductions could be attained in future iterations of these technologies, along with potential benefits when procuring raw materials in large quantities.

4.3 Potential for Localisation

The review of raw material sources for the innovations focused on the potential for local production or procurement instead of imports. It was found that treatment media and some electrical components were sourced internationally, but these components make up a small portion of the budget. The proprietary nature of the media used in the reactors poses a challenge to localization. The scale at which electrical component suppliers produce these components suggests that localisation would be a challenge. The international suppliers of these products are also able to improve the performance of these components regularly.

4.4 Operating business model

The Innovators are currently able to supply the NSSS either as an outright sale or a sale with a service contract for a specified period. This is deemed to be appropriate based on the customer that is being supplied and their ability to service and maintain the units.

These service contracts will reduce the upfront costs to the End User and spread this over a period. This option is dependent on the credibility of the End User to meet the monthly payments over a period and the cash flow of the Innovator.

4.5 Sampling and monitoring

Sampling and analysis accounted for 25% of the total annual operating costs in the Household scenario. The Innovators suggested that these costs might not be necessary once the value proposition is confirmed. The requirement for sampling and analysis would need to be carefully balanced between the benefit provided against the cost incurred by the End User. There may be a need to consider reduced frequency of sampling and analysis once the performance of the Solutions has been confirmed but this could still be included at some point to confirm the performance of the solutions during the operational phase.

4.6 Scaling up production

The Innovators have advised that their suppliers have been providing quotations for relatively small orders, sporadically. Innovators have advised that these suppliers have indicated that discounts can be provided should the quantity and frequency of orders increase. However, the suppliers have advised that these discounts can only be quantified once the orders are placed.

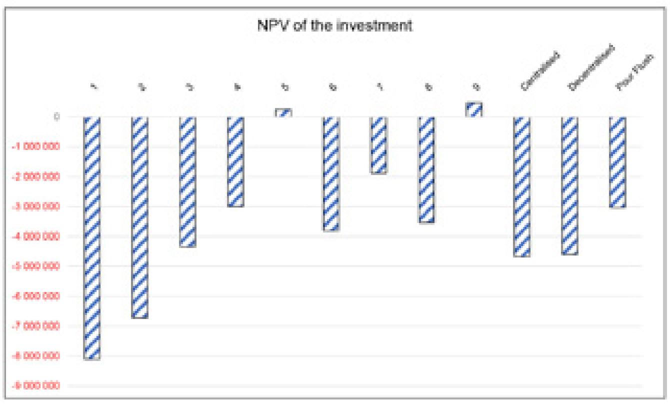

FIGURE 7: *50 % Reduction in Capex and Opex for informal settlements.*

In this regard, the project team conducted a sensitivity analysis to assess the impact that a 50 % reduction in the capital and operating costs of NSSS would have in the informal settlements scenario.

Figure 7 highlights that by achieving a 50% reduction in operating and capital expenditure, Option 5 and Option 9 present a net saving to the informal settlement over 15 years. Importantly, Options 4, Option 6, and option 8 also result in a scenario in which the informal settlement has net cash outflow, but this is lower than if the informal settlement had been connected to a conventional sanitation solution.

This highlights that there is a need to ensure a reduction in unit costing during production through economies of scale. The operating costs also need to be reduced to ensure that the benefits accrue to the End User. The purchase price of chemicals used in the treatment process could be negotiated down if there is an increase in demand. It should also be noted that the replacement cost of the units would reduce as the capital price of certain items is reduced.

4.7 The Use of Indicators

It is important to identify the most suitable indicator for a particular scenario and employ it to assess solutions for that scenario while recognizing that there may be subtleties to the indicator being utilized. For instance, in a school setting, capital costs per user could serve as a viable indicator; however, one must bear in mind that solutions are also tailored differently based on the gender distribution of learners at the school.

Furthermore, when comparing technologies across different scenarios, it is important to consider the usage of the facilities. For example, utilizing a volumetric basis (R/kl) in schools and informal settlements would yield varying results, as learners at schools use the facilities differently compared to users in informal settlements.

5. OBSERVATIONS, RECOMMENDATIONS, AND WAY FORWARD

5.1 The potential for NSSS

The NSSS assessed are more expensive than conventional sanitation solutions in markets that discharge lower volumes of wastewater. However, these solutions could be made more competitive by considering the following:

1. Aggregating the flows from various users to achieve better economies of scale; and
2. Consider aggregating raw material requirements from all NSSS within the SASTEP portfolio and consider bulk purchases for similar pieces of equipment.

It was also noted that suppliers to the NSSS have indicated that orders with higher volumes or increased frequency may be able to attract higher discounts. Thus, a programmatic approach in areas that are suitable for the NSSS may reduce the costs of these solutions once it has been proven that this is the most attractive sanitation solution in a particular context.

5.2 SASTEP

The Innovators were able to reduce the capital costs and operating costs associated with their NSSS throughout the study. This highlights the importance of programs like the SASTEP programme in developing sanitation solutions that improve access to a higher level of service and that could also provide financial and non-financial benefits to End Users.

Access to an acceptable level of sanitation services is an important priority in South Africa and the outputs generated by SASTEP could be utilised in communities that lack this access. It is therefore important that SASTEP is supported and capitalised by the Department of Science and Innovation, National Treasury, and the WRC.

5.3 The Market

There is an opportunity for NSSS in markets that produce large amounts of wastewater, such as informal settlements and schools. These solutions could be offered for outright sale or with a service component. The financial benefit will depend on the municipal tariff for wastewater discharge and water purchase. It is important to consider potential interest from private sector markets in utilizing NSSS.

5.4 Way forward

The initial investment required for an engineering project can vary based on the in-depth site assessment and its outcomes. Conducting this assessment can be time-consuming and relatively costly. Therefore, high-level desktop exercises are typically carried out before gathering detailed site information to confirm the project's potential and justify further investment.

The results of these preliminary exercises are primarily conceptual and serve as indicators rather than definitive conclusions. However, they suggest potential financial and non-financial gains from the further development and enhancement of NSSS for the End User. These benefits are not only in the form of water and sanitation tariff savings but also include potential savings associated with the utilisation of biogas for cooking and heating. Savings related to biogas would require further assessment as it would depend on the cost associated with the generation and containment of the gas.

In terms of concept, there are clear advantages to introducing and utilizing NSSS. Consequently, the next step would involve conducting a feasibility study to evaluate the applicability of the solution in a specific municipality, considering area-specific challenges related to access to sanitation and the proximity to the bulk sewer network.

The feasibility study should encompass the development of procurement documents for the implementation of NSSS, along with any necessary supporting documentation (such as bid committee documents and value-for-money considerations) to facilitate successful NSSS deployment in a municipal setting.

The findings of the feasibility study would serve as a blueprint that can be adopted by other municipalities. It would also contribute to knowledge sharing and skills development, fostering collaboration among Innovators, municipal officials, and other water sector professionals to address sanitation challenges using site-specific data.

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