WRC Working Paper: How Can South Africa Deliver Sanitation to All? An Overview of the Challenges & Opportunities

Sharing of ideas about a topic or to elicit feedback in developing strategy

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1. INTRODUCTION

On the 10 November 2018, the *Department of Water & Sanitation* (DWS) hosted *the Ministerial Interactive Session* at Birchwood Hotel, Johannesburg with the sector to understand and strategize a plan towards tackling South Africa's water and sanitation challenges. From the session that dealt with sanitation provision and the bucket eradication programme, the following key challenges were noted amongst different stakeholders:

- *Operation and Maintenance (O&M) of existing infrastructure*
- *Affordability of services*
- *Buy-in and partnership*
- *Accessibility to market*
- *To reduce the amount of water we use to flush*
- *Lack of awareness/education in the informal settlement in terms of the use of toilets and Health and Hygiene*
- *Unreliable data (information to develop technology)*
- *Value for money in terms of technologies that are implemented*
- *Frequency of emptying the pits*
- *Have verified data on sanitation provision programmes (including the bucket eradication programme and for urban informal areas)*
- *How to reduce water usage*
- *Procurement process in terms of prioritisations*
- *Rapid urbanisation*
- *Stigma "not being able to flush"*
- *No clear roles and responsibilities among spheres of government.*

In response to the challenges, DWS noted in the stakeholder session, possible solutions that resolve / alleviate the above challenges. The following is a list of solutions proposed by stakeholders:

- *There is a need to reduce & recycle and use grey water for flushing*
- *Choice of technology should be adopted by the sector and community*
- *Grants must come with conditions to champion technologies (i.e should include innovations)*
- *It must be declared that Sanitation should include Youth and Women*
- *Perception is that flushing toilets are dignity and anything else is unacceptable – alternative solution to waterborne are low flush systems*
- *We should ring-fence a budget to try new innovation*
- *An integrated national plan and implementation strategies to guide what is required*
- *Guiding the cost of sanitation provision including norms and standards*
- *Change the mentality of the communities*
- *Systematically address settlement planning, DWS MUST champion the integrated sanitation*
- *Create jobs by through different technologies solutions*
- *DWS must define itself and its role in eradicating the buckets AND EVEN BEYOND the programme*
- *Technology demonstration sites appropriate for the environment*

- *Partnerships with RDI experts (including technology developers and innovators)*
- *Public Private Partnerships*

Further, the stakeholders provided specific solutions with regards to addressing bucket eradication:

- *Expert panel must be established;*
- *Waterborne toilets for all (change of mindset) and responding to climate change;*
- *DWS MUST make use of the research that is currently in place;*
- *Continuous engagements with innovators*

The *Water Research Commission* (WRC), South Africa's premier water and sanitation knowledge hub, has developed this working paper in response to challenges and solutions put forward by stakeholders, specifically how solutions could be implemented. To understand why sanitation provision outside the sewered boundary remains challenging, a brief background of the challenge is presented in the next section.

2. SANITATION PROVISION: WHY IS IT CHALLENGING?

To develop solutions, it is imperative that we have an understanding of the difficulties associated with providing sanitation to the unserved populations. Solutions can only be developed once we have a proper understanding the nature of the challenge. This section provides an overview of the challenges that the country has faced in sanitation service provision.

2.1 HISTORICAL INEQUALITIES

Previous apartheid spatial geography planning meant that large proportions of the indigenous population did not receive adequate potable water and sanitation provision. Full waterborne systems were scarce in these areas. When South Africa's first democratically elected government came to power in 1994, the government provision of basic water and sanitation for unserved citizens became a priority.

Since then, a framework of legislation, policies and guidelines was developed to support the achievement of this goal. The *National Sanitation Policy – White Paper* developed in 1996 defined the basic level of sanitation for a household as a *Ventilated Improved Pit* (VIP) latrine, which falls under the UN technical category of improved sanitation (see **Figure 1**).

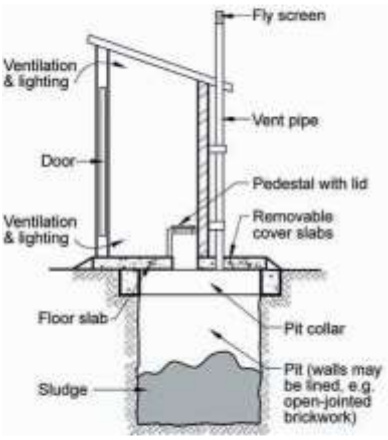

Figure 1. Side-view schematic of a Ventilated Improved Pit (VIP) latrine (from Guidelines for Human Settlement Planning and Design)

Later, the *White Paper on Basic Sanitation* (DWAF, 2001) highlighted the challenge of cost recovery from rural households with respect to water and sanitation which was followed by the *Strategic Framework for Water Services* (DWAF, 2003). The latter policy document provided guidance to *Water Services Authorities* (WSAs) in providing free basic sanitation infrastructure by the then target of 2014, promoting health and hygiene and subsidising the operation and maintenance costs. VIP latrines were considered an adequate infrastructure for sanitary purposes and according to the Strategic Framework for Water Services, this free basic sanitation service should be maintained at government expense (Still and Foxon, 2012). Further, as Still and Foxon (2012) noted, the policy document suggests but does prescribe appropriate technology with WSAs needing to address the following situations:

- *in urban areas and high-density residential areas, waterborne sanitation is considered the most appropriate solution;*
- *in rural areas, on-site sanitation technical solutions are deemed an appropriate solution; and*
- *in intermediate areas, such as peri-urban, the WSA would need to consider the most appropriate technology and needing to exercise caution when selecting waterborne options.*

2.2 RAPID URBANISATION

South Africa can be considered as a Young Urban nation; the country's population is urbanised at a rate of around 60-64% with a significant under 40 years population. The national rate of urbanisation is much higher that experienced in other developing countries (India at 32%, Vietnam at 33%, Nigeria at 47%, China at 54%) (de Kock and Petersen, 2016 Brand South Africa). **Figure 2**, as an example, shows the densification of peri-urban area in the city of Durban over a 5-year period. The urban migration trend experienced has meant that municipalities have to deliver sanitation services under challenging planning scenarios: 1) in informal areas without formalised housing arrangements and 2) government subsidised housing areas of which there is an ever-increasing backlog. For the former, it is technically challenging to provide sanitation services to individual homes within an informal housing arrangement. The laying of sewers in unplanned housing sites limits the municipalities technical approach. Temporary options such as chemical toilets can be provided but are expensive to implement while latrine technologies may require frequent emptying cycles in areas not conductive to such a task (planned road infrastructure, dense informal housing arrangements).

Figure 2. Comparison of urban development from 2008 (left) vs 2013 (right). Photos courtesy of eThekwini Water & Sanitation (Neil MacLeod).

For the subsidised housing, sanitation provision needs to be supplemented by a number of human settlement services, such as potable water supply and electricity, which can lead to increases in the service delivery timeframe. This challenge is exacerbated by the limitations of current technological approaches used to provide sanitation services.

2.3 SANITATION PROVISION CANNOT BE DECOUPLED FROM WATER SUPPLY

The majority of South Africa's urban population sanitation needs are addressed through reticulated waterborne systems. The requirement for the technical functioning of these systems is water. Research produced through the WRC and its partners have shown that South Africa is over-exploiting its water resources and that withdrawals are expected to increase over the next 20 years. It has been predicted that planned water supply enhancements are not adequate for our future water demands and that a basket of interventions and strategies are required to reconcile the future water demand and supply gap. As the Cape Town drought 2017 has shown; the flushing of 9-12 litres of potable water with faeces may not be viable in near future and represents one area amongst many where South Africa's high per capita usage (235 litres per person daily compared to a global average of 173 litres) could be reduced. Another avenue for alternate water supply could be the re-use of treated sanitation-derived wastewater. In neighbouring Namibia, this strategy of direct wastewater-to-tap has been relatively successful as water management strategy but has only been implemented in pockets within South Africa. The reasons for this have less to with technical capabilities than other factors (social, strategic).

The availability of water and the cost of its supply (in terms of existing infrastructure and cost for providers and users), it also major determinant in selecting for dry sanitation technologies as explained further in the next section.

2.4 TECHNOLOGY LIMITATION: WE EITHER PROVIDE A HOLE OR A FULL FLUSH

When considering technology choices for service provision, the choice has generally been full flush or latrine-based technologies. The technology choice is based on the following interlinked determinants: proximity in relation to existing sewer network, cost (on-site alternatives are generally around 5-50% cheaper than activated sludge process linked to reticulated sewerage), and availability of resources (water, energy, financial resources).

2.4.1 The "Hole" Solution: Latrine-Based Challenges

Apartheid spatial planning had led to large proportions of former homelands and rural areas without water and sanitation infrastructure. To deal with challenge, VIP latrines and their derivatives were installed since 1994 as it did require sewer laying and associated infrastructure (transfer pumps, wastewater treatment facilities, requirement for constant water supply). The dry sanitation solution, if properly serviced, operated and maintained, provides a barrier to sanitation-related infectious diseases.

Large-scale infrastructure programmes were implemented to build VIPs with around 30% of the entire South African population relying on this technology and its derivatives (Statistics South Africa, 2013). Latrines were built on the premise that sludge would not accumulate and therefore not require emptying. In reality, the opposite was proving true; latrines were filling and many thousands of these systems were reaching their capacity faster than anticipated (**Figure** 3). The consequence of the rapid latrine building programmes – while delivering essential services within the technical constraints – had brought upon another set of challenges related to the servicing, operation and maintenance of the implemented solution.

Latrines Challenges: A Summary

- *Latrines behave as waste storage vessels – limited capacity*
- *Household pits require periodic emptying (5-years)*
- *Latrine sludge contains infectious agents*
- *Sludge emptying and disposal challenging*

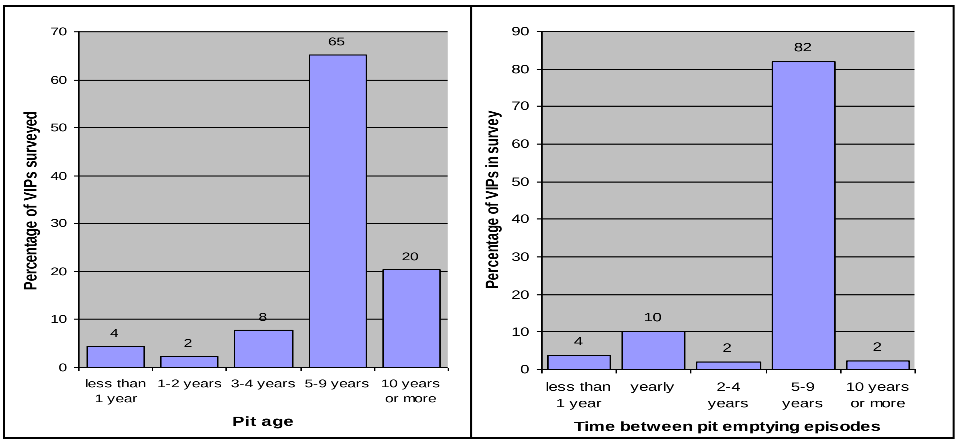

Figure 3. Pit ages and interval required before emptying (Still and Foxon, 2012).

A tipping point was being reached as many municipalities did not have operation and maintenance procedures, budgets and plans for managing VIP toilets with some pits requiring emptying as frequently as twice a month (Mjoli, 2010; Still and Foxon, 2012). A national audit of water and sanitation projects conducted on behalf of the then Department of Water Affairs and Forestry (now Department of Water and Sanitation) nearly 10-years ago indicated that at 60% of the facilities surveyed, municipalities were only conducting reactive maintenance while 40% of municipalities had inadequate maintenance capacity (SALGA, 2009).

This challenge has not been resolved; to date, there are many municipalities that struggle to deal with faecal sludge from dry sanitation systems. From a technical perspective, faecal sludge is a sticky paste containing a variety of pathogenic micro-organisms. The sludge is not conducive to a vacuum and is practically better to be emptied by manual labour using shovels and forks. This work is not pleasant and requires personnel be safe-guarded, using PPE, deworming, and immunizations, against infectious agents contained within the sludge. When vacuum trucks are used, it can require significant effort to gain access to latrines (where road infrastructure is limited) and water to enable the honeysucker to remove sludge from the latrine. Another challenge is related to the operational requirement for disposal; scientific studies commissioned by the WRC have shown the sludge to be highly concentrated in pathogens and nutrients. Due to its nature, Microbiological Class C landfills are recommended for sludge disposal of which there are limited number willing to accept this sludge of sludge nationally. Logistical costs required to transport sludges to recommended disposal route can escalate disposal costs while the low biodegradability and nutrient content of the sludge means that digestion-based systems and blending with wastewater streams are not an effective disposal strategy, respectively.

From a user perspective, dry sanitation technologies are not considered the “best” option. Dry sanitation is considered as the “poor person’s toilet”. Studies commissioned by the WRC and partners within South Africa have shown a strong user preference for a flush toilet over dry sanitation technologies. Often, the latrine’s servicing lifespan is significantly reduced by detritus intrusion into the latrines. These findings highlight the complexity of sanitation provision in which the service provider has to match user needs and preferences to limited technical, natural and financial resources. Further, it points to the lack of suitable technology alternatives that can encompass these design requirements.

2.4.2 2.4.2 The Flush Solution: Challenges

The flush toilet remains the “gold standard” from a user perspective. Although the flush toilet can be associated with various on-site systems, such as a septic tank, in this paper it is referenced in terms of the conventional reticulated sewerage system applied for urban areas. This system is typified by a network of sewers linked to communities and which transport large volumes of wastewater to a collection, treatment and disposal point. The inclusion of water in the design allows for the sludge challenge to be transported to a centralised facility whereas in dry sanitation, the sludge challenge is localised at point-of-generation.

<u>Flushing Challenges: A Summary</u>

- *High provision cost*
- *Stringent technical requirements (water, energy, HR)*
- *Affordability to user and provider*
- *Sludge disposal costs*

Historically, the roots of this approach can be traced back to the outbreak of waterborne diseases, especially Cholera, on the European continent. Once scientific evidence linking the outbreak of waterborne diseases to poor sanitation became clearer, there was an increased motivation to transport household human excreta away from ever-expanding urban populations. Water is an essential component of this approach in order to transport human excreta from point to the next. While this strategy led to the significant reduction of the outbreak of waterborne disease outbreak in Europe (evidence cited in Lofrano and Brown, 2010), is it wasteful as considerable amounts of limited and potentially potable water is contaminated with human excreta and other pollutants for the sole purpose of transporting pollutants from one catchment to the next.

While developed countries have continuously improved conventional wastewater-based strategies to become more reliable and efficient as time progressed, developing countries have struggled to be implement this technology successfully. There are number of reasons for this. There is a significant unserved population in developing countries and the infrastructure provision has to address these backlogs and in urban areas, also keep pace with the rapid population growth and urbanisation. Developing countries require significant investment for centralised sewerage infrastructure while meeting several technical requirements: excavations are needed for laying pipes, reliable water infrastructure and supply, and energy-intensive pumps and treatment systems.

Research has indicated that the financial investment required for such systems may beyond the reach for most developing countries as even in developed countries, these systems are directly cross-subsidised to enable them being financially sustainable.

Connection to a sewer system can be costly; a generalised estimate put forward by the WHO/UNICEF (2000) indicated that cost per person connecting to the sewer network is 5 to 50% higher than on-site alternatives. Further, the capital cost of treatment option can be nearly double to that of a septic tank (based on community of 10,000 people and in comparison, with activated sludge process) (World Bank Group, 2016). Cost can be major driver for the technical approach used. Von Sperling (1996) hypothesised that the four main aspects considered by developing countries in the selection of a wastewater treatment were infrastructure costs, sustainability, operational costs and simplicity. Conversely, the developed countries perceived efficiency, reliability, sludge disposal and land requirement as the major drivers for technology selection.

Besides the infrastructure investment, a suite of other resources, such as water, energy, and high-level designers, technicians and operators, are required to properly manage wastewater plants and their auxiliary equipment. The lack of these resources can result in infrastructure deterioration and / or unreliable services (evidence cited in: Eales, 2008; Hawkins et al., 2013; UN-Water, 2015). Eales (2008) noted that in South Africa, only a small percentage of plants were operated and maintained adequately with there being a critical shortage of skilled staff to operate and maintain the treatment works. A supplementary paper produced by the WRC on the Green Drop programme has highlighted similar themes. Other challenges are the design capacity of current wastewater treatment facilities to deal with increasing pollution loads, unstable energy supply, and the lack of investment in current infrastructure.

Some of these issues have manifested themselves in the bucket eradication programme in areas without bulk sewers, inadequate wastewater treatment capacity and adequate water supply. WRC Research Report 2016/1/12: *Evaluation of Sanitation Upgrading Programmes: The Case of the Bucket Eradication Programme* by Hlathi Development Services provided insights in what worked well and what did not in municipalities implementing the bucket eradication programme which are highlighted in **Table 1** below:

Table 1. Main insights into the Bucket Eradication programme.

What worked	What didn't	Challenges
Buy-in from all political levels and spheres of government	One-size fits all toilet	Adequate funds, specifically municipalities with limited revenue streams
Deployment of engineers to under-capacitized areas	Supply-driven approach with little emphasis on sustainability, specifically O&M	Affordability of waterborne services for the poor
Eradication of bucket system with improved sanitation	Limited emphasis on community involvement and education including hygiene campaigns.	Inappropriate cleansing materials by poor households
		Lack of funds for new or upgrades for WWTW
		Critical shortage of skills for O&M

2.5 Summary of challenges

From the Ministerial Interactive Session and a summary of research-based evidence provided above, sustainable sanitation provision is linked to three broad themes as shown in Figure 4. Sustainable sanitation cannot be achieved without these 3 interlinked factors.

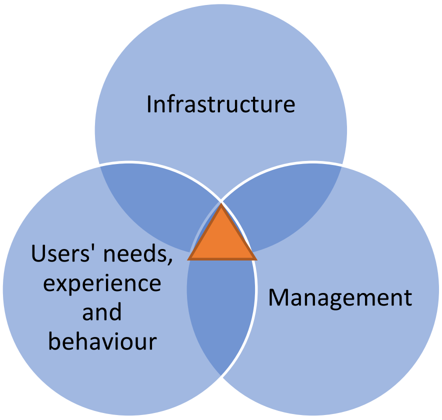

Figure 4. Sustainable sanitation requires all three-interlinked factors to be aligned (red portion on diagram).

Table 2 presents a re-organisation of the data obtained from the Ministerial Interactive Session under the themes of Infrastructure, User Needs and Behaviour and Management.

Table 2. Summary of challenges according to the three requirements for sustainable sanitation.

Infrastructure	**User Needs and Behaviour**	**Management**
O&M of existing infrastructure Technical know-how	O&M of existing infrastructure Educational programme for reduce detritus, community involvement in tech selection	O&M of existing infrastructure Planning
Affordability of services Technology selection	Affordability of services Ability to pay for upgraded services	Affordability of services Planning & Consultation
Buy-in and partnership Piloting novel solutions	Buy-in and partnership Community involvement	Buy-in and partnership DWS, Council, community
Accessibility to market Piloting novel solutions	Accessibility to market Market analysis of new solutions	Accessibility to market Piloting novel solutions
To reduce the amount of water we use to flush Piloting novel solutions		
Lack of awareness/education Piloting novel solutions	Lack of awareness/education Buy-in and partnership	Lack of awareness/education Community involvement
	Unreliable data M&E	Unreliable data Planning
Value for money Piloting novel solutions, M&E	Value for money Education, M&E	Value for money Piloting novel solutions, community involvement, water demand planning
Frequency of emptying the pits Technical know-how	Frequency of emptying the pits Educational programme for reduce detritus, community involvement	Frequency of emptying the pits Community involvement
How to reduce water usage Piloting novel solutions	How to reduce water usage M&E	How to reduce water usage Piloting novel solutions
Procurement process in terms of prioritisations Cost-benefit		Procurement process in terms of prioritisations Cost-benefit, ring-fence budget for new tech
Rapid urbanisation Piloting novel solutions		Rapid urbanisation Piloting novel solutions
Stigma “not being able to flush” Piloting novel solutions	Stigma “not being able to flush” Community involvement	Stigma “not being able to flush” Community involvement

Critical drivers for all three factors are to have the necessary leadership (to innovate in adversity and ring-fence budget for piloting new solutions), norms & standards, and policy and regulatory enablers to facilitate new solutions. Data capturing, monitoring and evaluation serve a tool to guide decision-making and planning and monitor the outcomes of interventions.

3. SOLUTIONS TO ADDRESS CHALLENGES

Recognising the need for solutions that provide sustainable sanitation solutions, the WRC has strategically invested in Research, Development and Innovation (RDI) products across the sanitation value chain and has developed products which targets the 3 interrelated factors. Some of technical innovations are at mature stage and have been demonstrated at scale e.g. the WRC Low Pour Flush and School Sanitation Management Model. The purpose of this section is to provide an overview of these RDI products developed through the WRC which have the potential to accelerate sustainable sanitation provision.

3.1 INFRASTRUCTURE SOLUTIONS

This section is divided into 2 sections; the first highlights on-site options while the second presents decentralised (catchment) systems.

3.1.1 Front-End Solutions – Improved Pedestals

This section provides an overview of innovative pedestal products developed and/or tested through the WRC that allow for greater efficiencies at the user-pedestal interface.

The WRC Low Pour Flush

The need for a technology that encompasses the benefits of both waterborne and dry, on-site sanitation led the WRC to fund the development of the Low Pour Flush system. The technology has been tested using international flushing protocols, piloted and subsequently upscaled to over 1,000 units with a partnership with the *Department of Science and Technology* (DST). Using a small amount of water (1 to 2 litres - which can be grey water also needing disposal and not additional potable water) to flush — a Pour Flush system can terminate in a simple soakaway (

Figure 5). This overcomes the considerable problems and expenses involved with constructing and maintaining sewers in rural settlements or tightly spaced informal settlements. It also represents a great saving of water over regular waterborne sewage and provides a number of the benefits of the full flush toilet, including having a water seal to limit odours. This allows the toilet to be installed inside the house – unlike VIP latrines – and can be retrofitted with a low flushing cistern (3 litres) giving the household additional options.

Household system without cistern

A school system which includes artwork from students to derive sense of ownership

Figure 5. Photographs of the WRC Low Pour Flush

A further benefit to municipalities of the Low Pour Flush system is that by keeping out the rubbish that frequently is disposed of pit latrines and aided by the addition of small quantities of water, a sludge is produced which is more easily, safely, and cheaply removed than that the sludges typically found in VIP latrines. This addresses one of the thorniest problems faced by sanitation departments at municipalities across South Africa today, as the systems built as part of basic service delivery begin to reach capacity. From the point of view of the user, the sights and smells of excreta are flushed away and forgotten, just as with a full waterborne system.

The demonstration projects showed that the Low Pour Flush were marginally more expensive to build than a standard VIP latrine. However, the lifecycle cost of the Pour Flush is less due to less emptying. Moreover, it is more superior in terms of user acceptance, aesthetics and safety. Based on the experiences in Jerseyvale, the Amathole District Municipality is requesting assistance with the roll-out of further units within its district to promote the technology within other rural municipalities. The demonstration and its benefits to the sector would have not been possible without the funding partnership and leadership of the DST which recognised how innovation can be used to uplift poor communities.

As part of the continued learning process, a Monitoring and Evaluation (M&E) is being funded by the WRC to evaluate Low Pour Flush system implementation in South Africa. The study is on-going but results to date have shown that the WRC has successfully enabled the scaling of an innovative product that meets user expectations for flush-style toilet but also the municipalities technical limitations in areas where there is restricted tapped water supply and a lack of sewers (**Figure 6**).

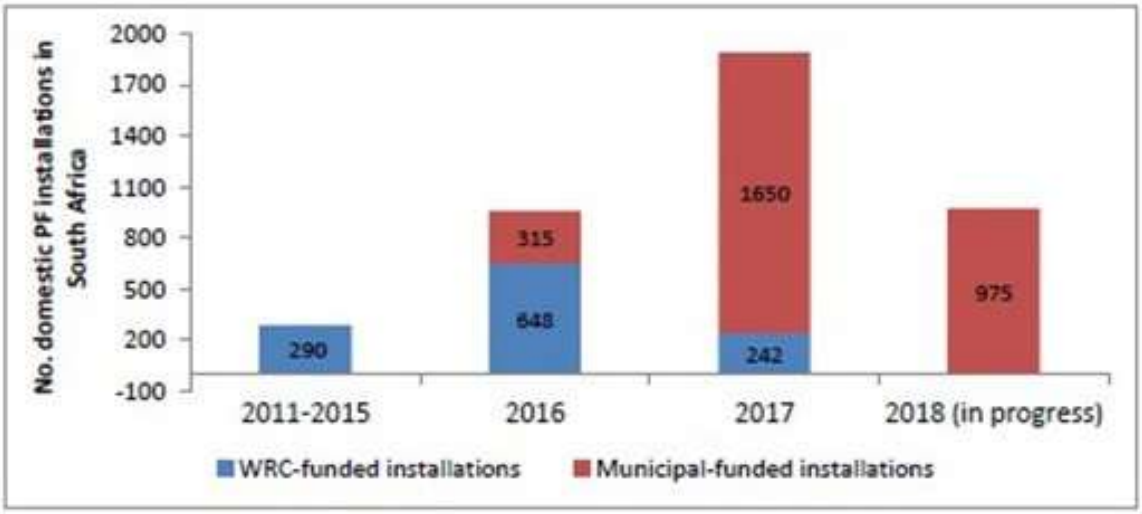

Figure 6. Scaling of innovation from pilot to demonstration. Once municipalities are "comfortable" (understand the risk-benefit) with technology through demonstration, they are more willing to implement at scale.

Technology benefits*: toilet outside sewered boundary, no trunk sewer requirement, cistern retrofit allows two (2) implementation options: i) without cistern which means that there are no water leaks, a major servicing factor that results in deterioration of service supplied and ii) with cistern which offers convenience.*

Implementation challenges*: user need for cistern for ease of flushing which brings about other operational challenges (leaks, incorrect cistern can lead to leach pit flooding); community involvement is required to understand to prevent retrofit with inefficient cisterns and explain choices e.g. if a community requests a cistern retrofit, they would need to understand the cost implication to the municipality and the user (adding cistern, larger leach pit or connection to septic tank, frequent desludging); pit emptying budget should be ring-fenced for a 5-year period – a lack of budget will lead to a deterioration of the product.*

The Arumloo

The Arumloo is an innovative microflush toilet capable of flushing on less than two litres of water. The product was developed from funding by the WRC. The product mimics the Arum Lily flower and the vortex created by innovative bowl design allows higher efficiencies for flushing (less than 2 litres) compared to a conventional full flush (9 to 12 litres).

Figure 7. The Arumloo toilet which can flush use less than 2 litres.

***Technology benefits**: low flush technology reduces household water usage; suitable for poor and high-income communities due to aesthetic design; can be connected to sewer or suitably designed septic tank or leach pit.*

***Implementation challenges**: commercialisation of the product to allow entry and spares & parts manufacturing; lack of policy enablers that facilitate the uptake of water-saving toilets.*

Female urinals

Urinals serve an important role in public ablution facilities; they reduce the number of pedestal toilets required and reduces queues for urinating. Female urinals for girls and women have been used with success in some countries and are easy for young children to use, are cheaper and faster to build than pedestal-style toilets.

From a health perspective, younger children, using urinals for urinating, may be easier, cleaner and safer than using pit and public pedestals, where they may have to use their hands to lift themselves onto a soiled toilet seat. For older learners, defaecating may happen only rarely at school and the primary need for a toilet may be for urination. Where public facilities are inadequate, it may be possible to add urinals more cheaply and quickly as an interim measure while resources are collected for improving toilets. Female urinals can sometimes be left unenclosed in the case of young girls who do not require privacy from each other. For older girls, urinal stalls with a water source can provide a means for cleaning and washing during menstruation. Provision of urinals for girls would have to take into account the need for bins for disposal of wiping materials.

Figure 8.Urinals designed by female designer. The urinal does not require water and can be used by female or males (in sex separated public ablution facilities).

While the concept of female urinals has been explored outside South Africa, there was little information available locally on the potential of female urinals for public toilets in South Africa. Though the concept was relatively new and unknown, it is clear that there are existing problems which female urinals can effectively solve. Poor situations in school and public toilets do not keep girls and women from using them, and thus improved options are likely to be used. The WRC through its research grantee field-tested a locally-available, commercialised unisex urinal within school and public environments. The outcomes from the pilot study showed that as long as the urinals are kept clean, adequate education is provided to users, and privacy is provided, adoption and acceptance of the technology in schools is likely.

Technology benefits*: expands technology toolbox; waterless capability through bladder valve; potential to extent technical capacity of public restrooms; opportunities to capture urine and convert into struvite already demonstrated and part of business model of technology developer; aids in sludge management.*

Implementation challenges*: community engagement and education on use of product; cannot handle faeces so educational component is important; older children prefer more privacy; reliant on regular servicing (emptying of bins for wiping).*

3.1.2 INNOVATIVE TREATMENT SYSTEMS (CONNECTED TO SEWER)

In this section, alternate wastewater treatment plants are presented which allow for less energy requirement, less advanced technical personnel for O&M, nutrient recovery and beneficiation opportunities. These systems have been piloted and demonstrated with research funding support from the WRC.

Decentralised Wastewater Treatment Systems (DEWATS)

Decentralised Wastewater Treatment Systems (DEWATS) is an approach that involves the use of flushing toilets (household or communal) and the treatment and disposal of the wastewater close to the source that it was generated. These treatment systems vary in scale from individual households to communal systems. DEWATS plants are increasingly becoming popular in developing countries, especially South East Asia, as on option for sanitation in densely-populated areas. The system can be used to treat wastewater from up to 1,000 households.

The modularised treatment system that typical consists of following treatment steps:

- *Primary treatment using sedimentation ponds, settling tanks or biogas digester.*
- *Secondary treatment using an Anaerobic Baffled Reactor (ABR) with anaerobic filters or anaerobic and facultative pond systems.*
- *Tertiary aerobic/facultative treatment using horizontal gravel filters and /or ponds.*

The modular arrangement is designed in such a way treated water meets requirements stipulated in environmental laws and regulations of a particular area. The technology does not require any moving parts (and thus no energy) and flow to the treatment system can be achieved via gravitational shallow sewers. Crucially, training is required for various personnel to facilitate dissemination of knowledge, implementation and maintenance of DEWATS plants, and should be constructed with locally available materials and implemented through a partnership between the local residents, the municipality and other stakeholders.

The WRC has funded the science behind the core treatment of the DEWATS process, the ABR, since the late 1990s. The research has shown the system have performance advantages over conventional septic tanks with specialised microbial consortia developing through the chambered system. The system was tested at laboratory-scale and pilot-scale and a demonstration plant commissioned in eThekwini municipality in the early 2010's to evaluate the system under field-conditions. The re-use of the treatment wastewater for urban food gardens was also scientifically evaluated to understand the public and environmental risk association with effluent irrigated crops. The system was a solution being evaluated by eThekwini Municipality to deal with the increasing challenge of providing housing and sewered infrastructure outside the waterborne boundary. New housing developments are continuously being established within the urban and peri-urban areas in order to meet the housing backlog, many of which are not able to be connected to the main sewer line. The city therefore looked to the DEWATS approach as a possible sanitation solution for future housing developments.

The municipality plans to implement two DEWATS outside the waterborne network based on the performance and operational learning established during the technical demonstration phase. The current challenge the municipality is facing is obtaining a Water Use Licence Application (WULA) from local DWS office. It appears – although not confirmed - that the strategy used – to remove solids, pathogen load, COD – but to retain nutrients to use as a liquid fertiliser for community food gardens – may conflict with general authorisations.

Technology benefits*: decentralised approach allows for water catchment management; does not require pumps and transfer stations; offers opportunity for biogas generation through anaerobic steps; community upliftment scheme through municipal run urban food gardens grown with liquid fertilisers.*

Implementation challenges*: obtaining WULA based on experimental programmes conducted on new technologies; stormwater intrusion can limit performance; plant may require regular screening if there is* *detritus intrusion – any programmes which implement the technology must place emphasis on sewer infrastructure; not connecting stormwater and detritus intrusion into sewer lines.*

Integrated Algal Ponds Systems (IAPS)

Like the DEWATS process, *Integrated Algal Pond Systems* (IAPS) offer simplicity and economy in comparison to activated sludge processes for micro-sized plants (less than 10 Megalitres/day). The process relies on the combined activity of methane fermentation and photosynthetic oxygenation by algae coupled with biological oxidation in the high-rate ponds to remediate domestic wastewater.

The IAPS was commissioned in 1996 at Belmont Valley wastewater treatment facility to treat 75m^3 wastewater per day. The demonstration unit consists of in-pond digester, an advanced facultative pond with 2 parallel high-rate oxidation ponds (HROP) and two algal settling ponds (**Figure 9**). The algal material generated is envisaged as a fertiliser substitute. The scientific evaluation of the process was performed by the Institute of Environmental Biotechnology, Rhodes University through WRC Research Project K5/2123.

Figure 9. The IAPS in Belmont.

The key finding from the demonstration IAPS unit was that the effluent generated was on the verge on meeting the stricter compliance standards for water discharge (effluent: COD = 94 mg/l, NH4-N = 2 mg/l, PO4-P = 4 mg/l, TSS = 31mg/l). Improved performance would have been achieved if the system was designed, constructed and operated with a tertiary treatment polishing unit; and the second HROP operated at its design hydraulic retention time (4 d instead of 2 d). Maturation ponds and slow sand filtration polishing units piloted as low-cost polishing steps for the IAPS unit showed that further reduce pollutant concentrations to within water discharge standards. The pathogen indicator analyses revealed that discharge limit is met only if the IAPS is correctly configured and the second HROP is operated at a hydraulic retention time of 4 d. The research the important of demonstration-testing before field implementation as learnings, both scientific and operational, can be used in adapting designs and operations.

***Technology benefits**: simplicity in design with less energy requirement than activated sludge processes; beneficiation of waste in form of algae.*

***Implementation challenges**: obtaining WULA based on experimental programmes conducted on new technologies; risk aversion coupled with selection of advanced technologies (with the interpretation that advanced offers better performance).*

Given the high proportion of reticulated wastewater treatment plants in the country that are do not have appropriate skilled staff and financial means to operate and maintain the plants effectively, the wider implementation of DEWATS and IAPS can provide a robust and technologically sound option for small towns and peri-urban areas.

3.1.2 Next Generation Sanitation – Eliminating the pain points of current technologies

Re-Invented Toilets (RT)

In his response to world challenges, Mr. Bill Gates recognised the need to shift the sanitation technology agenda. In 2011, the Bill and Melinda Gates Foundation's *Water, Sanitation & Hygiene* (WASH) programme initiated the *Reinvent the Toilet Challenge* (RTTC) to address the limitations of current sanitation approaches highlighted earlier.

The Foundation set itself the ambitious goal to develop the next generation of toilet system in a 5-year period. To achieve this target, grants were initially awarded to sixteen research teams from around the world to develop innovative toilet technologies - based on fundamental engineering processes - for the safe and sustainable management of human excreta. The technical requirements set by the Foundation was that the sanitation system had to fulfil the following: 1) protect public and environmental health, 2) recover valuable resources such as energy, water and nutrients, 3) operates off the grid without connections to water, sewer, or electrical lines, 4) cost less than US$ 0.05cents per user per day, 5) promotes economic sustainability, and 6) is an aspirational product that will attract both developing and developed country contexts.

The number of research teams involved in this initiative has expanded since 2011 with a number of technological advances made with respect to sanitation treatment process. The innovative, off-grid sanitation prototypes developed through the Foundation's initiative focussed primarily on mechanical, physical, heating, and chemical treatment processes, such as liquid /solid separation, hydrothermal carbonisation, combustion and electrochemical treatment, in order to treat human excreta almost immediately.

In the first phase of the RTTC, grantees provided the scientific testing and validation of the processes with the first prototypes showcased at the 2012 RTTC Fair in, Seattle, USA. The first prototypes underwent rigorous testing and evaluation, optimisation and improvement with demonstration-ready units showcased at the next RTTC Fair in 2014 Delhi, India. At the moment, demonstration-ready models are being field-tested in India, China and South Africa, to establish market readiness, ensure durability and reliability, develop specifications and manufacturability, and understand soft-issues relating to usage, including user acceptance and the re-use of beneficiated waste streams. The Foundation aims to establish a provision and servicing model similar to commercial household appliances which is envisaged to extend the technical capacity of the sector and deal with the constraints of current O&M approaches.

Addressing the technical limitations of current sanitation technologies

Through innovative design and treatment processes, the technologies developed under this initiative have the potential to address the limitations of current sanitation interventions by eliminating pathogens on-site, recycling / re-using limited resources, meeting user experience and acceptance, minimising environmental pollution, and the potential to link sanitation infrastructure to innovative management approaches. By treating human excreta at the source, it eliminates the need for sewers or in the case of on-site sanitation technologies, having to find ways to manage faecal sludges (Fig.1). Water is not wasted – the technologies significantly reduce requirements for water or re-use / recycle it. Further, human excrement is transformed into by-products of potential economic value allowing for linkages to new business and service delivery models that has the potential to reduce the financial burden to municipalities. Such innovative approaches not only challenge the way in which we approach unserved areas but also the way in which we manage water security and sanitation in formalised areas operating on conventional technologies. In the developed world, water supply and sanitation have followed a linear design trajectory - from achieving water supply, to sewered settlements, then drainage – to integrated urban water cycle management (Brown et al., 2009). Developing worlds appear to following the same route. The off-grid solutions developed by the Foundation have the ability to leapfrog this trajectory enabling developing countries to mitigate water security, achieve sanitation provision with no additional water and / or energy, and create opportunities for employment through new service and operation and maintenance models.

In the traditional, linear sanitation approach, any weakness in the management chain would result in disruption of the service. In the proposed option, the collection, emptying and transport cycle is reduced or eliminated by treating human excreta off-grid into safe, potentially value by-products. Quality assurance is achieved through specification and manufacturing standards which the Foundation has started. Locally, SABS has adopted

Figure 10. Reinvented Toilets (RT) cut the sanitation service value chain (emptying and transport).

Delivering Confidence in Solution through Field-Testing

In South Africa, the Water Research Commission (WRC) has been pioneering new sanitation thinking and solutions. In partnership with the Gates Foundation, UKZN, DST, DWS and eThekwini Municipality they have been driving an in-depth science and research programme to feed into the solutions of the future. Technologies developed under the RT portfolio are currently undergoing engineering field testing to evaluate field-based performance and collect data (user acceptance, technology limitations observed in field) for optimisation of the product as a final part of the commercialisation step.

Developing A New Sanitation Industry

The early indications are that greatest opportunities exist in non-biological processes with regards to this disruptive sanitation agenda, which also offer elements of valorisation and beneficiation. Recognising this progress and development, in 2017 the *Department of Trade and Industry* (DTI) launched the Water & Sanitation industrial platform as part of its *Industrial Pathway Action Plan* 2017 (IPAP).

The water and sanitation chapter of IPAP (2017), recognises that water is a critical input factor to industrial sectors like agriculture, agro-processing, forestry, manufacturing, energy production and mining. Citing reports, it cautioned that some regions of the world, including Africa, could experience a decline in growth rates of as much as 6% as a result of water-related losses. It identifies that not only does water underpins economic growth; leaders of the *World Economic Forum* (WEF) consider it a strategic sector in its own right. The WEF Global Risk Report has ranked water availability in the top three global risks for three consecutive years - 2015 to 2017 - highlighting the need to identify and implement intensive mitigation strategies. The report recognises that Sub-Saharan Africa is one of the regions with the lowest sanitation coverage in the world with only 70%.

Almost 66% of the African continent is arid to semi-arid, with poor water and sanitation infrastructure. The challenge of providing "traditional" centralised water infrastructure for most African countries is made more difficult and complex by the vast distances required to transport water, social inequalities, high unemployment, and fledgling water institutions without the capabilities to meet increasing demand. On the other hand, Africa contains many of the fastest growing economies in the world – if, in many cases, off a comparatively low base and marked by highly uneven distribution - resulting in rapid urbanisation and a growing tendency for internal migrant populations to agglomerate in mega-cities.

In this context, recognition of the importance of investment in water and sanitation - and the need to improve access and quality of drinking water and provide new sanitation solutions – is the necessary first step towards identifying and grasping the opportunities that a regionally shared industrial approach to water can provide. Specifically, on sanitation the IPAP present the action plan described in the next section.

Next Generation Sanitation Cluster Development

<u>Nature and Purpose of the intervention</u>

Development of off-grid sanitation technologies will lower water requirements for sanitation, enabling reallocation to alternative needs and economic sectors and more effective service delivery in rural, peri-urban and water-scarce areas. An off-grid sanitation market presents an expansion opportunity for manufacturing, service and supply sectors.

- *Expand sanitation industry to service the unserved 40% households and diversify the market with new products.*
- *Increase water availability for social and economic needs using efficient technologies.*
- *Unlock new private sector delivery mechanism for sanitation services.*

<u>Targeted Outcomes</u>

- *The establishment of the next generation sanitation CDP.*
- *Development of emerging industry capable to develop new technology, within the framework of localisation.*
- *Procurement and policy incentives for improved uptake.*
- *Development of high-end skills for advanced thermal sanitation technologies and artisanal skills for operation and maintenance.*
- *20 SMMEs per annum post-implementation.*
- *Potential 15,000 jobs at 20% market penetration for the currently unserved.*

Benefits & Implementation Challenges

The benefits of RT systems include disinfect of faecal waste at point of source, non-requirement for sewers, potential to operate without electricity supply, and water-conserving flush.

The implementation changes that are faced include modifying the *National Building Regulations* (NRB) to allow water saving sanitary fixtures, norms and standards, and lifecycle cost-benefits. At a national level, SABS has adopted the *International Standard Organisation*'s (ISO) standard for Non-Sewered Sanitation which allow for process confidence and durability. Post-implementation challenges anticipated in near future include revenue collection from municipalities if households move off-the-grid.

3.2 INNOVATIVE MANAGEMENT MODELS – MANAGING WHAT WE HAVE BETTER

Infrastructure not accompanied by an effective management can be expected to deteriorate. The WRC has noted the importance of management and training initiatives aimed at delivering effective management to water and sanitation infrastructure. This section details some of the key initiatives developed and then piloted by the WRC.

3.2.1 SCHOOL SANITATION MANAGEMENT MODEL

In 2014, the WRC sought to understand why school sanitation was failing with focus on rural areas which are served by pit toilets. This was in response to an unfortunate incident involving a child drowning in a school latrine; an incident that has again occurred in 2018. The study undertaken by Partners in Development, a Pietermaritzburg development engineering firm, showed infrastructure provision not accompanied by an adequate management programme resulted in failure, even if that infrastructure was relatively new. One of the challenges that a principal has to do is to use his / her budget to provide the necessary tools for educating children. Within this budget, a portion needs to be used keep toilet facilities hygienic. However, this is not ringfenced. Partners in Development developed a *School Sanitation Management Model* and provided for necessary training manuals and cleaning protocols which could be used to empower the principal to use a portion of his / her existing budget to keep toilet facilities hygienic. The products developed by Partners in Development also included a guideline of what toilets are available and other associated fixtures, and what are pros and cons for each choice (**Figure 11**).

Figure 11. School sanitation management products developed by the WRC.

Through the WRC funding, a pilot programme was tested using the new management model in 8 different schools under the jurisdiction of the KwaZulu-Natal Education Department which recognised the potential of new management model. In each school, the following were assigned: A Health & Safety Officer who was the school cleaner, a Health & Safety Manager who served as a staff member, and the principal who oversees all aspects of the school life. Training was provided for the Health & Safety Officer to ensure that they are adequately equipped and protected during their duties and have enough tools and supplies to the job. Consumables such as toilet paper, pads and liquid hand soap were budgeted for monthly supply in the beginning of the programme to ensure that learners' hygiene is protected. A cleaning protocol was established to ensure that the toilets are clean and free of disease transmission potential on a daily basis (Figure 20). The protocol recommended that the toilets are cleaned 3-times per day with focus being put on areas that are considered gems "hotspots". The programme also encouraged schools to come up with creative ways to engage learners in the monitoring of their toilets and how disease transmission occurs.

The programme has been relatively successful with Unilever extending the model to 150 schools based in KZN and Northern Cape and serving over 100,000 learners.


Before | After


Before | After

Figure 12. Implementation of the Model - Before vs After Photos.

***Technology benefits**: prevents over-reliance of tender processes managed by DoE which may take long periods to resolve; capacitizes school to ring-fence budget for general upkeep of infrastructure, hygiene education; cleaning protocols accompanied by training.*

***Implementation challenges**: cannot be implemented where infrastructure is beyond normal O&M requirements; job specification of cleaner has not been established; depends on leadership at school and willingness to improve school environment.*

3.2.2 SOCIAL FRANCHISING FOR O&M OF WATER & SANITATION FACILITIES

The WRC has successfully implemented a pilot project on Social Franchising for Operation and Maintenance of School Water & Sanitation Facilities in partnership between the WRC, Irish Aid, CSIR, the Department of Education (DoE) and Amanz'abuntu Services, a large water service provider based in the Eastern Cape. The project team envisaged franchising of the operation and maintenance services as way in which the quality of the water services could be consistent and guaranteed. At the same time, franchising would support the development of local micro-enterprises and broad based black economic empowerment within public service delivery area. Through the partnerships, it was envisaged that infrastructure owners would be access the higher level of expertise required for operation and maintenance, which is lacking in remote areas. Moreover, locally-based service provider solutions could be created or encouraged through micro-enterprises. For the pilot, Amanz'abuntu Services set up a subsidiary, Impilo Yabantu ("Water for People" in Xhosa) Services, to facilitate the training of local franchisors in the Butterworth Education District, Eastern Cape. Locals close to home base of each franchisee were recruited and trained. The trainee franchisors met with district staff and principals to establish a schedule and to allocate a service area that was in close proximity to trainee franchisors home base.

The trainee franchisors were supplied with basic cleaning equipment, a light delivery vehicle demarcated with the Impilo Yabantu logo and a digital camera to visually assess the effect of maintenance services on school toilets. Each franchise did an inspection of the facilities and reported back to the DoE managers on status of facilities and subsequently, the repair and maintenance costs for listed items agreed upon. This process enabled on-going service relationships to be developed. So far, around 400 schools in the Butterworth District have benefitted from the franchise. The improvement of sanitation facilities with the pilot area has been so successful that the DoE has requested that the programme be extended to a further 3 districts housing 1,000 schools.

Although Amanz'abantu still manages the franchisees as sub-contractors, it is envisaged that once franchisees revenue streams become established, they could engage the DoE and other interested parties independently and manage their own activities.

Through the African Development Bank, the concept is in the process of being demonstrated in East London, Eastern Cape. The East London project aims to support the cleaning and maintenance of school ablution facilities of the ECDOE, support hygiene initiatives including menstrual health management in schools, and beneficiate collected sludge from latrine toilets into bio-char; a charcoal substitute (**Figure** 13). Through the current project 302 schools have been serviced containing 90,000 learners, and 302 hygiene and menstrual health management educational training provided at schools. The majority of microenterprises established for franchising operations are led by female business owners.

Figure 13. The East London franchising project has been exploring the decentralised disinfection and conversion of collected sludge to bio-char (left) using low-tech kilns (right). The innovation allows sludge to be treated on-site reducing logistical costs for landfill disposal.

***Technology benefits**: PPP, BBEE and microenterprise development; quality of services consistent; cleaning protocols accompanied by training; health check for workers; ability of small businesses to access tenders, beneficiation of sludge instead of landfill disposal.*

***Implementation challenges**: procurement process does not include women, local job creation and specific for beneficiation of sludge; slow payment of services rendered.*

4. SUMMARY OF SOLUTIONS

The previous section provided an overview of technologies that address gaps in our sanitation service provision, ranging from technical solutions, such as new toilets to wastewater facilities, to management approaches.

4.1 PARTNERSHIP & LEADERSHIP

Many of the programmes initiated at a pilot and demonstration-scale have been achieved through partnerships with municipalities, DST and international donors, such the Bill & Melinda Gates Foundation and the African Development Bank. It is only through these pilots and demonstration that the operational requirements for a specific area are elucidated. This is accompanied by scientific monitoring and evaluation to optimise efficiencies and effectiveness of the solution to be scaled. Ring-fencing of a budget for new innovative solutions (5-10%) by DWS could offer improved benefits over the long-term as shown by other partnerships.

4.2 POLICY & REGULATORY ENABLERS

New innovative technologies often encounter policy and regulatory barriers that prevent their implementation. The slow issuing of WULA for example can set back municipalities in their plans to deliver sustainable solutions. In areas outside the sewered boundary and which are densified, DEWATS, for example, can provide an appropriate solution provided the system managed well. However, some of these barriers prevent uptake of novel technology with municipalities unwilling to place latrines instead due to their O&M expenses.

Many municipal water engineers have requested the following:

1) *Make the re-use of wastewater-to-tap a national policy. A national decision would allow municipalities to explore this option as part of a water management strategy. At the moment, municipalities have to go through lengthy consultative processes which delays planned interventions.*
2) *Make a national decision to reduce flushing potable water and recycle greywater flushing and have this driven through the NBR. This would allow the penetration of low flush toilets and household recycling system. Further, it will enable government to regulate (through SABS) products which cannot be done when not in place and users take unregulated measures during water restrictions.*
3) *Ring-fence budget for innovation.*

To formalise the understanding of these enablers and barriers, the WRC has a planned ToR research project that will delve into this issue. The project is expected to occur in March 2019.

4.3 DE-RISK PILOTING OF SOLUTIONS

A significant reason for the lack of technology uptake is risk-aversion even if the current option is not sustainable. To de-risk pilot solutions, assets could be zero-rated and risk mitigation plans included as part of the budget in case decommissioning is required.

4.4 PLANNING AND MANAGEMENT

Infrastructure and management cannot be separated. The WRC has developed several planning and management aimed at optimising operations. These products have been tested for the Blue & Green Drop programmes (WAP and W2RAP), rural household and school sanitation, and infrastructure audits (using ICT and GIS mapping). A budget could be ring-fenced to test these solutions, optimise for operations and incorporate as part of KPIs.

4.5 MONITORING AND EVALUATION

Continuous and reliable data capturing is necessary to gauge the outcomes of interventions and is key for planning and management. Numerous data capture tools have been developed by WRC to meet this need and has been piloted.

4.6 COMMUNITY ENGAGEMENT & EDUCATION

As evidence highlighted in this paper has shown, the lack of consultation has financial consequences. Evidence has shown that infrastructure can deteriorate beyond normal O&M requirements in a matter of 5 years without community consultation and agreement.