DETERMINING THE OPPORTUNITY AND FEASIBILITY OF AN INNOVATIVE SANITATION MARKET IN SOUTH AFRICA

Frost & Sullivan

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South African Sanitation Technology Enterprise Programme

WATER RESEARCH COMMISSION

Determining the opportunity and feasibility of an innovative sanitation market in South Africa

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by

Frost & Sullivan

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Project Scope

Geographic Scope:

The geographic scope of this project will cover South Africa.

Market Segments:

This project will cover single and multi-unit toilets within the following markets:

1. Residential
2. Commercial
3. Public

AIM AND OBJECTIVES

The primary objective of this project is to develop critical insight into the opportunity and addressable market of off-grid toilet technology, product application, and operation in South Africa

This project aims to assess the opportunities in the circular sanitation economy model and investigate the impact and opportunities of sanitation economies on women.

DEFINITIONS & ASSUMPTIONS

Sanitation Market Revenue

The sanitation market revenue refers to the turnover generated from building sanitation infrastructure in a specific year.

Sanitation Market Assets

In the report the asset base of the sanitation market is referred to. This accounts for all the toilets that are in the market and are operational. This is not a market revenue value; it is just presented for illustration purposes to show the entire size of the installed infrastructure base in South Africa.

Sanitation Market Operational Revenue

The operational revenue refers to the turnover generated per annum from servicing the current sanitation market infrastructure. This excludes cleaning services and only focuses on removal of waste and maintenance of current infrastructure.

Sanitation revenue was split into the following:

1. Capital revenue (including works) – including the construction revenue of the toilet buildings and installation
2. Capital revenue (excluding works) – excluding the construction revenue of the toilet buildings, only including the toilet and direct infrastructure, such as pipes, connections, services, toilets and pits.
3. Operational revenue – the revenue from operation and maintenance of the toilet facility

The market has been represented in variations of the above and also by the total asset base vs. the annual market revenue.

1. Total infrastructure base (including works) – this is the market revenue of all installed toilets in South Africa, including the construction revenue of buildings

2. Annual sanitation revenue (including works) – this is the annual revenue generated from new installation of toilets in South Africa (2019 base year).

3. Total infrastructure base (excluding works) – the market revenue of all installed toilets in South Africa, excluding the revenue of buildings

4. Annual sanitation revenue (excluding works) – annual market revenue generated from new installation of toilets in South Africa (2019 base year). This excludes the revenue of buildings

5. Annual sanitation operational revenue – the operational revenue will include the revenue generated from servicing the current infrastructure base, as well as, the new build of toilets in a particular year

EXECUTIVE SUMMARY

The Toilet Economy and **the Circular Economy** encompasses both the products and services related to toilets, and refers to both centralized and decentralized systems, as well as systems that are sewered and non-sewered. It also refers to innovative technologies and designs that adopt and apply principles related to the circular economy to develop toilet systems that are able to function in areas with a low or zero water supply; are energy efficient; and produce waste that could be beneficiated.

The purpose of this report is to provide and analysis of the sanitation economy in South Africa, highlighting the market potential for investment into the sanitation sector, with specific focus on off-grid technology. Combined with this, the report analyses the various sanitation technologies that can be applied to South Africa to overcome the challenges faced in the sector. It delves into the challenges of the sanitation sector and then provides examples of how technology can provide solutions to these challenges. The circular sanitation economy is also assessed with examples and the impact of waste re-use in the sanitation value chain is determined. The report concludes with suggestions and recommendations that will increase the efficiency and investment potential of the sanitation economy in South Africa.

In South Africa, the Department of Water and Sanitation is responsible for the provision of water and sanitation. There are a variety of sanitation solutions, both dry and wet, such as full waterborne systems, septic tanks, biodigesters, container-based systems, improved ventilated pit latrines, and composting toilets. These systems operate differently according to resources required, energy used, and most importantly, how the waste produced is processed. In South Africa, the majority of those with access to sanitation services use the flush toilet and are connected to South Africa's vast sewerage network. However, many areas across South Africa are water scarce, and do not have access to the sewage network, preventing the development of full waterborne systems. In these cases, alternative sanitations, utilizing low or no water, can be implemented.

This issue is not only common to South Africa. Globally, around 4.5 billion people lack access to basic, safely managed sanitation. To combat the issues faced by many water and energy scarce countries, the "Reinvent the Toilet Challenge" was developed to bring together innovators to showcase their solutions. These solutions also contribute to addressing the challenge of financial constraints that impact on the proper access to sanitation in poorer countries and communities. These solutions can provide full on-site sanitation solutions which include generation and containment, as well as treatment of waste in areas without access to sewer systems and water supplies. These solutions can bring sanitation to the world's poorest communities and contribute to the Sustainable Development Goals, particularly SDG 6. Historically, indigent communities were deprived of basic sanitation. These inventions can change that, and at low cost and can be suited to residential consumers, schools, and clinics.

The challenging nature of the sanitation landscape has allowed for new and innovative technologies to flourish. These technologies, developed both locally and abroad, incorporate aspects of resource efficiency, energy efficiency, new processes, and the idea of no longer viewing waste, as simply waste. The aim is to maximize the value that can be extracted from waste and to recover or regenerate usable products that re-enter the value chain.

On a global scale, poor sanitation is costing the global economy nearly USD 222.8 billion per year. In India alone, the sanitation economy is projected to have an estimated market value of USD 62 billion by 2021. Moreover, it is estimated that every USD 1 invested into the global sanitation economy, a global economic return of USD 5.5 can be expected. The opportunities to utilize this constant and high-volume supply of raw materials are endless.

However, end-user perception and acceptance of waste derived products has been highlighted as a barrier to entry. Many religious and cultural beliefs prevent the handling of waste, or simply view human waste as "taboo". Education and awareness around the safety, transformation and usability, and advantages of waste derived products is necessary. Regulations around the safety and quality of these products could be developed over time as a means of facilitating its growth and improving acceptability. Waste derived products range from energy sources such as biogas and briquettes to nutrients to produce a natural and sustainable fertilizer for the agricultural sector. These products can create revenue streams, which are able to significantly offset the high cost of sanitation provision for indigent and low-income communities. Companies such as Sanivation has brought sanitation to Kenya's poorest communities, through the incorporation of a circular economy business model which incorporates waste management and processing, to produce waste derived products. Various business models exist to provide affordable sanitation, and these include:

- **Product-As-A-Service:** *This model focusses on revenue generation, as customers are not purchasing the product, but rather paying for services they use.*
- **Integrated Utility Services Model:** *This model can be applied to reinvented toilets where utility companies offer a range of reinvented toilets to its customers*
- **Cross-Subsidization Model:** *The cross-subsidization model utilizes profits generated from the sale of RTs to less price sensitive customers to fund the installation of RTs to more price sensitive customers.*
- **Civic Crowdfunding Model:** *The civic crowdfunding model incorporates both micro-finance and web-based crowdsourcing to provide sanitation to communities who are unable to afford it.*
- **Advertising Model:** *The advertising model offers a source of revenue that can potentially offset the cost of sanitation for indigent and low-income consumers.*
- **Customer Experience Centre Model:** *A customer experience centre can create awareness around the RT and build strong relationships with potential customers.*

The Smart Sanitation Economy has changed the way we view the simple toilet even more. What the toilet could do versus what it can do. Smart sanitation incorporates technologies such as mobile applications, blockchain, sensors, and big data, to improve our daily lives, as well as improving efficiencies in the sanitation value chain. It has the power to connect service providers and customers, facilitate remote payments, and track health data to prevent the spread of diseases. Technology has the power to open multiple opportunities in the smart sanitation sector, which is still unexplored. Companies such as Loowatt in Madagascar, BRAC in Bangladesh and CleanTeam in Ghana have utilized the mobile money technology to enable customers to pre-pay for sanitation services or finance toilet systems.

GIS tracking of sanitation service providers has the ability to restructure and optimize the faecal sludge (FS) emptying and transport sector. The application of the tracking system and the analysis of the resulting data can provide information on the market size and thereby help to optimize the operation strategy, transport routes and efficiency. Essential health data can be captured about individuals, households, and communities through analysing human waste. This information can be used to provide valuable insight into basic human health. The data captured can provide insight into biome, blood related and genetic information. IoT in healthcare was estimated at USD 117 billion and expected to continue to experience significant growth.

These examples of incorporating technology into the sanitation sector have shown how it can facilitate growth and ease access to basic sanitation, along with showcasing how technology will change the way we view and interact with sanitation infrastructure and utilize the valuable information it has to offer. It has the power to prevent disease outbreaks and prevent pandemics across the globe, along with diagnosing illnesses in patients before any symptoms are displayed. The advantages associated with incorporating technology and utilizing the available data are endless.

The circular sanitation economy moves away from the traditional waste management system and incorporates a circular economy approach, using various sanitation technologies. Traditional waste management views human waste as having no value. However, with a circular economy approach, human waste is regarded as an input source for various systems that transform waste into a value-added product. Innovative waste processing systems can allow for the recovery of precious resources such as water; extract nutrients; and produce renewable energy.

South Africa can capitalize on waste beneficiation which can alleviate pressure on our water resources, provide renewable energy, while producing value added products. It will create new industries and provide necessary job creation. Effectively managing waste will further prevent the contamination of our vital water resources.

As an example of resource recovery, the example of a city of 4 million people was used and the possible output from waste recovery was determined in a hypothetical analysis. The results are presented in the graphic below. The estimated potential of economic value added is also depicted.

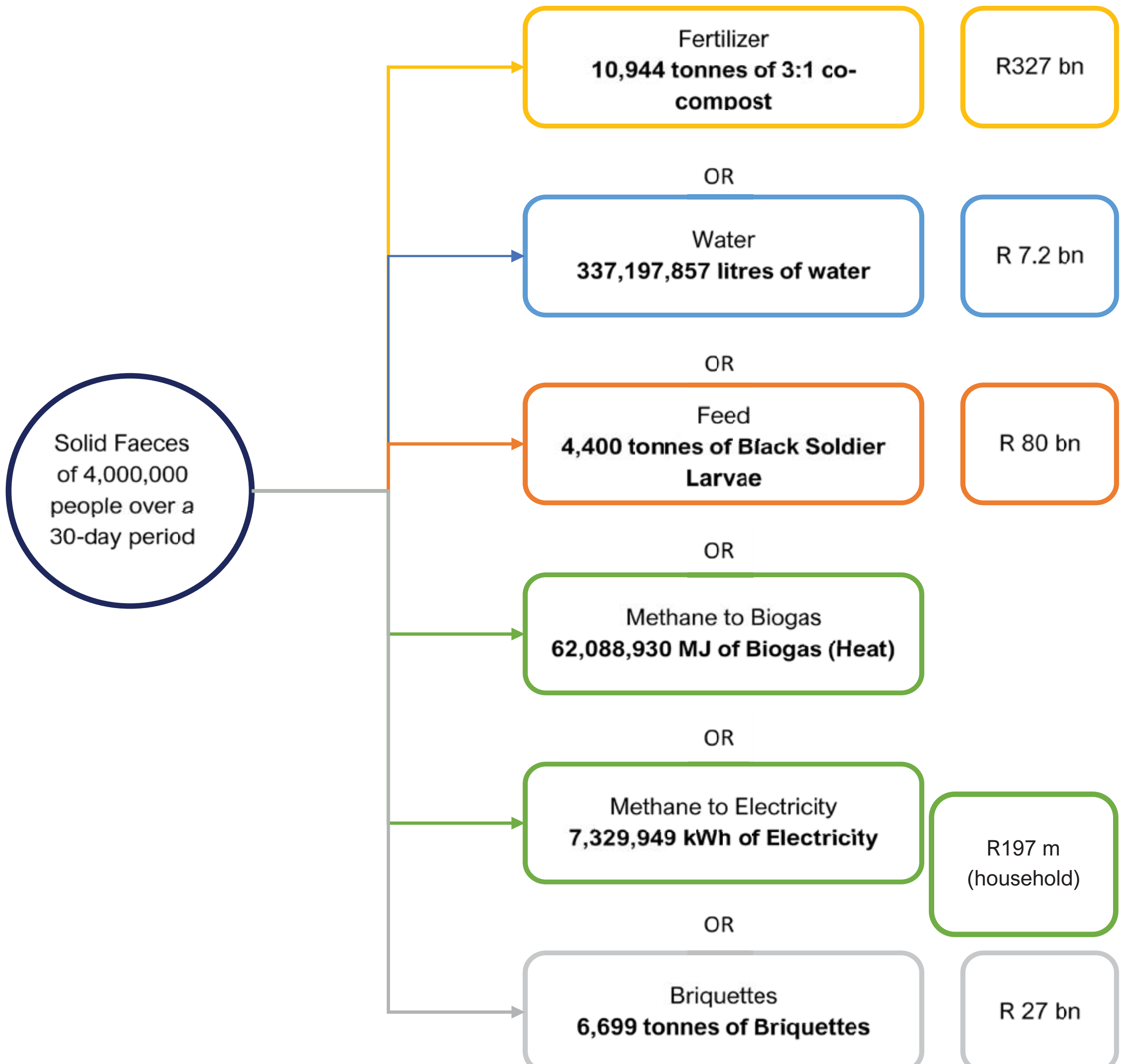


Figure 1: Revenue Potential of Waste Recovery in the Sanitation Economy

Market Opportunity Summary

For the purpose of this study, the sanitation market was divided into the residential, commercial and public sector (with focus on public schools). The various sanitation technologies and circular sanitation economy implications are then discussed under these broader segments.

The toilet economy in South Africa, broken down into the residential, commercial and public sector which focuses on public schools, is estimated to contain 37.3 million toilets. The residential sector dominates with 94% of the market share in terms of volume, followed by the commercial sector, and public sector with 6% and 1% respectively.

The total capital investment (capital base) into toilets (including buildings) in South Africa currently totals R2,178.2 billion. Similarly, the current infrastructure base excluding works also shows that the largest capital base is for flush toilets and pit latrines. The total investment into toilet infrastructure in South Africa (excluding buildings) totals R317.6 billion. The total operational revenue for sanitation in South Africa in the base year (2019) was R62.5 billion.

Table 1: CURRENT SANITATION INFRASTRUCTURE BASE (R Billion)

CURRENT SANITATION INFRASTRUCTURE BASE (R Billion)			
	Total Sanitation Market Capital (Including Buildings)	**Total Market Operational/ Servicing Revenue PA**	**Total Sanitation Market Capital (Excluding Buildings)**
Flush toilet connected to a public sewerage system	R 1,446.96	R 57.30	R 241.16
Flush toilet connected to a septic tank	R 112.72	R 0.48	R 32.21
Pour flush toilet connected to a septic tank	R 6.23	R 0.03	R 0.41
Chemical toilet	R 0.55	R 0.62	R 0.55
Pit latrine	R 598.83	R 3.78	R 42.30
Bucket toilet	R 6.27	R 0.22	R 0.09
Ecological sanitation systems	R 6.63	R 0.05	R 0.94
TOTAL	**R 2,178.20**	**R 62.50**	**R 317.64**

Annually, it is estimated that the installation revenue for sanitation in South Africa is R5.63 billion. This excludes revenues generated from buildings associated with sanitation infrastructure and only accounts for the revenue generated from toilet infrastructure. It also excludes the annual servicing revenue of the existing base of toilets.

Table 2: Market for Sanitation New Installations EXCLUDING WORKS (Excluding Buildings) - EXCLUDING SERVICING REVENUE - R Billion

Market for Sanitation New Installations EXCLUDING WORKS (Excluding Buildings) - EXCLUDING SERVICING REVENUE - R Billion	
ANNUAL SANITATION MARKET TURNOVER = NEW INSTALLATION REVENUE ONLY	
Flush toilet connected to a public sewerage system	R 3.62
Flush toilet connected to a septic tank	R 0.48
Pour flush toilet connected to a septic tank	R 0.01
Chemical toilet	R 0.01
Pit latrine	R 1.48
Ecological sanitation systems	R 0.04
TOTAL	R 5.63

The revenue generated annually in the sanitation economy from new installations and servicing of existing infrastructure is estimated at R107 billion. This includes the buildings associated with providing toilet infrastructure. The annual revenue generated from only construction of toilet infrastructure (including the buildings) is estimated at R45 billion.

Market Forecast Summary

Growth rates were calculated using the forecast of the construction industry, the new builds in schools and reduction of pit latrines and bucket toilets that are replaced by other systems. The replacement rates on-or-off grid were also considered in the forecast. The increased use of ecological systems presents a growing opportunity moving forward.

Table 3: Market Revenue Forecast for New Toilet Installations (Excluding Buildings) from 2021 to 2030

Forecast - Market Revenue for New Build Excluding Buildings (2021-2030) - R Billion	2021	2026	2030	CAGR
Flush toilet connected to a public sewerage system	R 3.62	R 3.92	R 4.21	1.71%
Flush toilet connected to a septic tank	R 0.48	R 0.52	R 0.56	1.71%
Pour flush toilet connected to a septic tank	R 0.01	R 0.01	R 0.01	2.05%

Forecast - Market Revenue for New Build Excluding Buildings (2021-2030) - R Billion	2021	2026	2030	CAGR
Chemical toilet	R 0.01	R 0.01	R 0.01	1.71%
Pit latrine	R 1.48	R 1.77	R 2.05	3.71%
Ecological sanitation systems	R 0.04	R 0.04	R 0.05	4.26%

Note: Increased growth in Pit Latrines is accounted by Ventilated Improved Pit Latrines

The Residential Market accounts for 94% of installed toilets, with 67% of toilets connected to the sewage network. Over 10 million pit and VIP pit toilets are being used by residential consumers. Access to sanitation services vary across income groups as indigent and low-income communities have access to low levels of basic sanitation. It is estimate that 34% of households require upgrades or replacement of sanitation infrastructure. This creates an opportunity for infrastructure and service provision, as government and municipalities aim to provide sanitation to those in need. The technology implemented to these communities may vary according to resource availability as well as topography and may result in a combination of wet and dry sanitation solutions.

The demand for sanitation services in the residential sector will be driven by population growth, the rate of urbanization, the desire to incorporate green and sustainable systems, as well as the development of new residential homes, complexes, and the deployment of RDP housing.

The Commercial Market is home to over 2 million toilet unit that reside abundantly in the office and banking sectors, the retail sector, and the industrial warehouse space. Rising utility costs, awareness around sustainable building designs and the need to incorporate resource efficient systems will drive the uptake of alternative sanitation solutions. This is coupled with the continued development of retail and office space.

The Public Market is estimated to have a total of 264,401 toilets present in public schools across South Africa. However, a total of 665,000 toilets is required to fulfil the Norms & Standards requirements for public schools. This creates a significant deficit of 400,000 toilets that require upgrades, replacements, or new installation.

The opportunity for upgrade and replacement of infrastructure was identified and analysed in this report. The report is also accompanied by a market opportunity estimate model in Excel. A brief summary of the key findings is presented below.

Significant economic activity can be gained through the involvement of the private sector in the provision of sanitation infrastructure and services to the residential and school markets to replace and upgrade deficits and insufficient services. The direct revenue contributions have already been represented and show that the schools market represents a R26.4 billion opportunity, with the residential market showing a R293.9 billion opportunity for new build (to replace old and ineffective infrastructure) and a R5 billion annual opportunity for operational and maintenance contracts. These are based on market prices from the private sector.

In addition to the direct benefits there are also benefits that filter through the economy as indirect benefits. This is calculated using the Input – Output Tables from Statistics South Africa and converting matrix using the Leontief inverse.

For schools the additional indirect revenue to the economy was calculated and represented in the table below. The R26.4 billion opportunity for school upgrades to 100% compliance will generate a total of R62.8 billion additional value added to the economy through additional indirect multiplier effects along the value chain.

Table 4: Indirect Value Added (GDPR) generated through upgrading schools to 100% compliance

	Construction Activity	**Plumbing and Sanitation Services**	**Operational Revenue and Maintenance**
Indirect Value Added (GDPR)	R 49,738,219,278	R 11,035,473,800	R 2,018,561,898

The opportunity in the residential market would generate R299 billion direct revenue by replacing inadequate infrastructure. This would translate to R391.5 billion in additional indirect value added to the South African economy.

Table 5: Indirect Value Added (GDPR) Generated Through Upgrading Inadequate Infrastructure in the Residential Market

	Construction Activity	**Plumbing and Sanitation Services**	**Operational Revenue and Maintenance**
Indirect Value Added (GDPR)	R 328,262,520,500	R 16,851,776,695	R 46,342,385,911

Note: The model used to analyse the broad economic value added is based on the input-output tables of Statistics South Africa (StatsSA) as converted into a matrix of multipliers representing various industries. The calculations represent the direct and indirect value-added impact on the economy. Indirect impacts are a result of the creation of added value in the value chain through backward and forward linkages in the economy. With each movement in the value chain, value is added to a product or service. This can either be done through beneficiation, incorporation of a product into a larger product or by adding value through labour or marketing activities to increase the value of the product or service.

1 OVERVIEW OF THE TOILET ECONOMY

1.1 What is the Toilet Economy?

The toilet economy encompasses both the products and services related to toilets which are used across the various income groups. It refers to both centralized and decentralizes systems, as well as systems that are sewered and non-sewered. It also refers to innovative technologies and designs that adopt and apply principles related to the circular economy to develop toilet systems that are able to function in areas with a low or zero water supply; are energy efficient; and produce waste that is beneficiated.

With increasingly water scarce regions globally, and specifically in South Africa, it is of utmost importance to develop toilet systems that can withstand these conditions without losing functionality, as well as providing toilet systems that are fit for use for all levels of income classes. Rural areas in South Africa are generally not connected to the central sewage network and are using systems that are often unsafe, and unhygienic. Around 20% of South Africans do not have access to basic sanitation services and lack proper service delivery, whereas in certain provinces, this percentage is much higher.

Currently, local municipalities are tasked with providing sanitation services, but most fail to do so due to capacity, costs, water supply and delivery models that are inadequate for communities, resulting in inadequate service delivery. Non-sewered areas cannot be serviced through conventional means and require innovative solutions to solve this problem. Bringing basic sanitation services to these areas will prevent the spread of diseases, reduce environmental pollution, reduce contamination of water resources, provide South African with their basic human rights, and prevent the loss of life as a result of dangerous pit latrines, especially to children.

1.2 Stakeholders

The section below details the main stakeholders involved in the South African sanitation sector.

1.2.1 Department of Water and Sanitation (DWS)

The Department of Water and Sanitation is the arm of national government that is responsible for water and sanitation policy, the provision of water and sanitation, resource planning, operating and maintaining the country’s 320 large dams, as well as overseeing the water sector institutions.

The DWS is responsible for regulating the use of water across the country, which includes authorizing the waste discharge, water abstraction, safety of dams, as well as setting the tariffs for raw water use and effluent discharge. The DWS is also responsible for the standards associated with water and sanitation provision and the tariffs associated with these services.

1.2.2 South African Local Government Association (SALGA)

The South African Local Government Association (SALGA) is an independent association of all South African local governments, with the mandate to represent, promote and protect the interests of local governments and to raise the profile of local government.

1.2.3 Water Research Commission (WRC)

The WRC has a mandate to promote coordination, cooperation and communication around water research and development. It also establishes the needs for water research and the priorities that should be followed. This includes identifying the priorities for water and sanitation funding in South Africa. It should also promote the effective transfer of intellectual property and technology that can enhance knowledge and capacity building within the water and sanitation sectors in South Africa.

1.2.4 COGTA

The Department of Cooperative Governance and Traditional Affairs helps to improve cooperative governance across the national, provincial and municipal governments to ensure that the provinces and municipalities carry out their service delivery mandates to ensure the sustainable development of their development functions. This would include service delivery related to sanitation and water.

1.2.5 SABS

The South African Bureau of Standards is responsible for setting standards, promoting these standards, testing and certification of products. They are involved in the sanitation sector through setting standards and certifications that constructure companies, plumbers and products need to comply to.

1.3 Regulations

The following regulations, white papers and acts pertain to the provision of sanitation and resources.

White Paper on Water Supply and Sanitation Policy (1994)

The sanitation sector in South Africa has been regulated by three policy documents, namely the White Paper on Water Supply and Sanitation (1994), the White Paper on a National Water Policy of South Africa (1997) and the White Paper on Basic Household Sanitation (2001). The water supply and sanitation policy of 1994 was created to address the millions of people that struggle to have access to the most basic needs and services. For the first time in the country, there was a policy that addressed the needs of all South Africans in a way that took into account the growing constrains on resources, both environmentally and economically. The goal of government through this policy was to ensure that all South Africans have access to essential basic water supply and sanitation services at a cost that is minimal and affordable for the people and the country as a whole. Their short term and immediate goal is to maintain service delivery and to rationalise the central Government Department, and ensure the smooth integration of previous functions, homeland staff and budgets into the new national Department. Their medium-term goal is to support the institutional local development and provide financial and technical aid for the development of physical water supply and sanitation services. In the long term, they hope to provide services to the people through a competent, democratic local government that is supported by provincial governments.

National Sanitation Policy (1996)

The National Sanitation Policy of 1996 starts where the previous White Paper on Water Supply and Sanitation Policy ended. The first White Paper policy remarked on the fact that there was more work to be done on the policy, and then to develop a national sanitation strategy. This then created the need for a white paper that deals directly with sanitation. The National sanitation policy addresses the same issues, which are the need for healthy living conditions. The main aim of the National Sanitation Policy of 1996 was to improve the health and quality of life for everyone in South Africa. Presently, there are many investment strategies that are being made in the provision of safe water supplies for all, but the health benefits that could come from this are limited because the promotion of sanitation is also limited. From past experiences it has been noted that there is a link to water supply and sanitation, with health and hygiene education. If these are put in place, then there may be real and lasting health benefits.

Water Services Act (1997)

The Water Services Act of 1997 was implemented to provide South Africans with the right to access basic water supply and sanitation. Although this was the main aim of the document, the other aims were to provide for the setting of national standards and of norms and standards for tariffs, to enable monitoring of water services and intervention by the Minister or by the relevant provinces, for water services development plans, to provide a regulatory framework for water services institutions and water service intermediaries, for the establishment and disestablishment of water boards and water service committees, along with their powers and duties, to ensure there is financial assistance to water service facilities and to provide general powers of the Minister. It was also implemented to provide for the gathering of information in a national information system and then to be able to distribute this information. The Water Service Act is concerned predominantly with the powers and duties pf the various administrative bodies which provide such services. The act defines greywater as form of wastewater generated by domestic purposes but excludes sewage. It also includes greywater in its definition for effluent. Moreover, utilization of greywater is only permissible with the approval from a water service institution such as the Department of Water and Sanitation, as their regulatory bodies are responsible in ensuring that the effluent does not pose a health risk and ensure proper safety precautions wherever greywater is accessible in any form.

Housing Act (1997)

The Housing Act (1997) is an act that was included in section 26 of the Constitution of the Republic of South Africa, to ensure South Africans have access to adequate housing. Its main aims are to provide and facilitate a sustainable housing development process, to lay down the general principles applicable to housing development in all parts of government and to define the functions of national, provincial and local governments in respect to housing development. The Act also aims to establish a South African Housing Development Board and to finance national housing programmes, ensuring each South African has access to housing in South Africa. This act repeals certain laws and provides for matters connected with it.

National Water Act (Act 36 of 1998)

The National Water act does not differentiate between forms of water, but rather focuses on defining the sources of water such as aquifers, surface waters, catchments, estuaries and other waterbodies. The Act does not differentiate between freshwater, greywater or blackwater. It does however acknowledge the scarcity of and uncertainty of South Africa's water supply and places emphasis on the importance of the state's role in managing, protecting, using, conserving and controlling the available water resources in a sustainable manner. The act further outlines the need of a National Water Resource Strategy. Use of wastewater generated by industrial activities or waterworks is listed as a specific controlled activity which requires authorization. Greywater, excluding sewage, generated by a single household may be disposed of to an onsite disposal facility, as long as the facility is located close to a water source, wetland, over an aquifer or below the one in a hundred-year flood line. These regulations require that the installed wastewater facilities do not impact water resources nor any other person's water use and must not be detrimental to the health and safety of the public near said storage.

National Environmental Management Act (Act 107 of 1998)

Similar to the previous acts and policy, the NEMA defines greywater as domestically produced wastewater excluding sewage and also actively promotes the reuse of greywater for irrigation of landscapes.

White Paper on Basic Household Sanitation (2001)

The Government of South Africa is constitutionally obliged to ensure that all South Africans have access to basic sanitation. To ensure that the government's responsibilities were met, this national sanitation policy was implemented. It's main purposes are to highlight the impact of poor sanitation on health and living conditions, as well as the environment, to articulate the government's policy on sanitation, to provide a basis for the improvement of local, provincial and national sanitation strategies, to ensure there is a framework for municipality driven implementation programmes, to promote coordination and coherence among the different circles of government and other players when addressing the sanitation problems and to ensure the sanitation improvement programmes are financed. This policy also includes measures that can be used to monitor the implementation of this document, and so that action can be taken when necessary. This policy greatly caters for areas with the greatest need for basic level of household sanitation, such as the rural areas and informal settlements.

National Health Act (Act 61 of 2003)

Greywater is defined as wastewater with no significant content of faecal pollution, predominantly sourced from baths, showers and sinks. The act further outlines safe water as tested water which does not pose significant health risk over a lifetime of consumption. Greywater may be used to flush toilets and for irrigation, preferably recycled, but must not be used for drinking, cooking or personal hygiene. Prior to greywater use, Water Service Institutions should be contacted to approve and test the greywater to be used by an Environmental Health Practitioner.

National Sanitation Strategy (2005)

The National Sanitation Strategy that was published in 2005 was implemented in order to take into consideration the recent developments around sanitation and to provide a coherent approach to sanitation services delivery in South Africa. This National Sanitation Strategy had the objective to eliminate sanitation backlog by 2010 and to discuss the roles and responsibilities in sanitation delivery, funding for sanitation, planning for sanitation, implementation approaches and regulating the sanitation sector. The National Sanitation Strategy also states that "informal settlements must not be treated as emergency situations for the purpose of this strategy but should be provided with viable and sustainable solutions. Solutions such as communal facilities and chemical toilets should not be used where the system is expected to have a duration of more than one month."

Free Basic Sanitation Implementation Strategy (2009)

The free Sanitation Implementation Strategy of 2009 is a document that envisions sanitation for all in South Africa. It was implemented to allow a basic sanitation service to all by 2014. In this document, it is stated that all must have access to basic sanitation which is accessible to a household, there must be a sustainable removal of human waste and wastewater from a premises and there should be communication of good hygiene, sanitation and related practices to the people of South Africa. Although there is a broader policy commitment by the government to extend the free basic services to all households, this policy is mainly aimed at poor households where free basic services are non-existent because of alleviated poverty. The main targets when the policy was implemented were to ensure all people in South Africa had access to a functional basic sanitation facility by 2010, that all bucket toilets were eradicated, that hygiene education and wise use of water were taught in schools, that all households had access to at least one basic sanitation facility and know how to practice safe sanitation by 2010 and that the free basic water policy was implemented in all water services authorities.

Status of Sanitation Services in South Africa (2012)

A report on the status of Sanitation Services in South Africa was released in March 2012. This report covered the findings from research carried out on the status of sanitation services in the country. The problem of inadequate sanitation is a human right and a development issue and failing to provide adequate sanitation to the people of South Africa directly impacts their health and social wellbeing. In 2008 it became apparent that the 2010 targets for sanitation were not achievable and this report was created to further analyse the situation and find ways to move forward. There were recommendations that were stated in this document, and the first was that there is a need for an establishment of a single unit that will be responsible for policy formulation, oversight, monitoring, regulation and support of the entire sanitation service value chain and its link with water resources management and water service delivery within DWA (Department of Water Affairs). The next recommendations were to amend the legislation to resolve oversight, planning, financial allocations, and accountability, and improve and coordinate support programmes to municipalities at a national and provincial level. They also recommended that the municipal staff skills be upgraded and that there is support for basic service delivery planning in municipalities where backlogs are most acute through sector-based service delivery management structures. The findings in this report were then presented to the Cabinet for discussion and so that actions can be made to resolve the problems. The report emphasised that the key focus should be on the households which are “un-served” or “under-served”.

National Sanitation Policy (2016)

Since the implementation of sanitation policy in 1994, the sanitation context and landscape has changed significantly in South Africa and the world at large. Some of these advancements and years of implementation has led to many challenges and problems that have been identified that require the sanitation policy to be reviewed and legislation to be amended. The National Sanitation policy was implemented to address these gaps and challenges that have been faced and identified over the years. This policy is aimed at reviewing the sanitation policy position from the collection, removal, disposal, and treatment of human excreta ad domestic wastewater, to the collection, treatment, and disposal of industrial wastewater. All the policy positions in the current sanitation policy of 1994, 1997 and 2001 that are not mentioned or highlighted in this policy for amendment, remain valid.

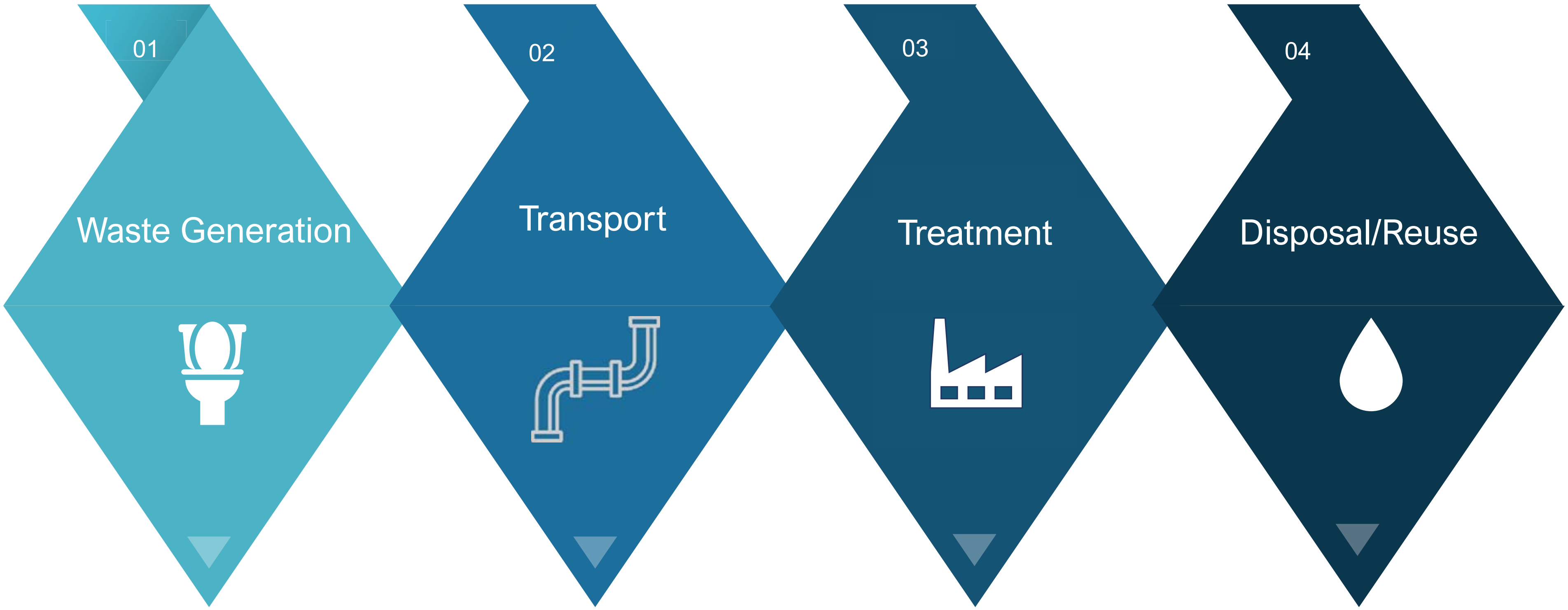
National Faecal Sludge Management Strategy (2020-2023)

The strategy provides a framework for management of a faecal sludge strategy. It allows for planning and establishing the methods for collecting and transport of sludge. This involves the planning of networks and the necessary locations, the emptying of manual pits, vacuum trucks, transfer stations, transport for treatment plants and the pre-treatment of sludge. The management strategy also aims to look at the technologies involved in the treatment of sludge and any new innovative technologies related to this. It will also monitor and evaluate the outcomes of the institutions and institutional frameworks involved.

1.4 Toilet Economy Value Chains

The following section briefly illustrates the three major types of value chains that are associated with the toilet economy. The sanitation value chains can be differentiated by the type of sanitation used, the mode of storage, the mode of transport, the type of treatment, the location of treatment and the type or method of reuse or disposal that may be applicable.

1.4.1 Conventional Sanitation Value Chain



Waste is generated at households, commercial properties, and public spaces. This waste is flushed with water using full water borne sanitation systems.

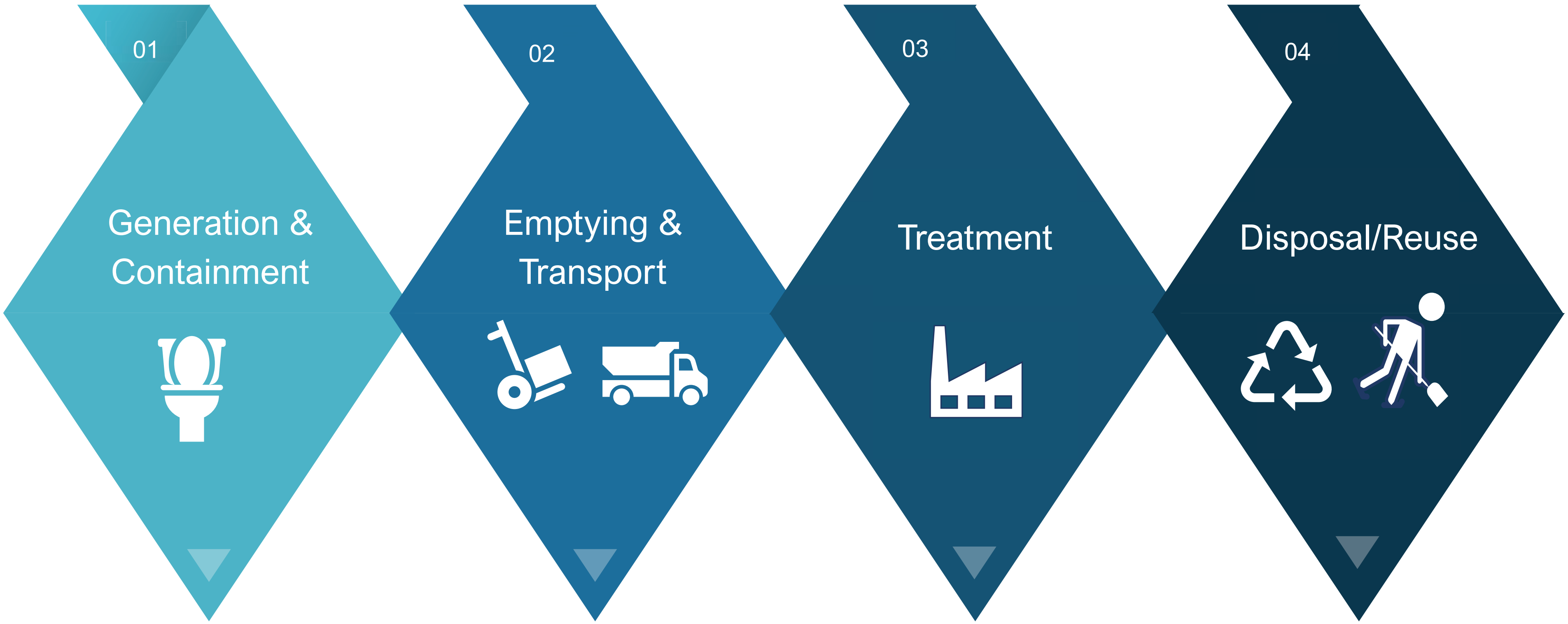
The waste is transported via a network of sewage pipes, connecting each toilet to a main link leading to a treatment facility.

Waste transported via the sewage network is treated at various sewage treatment facilities, undergoing various levels of treatment to remove pathogens, debris and particles.

Treated sewage results in sewage sludge and effluent which is disposed of.

Figure 2: Conventional Sanitation Value Chain

1.4.2 Containerized Sanitation Value chain



Waste is collected in containerized systems which are typically dry systems. Urine diversion mechanisms are often installed to reduce the volume and weight of the waste contained. Urine collection can also be done to harness the various nutrients present.

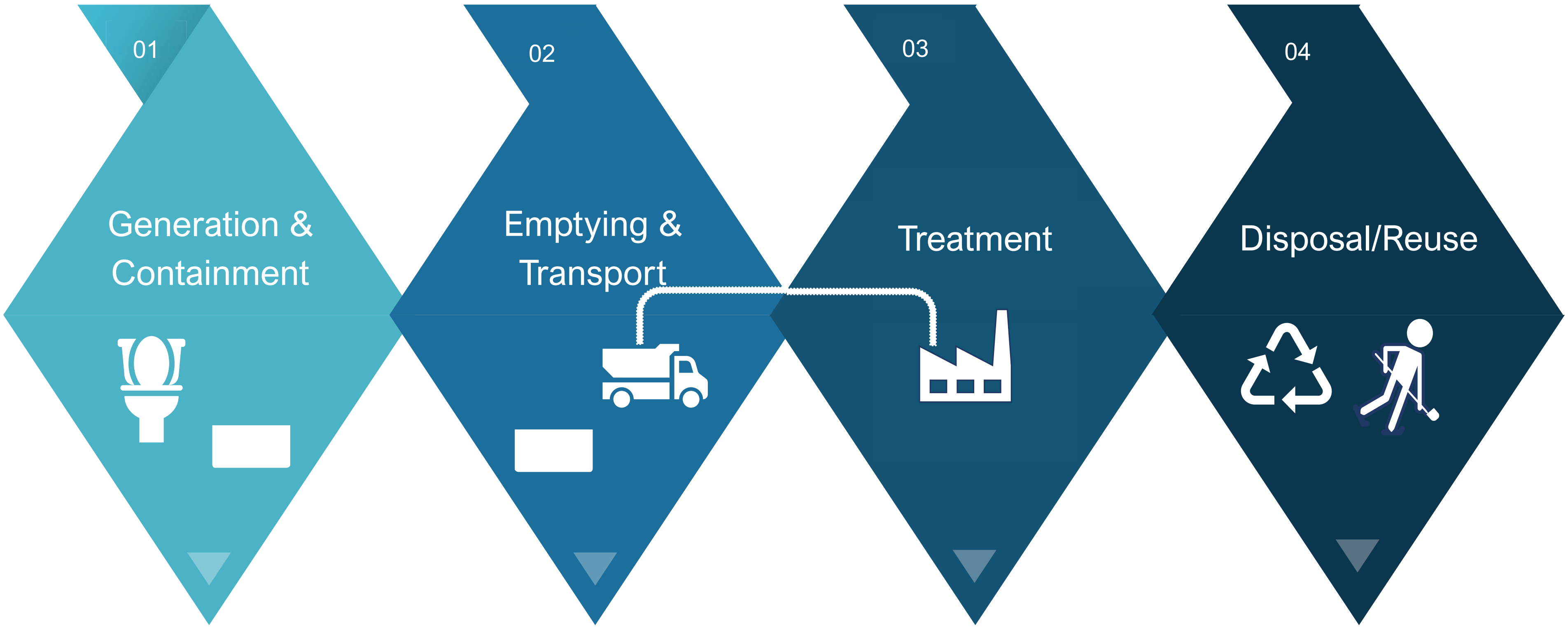
Once containers reach capacity, they are replaced with empty, clean containers. Containerized waste is collected from generation sites such as residential homes or schools. The waste is then transported to a treatment facility.

The waste is removed from the containers and treated. This can be done to remove pathogens or to produce secondary products to ensure resource recovery.

Resource recovery can take various forms to produce products such as compost, biogas, animal feed, and biochar.

Figure 3: Containerised Sanitation Value Chain

1.4.3 On-Site Sanitation Value chain



Waste is generated, collected and contained in tanks below ground. The level of onsite treatment depends on the technology which can range from pit latrines to septic tanks.

Once the tanks have reached capacity, they are emptied using a pump to remove the waste and load it to a vehicle to be transported to a treatment facility.

The waste is removed from the containers and treated. This can be done to remove pathogens or to produce secondary products to ensure resource recovery.

Resource recovery can take various forms to produce products such as compost, biogas, animal feed, and briquettes.

Figure 4: On-Site Sanitation Value Chain

1.5 Technology and Design

Conventional toilets, which are regular flush systems found in most urban households and buildings have been the standard sanitation systems used. These systems are applicable to residential, commercial and public sectors; can be easily purchased and installed; and are available in a variety of designs and price ranges. However, they flush between 6-13 litres of potable water with every use. The higher the usage, the higher the utility costs. Moreover, these systems cannot be installed in rural communities that do not have access to the central sewage network or access to water. To combat these issues, and easily provide access to sanitation, while reducing water usage, several innovative solutions have been designed.

Designing for a purpose

The factors mentioned below are important in the design of sanitation solutions as interaction between the technology and the user will be a key factor in its successful rollout.

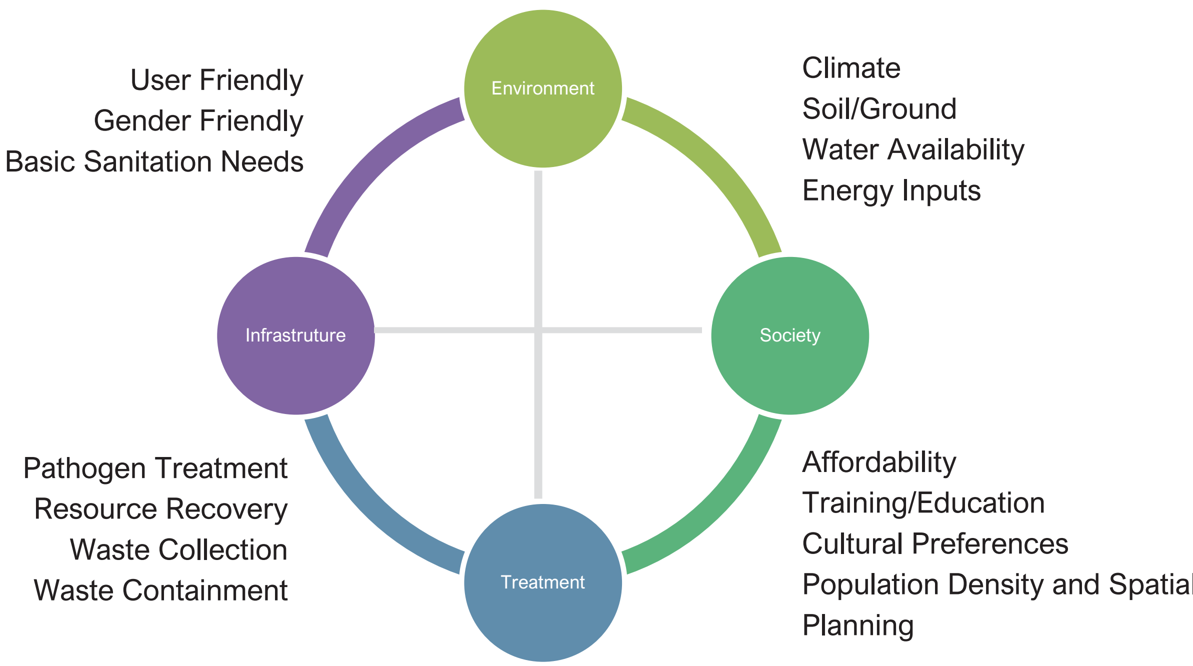


Figure 5: Factors for Designing for Purpose

Source: Department for Natural Resources and the Environment, Ecological Sanitation, 1998

Designing for Genders

The sanitation needs of males and females differ due to biological differences. These needs should be considered when implementing toilet facilities, for example in rural schools, which will be used by both males and females.

Poor sanitation systems disproportionality negatively affects female users for several reasons:

- It is easier for men to urinate outside if there is no toilet facility available. It should be noted that urinating outside is not encouraged. Social and cultural norms differ between genders. Females are unlikely to urinate outside due to it being perceived as undignified and lacks the aspect of modesty.

- Females are prone to sexual violence and harassment and are therefore at greater risk if they are forced to used toilets that are not well located, not well lit, and are not private and cannot lock. Separate toilets are required for males and females.

- For menstruating females, privacy is important. The facilities also need to be safe to use; with access to female hygiene products; provide safe, dignified and proper disposal containers in addition to standard products such as soap and water. Many young females in South African do not attend school during menstruation and miss valuable classroom time every month. This is due to the lack of female hygiene products, and lack of safe and private sanitation facilities at school.

- The use of menstrual sanitary products also has the potential to cause blockages to sanitation systems and the waste disposal of these products is noticeably absent in many shared and public settings. There are, however, new innovative technologies that are being developed that could mitigate these issues. For example, the Safe Hygiene for Everyone (SHE) technology is a unit that automatically disposes of sanitary pads in a sealed unit using a combustion process that allows for clean ash to be collected as the final product.

- Facilities should also be accommodating for pregnant and older females, as social and cultural factors influence their use of sanitation facilities.

- Females require more space and privacy to urinate as they are required to partially undress in order to do so. This is especially important for older females and those with physical disabilities.

Source: Water Aid: Female-friendly public and community toilets: a guide for planners, and decision makers, 2018

http://washaid.pratt.duke.edu/sites/washaid.pratt.duke.edu/files/u71/S.H.E.2020_July.pdf

Designing for Resources (Wet and Dry Sanitation)

1.6 Wet Sanitation Technologies

A. Full Water-borne Sanitation

A full water-borne sanitation system is the conventional toilet system used in urban areas. The toilet infrastructure in this case is a full flush toilet situated in homes, office buildings, and apartment buildings for example. Waste is collected and conveyed in a hygienic manner through the existing centralized sewage network infrastructure. Sanitation services offered by the governments/municipalities are provided at a fee paid for by residents or commercial users. The waste produced is properly treated in sewage treatment plants to remove harmful pathogens in the effluent.

Advantages	Disadvantaged
• The system is convenient and can be used in the privacy of residential homes, office buildings or commercial properties • Users do not have to manage waste • There is minimal risk of pollution or contact with harmful waste	• High use of fresh water as it flushes between 6-13 litres at each use. • Cost associated with sewage services • The conventional toilet has become the gold standard in rural communities who cannot afford to install these services • Lack of sewage network infrastructure systems can result in environmental contamination

Resource Recovery	Resources are not recovered from human waste, however, depending on treatment facilities, wastewater can be recycled
Gender	Toilet design is suitable for all genders
Applicable to	Toilets are designed to be applicable to residential (single and multi-units), commercial buildings, and public sectors.

B. Septic Tanks

Septic tanks provide a full level of service to users as a conventional toilet seat and flush system is installed. Once the toilet is flushed, the waste flows into a septic tank, where solid waste is separated from the liquid waste. The waste is treated using natural microbiological processes and liquid waste eventually seeps into the ground, while solid waste settles to the bottom of the tank. The size of the septic tank is based on the number of users and can range in capacity from 1,250 litres for 2-4 users to 2,500 litres for 4-9 users. A multichambered system can be used whereby waste is treated and then enters a bioreactor which results in a cleaner effluent.

Source: Jojo Tanks; Septic Tank Pro

Advantages	Disadvantaged
• Septic tanks can be installed in areas that are not connected to a sewage network and therefore can be installed in rural areas • No monthly service fees are required • Depending on the material used to manufacture the tank, the lifespan of tanks can reach up to 25 years • Septic tanks require emptying every 2-3 years, depending on frequency of use • Can be used in residential complexes where municipal infrastructure is insufficient	• The installation costs of septic tanks can be high • Electricity is required to run septic tanks • Water usage needs to be properly managed • Septic tank owners are fully responsible for systems operation and maintenance

Resource Recovery	Wastewater is recycled when a bioreactor is present
Gender	Toilet designs are suitable for all genders
Applicable to	Toilet systems can be installed in residential areas that both connected to the sewage network and those that are not. They are suitable for industrial areas and large residential complexes

C. Small Scale Biological Plants

Human waste that is generated is collected in a septic tank that is fitted with a bioreactor. Biodigesters can be used to treat human waste and produce methane and carbon dioxide. The system uses a variety of bacteria to treat organic waste and renders pathogens inactive, reducing faecal associated health risks. The biodigester is a vessel for the process commonly referred to as biomethanation.

Advantages	Disadvantaged
• Onsite production of biomethane can reduce the cost of energy • Can recover water used for irrigation • Renewable energy is produced • Modern biodigesters are scalable and can be manufactured from plastic • Are easily installed	• High capital costs to install systems • Requires optimal temperatures for effective biomethanation

Resource Recovery	Biomethane and water-rich nutrients are recovered during this process
Gender	Toilet designs are suitable for all genders
Applicable to	Can be implemented in rural schools or communities

D. Pour and Low Flush Systems

Pour flush toilets are designed to use approximately 2 litres of water to flush the toilet. The waste generated is flushed into the pit situated beneath the toilet seat.

Advantages	Disadvantaged
• Can be installed in water scarce regions as volume of water is controlled • The toilet can be installed indoors • Easily scalable and suitable to be used in schools, clinics and low-cost housing • Models that require a flush in order to produce water encourages and enforces hygiene practices • Grey water can be used to flush the toilet	• Toilets can potentially block due to toilet paper, newspaper or feminine hygiene products • Blockage caused by these products could make the pit emptying challenging

Resource Recovery	No nutrient recovery as waste is collected in a pit below the seat
Gender	These systems are suitable for all genders but require separate waste bins for feminine hygiene products
Applicable to	Toilets can be constructed in areas without access to sewage network where the ground is suitable for pit construction

1.7 Dry Sanitation Technologies

A. Pit Latrines

Pit latrines are sanitation systems with a drop-and-store method. Large pits are dug deep into the ground acting as storage units to contain human waste. The setup of these systems requires large areas, where the ground is suitable and stable for digging. The system is easy to install and does not require any water for flushing. Ventilated improved pit (VIP) latrines incorporate ventilation into the system, minimizing presence of foul odours, and reducing the breeding of flies and other insects.

Advantages	Disadvantaged
• No water consumption • Connection to sewage systems is not required • Once installed, the maintenance costs are low	• Cannot be installed in areas with unsuitable underlying geology, or areas prone to flooding • Fully lined pit latrines require frequent emptying • Can emit foul odours and be a breeding ground for insects if not ventilated • If not properly designed, the toilet is unsafe for use by small children as they risk falling into the pit • Possibility of contamination of groundwater and soil • The toilet cannot be constructed inside a building or home • Emptying the pit can be challenging

Resource Recovery	No resource recovery
Gender	These systems are suitable for all genders but require separate waste bins for feminine hygiene products
Applicable to	These systems are implemented in rural areas where no sewage network has been established. VIP latrines are often set up at schools

B. Container Based Sanitation Systems

Container-based sanitation (CBS) involves the use of sealable, removable containers used to collect waste. The containers, once full, are transported to treatment facilities by sanitation service providers. This is a cheaper and faster alternative to the lengthy and cost intensive installation process associated with standard sewage toilets. The waste collected can be converted into various secondary products such as briquettes.

Advantages	Disadvantaged
• No decommissioning of toilets is required and saves space as toilets are situated above ground • Toilets are suitable for areas with unstable soil, and areas prone to flooding • The toilet system is easy and safe to use and minimizes contact with harmful waste • It is easily deployed when compared to pit latrines	• Manual labour is required for waste removal • The removal of waste containers and replacement will require logistical planning to ensure they are properly managed • Training and education are required to ensure proper use of the toilet facilities

Resource Recovery	Resources can be recovered once the containers are collected and transported to a treatment facility
Gender	These systems are suitable for all genders
Applicable to	These systems are applicable to the residential sector and mainly used for single units.

C. Composting Toilets

Composting toilets are dry toilets which collect waste and convert it into compost. Toilet design can vary to incorporate urine diversion. The toilet design can incorporate single or multiple composting vaults or can be designed to use containers that can be removed to treat the waste offsite. Composting toilets break down faecal matter using micro-organisms which are added to the soil. These microorganisms break down human waste into organic substances to form humus, which can be used to condition soil. Other organic materials are often added such as wood shavings. These systems rely on the control of both air flow and temperature to create optimum conditions for composting. These systems area also designed to prevent foul odours by incorporating a ventilation system.

Advantages	Disadvantaged
• No water consumption • Connection to sewage systems is not required • Once installed, the maintenance costs are low • Certain designs harvest solar energy • Pathogens are reduced • Volume of waste is considerably reduced which allows for continuous storage of waste	• Requires higher level of care to maintain conditions for composting • Manual labour is required for waste removal • A small amount of energy is needed to operate certain designs, but solar power can be used in remote communities • If not properly maintained, it can produce unwanted odours • It is not suitable for multi-unit apartment complexes or buildings.

Resource Recovery	Resources are recovered as the human waste is converted into compost which can be used for agricultural practices.
Gender	These systems are suitable for all genders but require separate waste bins for feminine hygiene products
Applicable to	These systems are suitable for single unit residential holdings and public toilets in national parks. These toilets could be difficult to manage in public schools

D. Urine Diversion

Urine diversion toilets separate liquid and solid waste using a seat designed specifically for this purpose. The toilets require two vaults for collection and storage of solid waste and are fitted with a ventilation pipe to prevent foul odours. The urine collected is piped to a collection and drainage unit depending on whether the urine will be used as a fertiliser. Dry material is often used to cover the waste after every use, to absorb moisture. The dry waste is collected in a ventilated vault and solid waste can be managed in various ways which include: i) Two dehydration vaults, whereby the second vault is used once the first has reached its holding capacity, ii) a single vault which can be removed once it has reached its holding capacity, iii) the solid waste can be composted, iv) the solid waste collects in a shallow pit

Advantages	Disadvantaged
• No water is required to “flush” the toilet • Urine collected can be used as a fertiliser • Double vault systems reduce the risk of exposure to untreated waste • Double vault systems require less frequent emptying • Single, removable container systems can be changed as often as required • Minimal risk of groundwater contamination and can be flood resilient • Above ground design of vaults makes it suitable for areas with rocky ground which is unfavourable for pit construction	• Double vault systems require larger areas for construction and are associated with higher installation and O&M costs • Single systems that require frequent emptying should be done by service providers to prevent health associated risks • Collecting containers could result in higher costs than costs associated with dehydration •

Resource Recovery	Urine can be collected for use as fertilizer and solid waste can be composted depending on the type of waste management in place
Gender	These systems are suitable for all genders but require separate waste bins for feminine hygiene products
Applicable to	Suitable for areas prone to water scarcity, and no sewage network is present. May not be suitable in dense urban areas where space is limited

1.8 Global Technologies

Institutions across the globe have "reinvented" the toilet and produced a variety of alternatives to the conventional flush toilet many of us use today. New innovative systems have been developed to use less or zero water, to be more energy efficient, and if waste is produced, to be treated and reused or transformed into products such as fertilizer.

To combat the issues faced by many water and energy scarce countries, the "Reinvent the Toilet Challenge" was developed to bring together innovators to showcase their solutions. These solutions can provide full on-site sanitation solutions which include generation and containment, as well as treatment of waste in areas without an access to sewer systems and water supplies. These solutions can bring sanitation to the world's poorest communities and contribute to the Sustainable Development Goals. Historically, indigent communities were deprived of basic sanitation. These inventions can change that, and at low cost and can be suited to residential consumers, schools, and clinics.

The lessons learned can be applied to the South African context and a selection of technologies and case studies have been presented in the appendix to better contextualise the type of technologies that are available.

Many systems that are being developed have water shortages in mind, or where access to water may be limited due to the underlying infrastructure or rural area. These technologies, either recycle the water used in the system for flushing or collect rainwater. Another system has developed an air-flush module that minimizes the use of water and is ideal for composting recycling technologies. Sustainability of the systems used in South Africa is important, especially in rural areas and where access to sewerage systems is not possible or financially feasible.

2 OVERVIEW OF THE CIRCULAR SANITATION ECONOMY

2.1 What is the Circular Sanitation Economy?

The concept of a circular economy, an alternative to a linear economy, is one where resources are reused as much as possible to minimize the generation of waste. The aim is to maximize the value that can be extracted from them during their lifetime and the products or materials are recovered or regenerated at the end of their lifecycle. By definition the circular economy should be sustainable and regenerative by the design of its value chain. The value chains in the circular economy are designed to keep products or waste materials generated in use. Here the system is designed to preserve the value or reuse energy, labour and materials. Such systems make use of effective bio-based materials that can by cycled back into the economy, either in the same or another value chain. In another concept of the circular economy the value chain is designed to eliminate waste and pollution altogether. This is done by designing out the negative impacts of economic activity, either through new systems or technologies.

The circular sanitation economy moves away from the traditional waste management system and incorporates a circular economy approach, using various sanitation technologies. Traditional waste management views human waste as having no value. However, with a circular economy approach, human waste is regarded as an input source for various systems that transform waste into a value-added product. Innovative waste processing systems can allow for the recovery of precious resources such as water; extract nutrients; and produce renewable energy.

Improvement of the circular economy is gaining increased momentum and importance. On a global scale, poor sanitation is costing the global economy nearly USD 222.8 billion per year. The economic burden placed on Africa due to the poor sanitation, costs the continent nearly 10% of the global cost, a staggering USD 19.3 billion per year. Africa is also characterized as the continent with the highest mortality associated with this economic burden. This high mortality rate accounts for 75% (USD 14.5 billion) of the total economic cost. This is something that effective management of a circular sanitation model can drastically reduce.

Not only can the circular sanitation model decrease negative externalities, but it has been stated that every USD 1 invested into the global sanitation economy could provide a return of USD 5.5.

Source: Lixil, Oxford Economics, The True Cost of Poor Sanitation, 2016; The Toilet Board Coalition

2.2 Regulations

The following regulations and acts pertain to the circular sanitation economy.

National Sanitation Policy (GN70 of 12 February 2016: Government Gazette No 39688)

The policy refers to greywater in the same way as the Water Service Act, as a domestically produced wastewater excluding sewage. It furthermore places emphasis on the responsibility of water service authorities to manage and enforce wastewater regulations. The policy encourages the installation of decentralized as well as centralized greywater recycling systems to relieve the pressure on freshwater resources.

National Building Regulations (SANS 10400-Q: 2011, Third Edition)

The National Buildings Regulations defines greywater, similar to the previously mentioned acts and policies, as domestic wastewater excluding toilet water and no instructions regarding the storage, use nor the management of greywater within a property's boundaries. The NBR does however, under the addition of the SANS10400-XB, require the installation of greywater harvesting system to be in accordance with the building guidelines and the installation has to be done by a registered plumber. Maintenance of the installed harvesting system is the responsibility of the property owner. Circular Economy Roadmap

Fertilizers, Farm Feeds, Agricultural Remedies and Stock Act No. 36 of 1947

The act is in place to control the products that are placed in the market and the use of agricultural remedies. It is in place to either allow or prohibit the use of certain products that do not meet the necessary requirements for approval. According to the Act, an 'Agricultural remedy' is defined as "any chemical substance or biological remedy, or any mixture or combination of any substance or remedy intended or offered to be used-

a) For the destruction, control, repelling, attraction or prevention of any undesired microbe, alga, nematode, fungus, insect, plant, vertebrate, invertebrate, or any product thereof, but excluding any chemical substance, biological remedy or other remedy in so far as it is controlled under the Medicines and Related Substances Control Act, 1965 (Act 101 of 1965), or the Hazardous Substances Act, 1973 (Act 15 of 1973); or
b) As plant growth regulator, defoliant, desiccant or legume inoculant,
c) And anything else which the Minister has by notice in the Gazette declared an agricultural remedy for the purposes of this Act

The *Guideline of The Registration Process for Agricultural Remedies Act No. 36 of 1947* outlines the application procedure for obtaining approval for new agricultural remedies.

2.3 Application to South Africa

South Africa can capitalize on waste beneficiation which can alleviate pressure on our water resources, provide renewable energy, while producing value added products. It will create new industries and provide necessary job creation. Effectively managing waste will further prevent the contamination of our vital water resources.

Waste to Energy

Waste to value presents an opportunity to establish an entirely new value chain in South Africa. Municipal solid waste and biogas are of interest to the country.

Several sectors in the country produce organic waste that can be converted into energy, potentially reducing both waste-to-landfill and fossil fuel consumption.

Increasing pressure placed on our already strained sanitation infrastructure, coupled with water scarcity and, our country's sustainable development goals, could drive this sector going forward.

Wastewater Recycling

South Africa currently has 824 private and municipal wastewater treatment works located throughout the country, with a current theoretical capacity of 6 510 ML, and current demand of 5 129 ML. The primary waste type produced by these plants is sewage sludge.

An audit done by the DWA (the predecessor of the DWS) between 2009-2013 inspecting all 824 of these WWTW sites based on key performance areas such as risk management, asset management, and process control provided alarming results. The audit indicated that only 8.3% of WWTW plants were compliant in terms of effluent quality, and less than half (42.2%) were compliant in terms of local regulations.

Resource Recovery

Significant economic value can be generated from the toilet resources recovered from a community through the implementation of circular sanitation. Human waste can be recycled and reused in numerous ways, generating products that are competitive or even superior to the standard alternatives. Such products include fertilisers (phosphorus, potassium, and nitrogen-based), water, fuel, feedstock as well as unique products such as briquettes that can be utilized for cooking and heating in informal settlements.

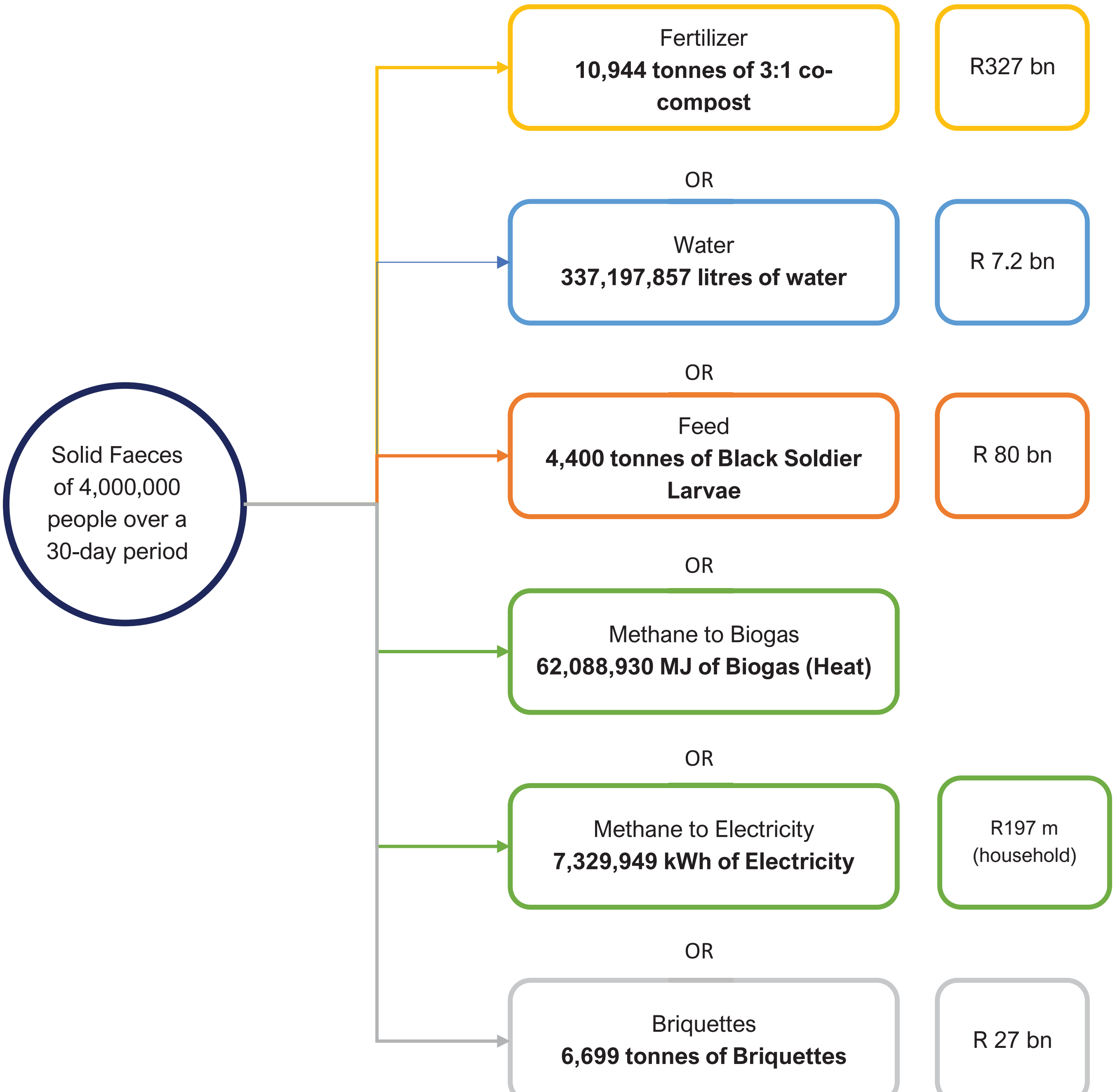


Figure 6: Toilet Resource and Revenue Potential

Figure 6 above depicts the waste outputs of a city with 4 million people and their corresponding circular economy resources the city is able to produce, depending on the processing route chose. Alongside these figures, are the potential value of the waste produced. However, these values do not represent revenues as it does not take into account the various operational and processing costs required to produce these products. It does however provide an indication that significant value is lost through the missed opportunities in processing the stable supply of waste produced.

One person has the potential to generate 0.091 kg of P:K:N fertilizer compost in one week. This fertiliser is on average sold for a value of R 31/kg, inferring that one person can produce fertilizer from the generated waste in one day that is worth approximately R2.8.

Recycled water has the potential to be resold back to industry or private customers for the use of irrigation at a value of R 0.02/litre. By effectively recycling water produced by one person, approximately 3 litres of grey water can be recovered. This is based on a low flush water recovery system operating on a 75% recovery rate. Therefore, each litre recovered has the potential to generate a revenue worth R0.06. Through recycling of wastewater, the pressure that is currently placed of freshwater resources can be considerably reduced. This especially vital for areas such as the Cape Town Metropolitan Municipality which is facing sever water shortages in the coming years.

The African middle class is the fastest growing social class in the world. A simultaneous higher standard of living brings about numerous challenges. Among these challenges is the need to provide food to the ever-rising population. Fishmeal is a commercially used feedstock for animal farming including aquatic farming. It has been estimated that, depending on the protein content, that fishmeal will be priced at an average cost of R 27/kg. Black Soldier Fly Larvae (BSFL) is an upcoming feedstock source that is already cheaper than fishmeal, priced at an average value of R 18/kg. Human waste is an optimal organic food source for the BSFL. One person can generate 0.0037 kg worth of human waste to feed BSF larvae, which in turn can be sold as a food source to animal farms for a value of R 0.67.

Human waste has the additional potential to be converted to energy through the release of methane gas which is burned to turn turbines and thereby produce electricity. On average, the price of electricity in the Cape Town Metropolitan Municipality is around R 2/kWh. Human waste produced by one person in one day is enough to generate 0.06 kWh of electricity, which can be sold for a value of R0.12 back to the consumer. This has the potential to take off the pressure on the energy generation of public utilities. This is also an opportunity to be installed in remote areas, which lack access to electricity, lifting rural communities out of energy poverty.

2.4 End User Behaviour Toward Waste-derived Products

There are a variety of products that can be produced from human waste such as briquettes which serve as a fuel source, and fertilizer which can be used in the agricultural sector. However, marketing these products to consumers may be challenging due to cultural and religious beliefs. The sustainability of circular economy practices relies on revenue streams which are generated through services as well as sales generated from secondary products. Revenue generated from the products is in turn used to subsidize the cost of sanitation services provided to indigent and low-income households who cannot afford it. Therefore, securing off-takers both businesses and individuals is important.

Consumer attitude towards waste derived products can create a barrier to entry into a circular sanitation market. End user markets need to be educated as much needed awareness around the safety and benefits of these products is required. Trialling of waste derived products will be necessary for both businesses and individuals to ensure compatibility and acceptance.

Land degradation and the lack of faecal sludge management is a common issue in sub-Saharan Africa. To mitigate this, human waste derived fertilizers can restore nutrients and supply much needed organic matter to restore soil health. The perception of excreta-based products being harmful, pathogen and heavy metal rich, prevents its widespread uptake. However, with the correct treatment methods, this can be prevented, resulting in a nutrient rich fertilizer.

A large percentage of South African agricultural produce is destined for export markets. Therefore, produce grown in South African soils are expected to adhere to international market standards and regulations. Many regulatory bodies do not allow the use of human waste derived fertilizers. In countries such as Kenya, they are acceptable according to agricultural standards. However, farmers have raised concerns over the number of certifications necessary for export, and how these can become quite costly. Contrastingly, in countries such as Ghana and India, there exists a fear around human waste, and it is considered “taboo” to handle human waste altogether in religions such as Hinduism.

These are barriers to expanding the market for human waste derived fertilizers, even as globally there is a need to find alternative and sustainable options. Commercial viability of these products relies on scale, as well as securing high and constant volumes of inputs. Large scale contracts could potentially be granted by government or local municipalities which would aid in the acceptance of waste derived products. The current perception and lack of customer acceptance will continue to pose a risk to the waste derived product market.

Source: Berta Moya, Alison Parker, Ruben Sakrabani, Challenges to the use of fertilisers derived from human excreta: The case of vegetable exports from Kenya to Europe and influence of certification systems, 2019; Berta Moya, Ruben Sakrabani and Alison Parker, Realizing the Circular Economy for Sanitation: Assessing Enabling Conditions and Barriers to the Commercialization of Human Excreta Derived Fertilizer in Haiti and Kenya, 2019

2.5 Global Circular Value Chain

Waste Generation and Collection

Waste is generated from both households and industries including the agriculture industry. Waste is collected and transported to treatment facilities which convert waste into a variety of products. Human waste can be collected and treated in the forms listed below:

1. Urine Diversion
2. Separation of Solid and Liquids
3. Combined Processing

Treatment

The treatment of waste will vary depending on its form (i.e. Combined solid and liquid waste or separated solid waste only). Waste can be treated through dehydration or composting to produce secondary products.

Products

A variety of products and by-products of the treatment process are created. These products such as water and energy can re-enter the loop into the treatment facility. Products created such as briquettes can be sold to industries or households for heating. By creating value from waste, it does not only “close” the loop by re-introducing materials back into the value chain, but revenue generated from these products can be used to subsidize or even offset the costs that households would pay for sanitation services.

2.5.1 The Economic Case for Resource Recovery

Globally the practice of resource recovery is implemented widely in Western Europe and Japan. Resource recovery is not only a sound environmentally friendly practice, but also has economic benefits to local economies.

Unfortunately, the generation of waste is a by-product of human and economic activity. But it can also be an input into economic activity. In order to achieve a green economy the principles of waste recovery needs to be effectively practiced at the microeconomic and macroeconomic level. At the broader level the recovery of waste limits the number of negative externalities that are associated with waste production on the general social welfare of the economy. Not only will resource recovery minimize these negative externalities, but it will also have a net positive impact on allowing renewed value-added benefits to be fed back into the economy. This limits the potential need for additional resource extraction.

Waste recovery can therefore have a number of benefits:

- Minimising negative externalities associated with the environment and socio-economic well-being of a community

- Additional value addition to the economy from the waste recovery process (creating jobs)
- Additional value addition to the economy from the generation of product or resources that can be re-used
- Net benefit of re-use that will minimize the need for additional finite natural resources

In many cases the existence of market failures prevents economic agents from making rational or optimal choices. The key market failure in this regard is the underestimation of negative externality cost to the community of environment versus the additional cost of waste re-use. This means that through microeconomic market forces alone, they would not make optimal choices to minimize the production or re-use waste. This presents the case for government market intervention to incentivize, tax or pay for practices that allow the re-use of waste.

In practical terms this means that the private sector alone will not be able to provide effective, sustainable sanitation solutions to communities or schools without government intervention. The key factor that needs to be taken into account is the correct mix of new sanitation technology that should be invested in as there is a trade-off between fully environmentally friendly solutions vs. traditional solutions based on price. The market analysis portion of this study tackles the affordability question vs. the outcome and gives an opportunity to assess the correct mix and appropriate actions that need to be taken based on the budget implications.

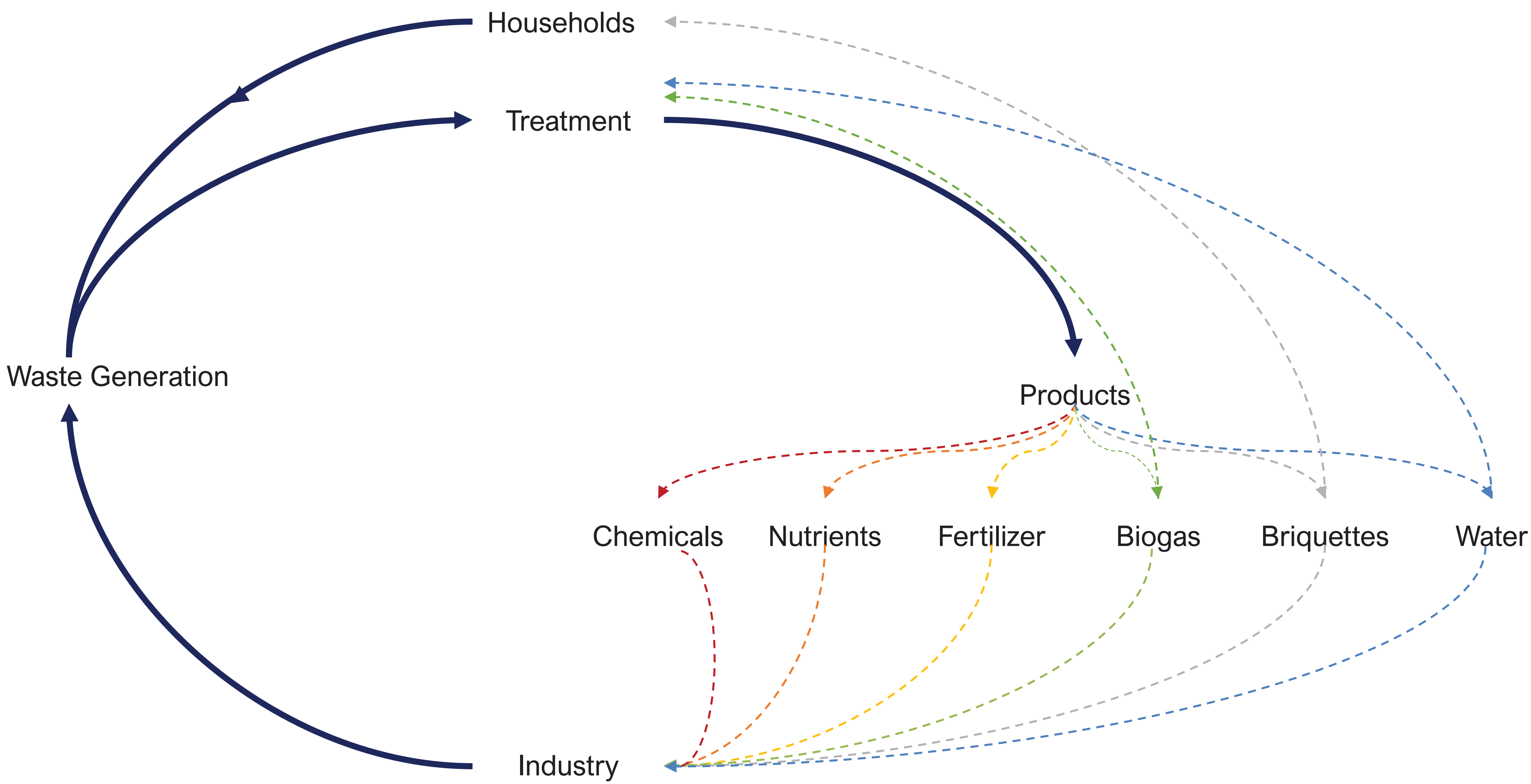


Figure 7: Circular Economy: Life Cycle

2.6 Waste to Energy

Waste to Energy (WtE) refers to the conversion of non-recyclable waste into various forms of energy, such as heat, fuel or electricity.

There are currently 3 technologies used in WtE conversion		
Thermal	**Biological**	**Chemical**
Recovering energy from waste using high temperatures, such as combustion, incineration, pyrolysis or gasification	Biological conversion technologies and processes are used to transform biodegradable waste such as food and agricultural waste	Esterification is commonly used to produce Fatty acid methyl esters (FAME), the primary component in biodiesel
Benefits of Waste to Energy		
Recycling of non-recyclable waste	Clean Energy Generation	Greenhouse gas reduction

Figure 8: Waste to Energy Conversions

From a circular economy perspective, faecal sludge is an excellent resource from which many benefits can be reaped.

Waste to Energy Value Chain

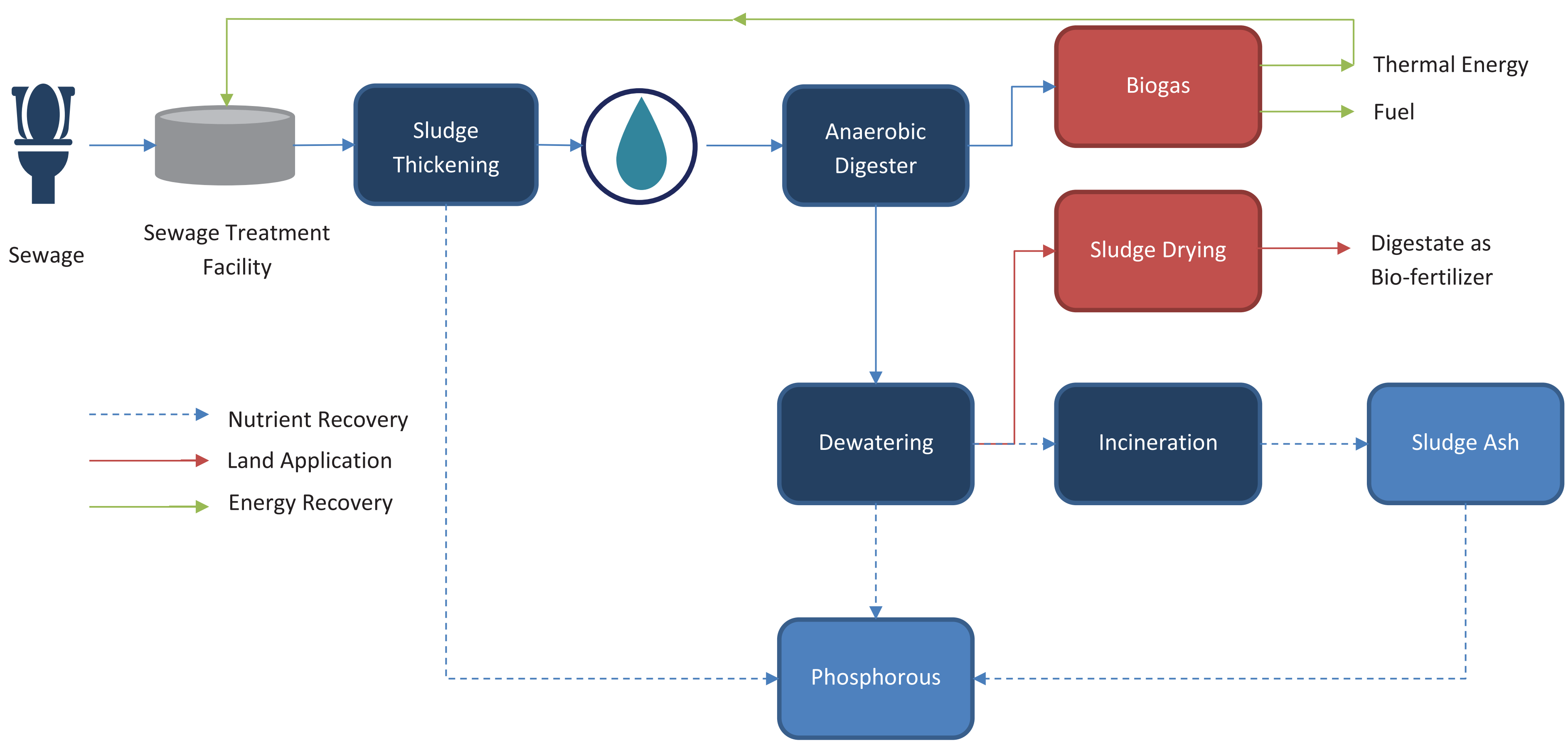


Figure 9: Waste to Energy Value Chain

In the sanitation economy the market can be segmented into:

1. Sludge Treatment Systems		
Thickening & Dewatering	**Sludge Digestion**	**Sludge Drying**
Sludge thickening is the process of reducing free water content in sludge. Dewatering refers to the reduction of floc bound as well as capillary water content in sludge	Sludge digestion is a process in which organic substances or solids decompose to form stable substances. Digestion reduces the total mass of solids and destroys microbes or pathogens, thereby making it easier to dewater or dry the sludge.	Sludge drying is a process of drying sludge and transforming it into green fertilizer. Thermal drying is commonly used to reduce the volume and weight of the sludge.
2. Sludge Recovery Systems		
Energy Recovery	**Digestate as Fertilizer**	**Nutrient Recovery**
Energy recovery from sludge includes the conversion of biogas from digestor to either thermal energy or fuel. Biogas is considered as a form of green energy.	Digestate is the product that remains after the treatment of the sludge by anaerobic digestion. It is rich in nutrients and hence used as a bio-fertilizer in many countries.	Recovery of phosphorous from sewage sludge is carried out mainly in land applications. It is done to reduce heavy metal contamination, improve the amount of phosphorous available for plants, and increase the possibility of developing substitutes for phosphate rock in the fertilizer industry.

The key drivers of the sanitation circular economy are summarized below:

1. Innovative technologies and business models for sludge recovery (this will have a medium impact in the next 5 years)
2. Mandatory phosphorous recovery in a few countries in Europe (medium impact in the short and high impact in the longer term – 5-7 years)
3. Stringent environmental regulations require treatment plants to have high quality sludge treatment systems and direct land disposal of sludge
4. Increased need for nutrient recovery due to declining phosphorous reserves (this will have a high impact in the next 2-7 years)
5. Need from energy use from biogas will increase

Source: Frost & Sullivan: Growth Opportunities in the Circular Economy of European Sludge Treatment Systems Market, Forecast to 2025

2.6.1 Case Study: Sanivation

Sanivation began operating in 2014 by bringing sanitation to Kakuma in Kenya. Sanitation's toilet technology is an example of Container Based Toilets (CBS) whereby faecal sludge is collected on a biweekly basis and transported to treatment facilities. The processed of treating faecal sludge converts the waste, into a solid fuel briquette. These briquettes are then sold off to be used as forms of biomass fuel.

Not only does Sanivation provide basic and safe sanitation to Kenyans, it is environmentally friendly and has taken a circular approach to sanitation practices.

250 Households	**$54**
500 Households	**$29**

Key assumptions:

- 1 kg of faeces is produced per household per day
- The briquettes produced from the waste are sold at 20 KES (0.2USD) per kg
- The sales of briquettes begin in second year of operation
- A ratio of 1:3 ratio of faeces to carbonized biomass in briquettes

Table 6: The Capital and Operational Costs, And Revenue For 500 Households Over A 10-Year Period

	Total System Costs over a 10 Year Period	Ongoing Costs per Household Per Annum
Capital Costs	USD 210,000	0
Operational Costs	USD 985,000	USD 197
Revenue from Products Produced	USD 1,050,000	USD 210
Total	USD 145,000	USD -13

The capital investment required for container-based sanitation may be higher than that of pit latrines. But pit latrines are not suitable for all environments such as areas that are prone to flooding or have unstable grounds, and do not provide a form of resource recovery whereby income can be used to offset the operational costs.

How it works:

Households can sign up to the sanitation service and enter into agreements to pay a monthly fee for the toilet use and services provided. The installation of a toilet system can take up to three days and materials are usually sourced locally. The toilet has a life span of approximately 5 years.

The system diverts urine and only captures solid waste in the container, which are lined with plastic bags to make collection and replacement easy. After every use, the solid waste is covered by a layer of charcoal dust which is delivered to households between 2-3 times per month. This is to inhibit odours and to make solid waste less visible for the next use. The containers are collected twice per week from each household using locally employed individuals. During these visits, the toilets performance is monitored, and the plastic bag is replaced. This waste is then transported to the treatment facility whereby sunlight is used to heat the waste to remove any harmful pathogens. The briquettes are produced through a series of mixing, grinding, compaction, and drying stages before they are packaged and distributed.

The briquettes have been tested against conventional products such as charcoal and wood. The briquettes were found to have a burning time of 4.5 hours, compared to 3 hours for charcoal and a mere 1 hour for wood. Briquettes also produce less smoke than charcoal and wood. However, the briquettes are sold at the same price as charcoal but due to longer burning times, less briquettes are required.

It can be challenging to get communities to buy in to the idea of a new toilet system, given that they often aspire to the gold standard of flush toilets or they are familiar with other technologies such as pit latrines. Establishing good relationships with the community, trialling the technology and the valued products with trusted member of the community will allow for easier expansion and deployment.

Local members can be approached to sell technology of products. Regular surveying of technology use in households can be done to collect data that can be used to improve the overall experience.

- Are they satisfied?
- Compared to other technologies they have used
- Does it need repairs
- Is it user friendly for their entire household?
- Why would they not use

There are many opportunities along the value chain to create jobs for the community, as well as procuring materials from local suppliers if possible.

Source: Sanivation, Bill & Melinda Gates Foundation, UNHRC, Container-Based Toilets with Solid Fuel Briquettes Guidelines, 2018; Toilet Board Coalition Virtual Summit: Circular Sanitation Economy Business Models, 2018

2.6.2 Case Study: AgriProtein

In 2008 AgriProtein had a vision to close the material impact loop on the environment by adopting a circular economy strategy approach to the aquaculture and agriculture production. The company set up their first pilot plant and achieved production volumes of 100 kg per day of insect protein by 2011. The production system is based on cultivating and farming black soldier flies (BSF) in order to utilize the larvae produced by them for a number of different products. AgriProtein completed construction of their first factory in 2015 with a capacity to produce 100 tons of food waste per day. The company secured global partnerships by 2019, after agreeing to a deal with Cristof Industries which enabled extended fundraising efforts, roll out of the facility design at a global level as well as acquisition of Circular Organics in Europe.

Products

Industrial consumption of protein is thought to be growing considerably in future. All kinds of industrial animal farming rely heavily on protein feedstocks such as land-based crops and marine fishmeal. Both protein sources are non-sustainable. Land-based crop protein requires large-scale land and water resources while fishmeal-based protein has dire consequences for the marine ecosystem. An estimated 5 million tonne shortfall in animal feedstock protein is expected by 2024. The company has set up their manufacturing process to derive three types of products from BSFL.

1. MagMeal™

Sustainable, high quality animal protein from black soldier fly larvae (BSF) than can be consumed by all kinds of monogastric animals including fish, chickens and pets.

2. MagOil™

A high natural oil extracted from the larvae containing high amounts of lauric acid. It is suitable as a replacement product to fish oil, coconut oil and palm oil and can be used in the aquaculture and pet food industry.

3. MagSoil™

The remaining residue or compost that is left over after the meal and oil production process. The soil is enriched in nitrogen, phosphorus and potassium and is therefore a valuable organic soil conditioner.

Process

Organic waste is recycled into protein, using the natural cycle of the black soldier fly species in an advanced and industrialised process. Up to 100 tons of organic waste is naturally consumed by larvae in the AgriProtein factory each day. Towards 2020, nutrient recycling is expected to begin benefitting the global Protein market.

Advantages

- Creating a natural, complete and sustainable protein for use in animal feeds
- Reduces greenhouse gas emissions, water pollution and toxic leachates from landfills
- Flies bred under scientifically determined and engineered conditions to stimulate mating, egg fertility and larval growth at optimum levels all year round
- Proven profitable business model that has considerable environmental benefits
- By-products are nitrogen-, phosphorus-, potassium rich compost for agricultural use

Innovative Attributes

- The larvae by-products fit various market applications (Aquaculture, zoo, poultry, farming, pet food and chemical-free crop production)
- Products are sustainable and cost-effective protein and fat substitutes
- Comparable to costly fishmeal, fish oil, soybean meal, palm kernel oil and coconut oil
- Continuous ingredients stock as BSF has a high and speedy reproduction ability
- 1 kg of fly eggs will produce 12 000 kg of larval protein within 18 days
- The use of waste as a feed source for insect larvae production provides a sustainable organic waste disposal alternative to landfills

Source: Frost & Sullivan Insect Proteins for Animal Feed Industrial Bioprocessing TechVision Opportunity Engine (TOE); AgriProtein

2.7 Wastewater Recycling

Wastewater is a precious resource in cities where water shortage is common due to industrialization and population growth or in rural areas where freshwater supply is limited. The reuse of wastewater for crops, landscape irrigation, groundwater recharge or recreational purposes can take vital pressure off freshwater resources. Wastewater is reused either directly or indirectly. Direct reuse includes uses without reintroduction of the wastewater into another freshwater body (e.g. golf courses) while indirect wastewater uses involve the mixing of the wastewater with another freshwater body of water before reuse.

The basic design of a wastewater treatment facility includes two main treatment stages. The Primary stage is responsible to remove solids from the wastewater that either float or can be removed by settling out due to gravity. The secondary stage makes use of biological processes to purify the wastewater. Microbes are employed which consume the organic matter as a food source.

Primary Treatment

The sewer pipes and pump stations direct wastewater into the wastewater treatment plant, where it flows through a screen and grit chamber to remove large and small solid materials. The sewage then passes through a sedimentation tank which removes suspended solids in the water, and the sewage is now referred to as primary sludge, which is pumped out for removal.

Secondary Treatment

Soluble organic material as well as other suspended materials that passed through the primary stage are removed. Primary effluent is pumped into an aeration tank. Primary effluent mixed with fresh sludge that is recirculated from the secondary clarifier is pumped into the aeration tank. Compressed air is injected into the tank, creating oxygenated conditions ideal for the microorganisms in the activated sludge to absorb all dissolved organics from the sewage. This sewage is then transferred to the secondary clarifier where gravity causes the activated sludge to settle out. Clear water is then skimmed from the surface, disinfected and discharged as secondary effluent. Part of the activated sludge (30%) that settled out is reintroduced to the aeration tank and mixed with the primary effluent, while the remaining sludge is mixed with the primary sludge and disposed of.

Other secondary treatments include the trickling filter and the oxidation pond. The trickling filter is comprised of a tank with stones of various sizes. The wastewater trickles down the stones which gather bacteria which in turn multiply and absorb the dissolved organics. The filters are also installed in combination with secondary clarifiers. Oxidation ponds are large, shallow ponds are designed to treat wastewater through the interaction of sunlight, bacteria and algae. Photosynthesis takes place due to the algae, supplying oxygen to the aerobic bacteria. Dredging removes the sludge accumulated at the pond floor.

Tertiary treatment

Highly polluted water might have to be treated in a tertiary treatment stage to meet the effluent standards. One such treatment is referred to as effluent polishing, based on the process of granular media filters.

Removal of phosphorus and nitrogen is usually achieved during the tertiary treatment stage. Phosphorus is usually removed by chemical precipitation, considerably increasing the volume and weight of the sludge. Nitrogen is removed by a process called nitrification-denitrification through the use of bacteria and microorganisms.

Source: Britannica, Wastewater Treatment Systems

Key Drivers for recycling of decentralized wastewater treatments

1. Simple Design with combined processes

Simple design of decentralized treatment systems with combination of various processes enables minimization of the footprint of the proposed treatment system. They are also designed to operate underground. Combination of several treatment processes also ensures adherence to effluent discharge charges and maintains the efficiency of the treatment process.

2. Government Standards for Effluents

Stringent effluent discharge standards have been imposed on several industries which are discharging wastewater without proper prior treatment. Low cost decentralized treatment systems will enable the industrial users to adhere to the discharge levels, thereby reducing the pollution of surface as well as subsurface water bodies by industrial effluents. The treated effluents and composts from these systems may also aid farmers to overcome extreme weather conditions.

3. Non-leachate systems

Decentralized treatment and composting systems are designed with watertight chambers, minimizing the potential leaching of contaminants into the soil without prior treatment. Decentralized treatment systems therefore prevent ground water pollution since they do not deprive the soil of nutrients which will decrease the productivity of the soil ecosystem.

4. Convenience of scalability

The ability of the decentralized system to be scaled according to the users' requirements enables easier commissioning of these systems. This scalability also does not involve complex engineering processes, thereby enabling the users to upgrade the installed systems in future with minimal associated costs.

5. Environmental legislation

Environmental legislative bodies around the globe have developed stringent discharge limits to control and mitigate the impact of wastewater on the water bodies nearby industries. Industries are therefore encouraged to set up wastewater treatment facilities to avoid heavy taxation should the effluent limits not be adhered to.

6. Water Scarcity

Water scarcity is a key problem faced by major industries that require adequate supply of water for its operations. In order to improve sustainability and reduced dependency on external water supply, industries tend to adopt wastewater reuse technologies.

7. Technology Development

Increased R&D and advancements in wastewater treatment technologies have been credited as key drivers for recent increased adoption rates of wastewater treatment solutions.

8. Corporate Social Responsibility (CSR)

Industries have adopted and incorporated the use of wastewater treatment facilities in order to be more compliant with environmental responsibilities and sustainable practices as part of their CSR.

2.8 Decentralized Technologies

2.8.1 Wastewater treatment

a. Upflow Anaerobic Sludge Blanket

This technology involves the injection of wastewater into a treatment blanket from below. The wastewater is passed upward through a granular sludge blanket where an anaerobic digester produces methane. The biogas is collected at the top of the reactor while treated effluent is removed through a side outlet.

Besides the UASB, there are three other major types of anaerobic wastewater treatments: anaerobic filter, fluidized bed and anaerobic contact.

b. Sequential Batch Reactors (SBR)

SBR are fundamentally enhanced versions of the activated sludge process, in which the treatment process is carried out in the same tank. This technology is usually employed to treat sewage from residential areas. Generally designed to consist of one or more tanks, the treatment follows a fill and draw activated sludge system where the process of equalization, aeration and clarification takes place in the same tank while the treated wastewater is drawn out from the other tank.

c. Constructed Wetlands

These are man-made wetlands that are created with the purpose of treating industrial or municipal wastewater and stormwater runoff. These wetlands, commercially employed for wastewater treatment, are an integrated system between water, plants, animals, microorganisms and the surrounding environment. They are designed to artificially simulate the features of natural wetlands and act as a natural biofilter removing pollutants from the water.

This treatment type usually involves two types: Surface flow wetlands, which consists of a shallow water basin with aerobic surface layer and anaerobic substrates. The other type is generally referred to as the Subsurface flow wetlands, which unlike the surface flow wetlands consists of a sealed basin with porous substrates with water flowing below the substrate layer.

d. Trickling Filters

Trickling filters are a fixed bed system in which microorganisms are bound to an inert packing material for secondary treatment of wastewater. The packing material is usually comprised of bed rock, gravel, sand, woodchips and plastic materials in a cylindrical container. This system is quintessentially an aerobic biological treatment unit and its robustness helps it to be installed as a decentralized wastewater treatment unit in densely populated urban areas. This technology is usually installed at a depth of 2.5 m, with low-cost filter material. The filter material is highly durable and designed with a large surface area for the breakdown of organics by the microorganisms to take place which are attached to the material.

In general, there are four types of filters: Low-rate filters which are suitable to be used for wastewater with low organic loading, high-rate filters which are to be used for wastewater with very high organic loading. The other two types, the intermediate and the roughing filters are suitable for intermediate organic loading rates.

e. Septic Tanks

Septic tanks are watertight systems made of concrete or polyvinyl chloride (PVC) which collects blackwater and greywater. This technology is regarded as one of the most common small-scale decentralized treatments for wastewater. Septic tanks in combination with drain fields comprise the septic system which acts as a small-scale sewage treatment plant in areas that are not connected to the main sewage network. They are highly efficient, underground decentralized wastewater treatment systems that are more economical than the conventional centralized counterparts. This anaerobic system consists of two chambers. First chamber is the inlet from the domestic sources where separation of liquid and solids occurs. The clarified wastewater then escapes to the second chamber through the vent in the compartment separating the two chambers.

As with the other technologies, there are two types of septic tanks: Gravity septic tanks are usually installed in areas with sufficient sloping of the ground, enabling draining of effluent into the drain field by gravity. Pressure septic tanks on the other hand are applied to areas in which no sufficient sloping of the ground is present and a pump must be employed which is used to pressurize effluent out of the tanks into the drain field)

The effluent quality as well as the by-product quality of septic tanks is generally considered to be of poor quality, but the low capital cost, ecological footprint and O&M are major drivers of this technology. This is also applicable to Trickling Filters, which, however, have a higher effluent quality. However, because of their high geographical suitability, their applicability to the imposed governmental policies as well as their high stakeholder participation, both of these technologies are highly suitable for adoption in the South African context.

2.8.2 Solid Waste Treatment

a. Aerobic Composting

Aerobic composting is the decomposition of organic residues, carefully monitored by microbes in the presence of abundant oxygen. Microbes decompose organic matter and produce CO_2, heat and ammonia.

Aerobic composting has two types: Windrow composting which involves the decomposition of 2-3 m high piles that are periodically turned to release heat to maintain oxygen exposure. The other type is referred to as In-Vessel composting where organic waste is enclosed and the composting process occurs under optimized conditions to maximize the process.

b. Anaerobic Composting

Anaerobic composting is the biological decomposition of organic matter with the help of anaerobic organisms. As the name suggest, the process occurs without the supply of any oxygen present. Microbes break down organic matter via fermentation to produce humus, organic acids and biogas.

Just as its counterpart, anaerobic composting has two types: Indian pit composting where a sloped hole is dug and filled with alternative layers of soil and organic residue. The other composting process, Passive composting, includes the stacking of organic waste into piles but are not agitated.

c. Rapid Composting

This is a process which utilizes the liquid culture of effective microorganisms (EM) generated through natural fermentation to accelerate the rate of decomposition of organic residue and also reduce the time taken for decomposition.

Again, the technology is available in two types: IBS composting which involves the special organisms called Cellulose Decomposer Fungus (CDF) and EM based composting which involves both aerobic and anaerobic bacteria.

d. Biomethanation

A biological process where organic compounds are converted to CH_4 and CO_2 in the absence of oxygen using microorganisms. The process consists of hydrolysis, acetogenesis and methanogenesis, making use of fermentative bacteria, acetogenic bacteria and methanogens. Biomethanation is used mainly for treatment of waste, such as food waste, sewage sludge, and also other industry wastes having huge amounts of organic waste.

Three types of biomethanation exist currently: Passive systems, low-rate systems, where flowing manure is the source of methane forming microorganisms and high-rate systems where microorganisms are trapped within a digester.

e. Vermicomposting

Process of utilizing various genus of worms to degrade kitchen wastes and other organic residues to create a heterogenous mixture which serves as an excellent soil amendment. The earthworms are voracious consumers of biodegradable matter and excrete out digested matter called Vermicastings.

Vermicomposting shows high overall performance efficiency when parameters such as expenditure, footprint, and product quality are considered. Other processes like material recovery facility and rapid composting are equally important for waste segregation and treatment. Vermicomposting is also one of the most economically viable treatment technologies as it requires very low cost of installation as compared to other treatment technologies for the same amount of solid wastes that can be composted. These three technologies have great geographical suitability, government policies and stakeholder participation.

Source: Frost & Sullivan, Decentralized Wastewater and Solid Waste Treatment Technologies, 2017; Frost & Sullivan: Industrial Wastewater Recovery and Reuse Technologies, 2017

3 OVERVIEW OF THE SMART SANITATION ECONOMY

3.1 What is the smart sanitation economy?

With the advent of new technologies and the highly interconnected social systems we currently have, there is now more potential than ever to improve public health through monitoring at the community and individual level. This can be directly translated to the provision of sanitation to communities where technology can be used to monitor the health of individuals, as well as provide information to the maintenance of key sanitation systems in the community.

The Toilet Board Coalition defines smart sanitation as a means to build resilience in cities, communities and sectors through the utilization of smart technology and Industry 4.0 solutions that will improve the collection and monitoring of waste for both individual and aggregate-level preventative health monitoring.

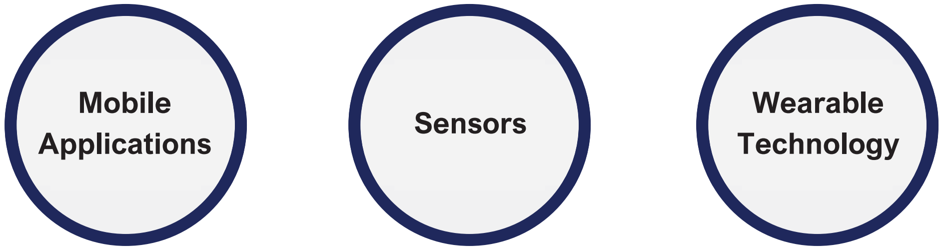
Employing these technologies in the sanitation sector will ensure a smart sanitation economy that can provide significant benefit to smart cities and even rural communities. In this economy, data of consumers and service providers are collected to monitor, improve and maintain systems within the sanitation economy. This includes collecting data on consumer health, the usage of public toilets, and sewage treatment facilities.

By gathering all this information, service providers can optimize offerings, and detect when maintenance is required at any facility. Healthcare professionals will be able to characterize waste and extract valuable insights into the health of consumers. Waste management services will be able to track the logistics of waste in real time through GPS tracking.

Toilet infrastructure will be installed with sensors in the residential, commercial and public sectors. Technology can be used to locate toilets; to collect data on remote school conditions; and all around be a facilitator of education surrounding health and hygiene. Not only are the social benefits evident, but economic value-added benefits could provide lucrative markets for private companies and investors. As an example, in India alone, the smart sanitation market is estimated to be worth USD 6 billion.

3.2 Smart Sanitation Technologies

Technology has the power to open multiple opportunities in the smart sanitation sector, which is still unexplored. Data is a powerful tool and can be used in the sanitation sector to produce valuable information about human health, and sanitation infrastructure needs. A variety of smart sanitation technologies exist in various parts of the sector and its value chain. These technologies have various purposes such as collecting data for analysis, driving efficiencies in businesses, and enabling access to outlying consumers. The industry is relatively unexploited which creates vast opportunities. Enablers such as mobile devices and connectivity are already in place, paving the way for mobile applications to bring sanitation services to consumers, especially those in low-income communities.



Mobile phone penetration has grown significantly and continues to do so. This results in more and more consumers having potential access to basic services. Mobile phones can be used as enablers and connect service providers and hard-to-reach consumers. Mobile applications have been shown to be effective in the energy industry, using the Pay-As-You-Go model, where mobile money has been used as an enabler in the energy sector as a means of providing consumers with access to much needed electricity.

The rise of mobile and digital applications has enabled Africa to leapfrog the need to build out extensive telecommunication networks. Low-income smart sanitation is made possible due to the emergence of mobile connectivity, IoT hardware advancements and increased incorporation of cloud services at a large scale. Even though PAYG business models are still in the early development phase, examples of incorporation of these applications in rural environments has proven successful. One of the challenges in setting up sanitation services in low-income and rural area is ensuring payment for these services. Many South Africans simply cannot afford to purchase a toilet system. Using mobile payments will enable remote payments to service providers and will allow service providers and users to connect and provide support when needed. Through communication between service providers and users, a trusted relationship can be built.

Companies such as Loowatt in Madagascar, BRAC in Bangladesh and CleanTeam in Ghana have utilized the mobile money technology to enable customers to pre-pay for sanitation services or finance toilet systems. For these services to be successful and scalable, entrepreneurs need to partner with large companies and utilities, especially mobile operators. These strategic relationships will enable scalability of these operations. An enabling and favourable environment is crucial for the success of these operations, and to attract the needed investment. Additional emerging mobile technologies applicable to the smart sanitation economy include apps that help promote female health as well as apps that focus on providing vital information on sexual and reproductive health and rights for adolescents.

Bundles services can be used to provide individuals with basic needs such as water, sanitation and electricity. Mobile applications allow for these services to be easily managed, and provide a mechanism for payments, apart from allowing much needed communication between service providers and customers. It can also allow for decentralized sanitation services to reach indigent, low-income communities.

Case Study: Loowatt

Loowatt is a smart sanitation technology provider basing its operations on not only building of toilets, but also on operating safe collection, transportation and treatment of faecal sludge. The company develops toilets and pre-treatment technologies that are suitable to be employed in both rural and urban environments as their operations are easily scalable. The technology is based on a closed loop system, enabling the possibility of the waste to be transformed into biogas, electricity and fertiliser. The container-based sanitation (CBS) business model partnered with GSMA Mobile for Development Utilities Innovation Fund, providing the company with the ability to track and monitor the servicing of toilets from remote locations through the use of mobile applications. This provides customers with a systematic emptying service and the possibility to utilise PAYG functions.

Another technology that is part of the smart sanitation framework includes use of **GIS tracking**. GIS tracking of sanitation service providers has the ability to restructure and optimize the faecal sludge (FS) emptying and transport sector. Through the application of the tracking system and the analysis of the resulting data can inform on the market size and thereby help to optimize the operation strategy, transport routes and efficiency. A toilet finder app that makes use of technology based on GIS systems can help individuals find public toilet facilities, thereby improving public sanitation. The app functions on the basis of displaying the closest toilet facilities and provides directions. CBS involves the use of sealable, removable containers that are transported to and from treatment facilities by sanitation service providers. This is a cheaper and faster alternative to the length and cost intensive installation of standard sewage toilets. As with standard service providers, GIS tracking can be employed here to maximize the sanitation process through the use of data collection apps, GPS tracker for route checking and supply chain tracking system with QR codes.

Smart toilet sensors are another sanitation technology applicable to the smart sanitation economy. The technology is aimed to optimize the toilet usability, waste collection routes and reduce operating costs. Augmented sensor and actuators enable objects in the sanitation stream to be monitored, managed and controlled remotely, enable the data integration of such physical processes into computer-based systems. This not only optimizes the efficiency of sanitation processes but directly translates to economic benefits due to reduces human intervention. Sanergy in Kenya is testing the viability of sensors installed in informal toilets with the aim to determine if sensor technology is a viable tool to optimize the waste collection process. Sensors are originally used to measure water flows, but these can be combined with motion sensors to analyse behavioural change in relation to hand washing. This can be applied to monitor basic hygiene levels in all environments. The continuously generated usage data can be powered by solar energy technologies and transferred via WIFI to populate databases which monitor statistics on performance and usage of users.

Essential **health data** can be captured about individuals, households, and communities through analysing human waste. This information can be used to provide valuable insight into basic human health. The data captured can provide insight into biome, blood related and genetic information. IoT in healthcare was estimated at USD 117 billion and expected to continue experience significant growth.

A sensor, embedded into the toilet infrastructure, will analyse and store the data collected from each use. A database will be established for each user, which can be accessed by the individual on his/her mobile device as well as by the relevant medical practitioners. It will allow for a new method of diagnosis and be able to predict and prevent the spread of diseases. Continued monitoring can improve treatment and will allow doctors to identify health concerns before individuals show symptoms. Sensors can also be used to monitor water flow and usage, and detect leaks, and damaged sanitation infrastructure. These can be especially useful in school and clinics to provide efficient maintenance.

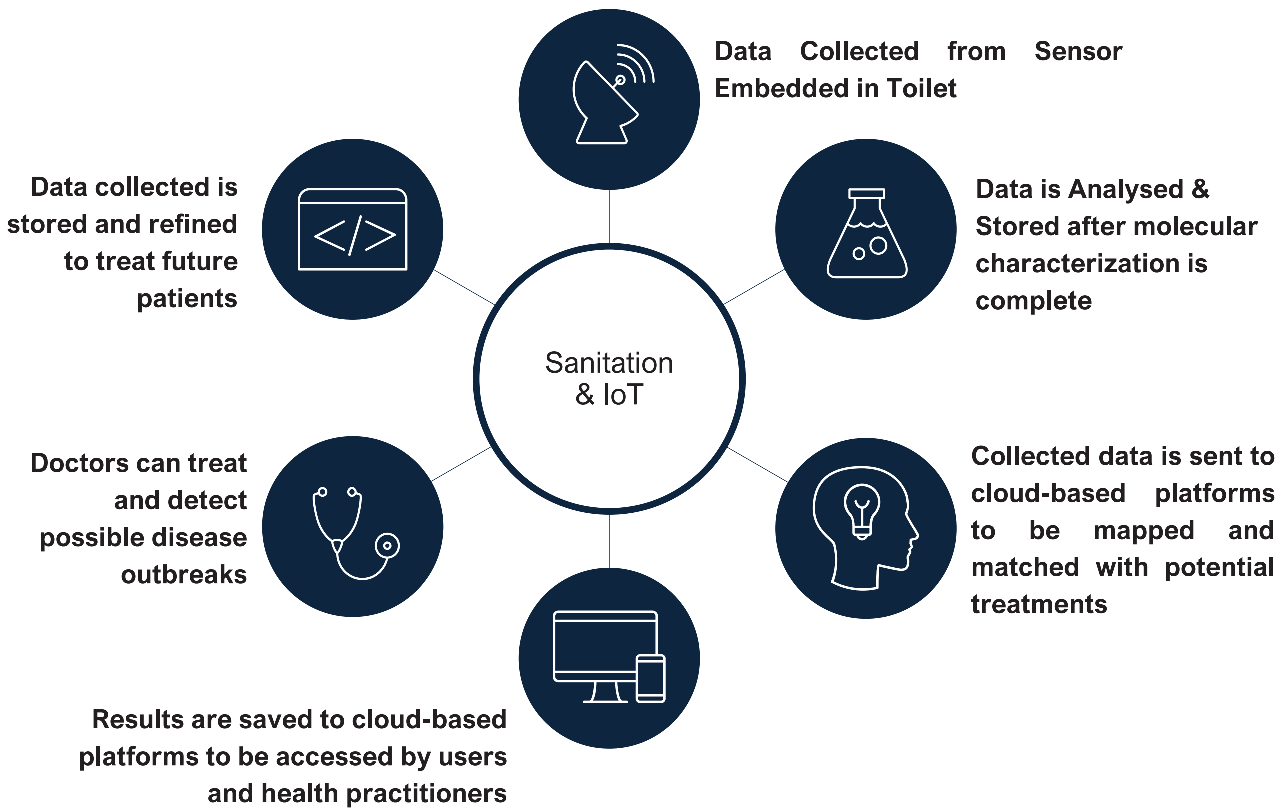


Figure 10: How Sanitation and IoT Work Together

Smart cities are on the rise, and smart sanitation will play a crucial role in providing sanitation to those that reside in it, as it should be a core function of the smart city. Blockchain has the power to bring about much needed transparency in the sanitation sector through a public ledger of data, as well as facilitate asset management, and open opportunities within the sector through various and multiple partners.

Table 7: Digital Applications for Sanitation

	INDIVIDUAL	COMMUNITY	SOCIETY
IOT	Smart Phones; Wearable Technology	Health Devices; Smart Homes; Connected Cars	Smart Grids; Smart Cities
EXAMPLES	Fitbit; Mastercard Pay pass	Blood Pressure Monitors; Remote Heating Systems	Smart Water and Electricity Meters
DATA	Health and Fitness Data; Mobile Money; GPS Location Data	Heartrate and Diet data; Speed and Airbag Data	Utilities Consumption and Billing
INTENDED AUDIENCE	Individuals; Employers	Health Practitioners; Insurers	Regulators; Utility Companies

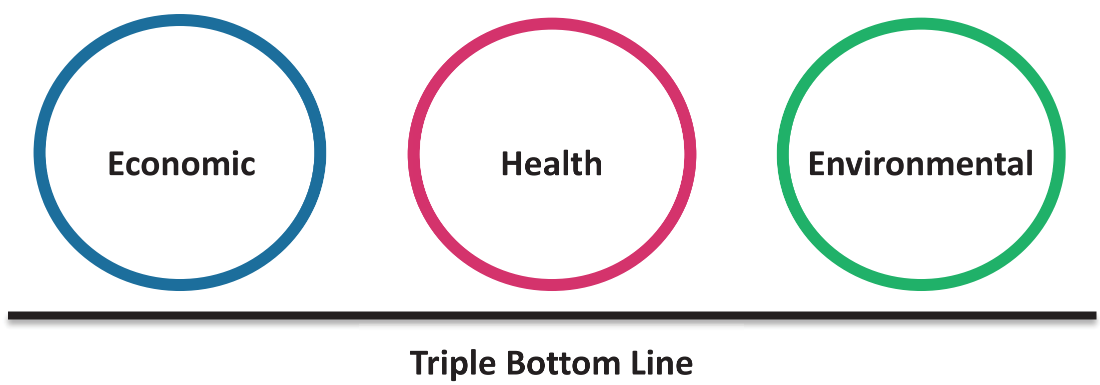
These examples of incorporating technology into the sanitation sector has shown how it can facilitate growth and ease access to basic sanitation, along with presenting how technology will change the way we view and interact with sanitation infrastructure and utilize the valuable information it has to offer. It has the power to prevent disease outbreaks and prevent pandemics across the globe, along with diagnosing illnesses in patients before any symptoms are displayed. The advantages associated with incorporating technology and utilizing the available data are endless.

Source: TBC, The Digitization of Sanitation, 2016; GSMA, Replicating Pay-As-You-Go Utility Models Beyond Solar and East Africa; Caroline Saul, Heiko Gebauer, Digital Transformation as an Enabler for Advanced Services in the Sanitation Sector, 2018

4 Business Models

Given that there are over 4.5 billion people globally without access to safely managed sanitation, new business models need to be implemented to make it affordable and sustainable when implemented. The conventional and traditional form of bringing sanitation to communities in an urban setting requires the installation of a sewage network connected to a treatment facility. Users of toilet facilities then pay their respective government for these sanitation services. But in low-income communities, collecting revenue is challenging, and local municipalities often fail to provide adequate services. In practice, if a government were to develop a conventional sewage system in currently non-sewered areas, it would require large capital investment from governments and time for planning, construction, implementation, and maintenance.

Decentralized models have been used in transport, energy and telecommunications. Over the years, several technologies, as discussed in Section 1.4, have been developed to bring off-grid sanitation services to these areas. These unconventional technologies and services can be implemented in new business models that can bring affordable, scalable, and sustainable sanitation to communities in need. Business models can be developed to bring economic benefit, a health and social benefit, as well as an environmental benefit. In doing so, these new business models can contribute to a variety of Sustainable Development Goals, by providing basic water and sanitation (SDG6), contributing to Zero Hunger (SDG2), and creating affordable and clean energy (SDG7). This is achieved by implementing circular economy approaches by adding value to waste. The end of the linear value chain creates numerous opportunities to upcycle waste into a variety of value-added products.



Business Models should consider a combination of these aspects:

Product & Service	**Distribution**	Finance
Pricing	Payment	**Sales**

Traditional business models in the sanitation sector view each aspect of sanitation separately such as the generation, collection, transport and treatment of waste. Reinvented toilets combine many of these aspects into a single product, which requires new and innovative business models. Conventional models are also based on a reliance on government and municipalities to oversee and carry out all aspects of the value chain. New models will lower the reliance on governments and should integrate players such as the user and private companies. One of the challenges for reinvented toilet technologies is deciding which players will pay for the products and services. In South Africa, the portion of the population that are currently underserved with regards to sanitation, are either not willing or simply unable to afford conventional sanitation services.

Models used to bring affordable sanitation to this market should consider different payment schemes and various service options, to allow for individuals to decide what and how they are going to pay for.

Product-As-A-Service

This model focusses on revenue generation, as customers are not purchasing the product, but rather paying for services they use. The distribution companies (can also refer to government/municipalities) who implement these technologies will retain ownership. A contract will be put in place for users to pay a monthly fee for services such as toilet use, waste removal, as well as service and maintenance.

In many cases, those that require sanitation services do not have the financial means to afford the high capital costs associated with reinvented toilet infrastructure. This is barrier to entry for low income or indigent consumers. This model can be coupled with franchising whereby technology providers allow smaller or local players to install and operate the technologies. This will lower the burden of high capital costs incurred by a single operator and share the investment risk.

This model could be specifically useful in low-income communities. Companies could consider trialling their technologies with prominent and trusted families in the community. Once familiarity and trust with products and service providers is achieved, it will facilitate the rollout of technology.

It is important to create trusting relationships with end-users to ensure they are satisfied with the product and have sufficient and correct knowledge of how to use the toilet correctly. Correct knowledge of toilet use will reduce the risk of infrastructure damage. Sanitation services can also be brought communities via localized “toilet malls”. These establishments can provide a variety of sanitation services which include toilets, showers, basic hygiene products. Users can pay a small fee to use clean, private and reliable toilet facilities while having access other basic hygiene practices. Examples include the Ikotoilet and Lootel.

The broader user experience will attract foot traffic, and the income generated from selling hygiene products such as sanitary towels can be used for the maintenance of the facility. Users need to be encouraged to use these alternative services that don't necessary fit the gold standard flush toilet.

One of the challenges in setting up sanitation services in low-income and rural area is ensuring payment for these services. Many South Africans simply cannot afford to purchase a toilet system. The Pay-As-You-Go model has been used in other industries, allowing individuals to services such as energy as they use. Using mobile payments will enable remote payments to service providers and will allow service providers and users to connect and provide support when needed. Through communication between service providers and users, a trusted relationship can be built.

For these services to be successful and scalable, entrepreneurs need to partner with large companies and utilities. These strategic relationships will enable scalability of these operations. An enabling and favourable environment is crucial for the success of these operations, and to attract the needed investment.

It is important for PAYG to partner with mobile operators.

Access to a large potential customer base

Access to channels for remote payments

Knowldege of how to market digital services to customers

It has been shown through examples such as Sanergy and Sanivation, that closing the value chain loop can provide sanitation to communities in need, while creating an economic opportunity. These models function by implementing sanitation solutions though toilet infrastructure. The waste is generated by the users, contained and transported to an offsite treatment facility. Here, the waste is treated and converted into value-added products. These products are then sold to businesses and to community members. The profits from the sales of these products are then used to make these services affordable to the community. Not only are these operations bringing sanitation to communities, their products such as briquettes can be used as a cheaper and environmentally friendly alternative to wood. Creating trusting relationships with large industry off-takers is an important component in ensuring a continuous demand for your product. Other products such as fertilizer and protein feed are also produced from waste and provide necessary agricultural inputs in farming areas. These methods also ensure that waste is properly treated and no longer pose health risks.

Integrated Utility Services Model

This model can be applied to reinvented toilets where utility companies offer a range of reinvented toilets to its customers. These could be both residential and commercial customers who are in the process of developing homes, estates, or commercial buildings. Reinvented toilets will form part of the building design. Customers would avoid the high upfront costs associated with the technology and the fees paid to the utility will cover the capital costs over the contract period. Packages can range from basic to more sophisticated toilets depending on the needs and financial capacity of the customer. Customers will be properly educated on how to use the technology. Services and maintenance will be undertaken by the technology provider.

Cross-Subsidization Model

The cross-subsidization model utilizes profits generated from the sale of RTs to less price sensitive customers to fund the installation of RTs to more price sensitive customers. Less price sensitive customers could purchase high-end, luxury versions of the RTs, which will allow standard RTs to be installed in indigent and low-income communities. This model can increase the production output of the RT manufacturer which could lead to economies of scales much faster. The RT provider should commit to providing sanitation to its price-sensitive consumers to ensure the basic needs of consumers are met.

Challenges with this model include clarifying price points used in the two markets, as well as the costs associated with operation and maintenance of RTs in more-price sensitive markets. Including operation and maintenance costs in the model could increase the implementation costs substantially.

Civic Crowdfunding Model

The civic crowdfunding model incorporates both micro-finance and web-based crowdsourcing to provide sanitation to communities who are unable to afford it. This model utilizes citizen investment as well as businesses, non-profits who pledge to provide the necessary funding. The model could work through investment made by donors where funds are matched by municipal governments. These projects could be rolled out on larger scale and could enable multiple RTs to be installed in various locations.

This model requires strong leadership and engagement from communities in the planning and implementation of these projects. This model creates an alternative approach to providing basic needs to unserved and underserved communities. Revenue streams include donations, crowdfunding, rewards-based donations among others. Online platforms should be used to market the opportunity, to ensure continuous community-based support.

Attracting crowd funders could be challenging, as well as maintaining an influx of funds for the operating needs of the RT. Fundraising for the installment of the RT can be achieved through large fundraisers.

Advertising Model

The advertising model offers a source of revenue that can potentially offset the cost of sanitation for indigent and low-income consumers. It involves a municipality entering into a contract with a RT provider whereby the municipality grants access to land, while the RT provider is responsible for the installation, operation, and maintenance of the system. Advertising space on each toilet is made available and the revenue generated through advertisements is used to offset the cost of sanitation services.

This model should create long-term revenue streams which stem from the private sector. Advertising costs can range from basic to premium depending on the technology advancement of the toilet systems. Convenience stores or forecourts may also enter into agreements to provide sanitation services to customers. Due to the off-grid nature of RTs, advertising agents are able to reach consumers in remote areas. However, it may be a challenge to attract advertising agencies that aim to promote products or services to indigent and low-income consumers. This model will only generate a revenue stream once the RTs are already installed, therefore financing the capital investment of the toilets may be challenging.

Customer Experience Centre Model

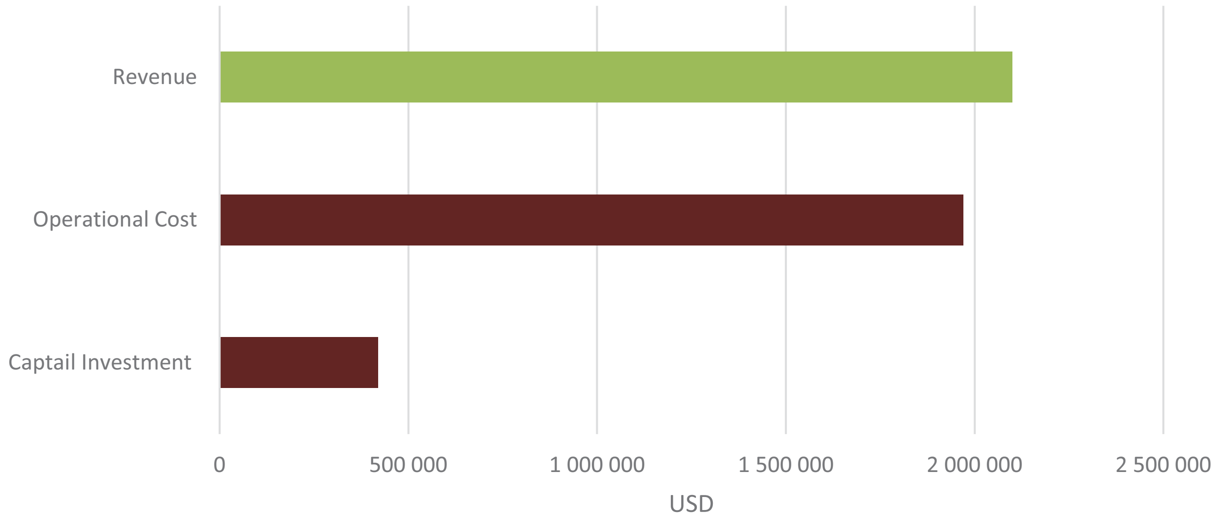
A customer experience centre can create awareness around the RT and build strong relationships with potential customers. Showcasing technology using the centre has been used to gain sales to customers such as Business-to-Business and Business-to-government, as it allows potential customers to interact with the product and the RT provider, and express their needs and offer feedback. The centre is used to educate potential customers and users, increase demand for the product, build brand recognition, create an events venue, and can be used to showcase complementary products as well.

When offering high-tech and unfamiliar products, this model works well to overcome the challenges associated with creating demand and can secure sales. However, high upfront costs are required to create an attractive and well-designed space, as well as skilled individuals to interact with potential customers.

Savings from beneficiated products

Circular economy business models have many advantages which include an added revenue stream created from processing waste. The raw material is in constant supply and can be utilized to produce products which will off-set the operational costs of sanitation services to indigent and low-income communities.

As an example, the capital investment and operational cost over a 10-year period, along with expected revenues for 1,000 households can be seen below. The data indicates that after the revenue produced from selling briquettes covers the capital investment, revenues are able to offset part of the operational costs associated with sanitation services.



Graph 1: Capital, Operational, And Revenue Generated From 1,000 Households Using a Circular Economy Business Model Over A 10-Year Period

The total cost of providing sanitation is drastically reduced in this case, creating an affordable solution to low-income households, and reducing the financial burden on governments and municipalities to provide sanitation services. This example further demonstrates the need to incorporate circular economy business models into the sanitation economy.

Source: GSMA, Replicating Pay-As-You-Go Utility Models Beyond Solar and East Africa; Toilet Board Coalition Virtual Summit: Circular Sanitation Economy Business Models, 2018; Sanitation Technology Platform, Creating the Path to Profitability for Reinvented Toilet, 2019; Ernst & Young, Toilet Board Coalition, Making Way for the Future of Sanitation, 2020; Sanivation, Bill & Melinda Gates Foundation, UNHRC, Container-Based Toilets with Solid Fuel Briquettes Guidelines, 2018; Toilet Board Coalition Virtual Summit: Circular Sanitation Economy Business Models, 2018

4.1 Product-as-a-service Model

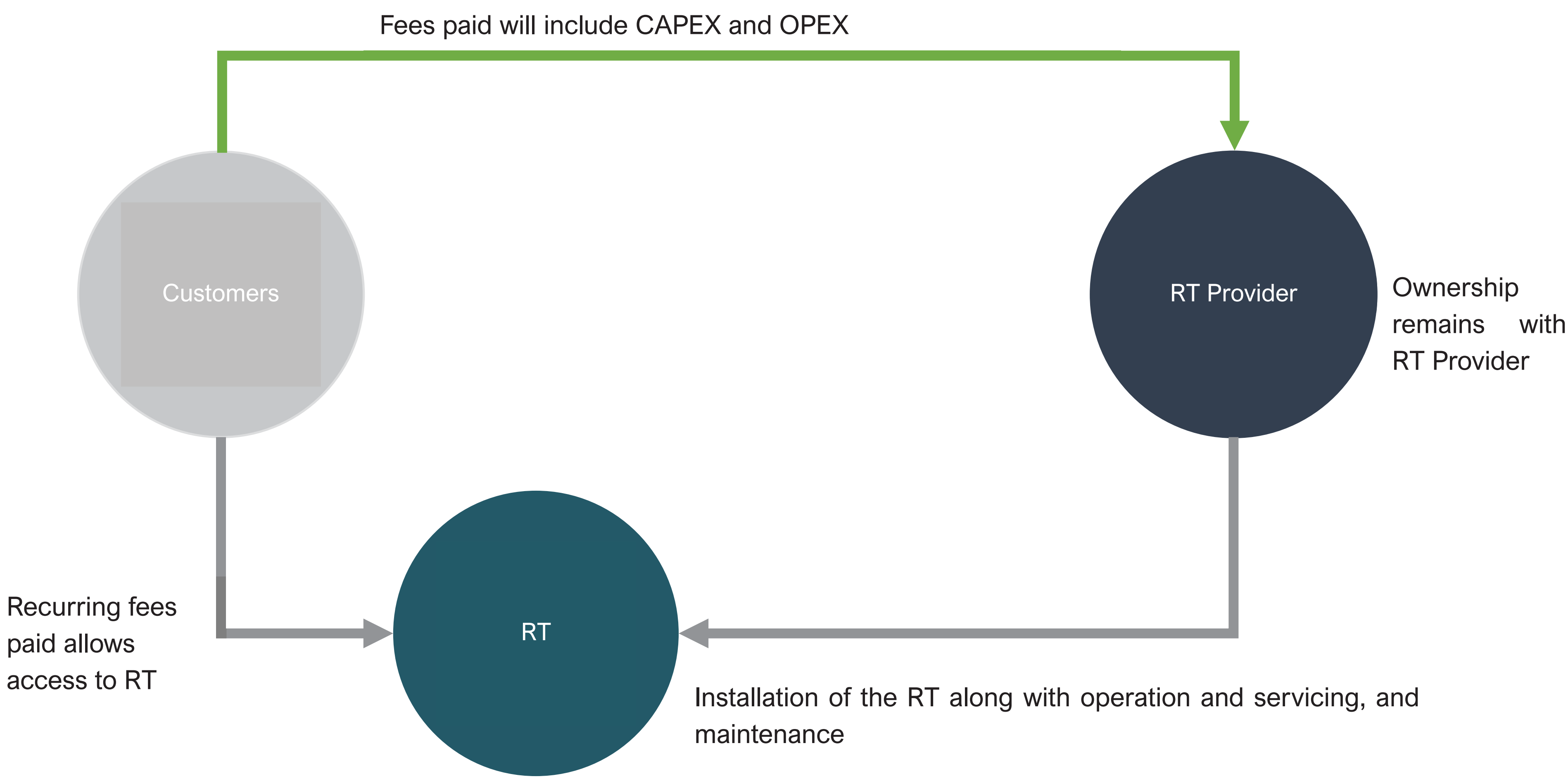


Figure 11: Product-As-A-Service Model

4.2 Integrated Utility Services Model

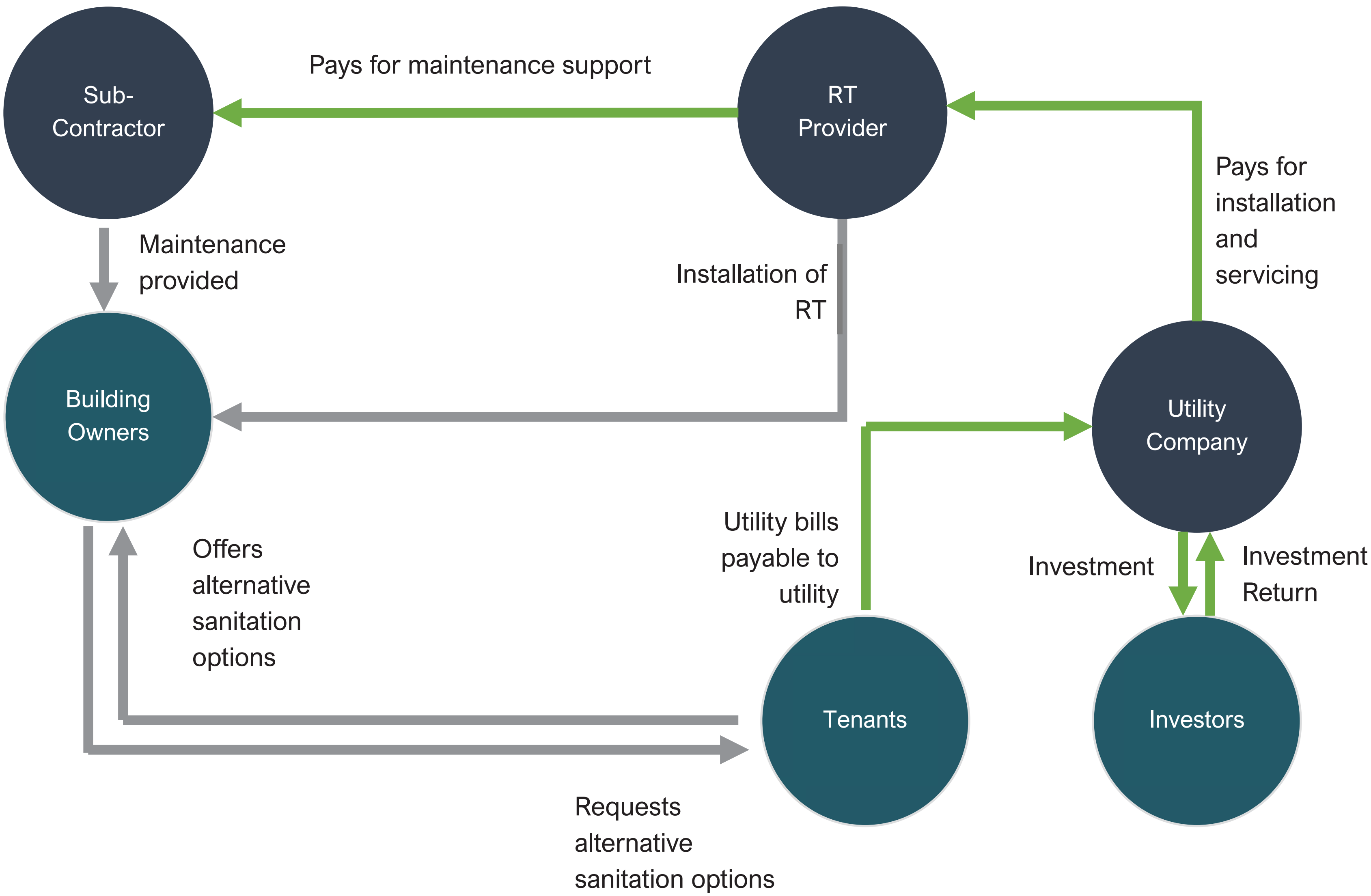


Figure 12: Integrated Utility Services Model

4.3 Cross-Subsidization Model

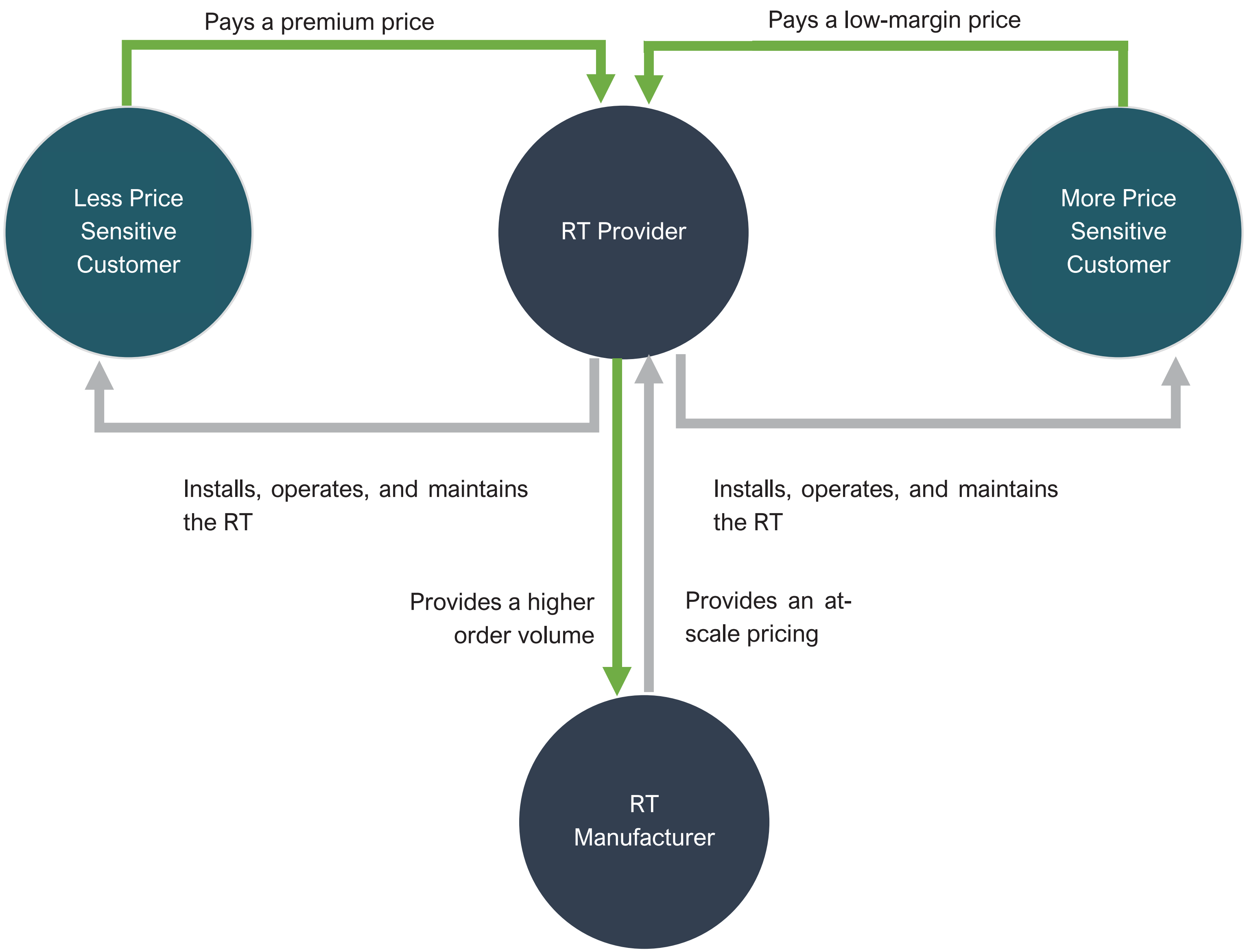


Figure 13: Cross-Subsidization Model

4.4 Civic Crowdfunding Model

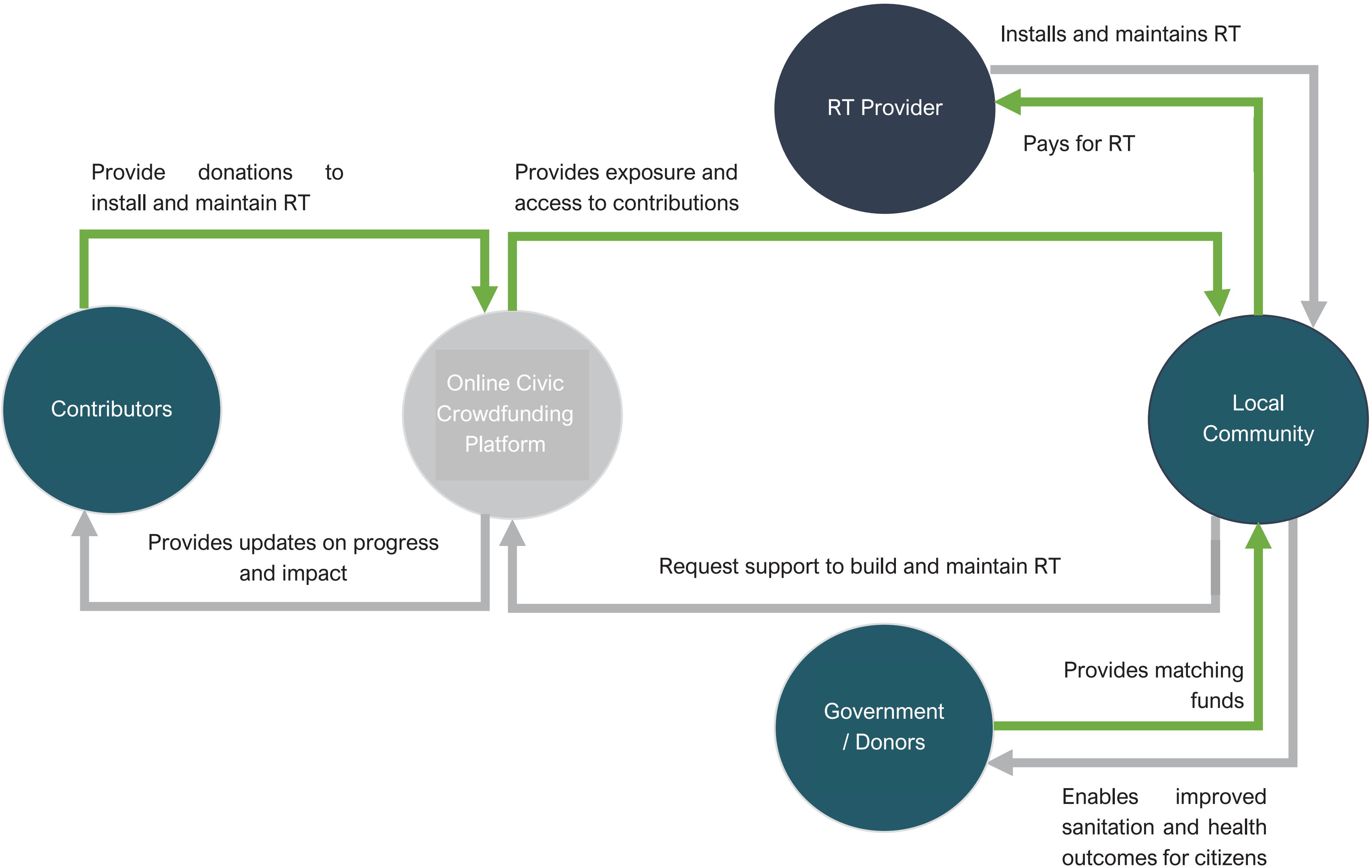


Figure 14: Civic Crowdfunding Model

4.5 Advertising Model

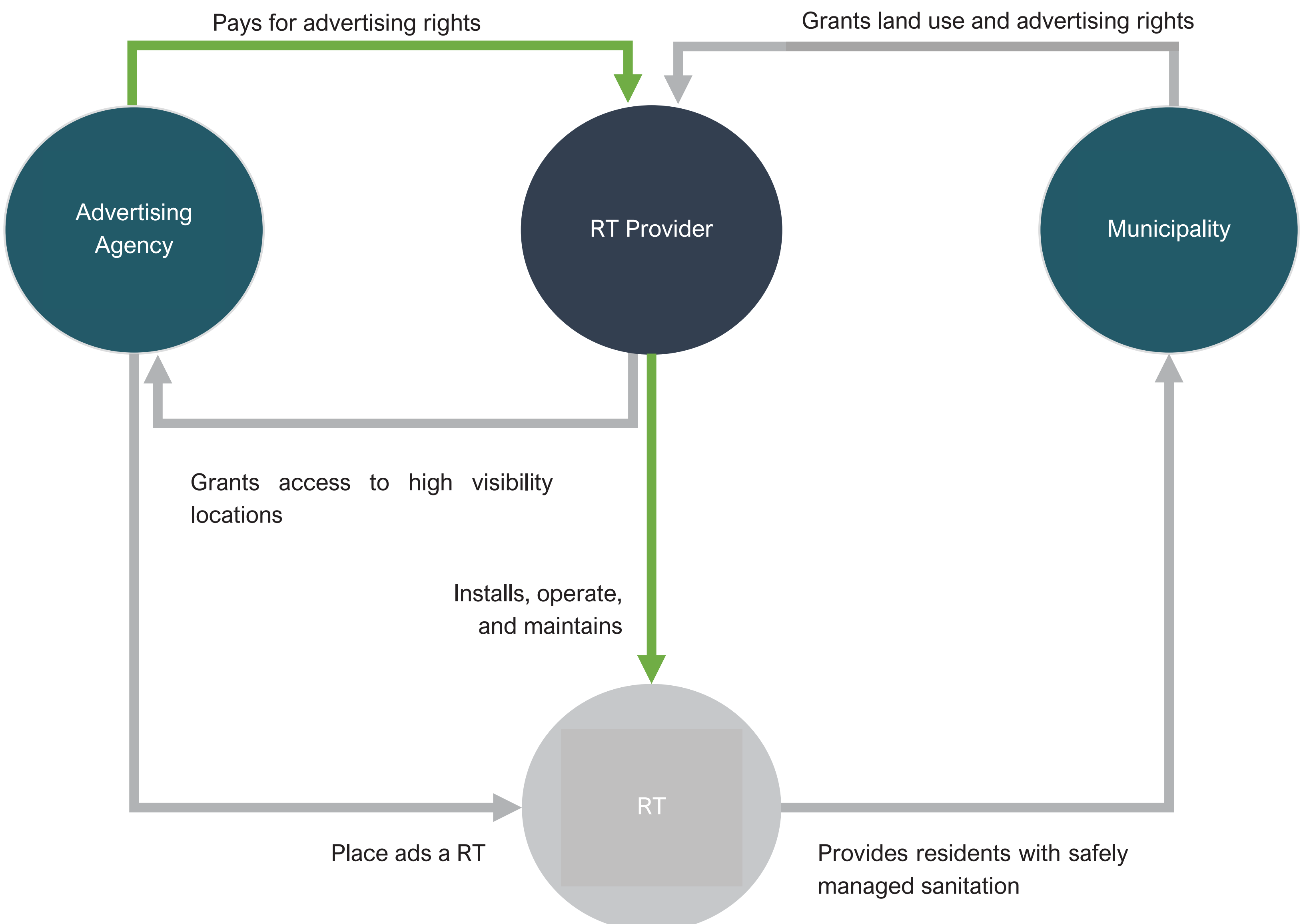


Figure 15: Advertising Model

4.6 Customer Experience-Centric Model

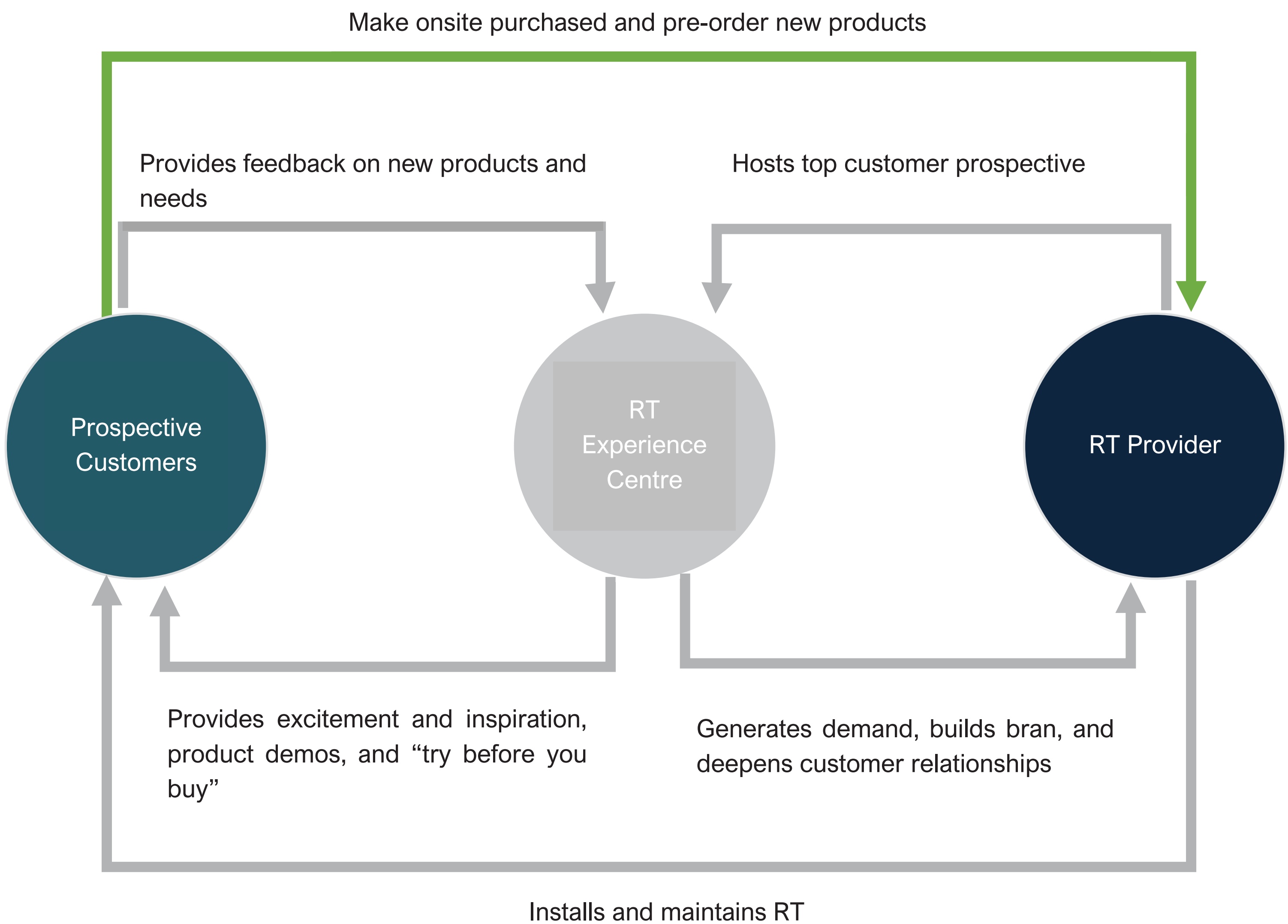


Figure 16: Customer Experience-Centric Model

5 MARKET CONSTRAINTS

The South African sanitation sector is faced with numerous challenges that hinder its growth and prevent basic sanitation from reaching a portion of the population. These challenges will be discussed below, along with the factors that drive and restrain the uptake of sanitation solutions in the residential, commercial and public sector.

5.1 Industry Challenges

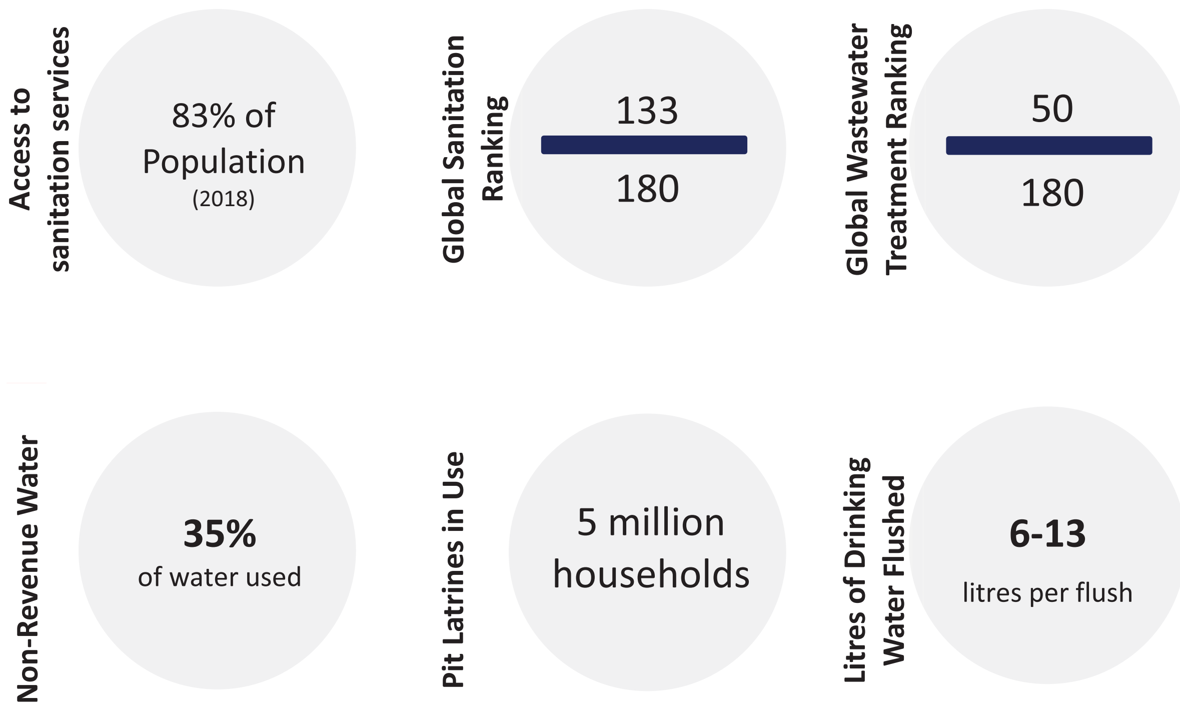


Figure 17: Key Facts: South Africa's Sanitation Sector

Source: Helen Suzman Foundation, Understanding Water Issues and Challenges, 2019; Environmental Performance Index; Statistics South Africa

Water Resource Management

To effectively provide sanitation services, South Africa's water resources need to be properly managed. Currently, many water resources are polluted through raw sewage and untreated effluent. Local governments oversee sanitation services and should be held accountable in upkeeping of water resources. The effects of climate change have caused South Africa to experience an increase in seasonal droughts. The Department of Water and Sanitation has also failed to establish catchment management agencies in all its catchment areas. If mismanagement of water and its resources continue, coupled with continued mismanagement, it will place an even greater strain on our sanitation sector.

Approximately 63% of all households have access to regular flush toilets and do not re-use water. The average toilet functions on a flushing system that consumes between 6 and 13 litres of drinking water. The increase in urbanization, population and demand for sanitation services has put a strain on the sanitation infrastructure, as well as rising demand of water which is pressurizing the supply.

Non-revenue water, which is the water lost due to leakages, theft, and billing errors, is estimated to contribute nearly 35% of water used. The Department of Water and Sanitation has also failed to establish catchment management agencies in all its catchment areas.

South Africa has various policies in place to prevent the release of untreated wastewater from industrial processes. The inherent fragmentation at different government levels responsible for water and wastewater management results in limited enforcement of these policies. As a result, industries are not penalized for releasing untreated wastewater.

Continuous release of grey water directly into the environment leads to increasingly polluted water resources. In addition, the declining water quality makes water treatment increasingly difficult and costly.

Financial Constraints

The Department of Water and Sanitation and its Water Trading Entity suffers from poor financial management, and has resulted in overspend, irregular expenditure and procurement. The expenditure does not match the outcome expected.

The mismanagement of funds results in low investment into infrastructure maintenance in an already near collapsed industry. These funds could be properly managed to expand the sewage network or install innovative toilet systems in rural areas to replace the current pit latrines.

Revenue collection from consumers for utilities and services have long been an issue. Between the years 2013-2018, collections were on average 11% less than expected revenue, causing municipalities to write off debt that cannot be recovered.

ZAR 117 Billion Allocated in MTEF to Water and Sanitation

To Serve Over 10 Million People Without Sanitation

USD 307 Highest Global Per Capita Spend on Water, Sanitation and Hygiene Annually

USD 141 Per Capita Spend on Water, Sanitation and Hygiene Annually in South Africa

Source: Statista

The average global spend on sanitation for various countries places the Netherlands at the top of the list with an annual spend of USD 307 per capita expenditure. South Africa is ranked 4th with an annual per capita expenditure of USD 141. This presents the extent of the challenge faced in South Africa, where expenditure is not equal to the outcome expected. The average spends across 50 select countries totalled USD 57.

Source: National Treasury: 2020 Budget Review; Statista

Infrastructure Deterioration

The current state of the South African water and sanitation infrastructure is poor, which is generally attributed to numerous factors which include:

- Low maintenance
- Low or no enforcement of policies
- Vandalism
- Misuse and mismanagement of funding
- Low level of investment
- Shortage or lack of proper skills required for upkeep

Low enforcement of water effluent standards paired with limited wastewater infrastructure has resulted in many of the existing water resources becoming increasingly polluted and more difficult to treat using existing facilities. This has exacerbated the need to repair and expand upon existing water and wastewater treatment infrastructure.

Leadership and Skills Shortage

The water sector in South Africa is critical for the economy in ensuring supply of water to meet the basic needs of its people. The skills required in this sector are acquired through training programmes at various Technicon's and degrees through universities allowing engineers and technicians to acquire the relevant skills. However, South Africa is experiencing a loss of expertise through emigration of their skilled labour force to other countries as the working environments are more favourable overseas.

The Department of Water and Sanitation experiences high levels of attrition, leading to high vacancy levels. The skills shortage hinders the process of employing appropriately skilled workforce to ensure specific roles and functions can be carried out.

According to the Energy and Water Sector and Education Training Authority (EWSETA), the following are priority skills for the water sector:

1. Water Quality Analyst: Wastewater Treatment Officer/Technician
2. Engineering Manager
3. Civil Engineer
4. Mechanical Engineer
5. Environmental Engineer
6. Project Manager
7. Water Plant Operator
8. Environmental Scientist

These skills/experience can be obtained through degrees, learnerships, and other skills programs in order to produce skilled individuals who are applicable to work in this sector. EWSETA continues to partner with private and state-owned companies to further develop employee skills.

Training and upskilling of South Africa's high level of unemployed youths can help to further mitigate the issues surrounding constant repairs and maintenance required by the deteriorating sanitation system. The unemployment rate for individuals aged between 15-24 years is currently 55%, while the unemployment rate of individuals aged between 25-34 years in 34%

According to StatsSA, the vacancy rate in the Waste Management and Wastewater Management departments are currently 15% of total vacancies (excluding managerial positions) within municipalities.

Source: EWSETA, Annual Performance Plan, 2019-2020; Stats SA, Non-financial census of municipalities for the year ended 30 June 2018 (Note: The 2019 statistics release is expected August 2020); Stats SA, Youth Unemployment Rate, 2019

5.2 Drivers and Restraints

The section aims to highlight the drivers and restraints affecting the residential, commercial, and public sanitation sectors in South Africa.

Table 8: Summary of The Drivers and Restraints Affecting the Residential, Commercial and Public Sector

	Drivers	Restraints
Residential	• Poor Service Delivery • Sustainable Development Goals • Population Growth and Urbanisation and Willingness to Pay	• Cost of retrofitting • Reliability and Availability of Innovative Technologies • Flush Toilets: The Gold Standard
Commercial	• Water use and wastage by users • Greening of Commercial buildings • Space Saving Technologies	• Aesthetic and Quality of Products • Cost and Difficulty of Retrofitting • Regulations
Public	• Water Use and Wastage • Improve Access to Sanitation • Beneficiation	• Availability of funding/Investment • Maintenance • Education

5.2.1 Residential Drivers and Restraints Explained

Drivers

Poor Service Delivery

Residents in areas with poor service delivery, where government/municipalities have failed to provide basic sanitation will look at alternative solutions that are off-grid and require zero or low water usage. Alternative toilet infrastructure will particularly be useful in drought-stricken areas with low sewage infrastructure. Despite the shortfall of water and sanitation infrastructure, existing infrastructure is poorly maintained and, in some cases, no longer operational.

Sustainable Development Goals

South Africa is faced with a dual economy. On the one hand is the developed side, which has been exposed to the flush toilet as the norm, and now want to improve the current state of their systems. This portion of the economy will aim to install systems that reuse, reduce, and recycle water. These systems are generally only installed with individuals with high disposal income. The underdeveloped economy, where disposal income is considerably lower, users are not expected to implement such systems.

Population Growth, Urbanisation, and Willingness to Pay

Urban water and wastewater infrastructure are extremely limited for the current urban population. Urbanization increases the pressure on existing infrastructure. With more people moving to the cities, additional pressure is placed on infrastructure, driving the need for more sanitation solutions. However, there remains a larger percentage of the population without sanitation in indigent and low-income communities that cannot afford to pay for basic sanitation services. This creates an even burden on government and municipalities to provide sanitation services that are financially viable and sustainable in the long run. Innovative business models will be required to implement services to these communities.

Restraints

Cost of Retrofitting

The cost of retrofitting existing toilet infrastructure could hinder residential consumers from installing alternative technologies. The upfront costs of installation could be balanced out by the low/zero water use and savings associated with water utilities and sewage removal, but likely to take approximately 10 years. Many residential consumers, who reside in urban areas with proper sanitation infrastructure and access to water, will be unlikely to invest in change.

Reliability and Availability of Innovative Technologies

Residential consumers may also be hesitant to install new technology, as the concept of unfamiliarity scares people off new innovations in addition of concerns about the availability of maintenance and servicing.

Despite the availability of innovative and sustainable substitutes, poor access to these products obstruct consumers from making fully informed decisions on their preferred choice in technology, as retail outlets do not stock these products.

Flush Toilets: The Gold Standard

Residential consumers residing in rural areas without access to basic sanitation services desire a flush toilet, as this is the norm in urban areas. Many rural consumers are unwilling to adopt innovative technologies whereby no or little water is used. Without educating these communities on the benefits of these systems, it will be difficult to alter the mindset of these communities.

5.2.2 Commercial Sector Drivers and Restraints Explained

Drivers

Water Use and Wastage

It is estimated that in commercial buildings, toilets are flushed more frequently than toilets in residential buildings. On average, it is estimated that an employee will flush the toilet two to four times a day during an average eight-hour workday. The cost of utilities (water and electricity) account for a large portion of expenses to operate commercial properties. This is due to the volume and frequency with which toilet facilities are used. Utility costs can be notably reduced by installing low flush water toilet systems. It is estimated that a buildings' water use can be reduced by approximately 60% if flush volume is reduced from 8 litres to 3 litres. According to SAPOA, municipal charges have increased over the years and account for the largest percentage of operating costs, approximately 60%.

Greening of Commercial Buildings

Green Building Council South Africa (GBCSA) is internationally recognized and is considered a trusted mark of quality for the design, construction and operation of buildings, interior fit outs and precincts. The GBCSA has developed the Green Star SA rating in order to provide South Africa and Africa as a whole with an objective measurement tool for green buildings. The system is geared to award environmental leadership in the property industry. The green star rating system is based on credit tools for nine different categories including water use, each with a range of credits that address environmental and sustainable aspects in terms of designing, constructing and operating a building. In recent years, a trend has emerged that sees many companies shifting towards creating a greener built environment. In doing so, companies will opt to install environmentally friendly solutions that could reduce water and energy use, while simultaneously implementing water re-use measures. This includes systems where grey water is recirculated for toilet flushing. Furthermore, newer build commercial buildings have gone off grid and no longer rely on municipal water by installing their own filtration plants.

Space Saving Technologies

Given that innovative solutions are often more compact, in cases where basins are built into the design, implementing these solutions results in freed up space in a market where space equates to revenue generated. This could drive the uptake of compact sustainable solutions in newly developed commercial buildings.

Restraints

Aesthetic and Quality of Products

The commercial market is slightly different to other markets whereby quality, and finish of the product is important. Many alternative toilet systems are not available in various designs and fail to meet the aesthetic requirements of these buildings. This will deter its implementation and result in the use of conventional systems.

Cost and Difficulty of Retrofitting

Retrofitting of a toilet entails the process of either adapting or replacing an older, high water-using toilet fixture with a newer, modern and water efficient technology now on the market. Retrofitting offers a considerable water saving potential for both homes and businesses. Toilet retrofitting includes generally two options. The first option involves the installation of a water-saving device inside the tank. Such devices include the water retention device, the water displacement device or the alternate flushing device. The second option is often applied to toilets that are 15 years or older and therefore characteristically flush with considerable amounts of water. This option usually involves the replacement of the old toilet with a newer, ultra-low-volume toilets. Naturally, the first option is a more capital cost friendly option as the devices are generally cheap. However, by retrofitting older toilets with newer water-saving but capital-intensive toilets, considerably higher long-term money savings can be achieved.

Regulations

In general, the Water Service Act of 1997 requires both industrial bodies as well as the residential sector to acquire permission from a water service institution prior to installation of any treatment or storage facilities. This is primarily because these regulatory bodies are responsible in ensuring that the effluent does not pose any health risk and to ensure proper safety precautions wherever greywater is accessible in any shape or form. The City of Cape Town has passed a legislation that came into effect in November 2017 which allowed commercial buildings to produce water on a larger scale.

5.2.3 Public Sector Drivers and Restraints Explained

Drivers

Water Use and Wastage

The cost of utilities (water and electricity) accounts for a large portion of expenses for to run public properties. This is due to the volume and frequency with which toilet facilities are used. Utility costs can be notably reduced by installing low/zero water toilets.

Given that many public toilet facilities are not regularly maintained and serviced, issues related to blocked/leaking toilets often go unnoticed for periods of time. Installing low water use toilets will reduce the possibility of non-revenue water losses.

Improve Access to Sanitation

With many South Africans without basic sanitation, installing off-grid, low water usage toilet systems are a way of providing these basic services to people especially in water constrained areas in South Africa.

Rural schools no longer need to rely on the central sewage system. Alternative toilets can be easily installed in areas with low/no access to water. Installing sewage pipes is costly, and time consuming. The use of septic tanks and pit latrines are costly to manage and require frequent disposal.

Beneficiation

Alternative toilets do not only provide basic sanitation solutions but convert waste into useful products such as fertilizer and briquettes. These products are specifically useful in rural areas where briquettes can be used as a source of fuel and fertilizer can be used in agricultural purposes.

The conversion of waste reduces the need for disposal, which if not done correctly, causes significant health risks for surrounding communities.

Restraints

Availability of funding/Investment

Although the need for investment in sanitation infrastructure is being increasingly recognized, the availability of funding is a persistent issue. Water is not a high revenue commodity and non-payment is fairly common, resulting in decreased municipal funds for water projects.

This is further compounded by the reliance on multi-lateral and bi-lateral organizations for funding of water related projects.

Maintenance

The lack of maintenance and servicing of these units in rural and remote locations will lead to infrastructure deterioration and eventually fail to serve its intended purpose.

However, employing and training individuals in these areas to service and maintain toilets will provide necessary job creation.

Education

A lack of education on basic sanitation, wastefulness, and the use of new toilet infrastructure is required for the implementation of these technologies to work. Many rural communities continue to practice open defecation, which leads to pollution of precious resources. Many strive toward conventional flush toilets, hence the mindsets of these induvial need to be altered. This would essentially be easier to overcome in the younger populations.

6 COMPETITOR ANALYSIS

6.1 Conventional Ceramic Toilets Industry

The global ceramic sanitary ware market is expected to reach approximately USD 45 billion by 2025. As urbanisation occurs in developing countries, the demand for ceramic sanitary ware continues to grow. This is due to developing countries increasing basic hygiene levels and gaining access to basic sanitation services. Governments and municipalities in developing nations continue their attempts to provide basic services to their country's most vulnerable, and in many cases, in the form of standard ceramic toilets. Conventional players such as Villeroy & Boch and Simas are incorporating resource efficient systems into their range of products, which flush approximately 4.5 litres of water.

The commercial sector will continue to drive the growth of the ceramic ware industry as frequent use of sanitation infrastructure requires higher levels of replacement when compared to the residential sector. The rise in new developments such as hotels, shopping malls, and office parks will continue to create a demand for ceramic ware.

New entrants producing alternative toilet technologies will disrupt the current market share but will provide a low level of threat to conventional toilet manufacturers in urban areas. It is difficult to market dry sanitation solutions when individuals are aspiring to the flush toilets. It takes education and a change in mindset for individuals to take up the idea. Another barrier to entry for these companies is shelf space. Many products suitable for off the rack buying, and can be easily installed by regular plumbing services, are not marketed to the general public. It is challenging for these companies to penetrate chain stores, despite producing quality products in line with SABS. No incentive or any competitive advantage exists for these companies when these products are sustainable and locally produced. There is currently little to no incentive for regular consumers who have access to flushing toilets to invest in alternative solutions. Consumers are known to panic buy when disaster hits such as water shortages which plagued South Africa. This resulted in boosted sales for water saving, water efficient, and off grid solutions. Residential consumers in urban households are however more likely to opt for innovative system whereas rural residential consumers will continue to strive for flushing toilets.

Conventional toilet suppliers have always had a high bargaining power as they are providing a product that is known, and familiar. The government, in an attempt to provide sanitation to communities without access to the sewage network, are looking into supplying off-grid sanitation solutions that are safe to use. This will provide sustainable toilet solutions with a competitive edge against regular flush toilets.

6.2 Company Profiles

The profiles of leading ceramic sanitation equipment suppliers can be found below.

Ceramic Industries Ltd		
Ceramic Industries Ltd is the largest producer of floor and wall tiles, as well as a major sanitaryware manufacturer in South Africa. It has 6 tiles factories (Vitro, Pegasus, Samca floor, Samca wall, Gryphon and Centaurus), 1 acrylic bath factory (Aquarius) and one sanitaryware factory (Betta). Betta Sanitaryware supplies approximately 50% of the local sanitaryware market.		
End User Groups		
Residential: Urban households Suitable for **Commercial** and **Public buildings**		
Effluent Type: Standard effluent flow connected to the sewage systems		**Manufacturing capacity:** The production facilities in Johannesburg have a maximum manufacturing capacity of 2 million sanitaryware pieces per year
Contact Details	**Website:** www.ceramic.co.za **Email:** +27 (0)16 930 3600 **Tel:** info@ceramic.co.za	

Vaal Sanitaryware	
Vaal Sanitaryware is a subsidiary of Lixil Group Corp. along with other brands such as Cobra and GROHE. The company is a leading manufacturer and supplier of fireclay and vitreous china sanitary products. Together with Betta sanitaryware the companies are responsible for approximately 80% of the sanitaryware supply pf the local market.	
End User Groups	
Residential: Urban households Suitable for **Commercial** and **Public buildings**	
Effluent Type: Standard effluent flow connected to the sewage systems	**Manufacturing capacity:** The production facilities in Johannesburg have a maximum manufacturing capacity of 806 000 sanitaryware pieces per year
Contact Details	**Website:** www.lixil.co.za/brand/vaal **Email:** sales.africa@lixil.com **Tel:** +27 (0)861 21 21 21

Lecico South Africa	
Lecico South Africa is part of Lecico, one of the largest producers and global exporters of sanitaryware ceramics in the world. The company was founded in 1959 in Egypt and is a public company listed on the London and Cairo Stock Exchange. Over the past 20 years, the company has been accredited as one of the largest ceramics importers into South Africa with an established distribution network in most African markets, with added duty & logistical savings in many African countries. Lecico South Africa is the sole distributor of Lecico products in southern Africa.	
End User Groups	
Residential: Urban households Suitable for **Commercial** and **Public buildings**	
Effluent Type: Standard effluent flow connected to the sewage systems	**Manufacturing capacity:** The two production facilities in Egypt have a maximum manufacturing capacity of 6.2 million sanitaryware pieces per year

Contact Details	**Website:** www.lecicosa.co.za **Email:** info@lecicosa.co.za **Tel:** +27 (0) 21 531 9484

Geberit Southern Africa (Pty.) Ltd, Johannesburg	
Geberit Southern Africa is part of Geberit International, a company based in Switzerland with 29 production facilities of which only 6 are located outside of Switzerland, mainly in Europe, Asia and America. The company offers an extensive range of sanitaryware in addition to faucets and other supply systems	
End User Groups	
Residential: Urban households Suitable for **Commercial** and **Public buildings**	
Effluent Type: Standard effluent flow connected to the sewage systems	**Revenue:** CHF 647 million
Contact Details	**Website:** www.geberit.co.za **Email:** sales.za@geberit.com **Tel:** +27 (0) 11 444 5070

Bijiou	
Bijiou is a local company that offers its products in several retail stores but most prominently with Tile Africa in the major cities of South Africa (Cape Town, Johannesburg, Durban).	
End User Groups	
Residential: Urban households Suitable for **Commercial** and **Public buildings**	
Effluent Type: Standard effluent flow connected to the sewage systems	**Revenue:** N/A

Contact Details	**Website:** www.bijiou.co.za **Email:** info.cpt@macneil.co.za **Tel:** +27 (0)21 507 3040

Roca Group	
Roca is a Spanish producer of sanitary products with a presence in more than 135 countries. The company acquired Swiss manufacturer Keramik Holding LAUFEN in 1999 forming the Roca Group. The company further acquired Indian sanware company Parryware in 2006. The company has production plants in Europe, South America, Asia and Morocco. The company exports its products to South Africa.	
End User Groups	
Residential: Urban households Suitable for **Commercial** and **Public buildings**	
Effluent Type: Standard effluent flow connected to the sewage systems	**Net Income:** EUR 95 million
Contact Details	**Website:** www.roca.co.za **Email:** info@roca.co.za **Tel:** +27 (0)11 327 6536

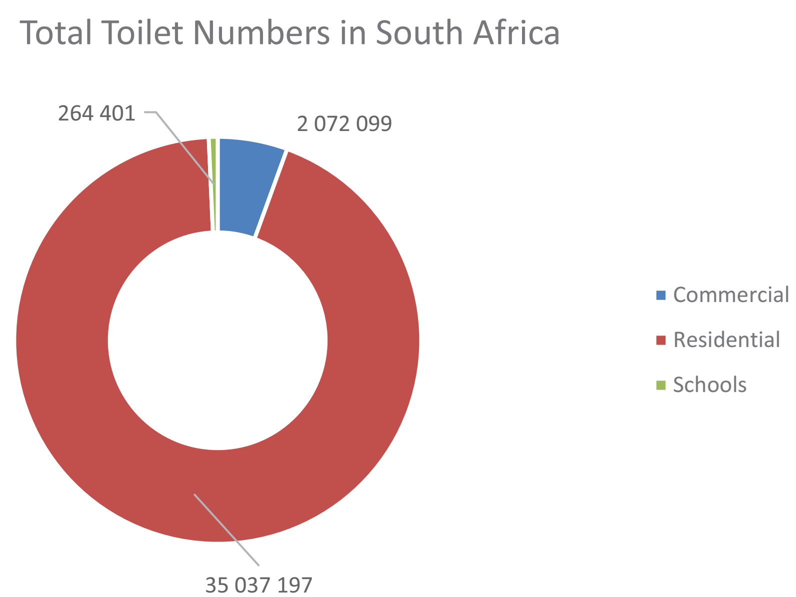
7 THE TOILET ECONOMY ASSESSMENT

7.1 The Total Toilet Market

An assessment of the toilet economy was conducted to determine the current and future size of the market. The market is made up of the residential sector in both a rural and urban setting within the different income classes that are present in South Africa, and the commercial and public sectors. Each sector will be individually discussed below in terms of their market size, the technology application used, and how the growth of the sector is affected.

In the public sector, users are referred to those individuals or institutions that make use of the toilet facilities, whereas consumers are referred to those that purchase and have toilet facilities installed. In this case, examples of users are public schools, rural households, public toilets, whereas consumers are government departments, municipalities, commercial property owners.

The total number of toilets in South Africa is estimated at 37.3 million units, with the residential market dominating the market with 94%. This is followed by the commercial sector with 6%, and the public school's sector with 1%.



Graph 2: The South African Current Toilet Market

Market Estimation Summary

The market for sanitation is estimated in rand, taking account of the commercial, residential and public toilets. The market was also sized by the number of toilets in each type, i.e. Flush (sewer), flush (tank), pit latrines, chemical toilets etc. These are all indicated in the model.

The rand estimate was based on the number of toilets and the estimated cost per seat for each toilet type. Costs per seat were determined from various sources, both secondary, primary and from looking at quotes. The annual operational cost per toilet type was also determined and similarly based on primary, secondary and quoted information available. Primary information was from interviews with industry stakeholders and toilet manufacturers or suppliers. Secondary information refers to reports in the public and private sector. Quoted information was used to corroborate information found and could be listed in newspaper articles or independent studies.

Source: Online quotes for toilet installations of various types and technologies. South African Property Owners Association (Municipal Services Cost Report), Metro Tariff Reports, South African Sanitation Technology Demonstration Programme

Sanitation revenue was split into the following:

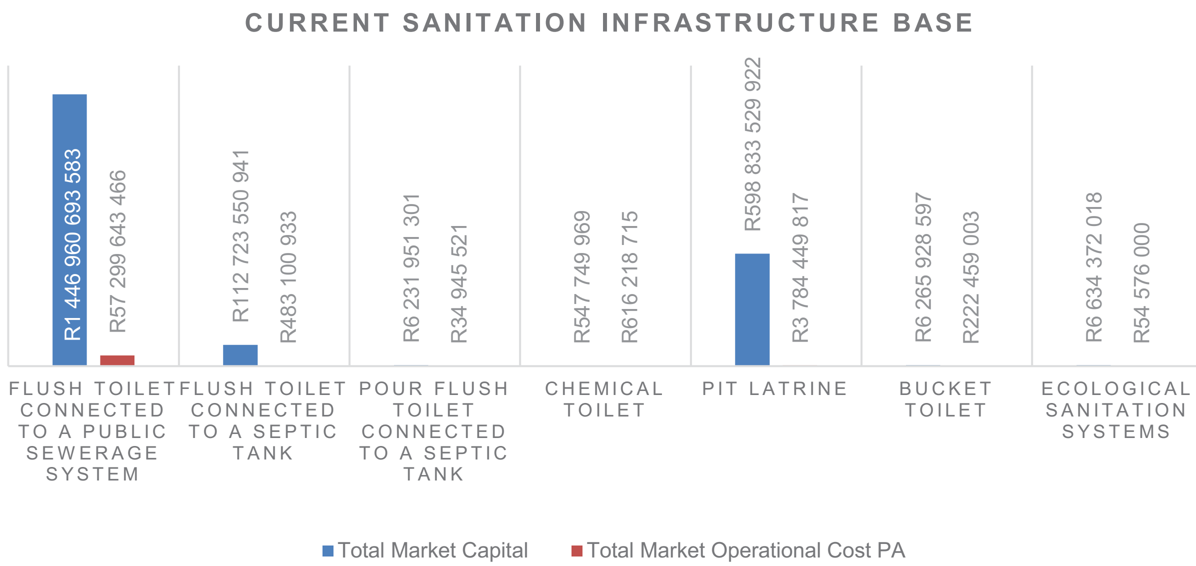
1. Capital revenue (including works) – including the construction revenue of the toilet buildings and installation
2. Capital revenue (excluding works) – excluding the construction revenue of the toilet buildings, only including the toilet and direct infrastructure, such as pipes, connections, services, toilets and pits.
3. Operational revenue – the revenue from operation and maintenance of the toilet facility

The market has been represented in variations of the above and also by the total asset base vs. the annual market revenue.

1. Total infrastructure base (including works) – this is the market revenue of all installed toilets in South Africa, including the construction revenue of buildings
2. Annual sanitation revenue (including works) – this is the annual revenue generated from new installation of toilets in South Africa (2019 base year).
3. Total infrastructure base (excluding works) – the market revenue of all installed toilets in South Africa, excluding the revenue of buildings
4. Annual sanitation revenue (excluding works) – annual market revenue generated from new installation of toilets in South Africa (2019 base year). This excludes the revenue of buildings
5. Annual sanitation operational revenue – the operational revenue will include the revenue generated from servicing the current infrastructure base, as well as, the new build of toilets in a particular year

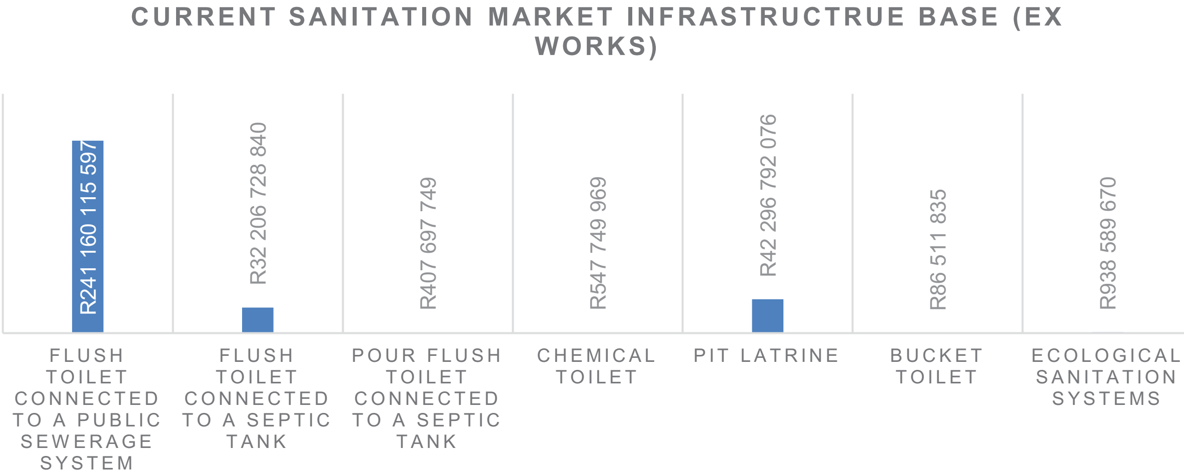
NOTE: *When referring to the market size of sanitation in South Africa the Annual market of new installations and total operational revenue of servicing all past and new infrastructure is included in this number. The installation revenue is represented separately from operational revenue for reference purposes.*

The graph below illustrates the monetary size of the current sanitation **infrastructure base market in South Africa**, by the various technology types that are present in the country across the different markets. The chart indicates capex and opex. The data indicates that flush toilets connected to sewer systems, and pit latrines, have the largest capital investments across the technology types, along with the largest operational revenue potential for municipalities. The total capital investment into toilets (including works) in South Africa currently totals R2,178.2 billion.



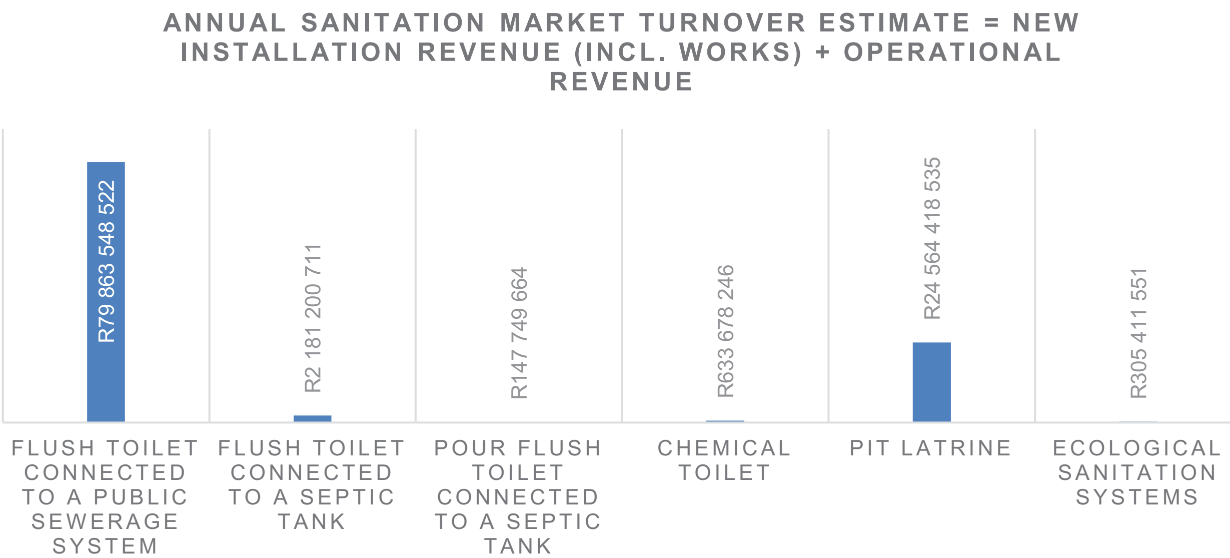
Graph 3: The Total Current Sanitation Infrastructure Market in Terms of Total Capital and Operational Revenue

Similarly, the current infrastructure base excluding works also shows that the largest capital base is for flush toilets and pit latrines. The total investment into toilet infrastructure in South Africa (excluding works) totals R317.6 billion. The total operational revenue for sanitation in South Africa in the base year (2019) was R62.5 billion.



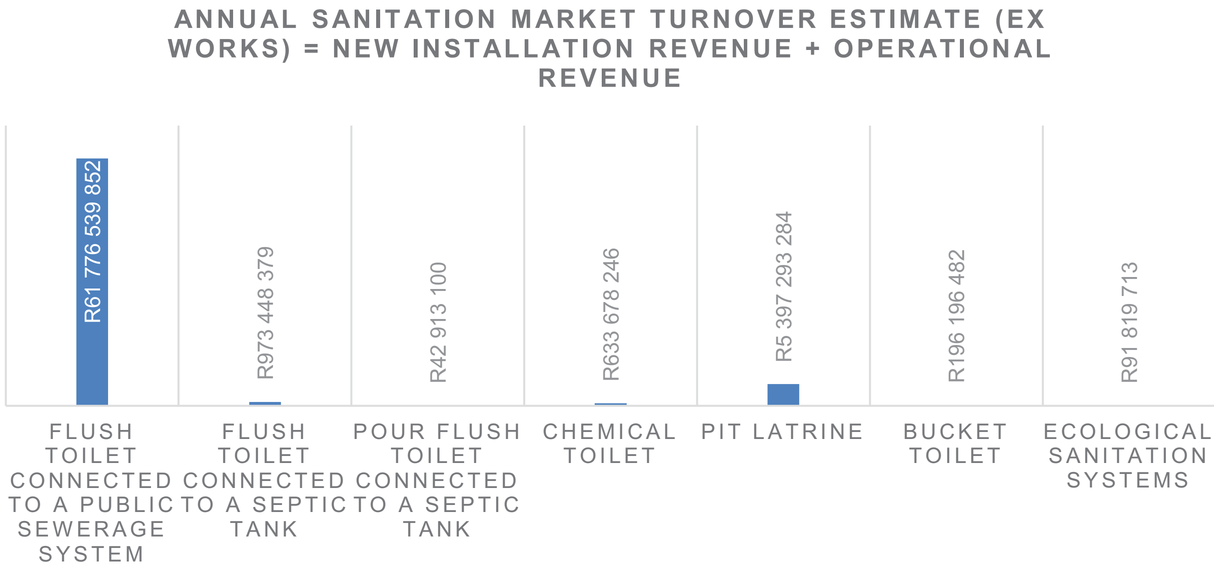
Graph 4: The Total Current Sanitation Infrastructure Market in Terms of Total Capital Excluding Construction Works

If we consider the annual sanitation market (including works), it will include the revenue from new installations with construction revenues for buildings, as well as the total annual operational revenue. This market is presented in the chart below and totals R107.4 billion in the base year.



Graph 5: The Total Current Sanitation Infrastructure Market in Terms of Total Capital and Operational Revenue

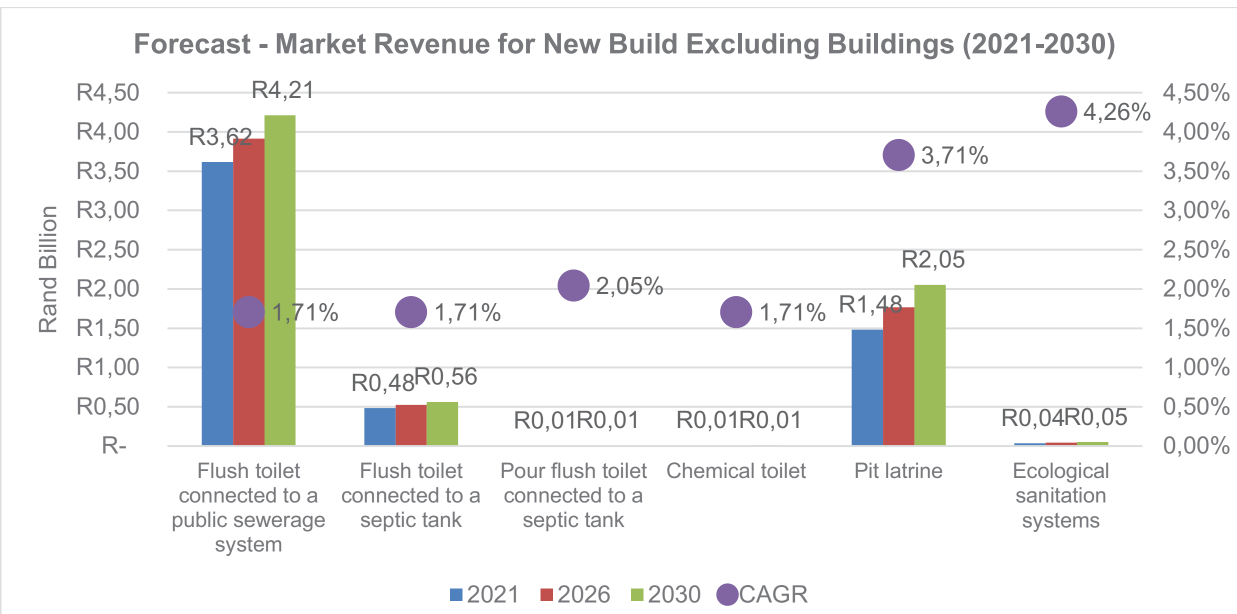
If the construction revenue (including buildings) is excluded from the market, the annual revenue totals R69.1 billion. This indicates that approximately R38.3 billion was allocated to construction of buildings in the sanitation market in 2019.



Graph 6: Annual Sanitation Market Turnover Estimate (Ex Works) = New Installation Revenue + Operational Revenue

Market Forecast Summary

The forecast of the market revenue was also done. The chart below shows the revenue growth from 2021 to 2030 for new installations that exclude the construction revenue.



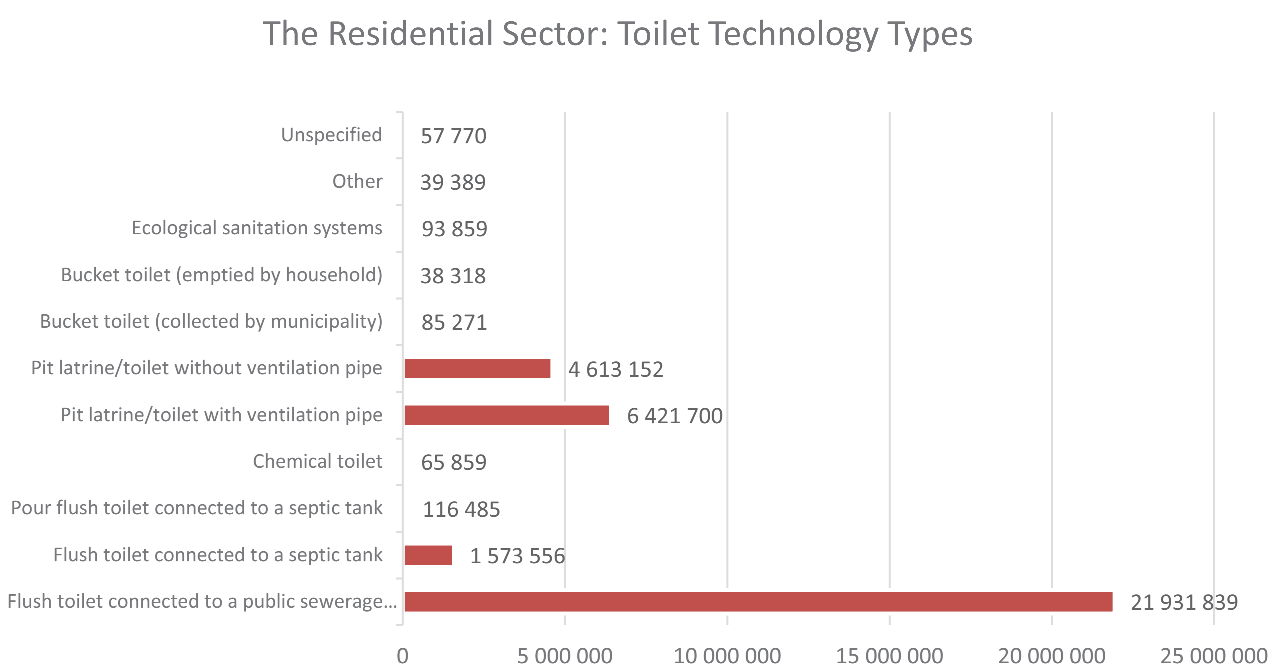
Graph 7: Market Revenue Forecast for New Toilet Installations (Excluding Buildings) from 2021 to 2030

Note: Increased growth in Pit Latrines is accounted by Ventilated Improved Pit Latrines

Growth rates were calculated using the forecast of the construction industry, the new builds in schools and reduction of pit latrines and bucket toilets that are replaced by other systems. The replacement rates on-or-off grid were also considered in the forecast. The increased use of ecological systems presents a growing opportunity moving forward.

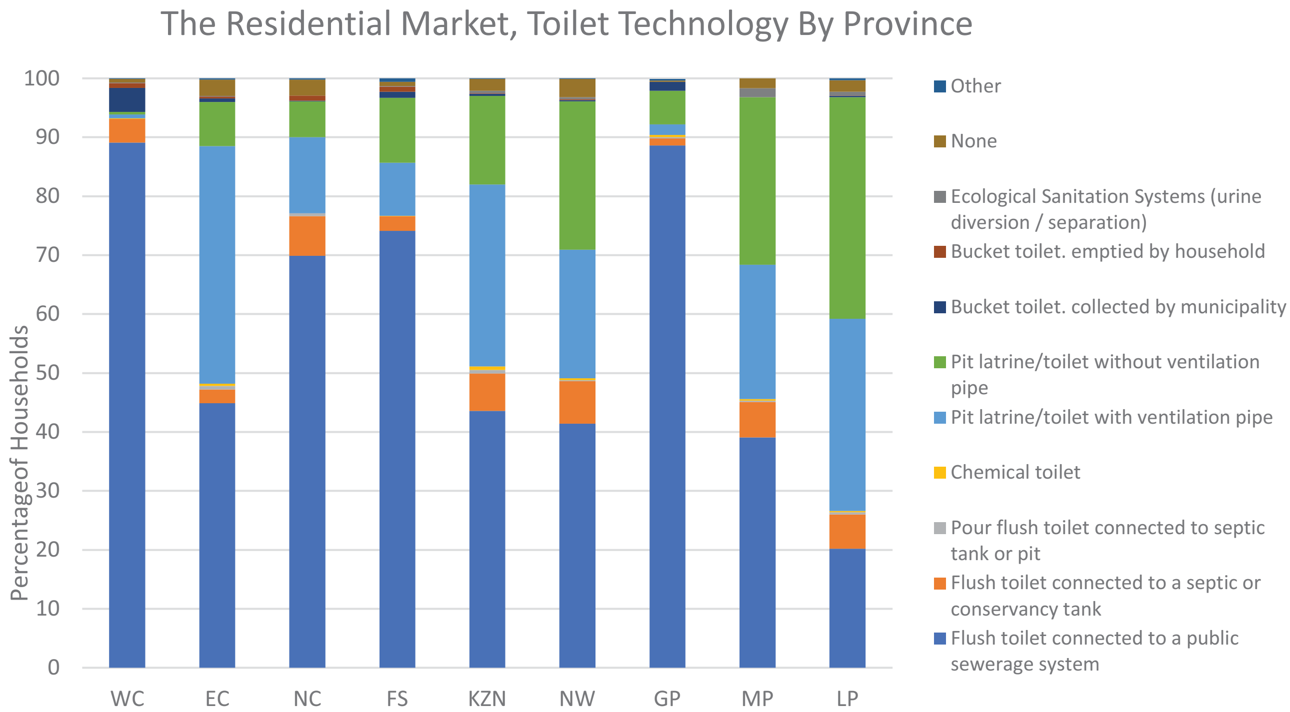
7.2 The Residential Toilet Market

The residential sector in South Africa is comprised of over 16.5 million households distributed across the provinces. These households vary in the number of occupants, income groups, geographic location and social settings, and the services they have access to. All these factors contribute to the makeup of technologies used within the sanitation sector. It is estimated that a total of 35 million toilets are present across South Africa's residential sector. The majority of households in South Africa have access to flush toilets that are connected to the country's vast sewage network. Flush toilets are present in 63% of households. Pit toilets are considered unacceptable as a form of basic sanitation and need to be replaced. The large number of bucket toilets in use also presents an opportunity for replacement.



Graph 8: The Residential Sector: Total Toilets Installed by Technology Type

The distribution of sanitation technologies varies across the provinces, where provinces such as the Eastern Cape are home to 40% of households with pit toilets compared to just 0.7% in the Western Cape. Only 20% of households in Limpopo are connected to the sewage system with a shocking 70% of households using pit and VIP toilets.



Graph 9: The Residential Market: Toilet Technology Type by Province

Multiple technologies in the residential sector are not acceptable forms of sanitation which include pit toilets, and bucket toilets, while an estimated 232,000 households do not have any form of sanitation. Pit toilets, VIP pits, and bucket toilets are most commonly found in informal and traditional dwellings. Many of the toilets in place are not adequate forms of sanitation and are often broken, dirty, lack sufficient lighting and are not safe to use. Improper construction of pit toilets on unstable land, and in areas prone to flooding create high risks for users. The implementation of toilet facilities in indigent and low-income areas is not enough. Often toilets are not serviced and well maintained and lead to the deterioration of infrastructure. The constant installment and replacement or servicing required leads to high and unnecessary costs incurred by government. When implementing sanitation facilities to these communities, it is important to consider various factors, as outlined in Section 1.7.

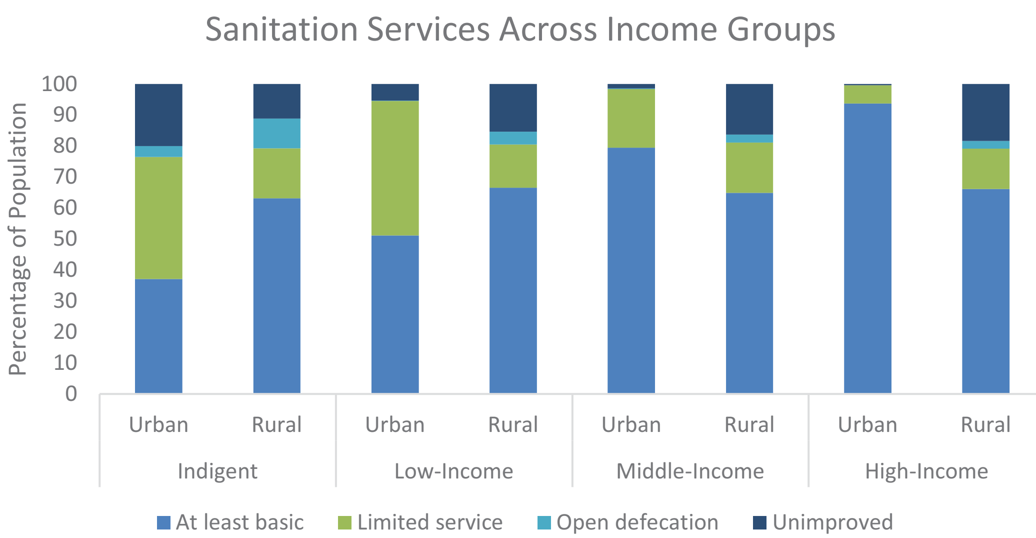
The residential market can be further broken down into toilet facilities that are privately owned, vs public, as well as those present in rural and urban environments.

Table 9: Residential Toilet Market: Public Vs Private and Rural Vs Urban

Public	5,020,482	**14%**
Private	30016715.59	**86%**
Total	**35,037,197**	

Rural	11,912,647	**34%**
Urban	23,124,550	**66%**
Total	**35,037,197**	

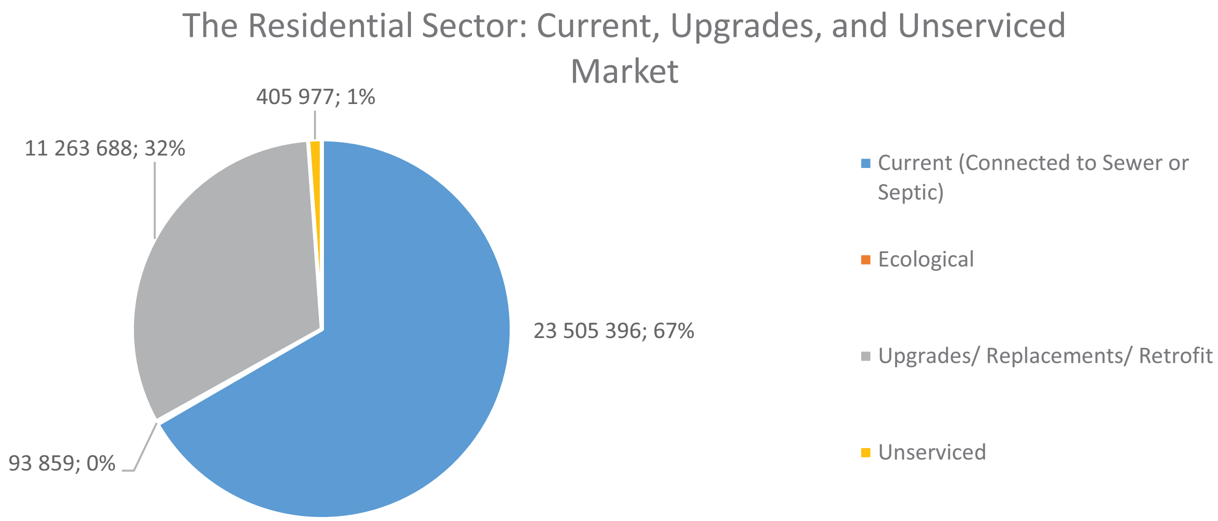
According to Statistics South Africa, approximately 14% of South Africans reside in RDP housing. These housing projects often go unfinished and result in poor quality housing. This is due to project often being handed to inexperienced contractors who are incapable of undertaking projects of this scale and nature. This results in wasted funds and creates an even greater backlog for those waiting for housing. In Johannesburg alone, the backlog is estimated to total 300,000 units. For projects of this nature to be rolled out effectively, private sector involvement is needed; supervision on site is required to facilitate projects in reaching completion; contractors of choice should be screened and properly trained before undertaking projects. Control and management of the entire process is required for future projects to a success and provide quality housing.



Graph 10: The Residential Sector: Sanitation Services Across Income Groups in South Africa

Sanitation services differ vastly among those living in rural and urban areas and within the various income groups of South Africa. Trends have shown that open defecation has decreased over the last 10 years considerably with an increase in basic sanitation services. Indigent and low-income groups are still subject to limited services. There is still a desire for the flush toilet within these communities. However, providing flush toilets connected to the sewage network is just too costly and, in some areas, it's not possible for construction of the piped network to take place due to the terrain.

With approximately 67% of all households having access to a flush toilet connected to a sewer or a septic tank, the rest of South Africans rely on pit toilets and ecological toilets. Around 34% of households require upgrades or serving of their sanitation facilities. Many of these systems in place are not adequate and do not meet the basic needs of sanitation facilities.



Graph 11: The Residential Sector: Current, Upgrades, and Unserviced Market

Graph 10 above breaks down the total toilet market to further understand the need for sanitation upgrades and identify the percentage of the market that goes unserviced. Upgrading and providing new sanitation to the unserviced market within the residential sector creates opportunity within the sanitation sector within toilet infrastructure, construction, and servicing and maintenance.

The opportunity for replacing the current pit, bucket and portable toilets is represented in the table below. The revenue generated from the replacements through new builds totals R293.9 billion. 16,859 chemical toilets, 4.6 million pit latrines and 123,500 bucket toilets are replaced in this scenario with 1.25 million septic tank flush toilets, 1.6 million VIP toilets and 1.99 million ecological toilets. An additional annual opportunity of R5 billion is created for operational maintenance from the new toilets in the market. This is calculated by taking the total additional operational turnover of R7.3 billion minus the R2.3 million operational revenue replaced by the new build.

Table 10: Opportunity to Replace Pit, Bucket and Mobile Toilets for the Residential Market

	New Build Market Revenue (Incl. Works)	New Build Additional Operational Revenue Per Annum	New Build Revenue (Ex. Works)
Flush toilet connected to a septic tank	R 88,119,160,753	R 377,653,546	R 25,176,903,072
Pour flush toilet connected to a septic tank	R 2,511,418,132	R 13,978,209	R 181,716,711
Pit latrine/toilet with ventilation pipe	R 86,371,865,904	R 545,844,506	R 6,100,615,064
Ecological sanitation systems	R 16,946,910,342	R 6,364,457,706	R 17,502,258,691

With an increase in population growth, and urbanisation, the demand for sanitation services will increase, creating strain on an already fragile sewage and wastewater treatment system. Moving forward, new residential builds in urban and rural areas should reconsider sanitation technologies. In many of existing households, it's not always simple to replace or retrofit systems.

When we consider retrofitting existing households with reinvented toilet systems, it is important to note the piping systems in place.

Residential sector piping systems can be broken down into two:

a) Housing that contains a single pipe for black and grey water

b) Housing that contains separate pipes for black and grey water

In South Africa, we find that very old houses were installed with separate piping systems for black and grey water. These houses form part of the market that can undergo retrofitting of new toilet technologies that are able to recover grey water, and feed this into the toilet system, or be used for irrigation. Many houses however have single piping systems for grey and black water, firstly making retrofitting costly, and secondly more complicated.

Table 11: Selection Criteria for Residential Consumers

Selection Criteria	Importance to Consumers	
	Rural	Urban
Quality of Product	M	M-H
Price	L	M-H
Reputation of Company	M	H
Technical Specifications/ Aesthetics	L	H

Technologies and Applications

Technology applications for the residential sector will differ between rural and urban settings.

For urban areas:

1. Full waterborne systems connected to the sewage network or septic tank will continue to be the preference to many users where sewage networks are already in place. Septic tank systems are applicable to housing estates or small-scale farms.
2. Full greywater recycling systems can be installed in single unit housing or multilevel apartment blocks where grey water is recycled and used for flushing of toilets.
3. Composting toilets can be installed in urban residential settings where adequate space is available.

For rural areas:

1. Many rural areas are too densely populated to install sewage network, and this process is costly and time consuming. Containerized toilets can be a simple and effective means of providing adequate and functioning sanitation solutions. Dry solutions are preferred as access to water for flushing is not always possible. These solutions are able to incorporate circular economy practices and produce secondary products which are able to subsidize the cost of sanitation services to users of indigent and low-income classes.
2. Bioreactors can be installed to service small communities while producing secondary products such as biogas which can be used to by the community without access to electricity or conventional gas for heating, cooking and light. Feedstock availability and quantity is extremely important in creating viable operations. The capital costs associated

with biodigesters are extremely high and it can become challenging to create substantial return on investment. Operations need to be optimized to ensure maximum benefits are being derived as well as decreasing the payback period. The cost of electricity decreases with scalability. Careful consideration should be taken before installation to ensure operational viability. However, if viability can be proven for a community, these systems provide much needed waste management.

3. Pour flush systems can be installed in areas where the ground is stable to support a pit, and has appropriate water table. Pour flush toilet seats are offset and are not directly above the pit, which creates a more user friendly and safer toilet. The pour flush system is suitable for areas with limited access to water.

7.3 The Commercial Toilet Market

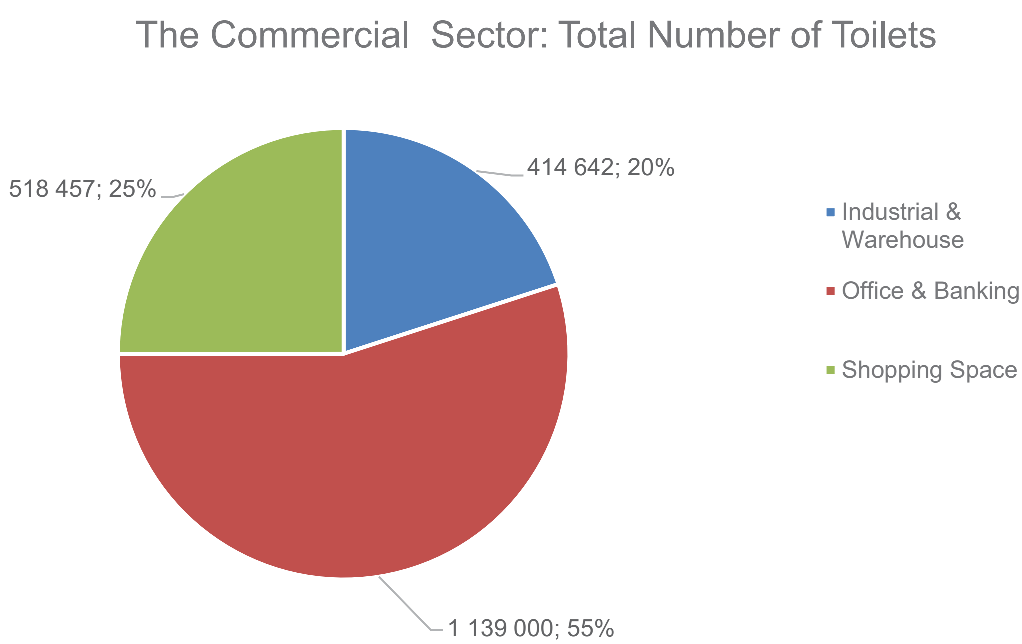
The commercial sector in South Africa is made up of variety of subsectors which include shopping centres, office space, and industrial warehousing. Sanitation facilities and sanitation needs differ across these subsectors due to the number of users, the areas they are situated in, the resources available. For example, the shopping centres often have high foot traffic compared to industrial warehousing.

For the purpose of this study, the sector was subdivided into Industrial & Warehouse, Office & Banking, Shopping Space and other. The other subsector entails operations such as churches, sport, recreation clubs, schools, nursery schools, creches, hospitals and all other non-residential space. Note that commercial activities related to accommodation were grouped under residential as these facilities are not grouped separately under commercial developments within residential areas. To enable calculation of the number of toilets available in each subsector, certain economic sectors were grouped together as highlighted in the table below:

Table 12: Economic Sector Groupings

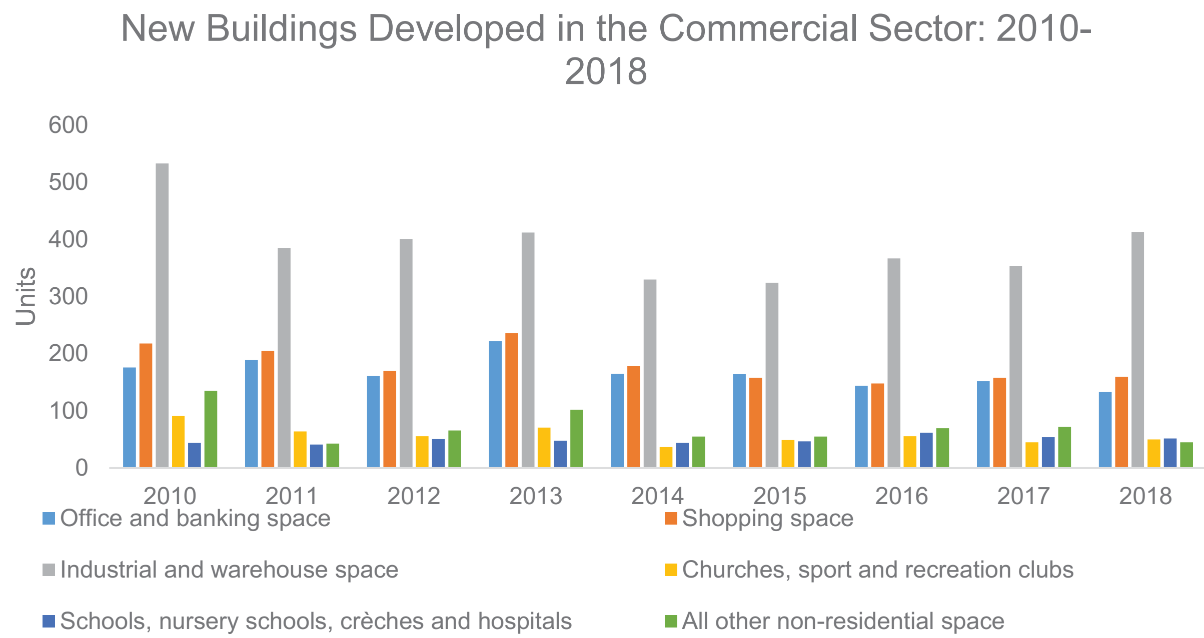
Commercial Sector	Economic Activities
Office and Banking space	Finance, Community and Social Services
Shopping space	Trade
Industrial and Warehouse space	Mining, Manufacturing and Utilities

All other commercial sectors were grouped into the “other” subsector category. However, because this category spans across such a wide range of sectors, assigning a group of economic activities proved impossible.



Graph 12: The Commercial Sector: Total Number of Toilets by End User Industry

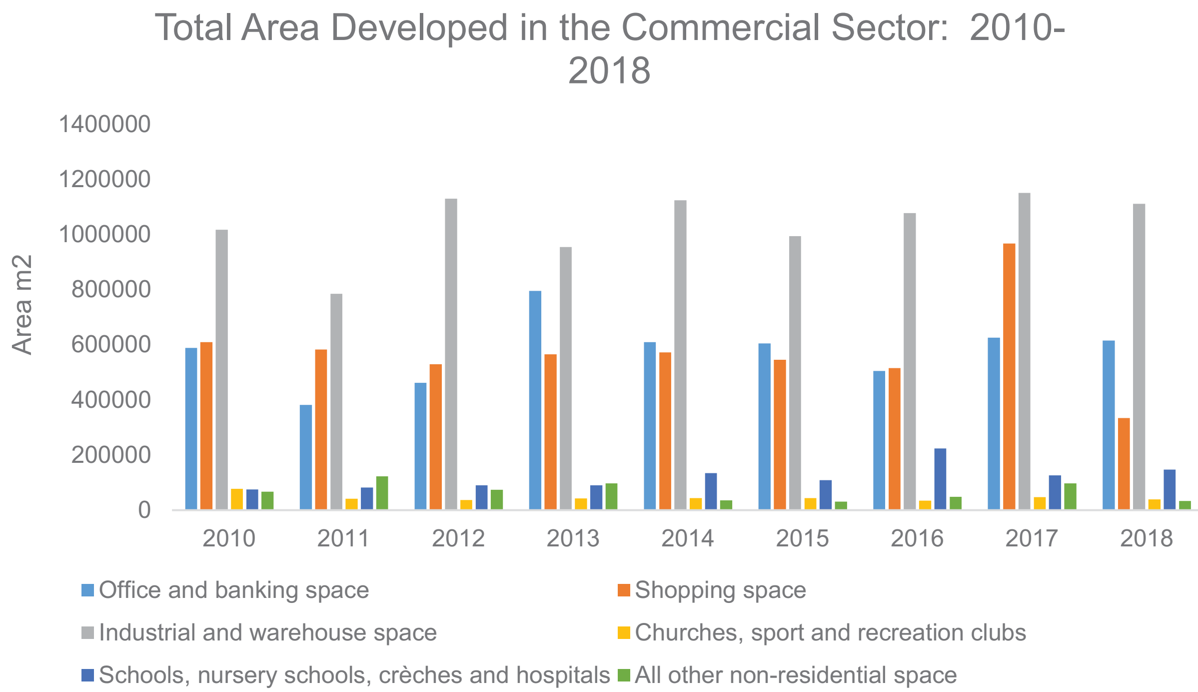
Most people are employed in community and social services, closely followed by trade. The retail space in South Africa is home to over 2,000 shopping malls covering approximately 25 million square meters. To determine the number of toilets required by each subsector, the number of employees was multiplied with the standard requirement outlined in the South African standards of the national buildings' regulations. This results in more than half a million toilets required for the retail space alone. The office and banking space require the most toilets with 1.14 million toilets.



Graph 13: The Commercial Sector: Number of buildings developed in each commercial sub-sector between 2010-2018

This study decided to focus on applying the research of the commercial sector on new buildings Retrofitting older toilets with new water-saving equipment or replacing them completely with new, more modern, low-water using toilets is a complex and costly process. There exists a high opportunity in the new buildings sector. Between 2010 and 2019, a total 9,446 buildings were constructed in the commercial sector, which is equivalent of nearly 25 million square meters of commercial development. The values for 2019 is a forecast value as these number have not yet been released. The construction of new buildings has slowed down after 2010. Industrial and warehouse space has dominated the commercial buildings sector ever since, constructing around 300 – 400 new buildings every year. The development of the office and banking space and the retail space has stayed close to one another, developing around 150-200 buildings a year.

Industrial and warehouse space is also developed the most area over the last decade, developing buildings in the range between 1 – 1.2 million m^2. This sector generally overshadows the other sectors due to the large space required for storage and industrial activity, but generally employs less people and therefore requires less toilets to be installed. As with the number of buildings, the office and banking space and the shopping space developed areas at a similar rate. Because of the high number of employees and potential visitors, the number of installed toilets in these sectors outnumber the other sectors. The other sector developed the smallest area in recent years, primarily because of wide range of economic activities it entails.



Graph 14: The Commercial Sector: Number of Buildings Developed in Each Commercial Sub-Sector Between 2010-2018

Table 13: Selection Criteria for Commercial Consumers

Selection Criteria	Importance to Consumers		
	L	M	H
Quality of Product			X
Price		X	
Reputation of Company			X
Technical Specifications/ Aesthetics			X

Utility costs in the commercial sector continue to grow, and property owners can reduce these costs by implementing water efficient systems, or full grey water recycling systems. It will also decrease their reliance on the already strained water supply in many regions across the country. Many commercial buildings are also striving towards Green Building certifications.

Technologies and Applications

1. Full waterborne systems connected to the sewage network or septic tank will continue to be the preference to many users where sewage networks are already in place. Septic tank systems are applicable to commercial buildings.
2. Full greywater recycling systems can be installed in single unit housing or multilevel apartment blocks where grey water is recycled and used for flushing of toilets.
3. Biological plants can be installed in large business parks such as technology parks if they are situated in areas where the sewage network is unable to handle the increase in pressure on its system.

7.4 The Public Sector Schools Market

The sanitation sector plays a significant part in the schooling experience of learners and staff of public schools. Many public schools across South Africa, particularly in the Eastern Cape, Limpopo, and Kwa-Zulu Natal, are severely plagued with inadequate and insufficient sanitation facilities. Sanitation at public schools has sadly resulted in the death of students due to the illegal pit toilets still present at many schools across the country. The Norms & Standards which outlined the minimum infrastructure guidelines for schools in 2013 has still not been met, with a deadline set for 2016, which had been extended to November 2020.

Access to basic sanitation is still largely lacking in many public schools across the country. Many schools have sanitation facilities in place that are often broken and dirty, are not suitable for students and especially students with disabilities, and do not meet the basic needs set out by the Department of Basic Education. The Department of Basic Education states the following in their regulations relating to minimum norms and standards for public school infrastructure:

1. All schools must have a sufficient number of sanitation facilities, that are easily accessible to all learners and educators, provide privacy and security, promote health and hygiene standards, comply with all relevant laws and are maintained in good working order.
2. The choice of an appropriate sanitation technology must be based on an assessment conducted on the most suitable technology for each particular school.
3. Sanitation facilities could include one or more of the following:

a) waterborne sanitation;
b) small bore sewer reticulation;
c) septic or conservancy tank systems;
d) ventilated improved pit latrines; or
e) composting toilets.

4. Plain pit and bucket latrines are not allowed at schools.

Source: Department of Basic Education, Regulations Relating to Minimum Uniform Norms and Standards for Public School Infrastructure

According to the Department of Basic Education, nearly 6,000 schools have PIT toilets still present across the country. The Department of Basic Education launched the SAFE (Sanitation Appropriate for Education) program aimed at eradicating pit toilets mainly situated in the Eastern Cape, KwaZulu-Natal and Limpopo.

Many schools do not have adequate number of toilets allocated to the students enrolled. In a report published by Equal Education, it was found that out of 38 schools, only 7 schools met the basic requirement above for working toilets. Many schools have a ratio of more than 51 students per working toilet. This stands in strong contrast to the outlined standard, which indicate that for secondary schools, one toilet should be allocated for every 16 to 35 students. For primary schools, one toilet should be present for every 4 to 33 students. The range covers the number of learners enrolled in the school which is between 0 and 1200.

ZAR 2.8 Billion Allocated in the MTEF to the Basic Education Budget for Sanitation Facilities

To serve over 6,000 schools without proper sanitation

Source: South African National Treasury, 2020 Budget Review

Allocation of funds to develop and improve basic sanitation in schools has been outlined, but it is not enough to simply utilize these funds to provide sanitation services to schools in a tick-box exercise. The lack of infrastructure upkeep and the low-quality construction of infrastructure needs to be dealt with, as schools are being provided with only the basic sanitation infrastructure. However, many students in the country still do not have access to clean, safe, and usable toilets. Sanitation infrastructure continuously requires costly upgrades which is based on a build-deteriorate-upgrade cycle.

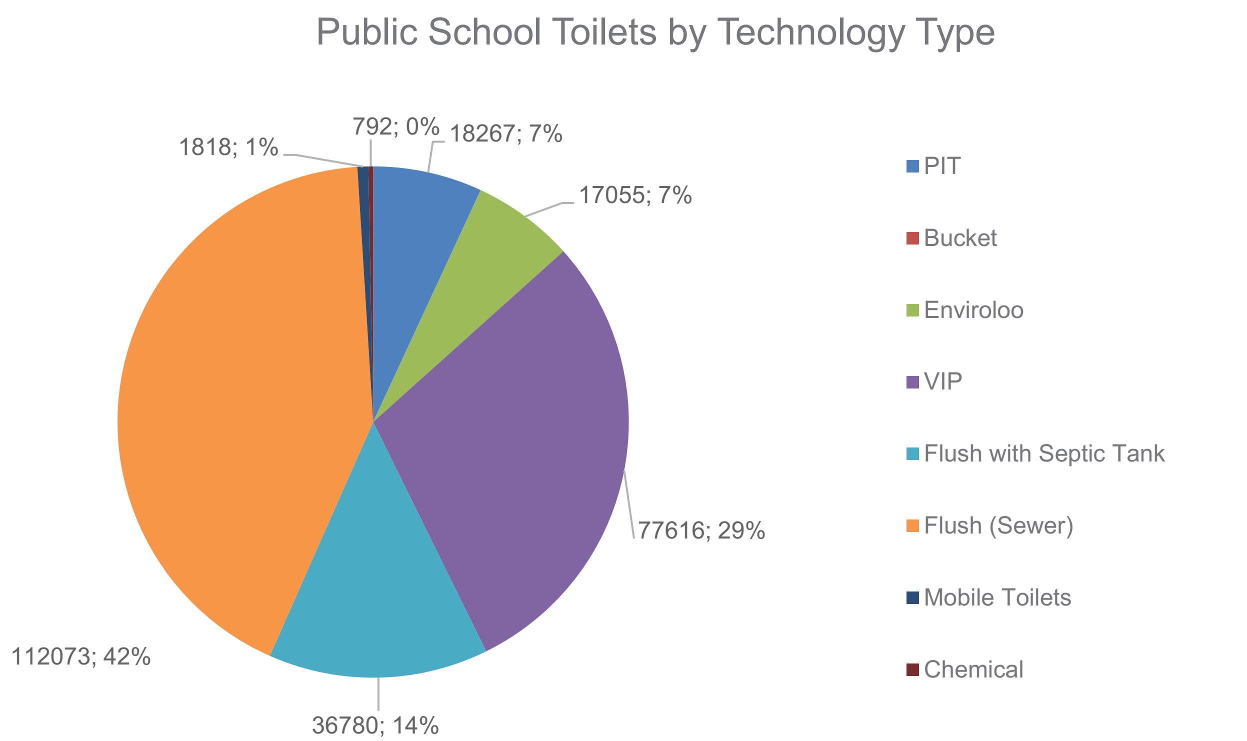
The lack of insufficient and accurate data published by both the national and provincial education departments prevents an exact state of the sector to be depicted. Using the Norms and Standards data, along with the number of students in each school across South Africa, the number to fulfil the targets set out has painted a picture for what the total number of toilets in public schools should be. It is understood that this figure is not exact, due to schools providing over and above the minimum requirement, hence the numbers have been adjusted accordingly.

What is known, is that South African schools have not reached the 100% fulfilment mark yet, as the severity of the sanitation backlog has time and again been at the centre of attention. Without accurate and current infrastructure data of each school in the country, it becomes increasing difficult to create strategies for implementation and more importantly identify budgetary requirements.

Table 14: The Total Number of Toilets Estimated to Fulfil Norms & Standards at Different Fulfilment Scenarios

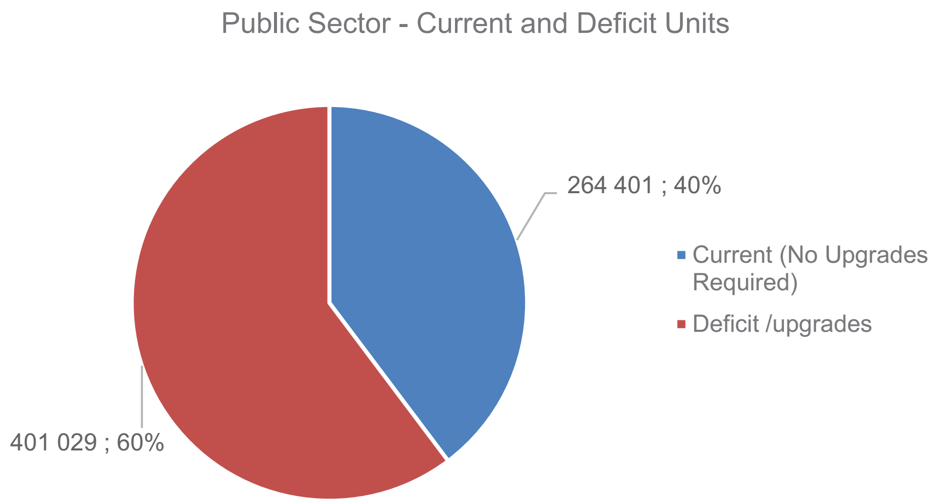
Province	Scenario 1: 100% Fulfilled	Scenario 2: 75% Fulfilled	Scenario 3: 50% Fulfilled	Scenario 4: 25% Fulfilled
Western Cape	50,904	38,178	25,452	12,726
Eastern Cape	120,064	90,048	60,032	30,016
Free State	35,337	26,502	17,668	8,834
Gauteng	84,666	63,500	42,333	21,167
KwaZulu-Natal	160,672	120,504	80,336	40,168
Limpopo	100,099	75,074	50,049	25,025
Mpumalanga	52,889	39,667	26,445	13,222
North West	44,652	33,489	22,326	11,163
Northern Cape	16,146	12,110	8,073	4,037

Total	665,430	499,072	332,715	166,357



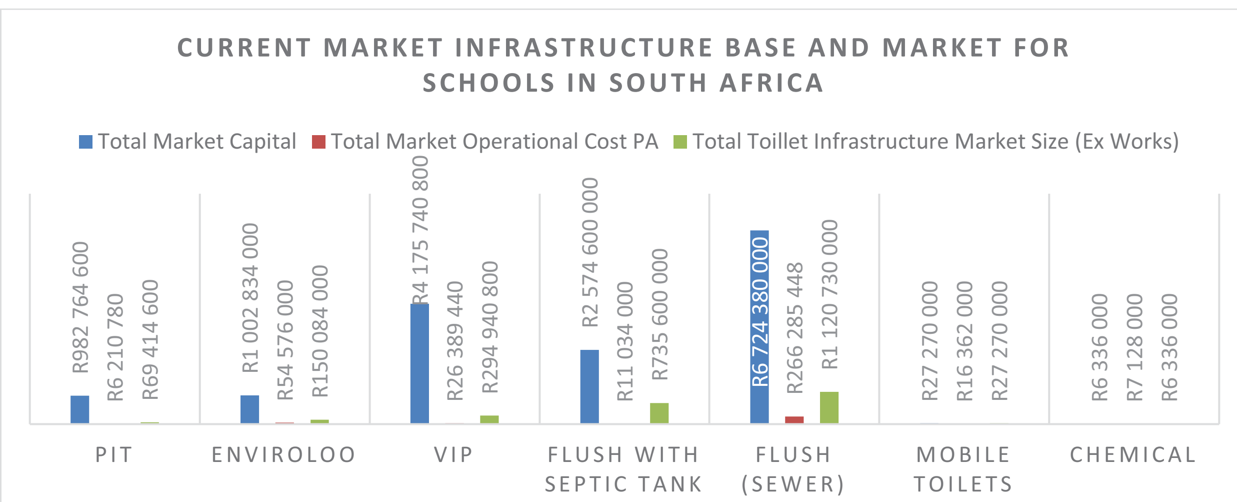
Graph 15: Public Sector Schools: Toilets by Technology Type

Approximately 42% of toilets present in schools are flush toilets connected to the sewage network, and a further 14% of toilets connected to a septic tank. Unfortunately, 7% of toilets in public schools remain pit toilets, which are currently deemed illegal according to the Department of Basic Education. According to Norms & Standards, schools are not allowed to have pit toilets, along with chemical and bucket toilets. There are schools where learners only have access to pit toilets, and no other safe and acceptable form of sanitation. Although the data suggests that 78% of schools adhere to the technology requirements, it does not suggest that the toilets are in adequate and working condition, nor that the toilets present are sufficient in numbers to cater for enrolled students.



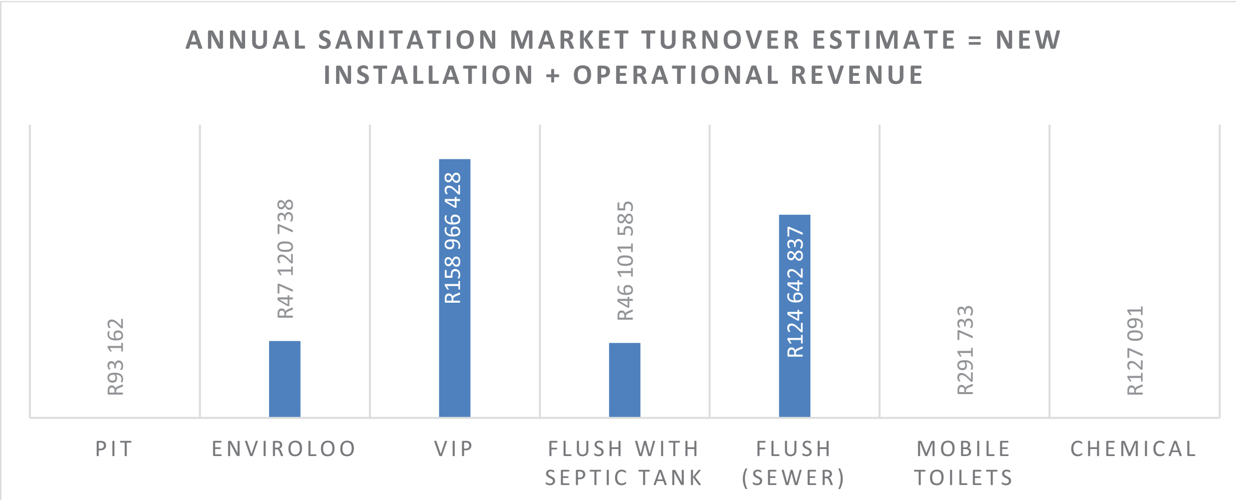
Graph 16: Public Sector Schools: Total Number of Toilets Indicating Current and Deficit Units

It is estimated to have a total of 264,401 toilets present in public schools across South Africa. However, a total of 665,000 toilets is required to fulfil the Norms & Standards requirements for public schools. This creates a significant deficit of approximately 400,000 toilets that require upgrades, replacements, or new installation.



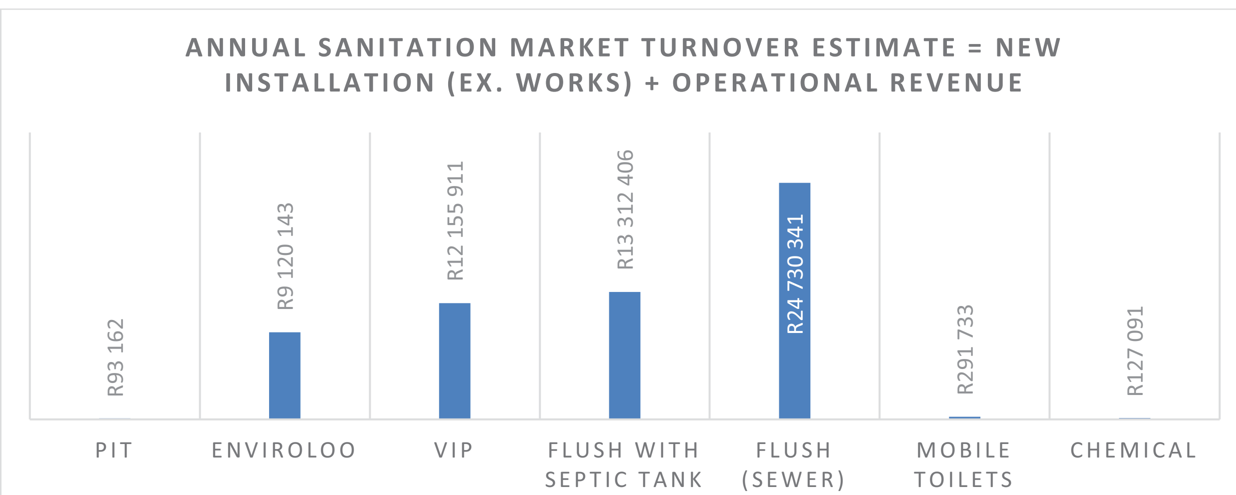
Graph 17: The Total Current Infrastructure Base for Sanitation of Public Schools Including Operational Revenue

In the chart above, the total existing infrastructure base of school's sanitation infrastructure is depicted. This estimates the existing capital sanitation infrastructure for schools in 2020 rand. Further to this, the operational revenues were estimated for the maintenance and operations of the current infrastructure per annum. The chart also represents the estimate of the ex-works infrastructure base. The current infrastructure base for toilets at schools is estimated at R15.5 billion. This represents the total capital in the market including the works. The annual operational revenue estimated for the current infrastructure base is R388 million.



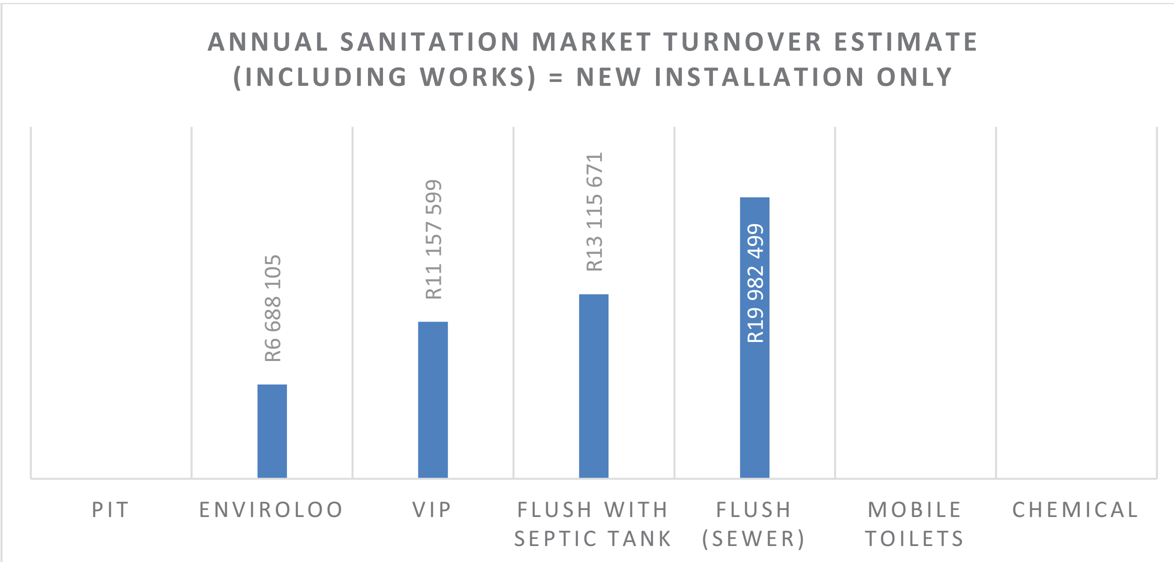
Graph 18: Public Sector Schools: Annual Sanitation Market Turnover Estimate = New Installation + Operational Revenue

The annual market size for new installations in schools, including works and operational revenue is estimated at R377.3 million. The operational revenue for flush toilets connected to sewers is the highest and also represents the highest value cost per seat. Note that the annual market size estimate represents the average yearly turnover and does not account for special build programs in certain years, that will increase the market value in a particular year.



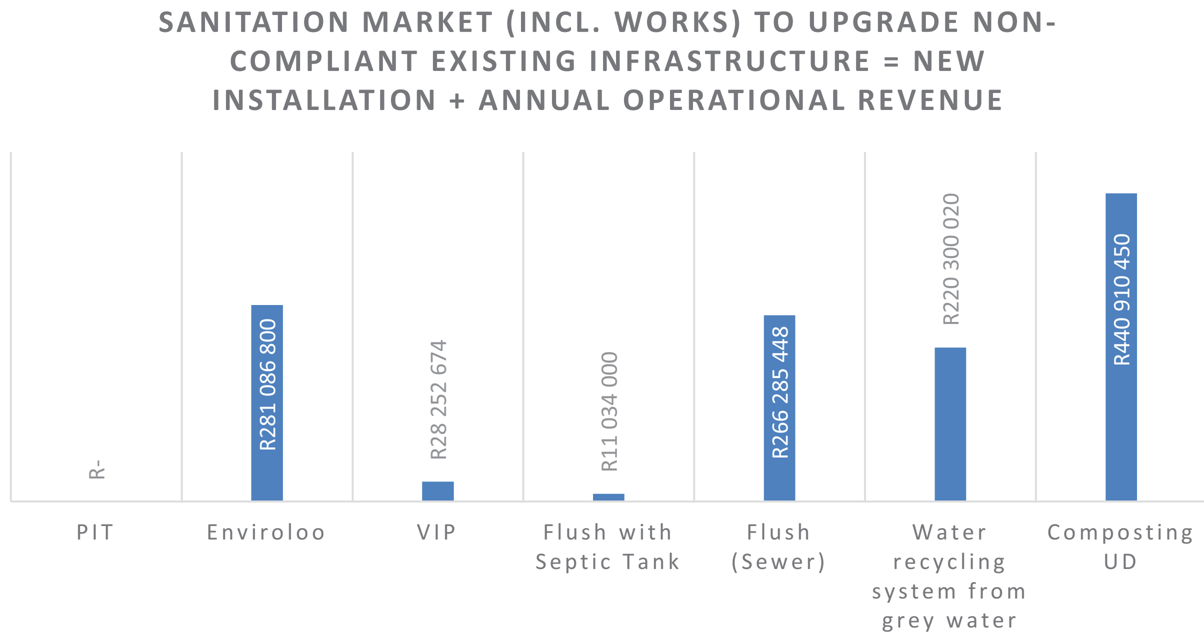
Graph 19: Public Sector Schools: Annual Sanitation Market Turnover Estimate = New Installation (Ex. Works) + Operational Revenue

Chart 19 represents the annual market turnover for new installations excluding works and including operational revenue. The market turnover for this is estimated at R59.8 million per annum.



Graph 20: Public Sector Schools: Annual Sanitation Market Turnover Estimate = New Installation Only

The revenue for the installation of new toilets (including works), excluding operational revenue, is represented in the chart above. Flush toilets have the largest revenue split for the various toilet types, at R20 million, with the total market for new installations valued at R51 million.

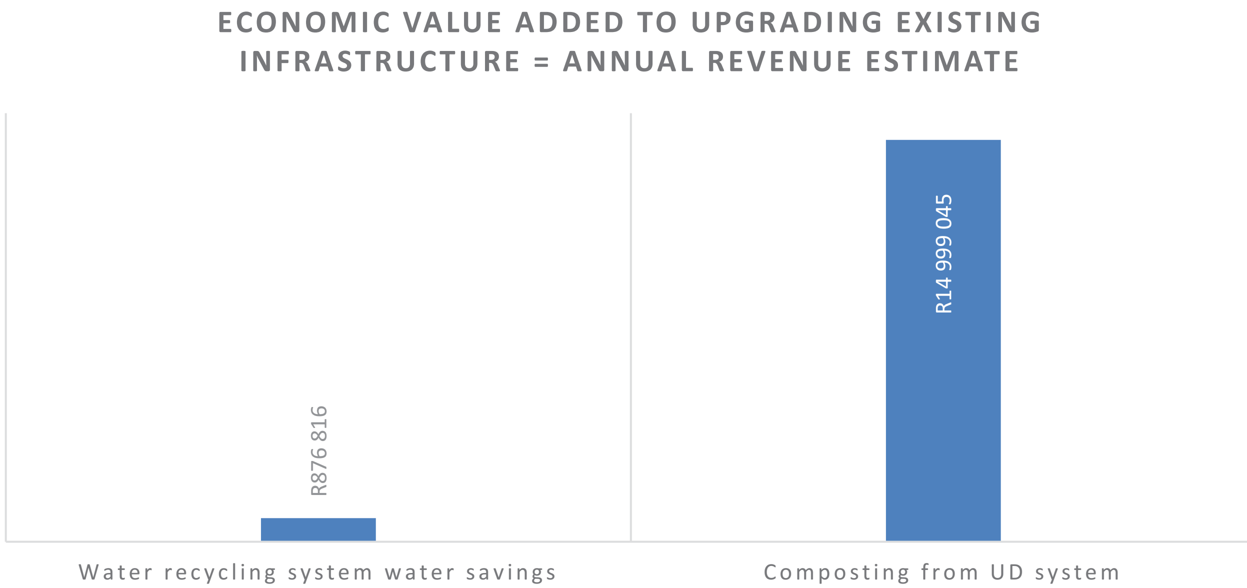


Graph 21: Public Sector Schools: Sanitation Market (Incl. Works) To Upgrade Non-Compliant Existing Infrastructure = New Installation + Annual Operational Revenue

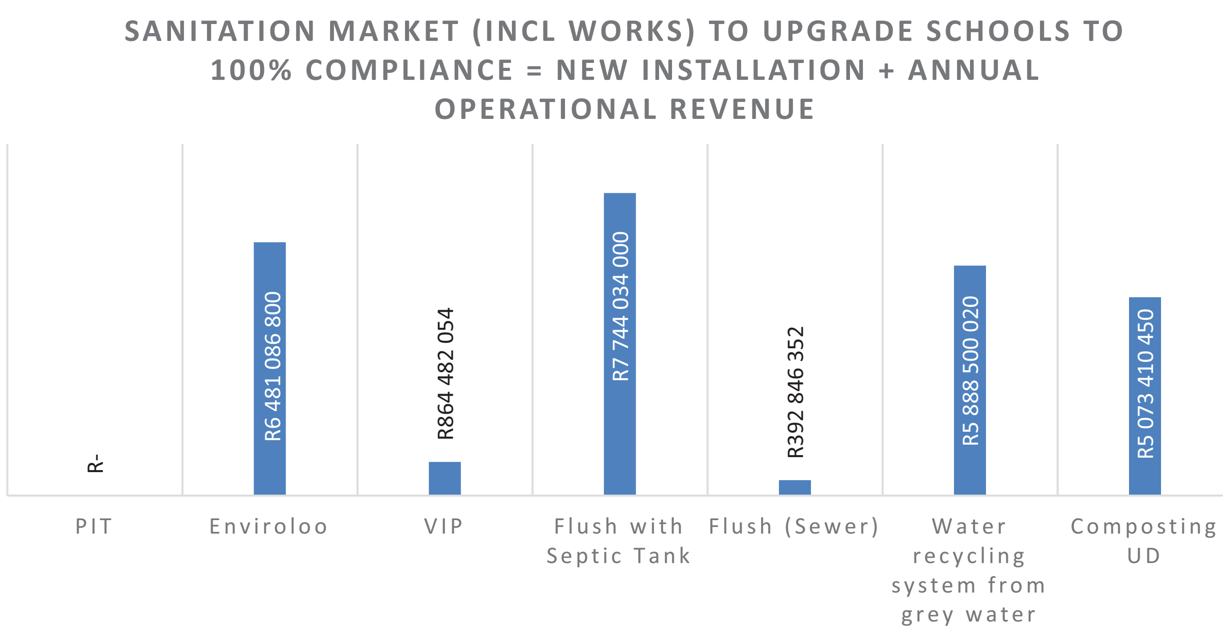
The chart above indicates the potential revenue generation for upgrading the current non-compliant schools toilet infrastructure to compliant. This would mean that the current pit latrines, chemical and portable toilets would be replaced. For this example, the non-compliant infrastructure is off-grid and it was assumed that replacing these with flush toilets would not be feasible due to the cost of grid connection and possible rural nature of the location. The non-compliant toilets were replaced by environmentally friendly and cost-effective alternatives.

18,267 pit latrines and 2,600 mobile/chemical toilets were replaced by adding 3,653 Enviroloos, 5,480 VIP toilets, 3,653 water recycling systems and 8090 composting UD toilets.

This would translate into a turnover of R1.25 billion for the replacements. Additionally, it is estimated that R15.9 million additional value can be added back into the economy through water savings and compost production (calculated as an annual value).



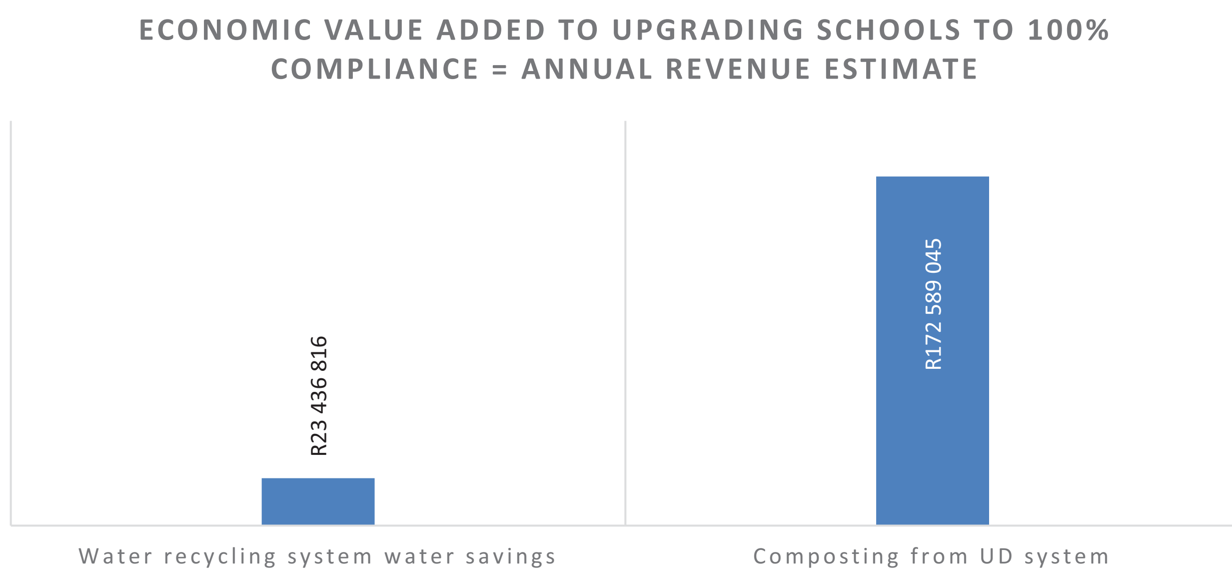
Graph 22: Public Sector Schools: Economic Value Added to Upgrading Existing Infrastructure = Annual Revenue Estimate



Graph 23: Public Sector Schools: Sanitation Market (Incl Works) To Upgrade Schools To 100% Compliance = New Installation + Annual Operational Revenue

The upgrade of school's toilets to comply to the estimated 100% compliance (to have enough toilets per student), is represented in chart 23 above. This would involve replacing the current non-compliant infrastructure and then adding the necessary toilets to meet the demands of 100% compliance. 18,267 pit latrines will be replaced, as well as 2,600 mobile and chemical toilets. In this scenario, these will be replaced and additional toilets added by 103,653 Enviroloo toilets, 15,480 VIP toilets, 110,000 flush with septic tanks, 2,029 flush with sewer, 97,653 water recycling systems and 93,090 composting UD toilets.

This would lead to an investment and operational revenue of R26.4 billion. Additionally, the economic value-added estimate generated from water savings and composting could generate an additional R196 million per annum.



Graph 24: Public Sector Schools: Economic Value Added to Upgrading Schools To 100% Compliance = Annual Revenue Estimate

Table 15: Selection Criteria for Public Sector Consumers

Selection Criteria	Importance to Consumers		
	L	M	H
Quality of Product		X	
Price	X		
Reputation of Company		X	
Technical Specifications/ Aesthetics	X		

Technologies and Applications

Containerized toilet systems that utilize dehydration of human waste are ideal for schools with no access to water and sewage infrastructure. These dry systems require low operational costs and easy to install and user friendly. Certain designs are manufactured using ceramic toilet bowls, which are used in full water-borne toilets.

Containerized toilets where fresh waste is collected and treated may be an option if the school is situated in or near an area where processing may occur. The toilets should be installed with a maintenance plan to ensure that regular collection of waste occurs, to prevent rendering toilets unusable. Maintenance of toilets in public schools is a huge concern, as it has resulted in the deterioration of sanitation infrastructure.

Composting toilets are not applicable to schools, as maintaining the composting environment requires consistence work and may become difficult to manage.

Full waterborne systems connected to the sewage network or septic tank will continue to be the preference to many users where sewage networks are already in place. However, many public schools are situated in rural areas without access to water and a sewage network. Septic tank systems could be installed in schools with access to water, but in areas with weak or deteriorating sewage infrastructure.

VIP pit toilets are allowed under the norms and standards. These toilets are often poorly constructed and serve as a safety hazard for learners. If water is available, a pour-flush system may be introduced.

It is not possible to recommend one technology suitable for public schools as the implementation of certain designs depend on a variety of factors. Factors to be taken into consideration are listed below:

- Ground composition and stability for pit construction
- Availability of water

- Space
- Sewage network availability
- Ground water availability for boreholes

Manufactures rarely offer maintenance and servicing which often becomes the burden of the public school. Public schools are not allocated large maintenance budgets, and often these budgets are not spent on sanitation. The sanitation facilities degrade over time, often becoming completely unusable to learners and staff. Maintenance and the serious lack thereof continue to create even further setbacks. Many schools often use maintenance budgets on unplanned maintenance that arises.

If projects were implemented with service and maintenance contracts, it would negate the need to do full overhaul and replacement of sanitation facilities and continue to provide safe and adequate facilities at school.

Implementing sanitation infrastructure is only part of the solution in ensuring basic hygiene and sanitation. Provision must be made for the safety and privacy of learners, as well as providing basic amenities such as hand washing facilities, soap, toilet paper, and feminine hygiene products to female students who are unable to afford it.

Women are disadvantaged to a greater extent that men, especially in schools where female students refrain from attending school while menstruating. This is due to the inadequate toilet facilities available to them at school. It is estimated that 1 in 10 girls in Africa miss school during menstruation. Female students could miss 3-4 school days a month. This prevents female students from reaching their full potential and has a negative impact on their social status. Feminine hygiene products should be provided along with adequate sanitation facilities to female students to prevent absenteeism. Many female learners refrain from using the school toilet facilities through the duration of the school day due to the poor conditions, while being fully aware of the health risks associated with not relieving themselves.

8 LOGISTICS ANALYSIS OF WASTE TYPES IN THE CIRCULAR ECONOMY

The section below details the various types of wet and dry sanitation and provides detail to the operation and management of technology types as well as power sources in certain cases. It provides information on the method used to transport waste from generation sites, along with the treatment processes used.

Table 16: Logistics Analysis of Waste Types in The Circular Economy

	Smart Sanitation Technology	Operation & Management	Transport Type	Waste Treatment
Wet Sanitation	**Full waterborne Flush Toilets**	4-5 years to service flippers, trip levers, fill valves, fittings and plumbing connections	Sewage Network	Sewage Treatment plants
	Septic Tanks	Emptying of pit is messy, expensive and technically difficult Regular cleaning to avoid overflow	Wastewater can be either drained into drain field or sewage network Faecal sludge collection, composting and recycling is suitable for SMMEs	Sewage Treatment plants for faecal sludge
	Small Scale Biological Plants	Easily maintained as long as no solid or foreign material enters system and solid waste should be dislodged every 2 – 3 years	Faecal matter other organic matter settles at the bottom of bioreactor and are converted to water and gas by bacteria	Wastewater is rich in nutrients and poor in CO_2 and CH_4, ideal for plants but unsafe for domestic use
	Pour and Low Flush Systems	Offset pour-flush toilets are easier to empty as floor does not have to be broken periodically to empty the pit	Human waste is flushed directly into pit below. Needs to be emptied using a vacuum tanker or manual labour once full	Composting, landfilling or incineration

	Smart Sanitation Technology	Operation & Management	Transport Type	Waste Treatment
Dry Sanitation	**Pit Latrines + VIP**	Emptying of pit is messy, expensive and technically difficult Pits generally need to be emptied every 5 – 9 years	Most pits are emptied using a vacuum tanker or using manual labour tools	Composting, landfilling or incineration
	Container-based Sanitation (CBS)	Minimal O&M associated, only ensure toilets do not overflow and no foreign material (e.g. Plastic) enters system	Collection should occur twice per week by 1 operator per 50 households, either by barrels and dolly carts or small vehicles	Both wet and dried faecal sludge can be transformed into Briquettes that can be sold as an energy source
	Composting Toilets	Emptying frequency depends on capacity of container, feeding rate and composting conditions	Not necessary, can be composted on site	Composting of waste in heaps in dry, hot climate
	Urine Diversion dehydration toilets (UDDTs)	Once full, dehydration tanks rest for 6 months before removal of dried faeces	Can be removed via wheelbarrow or other forms of transportation	Separated dry waste can be used for fertilizer

Smart Sanitation Technology	Operation & Management	Waste Treatment
The empower sanitation platform (USA)	Ash/dried solids emptied weekly by user **Power System** Currently processed by grid power; Optional solar panels (500 W) for supplement and off-grid energy	Mesh belts used for initial separation. Baffle tanks in liquid processing stream allow for additional settling of solids. Separate treatment of liquid and solid waste. Liquid waste is treated in a hybrid processing which includes activated carbon filtration with electrochemical disinfection. A post baffle filter is used for Helminth egg removal. The disinfected liquid is recycled for flush water use. The solid waste is processed after separation and are dried is 90 degrees Celsius. Combustion option may increase solids processing capacity across multiple units
Clear environment technology (China)	**Operation & Management** Membranes to be monitored and replaced as needed every two years. Solids may need to be emptied every year **Power System** The system requires external power either from grid electricity or from solar panels	Initially treated with physical precipitation, a special aerobic media is placed in the aerobic reactor and proprietary bacteria, specifically developed for treating wastewater is attached on the media as a biofilm. This biofilm can effectively biodegrade more than 50% of the organic pollutants and reduce its concentration. The wastewater is then treated by a membrane biological reactor (MBR) to separate pollutants in large size, which can be refluxed in the biodegrade process, producing clean water. This clean water is further disinfected via UV to kill all bacteria
Eco-San Toilet (China)	**Operation & Management** Solid wastes need to be emptied every ½ year by user. Membrane filters need to be replaced once a quarter **Power System**	This process does not separate the liquid from the solid waste. The mixed waste settles passively in a septic tank with anaerobic digestion. Active pre-processing with an anaerobic/aerobic system is available. An electrochemical system oxidizes the effluent from the septic tank and biological treatment unit at a semiconductor anode where water is reduced at the metal cathode to form H_2. Chloride can be added if there is an insufficient amount in the waste.

	Solar Panels with energy storage via battery stack and/or grid electricity	Membrane microfiltration is currently included for polishing the final effluent. Faeces are macerated with the urine and flush water; all are processed together
Nanomembrane Toilet	**Operation & Management** Water/ash to be emptied daily (by user), Ash to be emptied weekly and membranes to be cleaned quarterly **Power System** The lifting of the toilet seat powers the bowl. Excess heat from the combustor is used as the driving force for water separation	Solids and liquids are separated by gravity sedimentation. Liquids flow over a weir to liquids processing stages while the solids are extracted using a screw. Liquid processing involves a hydrophobic membrane which separates clean water from the contaminated urine. The clean water is then sent to a storage tank for later use. The solids are processed by drying, followed by pelletisation and combustion to ash. The combustor being developed is a micro-combustor that can be fed at < 1 g/min of dried faecal waste.
HTClean (Switzerland)	**Operation & Management** Non-hazardous, non-odorous, solid waste cakes and excess liquids to be regularly disposed by user **Power System** System requires electricity	Solid and liquid faeces are separated after processing by a mechanical filter press. The user input is initially stored in a holding tank. The composited material from the storage tank is passed through a pre-heater then loaded into a reactor chamber and heated above 160 C. at a pressure up to 25 bar. After cooling the reactor is discharged and solids and liquids are separated, resulting in a small filter 'cake'. The produced liquid is retained and then cleaned for use in the toilet flushing system. Water vapor released from the reactor after processing is used

	Blue diversion autarky EAWAG	Operation & Management Water refill, fertilizer harvesting from urine and faeces treatment, supply of chemical reagent Power System Water wall and urine processing can be operated using solar power	Urine is separated from solid waste in a urine-diverting pedestal while solids are separated in an Aquatron. The urine processing involves chemical stabilization and then undergoes passive evaporation, resulting in a solid product that can be harvested as fertilizer. Water processing includes three units that are used for the treatment of used flushing and handwashing water. These three units include membrane bioreactors with ultrafiltration, activated carbon filters and electrolysis to produce residual chlorine. The solid faeces as well as toilet paper and some flushing water are fed into a small-scale, batch-processing supercritical waster oxidation reactor
	toilet/Eram Scientific Solutions	Operation & Management Not available Power System Currently powered by grid power	No separation of solids and liquids is required. Waste stream is flushed and sent to the biological pre-treatment holding tank. Waste is then pumped to the electrochemical reactor (ECR). The quality of the effluent following the final filtration using water filters and strainer is confirmed using sensors and remote monitoring. Water is then stored for reuse as flushing in the eToilet
	Zyclone Cube/SCG Chemical Co., Ltd	Operation & Management Media to be replaced every 3 years, electrodes every 3 years and fertilizers to be collected every month Power System	Liquid/solid separation is achieved at an effectiveness of greater than 98%. The separated liquid is firstly filtered in a plastic media chamber to remove coarse solid particles. The next two chambers are filled with synthesized media at 2 and 1 cm diameter, respectively. In the anaerobic chamber, the organic loading is reduced prior to an aerobic chamber equipped with microbubble aeration that further removes COD, TN and TP contents. In the next chamber TN is greatly reduced by zeolite media in an anoxic condition. The liquid

		System requires electricity	is then recirculated to the anaerobic chamber in order to increase the overall treatment performance. Finally, pathogens are inactivated in the final chamber prior to liquid discharge. Solids are collected and disinfected and reduced in moisture content by screw heating device. The heating device could inactivate helminths 4-5 log value and E. coli 6 log values
	Newgenerator	Operation & Management Levelling tank cleaning every 6-18 months preventative maintenance every 6 months Power System Currently using solar panels to charge deep-cycle batteries that power the system. Biogas generated is dependent on the strength of the influent and can be used for various uses such as heating and cooking fuel	No separation is required, urine, faeces and wash/flush water are processed as a single stream. Mixed waste enters an anaerobic membrane bioreactor. Liquid is filtered with a commercially available nanomembrane, operated at sub-critical flux to optimize longevity of the membrane. Biosorption and hydroponic processing is used to remove additional organics and minerals. Electro chlorination is the final step. The mixed waste stream is processed by an anaerobic microbial baffled reactor, where the organic materials are digested. Residual, undegraded solids will need it be removed
	The Toronto Toilet	Operation & Management Solids (ash) to be emptied monthly by user Power System	Multiple gravity based solid/liquid separation designs have been evaluated and field tested. Effective solid/liquid separation is achieved without modifying user behaviour. Liquid pasteurization is achieved by recovering the heat captured in steam during solid drying process. Further effluent treatment is intended to be adopted from other projects being conducted. Solid material is transferred via a

		Solar panels or other off-grid energy sources may be used to supply the <200 W/day required. The aspirational goal that projections show is possible is to achieve a power requirement low enough to fit within the capacity of solar or other off-grid home systems that are common in many regions	pump and is injected into a column where it is in-situ mixed with granular beads which are still hot from the preceding smouldering cycle. Once the mixing/drying process concludes, air is introduced, and smouldering begins. Post smouldering gases pass through a catalyst for further treatment and heat generation

9 BUDGET, ECONOMIC AND VALUE CHAIN IMPACT ASSESSMENT

9.1 Current Status Quo and Bottlenecks

The sanitation sector in South Africa has been deemed a difficult market to work in due to factors such as corruption, lack of transparency, and inefficiencies across various levels of the sector.

Table 17: Potential Providers of Sanitation Services

Municipalities	Tasked with providing basic level of service to the public which include water and sanitation. However governmental departments are often unable to provide services to all due to various issues such as financial constraints or mismanagement of funds; political and institutional constraints, among others.
Small Independent Providers	Players often operate in areas with low levels of service delivery, by providing basic services such as water and sanitation services.
Non-Governmental Organizations (NGO)	NGOs are organizations who volunteer their time and funds to provide basic water and sanitation services to those in vulnerable and underserviced communities.
Private Sector	Private sector players are involved in service delivery bringing access to funds and operational efficiencies to the sector.
Partnerships	Various players may work together and collaborate with municipalities to provide sanitation services to low-income areas in need

The workings of the public sector in implementing sanitation solutions are often plagued with inefficiencies in the form of the time taken to implement projects, to the payment of contractors and manufacturers. Issues surrounding late and outstanding payments have been highlighted which has often resulted in incomplete projects as companies, construction or toilet manufacturers cannot operate without payment. The diagram below depicts the various levels orders are generally passed down. The National Department of Basic Education does not have the capacity to implement projects across the country, but rather each provincial department is tasked with ensuring basic sanitation for all. These projects are then handed over to implementing agents such as the DBSA, The Mvula Trust and the Department of Public Works, who subcontract projects to consultants who in turn hire contractors to construct and carry out the project at hand.

Figure 18: Hierarchy System for School Sanitation Infrastructure Implementation

The multiple levels of authority that subcontract projects to implementation agents, consultants, and contractors, significantly inflate the cost of sanitation at each level. The provincial departments should directly issue the projects to contractors to avoid this. It has been recommended that the Department of Public Works should carry out these projects as a preferred implementing agent as they are the custodian of public assets. However, it is not certain the same issues which surface through various other implementing agents will not occur.

Corruption in the sector is rife and may exist in many forms such as corrupt public sector officials, in manufacturers and construction companies through the procurement process, and in the fine details of product specifications. Manufacturers often refrain from speaking out against corruption, and the lack of transparency within the sector, as it could lead to the detriment of their business in the future. It is not uncommon for construction companies owned by public officials to be prioritized and favoured.

There has been a reduction in the education infrastructure budget which has resulted in provinces having insufficient funds to deal with infrastructure backlogs at public schools which include sanitation, electricity, water, and inappropriate materials used in the school's construction. This will in turn reduce the funds available to address much needed maintenance.

The lack of available and sufficient funds has been cited as a reason for many provinces not being able to address the infrastructure challenges. However, provinces such as Limpopo, are continuously underspending their budgets. This is partly due to the lack of capacity to carry out the projects and the inability to find the necessary technical expertise.

The spending patterns of provinces such as Limpopo could lead to treasury decreasing infrastructure grants even further in the future. Unspent money is returned to treasury unless provinces are able to motivate why funds should be rolled over to the following year.

Due to the nature of the budget allocations to the water and sanitation sectors occurring over the period of March -May of each year, project rollout often occurs from August. Concerns have been raised that project completion is not always reached and the full budget is not spent, and that project work is often only carried out for 6 months of the year. It has been recommended that a rollout over a specific period and budget be followed. This will allow manufacturers to commence production planning and raw material resourcing, which also be highlighted as a challenge. Manufacturers often resort to 24 hour/ 7 days a week production due to high unforeseen demand. If a yearly rollout is in place, it will allow manufacturers to operate at standard production capacity throughout the year.

There is also the issue of contractors abandoning sites, often due to payment issues, or underestimating project costs. Contractors have cited not being able to access the construction site as a reason for abandoning projects. This further highlights issues within the contractor selection process. These are serious barriers to progress and create an even greater backlog. If these issues are not dealt with, the sanitation backlog will continue to increase, and simply reverses any progress made.

9.2 Relative Cost of Implementation

The cost of projects within the sanitation will vary from project to project depending on a variety of factors such as location, resources availability, and the current state of sanitation facilities at a particular site. The sector often refers to “cost per seat” which can be described as the cost required to construct and install a toilet.

The cost per seat values below have been calculated based on the cost of implementing VIP toilets to high priority schools in the select provinces by the Department of Basic Education. These costs include new VIP pits, boreholes at some schools, preliminaries, contingencies, escalation, PSP fees and implementing agent fees.

Table 18: Varying Cost Per Seat for Each of South Africa’s Provinces (Public Sector Costs)

Eastern Cape	R96,960
Free State	R108,206
KwaZulu-Natal	R93,098
Limpopo	R94,071
Mpumalanga	R90,493
North West	R90,134
Average	**R94,134**

The calculations above indicate that the cost per seat allocation is approximately R94,000. However, it has been calculated that a cost per seat for dry sanitation can total between R50,000 and R70,000. The costs of implementing certain toilet technologies such as waterless urinals can cost approximately R25,000 a seat, where toilets are not situated in conventional brick and mortar ablution blocks.

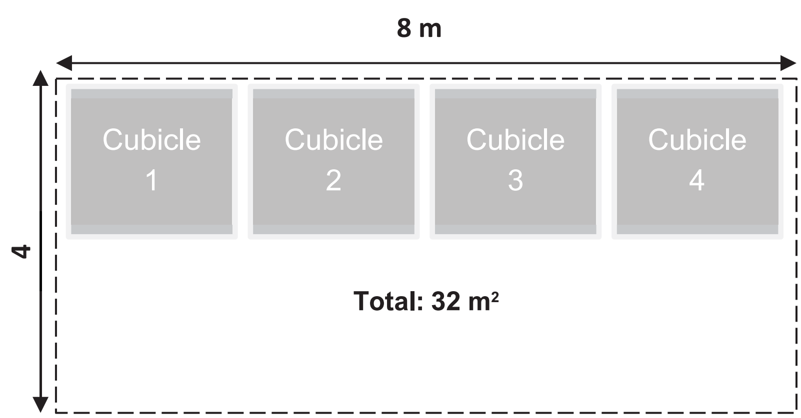


Figure 19: A Four Cubicle Ablution Block (*Source: Aecom, Africa Property Construction Cost Guide, 2018)*

Figure 19 above depicts a simplified sketch of a four-cubicle ablution block, using specifications from the Norms & Standards. According to the Norms & Standards, a single cubicle should have an internal space of 3,24 m^2. Using average building costs for schools, the average cost of constructing the four cubicle ablution blocks costs approximately R200,000. If four toilets are installed, costing on average R10,000, the average cost per seat would amount to R60,000.

The following tables provide costs estimates for two scenarios when implementing sanitation facilities in school:

Table 19: Public School With 200 Learners (Governmental Cost Per Seat)

Number of Toilets	14
Average Cost per Seat	R93,000
Total Capital Cost	R1,302,000

Table 20: Public School With 200 Learners (Industry-Based Cost Per Seat)

Number of Toilets	14
Average Cost per Seat	R60,000
Total Capital Cost	R840,000

The difference in costs might not seem as significant, but when taking into account the vast deficit of toilets, the difference in the cost per seat value becomes extremely important.

Table 21: Relative Cost Per Seat and Opex Costs (Private vs. Public Sector Estimates)

	Private Sector Cost per Seat	Private Sector OPEX (PA)	PVT Sector Cost only Toilet and piping, Ex Works	Public Sector Cost per Seat	Public Sector OPEX (PA)	Public Sector Cost only Toilet and piping, Ex Works
Flush toilet connected to a public sewerage system	R 60,000	R 2,376	R 10,000	R 93,000	R 3,683	R 15,500
Flush toilet connected to a septic tank	R 70,000	R 300	R 20,000	R 103,400	R 465	R 31,000
Pour flush toilet connected to a septic tank	R 53,900	R 300	R 3,900	R 83,545	R 465	R 6,045
Chemical toilet	R 8,000	R 9,000	R 8,000	R 12,400	R 13,950	R 12,400
Pit latrine/toilet with ventilation pipe	R 53,800	R 340	R 3,800	R 83,390	R 527	R 5,890
Pit latrine/toilet without ventilation pipe	R 53,800	R 340	R 3,800	R 83,390	R 527	R 5,890
Bucket toilet (collected by municipality)	R 50,700	R 1,800	R 700	R 78,585	R 2,790	R 1,085
Bucket toilet (emptied by household)	R 50,700	R 629	R 700	R 78,585	R 975	R 1,085
Ecological sanitation systems	R 58,800	R 3,200	R 8,800	R 91,140	R 4,960	R 13,640

	Private Sector Cost per Seat	Private Sector OPEX (PA)	PVT Sector Cost only Toilet and piping, Ex Works	Public Sector Cost per Seat	Public Sector OPEX (PA)	Public Sector Cost only Toilet and piping, Ex Works
VIP	R 53,800	R 340	R 3,800	R 83,390	R 527	R 5,890
Water Recycling System	R 60,000	R 300	R 10,000	R 93,000	R 465	R 15,500
Composting (UD)	R 54,000	R 500	R 4,000	R 83,700	R 775	R 6,200

The capital, operational and maintenance costs of the various toilet technologies is dependent on several variables which are context specific. This makes estimating these costs for various technologies quite complex and could even vary between province and rural or urban areas. The costs above were calculated as the average estimates.

Table 22: Factors Affecting the Total Cost of Sanitation Services

Collection Rate	If containerized, how often will waste be collected
Frequency of Cleaning	How often are toilet facilities cleaned and restocked with consumables
Cleaning Staff	How many cleaning staff are required to adequately maintain the toilets?
Maintenance Cost	What type of maintenance is required? What is the cost of maintenance? How often is it required?
Operational Cost	What is the day-to-day cost of operating the toilet? Is it wet or dry sanitation?
Capital Cost of Toilet	What is the capital cost associated with the toilet hardware?
Capital Cost of Construction	What is the capital cost of constructing and ablution block or pit for VIP toilets? Are ablution blocks brick and mortar or container based?
Security Costs	Are schools safe from vandalism or theft?
Level of Service	What level of service is being offered?
Infrastructure	Pre-existing or construction required
Population Density	How many users will make use of facilities? How many users is the technology intended for?
Public or Private	Are toilets installed for personal use or communal?
Environmental Effects	Is there a possibility of groundwater contamination?

9.3 Economic and Value Chain Assessment

Significant economic activity can be gained through the involvement of the private sector in the provision of sanitation infrastructure and services to the residential and school markets to replace and upgrade deficits and insufficient services. The direct revenue contributions have already been represented and show that the schools market represents a R26.4 billion opportunity, with the residential market showing a R293.9 billion opportunity for new build (to replace old and ineffective infrastructure) and a R5 billion annual opportunity for operational and maintenance contracts. These are based on market prices from the private sector.

In addition to the direct benefits there are also benefits that filter through the economy as indirect benefits. This is calculated using the Input – Output Tables from Statistics South Africa and converting matrix using the Leontief inverse.

For schools the additional indirect revenue to the economy was calculated and represented in the table below. The R26.4 billion opportunity for school upgrades to 100% compliance will generate a total of R62.8 billion additional value added to the economy through additional indirect multiplier effects along the value chain.

Table 23: Indirect Value Added (GDPR) generated through upgrading schools to 100% compliance

	Construction Activity	Plumbing and Sanitation Services	Operational Revenue and Maintenance
Indirect Value Added (GDPR)	R49,738,219,278	R11,035,473,800	R2,018,561,898

The opportunity in the residential market would generate R299 billion direct revenue by replacing inadequate infrastructure. This would translate to R391.5 billion in additional indirect value added to the South African economy.

Table 24: Indirect Value Added (GDPR) Generated Through Upgrading Inadequate Infrastructure in the Residential Market

	Construction Activity	Plumbing and Sanitation Services	Operational Revenue and Maintenance
Indirect Value Added (GDPR)	R328,262,520,500	R16,851,776,695	R46,342,385,911

Note: The calculations for the above tables are included in the model summary Excel.

In addition to the indirect value added, the use of sustainable toilet technology will also contribute to revenue generation in the circular economy model, where the waste output from toilets can be transformed into product with economic value. For instance, upgrading schools to 100%

compliance with UD composting and water recycling technologies could potentially add R200 million back into the economy per annum with water savings and composting.

Not only is the economic benefit important, but the socio-economic benefits are also important to the local communities. The positive externalities associated with water savings will have significant positive impacts on local communities where the precious resource can be used for local consumption and farming. Water shortages are common in South Africa and the Northern, Eastern and Western Cape are the most significantly negatively impacted.

Local community involvement in composting is also beneficial to small-scale farming and could provide a unique platform for school-learners to become involved in sustainable development practices in rural communities.

In the circular economy value-chain there is further potential to involve the private sector in the processing of waste to create fertilizer. For example, for each UD toilet in the broader economy there is the potential to create R1,854 worth of composting fertilizer, or 59kg, per annum on average. At a school, this dynamic changes as more learners will be using a single toilet. At a school with up to 200 learners, 14 toilets would be required. If these were UD composting toilets, this would mean that each toilet could potentially generate up to R25,000 of fertilizer per annum. This would mean that the school could potentially generate R363,300 additional value from fertilizer per annum and sell this to the local community.

10 CONCLUSIONS

The sanitation sector in South Africa is a multifaceted one, with multiple stakeholders, all working towards providing each and every South African with their basic human right to safe and affordable sanitation. The sanitation economy in South Africa comprises of a variety of toilet technologies, varying levels of services, and treatment processes of human waste. Vast opportunities exist within this sector which will not only provide sanitation services to those in need, but also transform the way we view both waste, and the simple toilet we commonly use today.

The report has mentioned the challenges in the sector, which relates to water resource management and supply, financial constraints relating to inadequate reporting and spending irregularities, the cost of retrofitting and degrading or outdated infrastructure.

Within the residential, commercial, and public sectors, there exists opportunity to provide both infrastructure and services within the sanitation sector. This is due to the growing demand for sanitation services in the residential sector, which is driven my population growth, the rate of urbanization, the desire to incorporate green and sustainable systems, as well as the development of new residential homes, complexes, and the deployment of RDP housing. Rising utility costs, awareness around sustainable building designs and the need to incorporate resource-efficient systems will drive the uptake of alternative sanitation solutions, coupled with the continued development of retail and office space. The public schools sector currently has an estimated deficit of 400,000 toilets that require upgrades, replacements, or new installation in order for all schools to fulfil the requirements set out by the Department of Education. The direct and indirect economic benefits of this have been presented in this report and show significant potential for the private sector to become involved in the provision and operation of upgraded toilet technologies to replace the old and provide new systems.

To further develop the sanitation economy, incorporation of both a circular and smart aspect of sanitation is required. Human waste is known and has been shown in various cases around the word and in South Africa, that is has a significant value attached to it. It can be processed to produce a variety of products such as energy in the form of electricity and briquettes, feed, water, and fertilizer for agricultural use. These processes create valuable products, creating a revenue stream, which is commonly generated through the payment of services, New and innovative toilet and sanitation design includes both wet and dry systems. These systems operate differently in terms of resource use, waste collection, and processing. These sanitation systems have been designed to provide safe, and affordable, and sustainable solutions.

Providing safe and affordable sanitation is a challenging and complex task, due to spatial planning, diverse geography, varying access to resources, and infrastructure, finance availability, and so much more. The significant gap in access to basic water and sanitation has created vast opportunities in the sector in the form of infrastructure development and service provision.

The key areas of opportunity lie in replacing the current pit, bucket and portable toilets in the residential sector and to upgrade and build new infrastructure in schools that ensure 100% compliance for sanitation standards for learners. The conversion of unimproved sanitation systems to improved systems has been analysed and found to be a major opportunity for private public participation to generate market revenue and additional economic value added.

11 RECOMMENDATIONS ON SECTOR IMPROVEMENT

11.1 Monitoring and Reporting of Basic Infrastructure

As identified in the challenges in this report, the significant sanitation backlog and slow progress being made to eradicate this is a result of poor planning and a lack of accurate and comprehensive baseline data. A baseline for the current state of water and sanitation infrastructure is required for effective planning to take place. There is no clear picture of the infrastructure requirements of each province. Provincial reports on the state of infrastructure at public schools is not uniform and does not contain clear and detailed plans on how issues are going to be addressed. Often the data provided by the provincial and national departments contradict one another and a host of discrepancies can be found in the data. In August 2018, a list of priority schools in select provinces was put together, and since then, no new audit has been done for the country. Many schools were unable to reopen after being closed due to the Covid-19 pandemic, due to a lack of available water. Yet the data published in the Norms & Standards states that no school is without a water supply.

These provincial reports, which are assumed to support the National Department of Basic Education's figures, do not correlate. These reports do not only show that in some provinces little to no work is done to improve sanitation services, but the full budgets allocated to sanitation goes unutilized. This results in no clear and accurate representation of the sanitation infrastructure present in public schools. Provinces have not adhered to the Norms & Standards deadline, and do not provide detailed enough plans as to how and when these issues will be eradicated.

Working through the provincial Department of Basic Educations Norms & Standards Progress Reports, it is noted that the reports are not at all consistent across the 9 provinces. In certain provinces such as KwaZulu-Natal, the exact figures are used for reports of different years with these figures being signed off by the same officials involved in approval control. Therefore, no thorough checks are conducted, or no work is done to establish the current state of infrastructure each year. It is not clear how progress is measured, or if new audits are conducted each year. The report claims to have "spearheaded a programme to eradicate pit latrines', however the exact same number of schools are still utilizing pit latrines. The provincial report by the Limpopo Department of Education notes that the sanitation backlog will take approximately 10-12 years to be fully addressed with its current allocation of 20% of its budget. However, the same report notes that the budget allocated to infrastructure is underspent each year, which reports the trend noted as far back as the 2011/2012 budget.

It is recommended that a full independent audit of public schools is done across the provinces, as this is likely the only way an accurate representation of the sanitation system in public schools can be provided. However, it is possible to calculate the number of toilets required to fulfil the Norms & Standards which will result in public schools across the country having appropriate and acceptable sanitation systems.

Once an accurate baseline has been established, comprehensive planning is required which takes into account availability of resources, the capacity of the department to carry out the projects, and the necessary skills and expertise needed. If not, the backlog of not only adequate water and sanitation will continue to increase. This is coupled with misused funds allocated over the years to these projects that have failed, those that have been poorly implemented and required significant maintenance or complete replacements, and those that are yet to achieve their targets.

11.2 Non-Paying Customers

Many South Africans who do not have access to basic water and sanitation are non-paying customers. These customers are from indigent and low-income groups and water and sanitation services are paid for by government, investors, or developers. To provide viable and sustainable sanitation solutions to these customers, a circular sanitation approach can be incorporated to subsidize the cost of sanitation and to make implementation easier and more cost effective.

The Product-As-A Service model can be used here as it focusses on revenue generation, and customers are not purchasing the product but rather paying for services they use. The distribution companies (can also refer to government/municipalities) who implement these technologies will retain ownership. A contract will be put in place for users to pay a monthly fee for services such as toilet use, waste removal, as well as service and maintenance.

These solutions will require proper waste management solutions to be implemented to ensure proper and safe collection and transportation of waste. The solution should incorporate smart sanitation technology to ensure clear communication between manufacturers and customers as well as to be used as a means of remote payment, as payment collection in remote rural areas can become an issue.

Flexible and innovative payment solutions are required to increase collection rates. Collection rates can be improved through accurate and improved metering; through aligning billing cycles with income cycles; and avoiding any charge discrepancies which will lead to unsatisfied customers. It is important to test the willingness of indigent and low-income customers to pay for reliable services. Often vendors or resellers charge low-income households inflated prices for basic services. If households are willing to pay for these services out of desperation, these same households could be willing to pay for basic services provided through municipalities at reduced rates.

The use of a mobile app payment solution can ease this process while allowing users to track their usage and the services they are paying for. Using mobile payments will enable remote payments to service providers and will allow service providers and users to connect and provide support when needed. Through communication between service providers and users, a trusted relationship can be built. This will also require partnerships with mobile operators. Connectivity and availability of data is required to enable the use of smart applications. Perhaps applications of this nature can have zero data charges, further encouraging its use.

The waste produced from these communities will be converted into secondary products off site. For this to be a viable operation, large off takers of secondary products need to be secured. These off-takers will purchase the bulk of the products, and residents and small, local off takers will purchase products in smaller quantities. Demand for by-products can be created using incentives and regulations which are in place to encourage the use of these products.

The customers' needs are important in establishing the level of service required, and the types of service options they are interested it. The local community can be involved in service delivery at various points of the value chain, which is an opportunity to create meaningful and much needed employment, boosting local economies. The benefits of improved service delivery through the municipalities should be created among community members, which can be done through prominent locals or NGO's present. Improved service delivery will also reduce illegal connections which often lead to the design capacity of systems being exceeded.

11.3 Regulations to Facilitate Water Reuse

The laws and regulations currently available for municipalities in various provinces indicate that there is no clear definition of greywater and black water that is consistent across the provinces. Given South Africa's encounter with droughts, and the effects of climate change going forward, the country simply cannot continue to flush potable water. This is unsustainable and places increasing pressure on our already stressed water supply. The demand will continue to increase with urbanization and the continuous development of commercial buildings.

By implementing regulations that facilitate the re-use and recycling of water in both the residential and commercial places, it will reduce the pressure on our water supply, and allow for properties to become self-sufficient. However, to maintain its customer base and revenue stream, municipalities may offer these systems to its customers. Municipalities can oversee the capital costs of recycling systems and customers can pay monthly rates fee to cover this. This can be done using the Integrated Utility Services Model. Utility companies should offer a range of sanitation solutions to its customers. These could be both residential and commercial customers who are in the process of developing homes, estates, or commercial buildings. Reinvented toilets will form part of the building design. Customers would avoid the high upfront capital costs associated with the technology and the fees paid to the utility will cover the capital costs over the contract period.

Regulations should incentivize customers to install alternative systems, and these can be incorporated into new residential homes, residential complexes and estates, apartment buildings and commercial properties. Current properties that are unable to retrofit water and sanitation systems to the degree of water recycling, then have the option to install systems that flush approximately 2 litres of water.

However, many reinvented toilet manufactures have highlighted the difficulty in obtaining representation to customers. New customers are often only presented with conventional toilet system when many reinvented toilet solutions are available at similar prices. Similar issues are present in tendering processes, where reinvented toilet manufacturers compete with conventional suppliers. A clear definition of black and grey water is required, along with effluent standards for various uses. Regulations need to be developed that support the implementation of sustainable sanitation systems across sectors.

11.4 Involvement of the Private Sector and Exploiting the Economic Potential of the Circular Sanitation Economy

The fundamental success factor to providing sustainable sanitation services to the public will be to involve the private sector in taking advantage of the significant market opportunity of providing and servicing sanitation infrastructure. As previously noted in the analysis, the involvement of the private sector can improve efficiency in servicing the installed base of sanitation infrastructure but it is very important to note that not all types of toilet infrastructure are lucrative for the private sector to build, own or operate. One of the key barriers to entry in the sanitation market is the volumes needed to make servicing profitable.

In the context of this analysis the opportunities that were focused on were related to the upgrade and build of toilets in areas which are off-grid, in order to provide and improve the sanitation systems with new solutions that would involve the private sector and the local community in the circular economy. Targeting private sector involvement in provision of school sanitation could be a first step. We have already identified that there is potential opportunity for providing systems that offer water savings, such as water recycling systems or Enviroloos.

Considering the challenges to private sector involvement, the following factors are noted:

- Public tenders for toilet infrastructure build are vastly more expensive than private sector build
- Once-off tenders for build result in high cost and the outcomes are extremely varied in terms of infrastructure volume and quality
- Many providers of infrastructure win tenders, but are not able to provide adequate servicing of the infrastructure
- Sometimes the providers of infrastructure are not dedicated sanitation companies
- Once infrastructure is built it is not serviced sufficiently and prone to degradation

Dedicated sanitation companies that specialize in the provision and construction of a toilet technology type have to ability to sustainably service and offer new builds on an annual basis.

This is the key differentiator in looking at companies that have provided toilet builds for the public sector. This is also a key differentiating characteristic that could provide a solution to more private sector involvement.

In the report we have identified and estimated the opportunity for improving sanitation for the commercial, residential and public sector (schools). The revenue potential is significant when considering the need to improve sanitation in the residential and school segments, but the current system of infrastructure build has not provided the necessary success rate. It is suggested public private partnerships are formed to allow the public sector to offer potential build, own, operate PPP contracts to dedicated toilet technology providers. The PPP model may also allow for transfer of ownership after a specified period of time to the public sector, however the incentive would be greatly increased for private sector involvement if these contracts are renewed on an annual basis depending on the level of service provided. This would mean that the private sector would own and service the infrastructure, placing more responsibility on the private sector for involvement in provision of infrastructure, utilizing a system that requires continuous involvement. This would improve service provision, improve the speed of build and offer private companies more lucrative incentives. The private sector would then also become more actively involved in assessing old infrastructure that would need improvement. In order so service some of these toilet technologies it may be necessary to employ staff on the ground. This could prove beneficial to job creation in the private sector and minimises the need for additional municipal contracts that may have been required to service the infrastructure if owned by the municipality.

In order to take advantage of the circular economy benefits and value-added economic potential, it will be important to incentivize these private companies to invest in solutions that could potentially add value back into the community. It will also be possible to offer them investment potential for profit returns from larger schemes, such as biogas or power generation schemes. This would also offer them an additional revenue stream from the output of their toilet technologies that previously had no value or was costing them money to dispose of safely.

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12 APPENDIX A

The section below details inventions from the expo from various countries. Each technology is accompanied by a technology readiness level (TRL) to give an indication of the stage the technology is at with respect to research, development, and deployment.

Technology Readiness Level

Research	1
	2
	3
Development	4
	5
	6
Deployment	7
	8
	9

A. USA

Duke Center for WASH-AID: The Empower Sanitation Platform TRL Stage: 7 – Technology Demonstration			
Community toilet with both liquid recycling and solids processing. The toilet is compatible with pedestal and squat plate styles. Onsite processing includes electrochemical disinfection and recycling of liquids as well as drying and sterilization of solids with optional combustion. User amenities may include body wash and hand wash stations in addition to menstrual pad dispenser and other disposal options.			
Maintenance Requirements Life Expectancy	Ash/dried solids emptied weekly (by user) Life Expectancy: 10	Capacity (Users/day)	10 to 50
Segmentation	Household and Community: Designed for 10 to 50 users per day. The processing system can be community block	Estimated Cost ($/users/day)	TBD

B. China

Clear Environment Technology: Recycling Toilet TRL Stage: 8 – Production & Deployment			
The Clear toilet uses a full-water cycling process for treatment of sewage. A rain collecting system can also replenish the water to the processor for self-renewal. Blackwater from the toilet is pumped up to the sewage processor for treatment and then recycled to the storage tank for flushing. An advanced unique "Biofilm-MBR" treatment process is employed as the core technology for treatment, producing a stable and clean effluent that is further disinfected to ensure safety of the effluent for reuse.			
Maintenance Requirements Life Expectancy	Membranes to be monitored and replaced as needed every two (2) years. Solids may need to be emptied every year. Life Expectancy: 10 Years	Capacity (Users/day)	1000
Segmentation	Multi-unit: Tourism sites, schools, or public/community applications Technology could be potentially scaled down to serve as a single household unit, up to 10 users per day,	Estimated Cost ($/users/day)	$ 0.3

Yixing Eco-Sanitary Manufacture Co.: Eco-San Toilet **TRL Stage: 8 – Production & Deployment**			
Eco-San is one of the leading developers of the CalTech technology, focusing on school and public toilets, and containerized toilet units. The backend processing technology capitalizes on anaerobic digestion of solids and an electrolysis system to convert waste into water, hydrogen, and solid fertilizer. Eco-San is piloting three units in China, and two in South Africa. Eco-San's sister company, Yixing Entrustech, is producing and reducing the cost of the electrodes that drive the electrolysis treatment process to make available to all partners.			
Maintenance Requirements Life Expectancy	Solid wastes to be emptied half a year (by user). Membrane filters to be replaced once a quarter. Life Expectancy: 5-10 year	Capacity (Users/day)	50-800
Segmentation	Multi-unit: Core processing technology scalable for schools, or public/community application	Estimated Cost ($/users/day)	$ 0.2

Envirosystems: EnviVac low-flush vacuum toilet **TRL Stage: 8 – Production & Deployment**			
Established in 2003, EnviroSystems Engineering and Technology Co., Ltd. is focusing on new types of vacuum drainage technology, sewage and waste resource recycling technology, as well as ecological town construction technology. The exhibited EnviVac air flush toilet aims to develop a better alternative to the dry composting toilet which has a no water consumption, while maximizing the available waste of resource recovery.			
Maintenance Requirements Life Expectancy	Minimal/no maintenance Life Expectancy: 10 Years	Capacity (Users/day)	200
Segmentation	Air-flush toilet interface can be used in single stall as a urinal, squat, standard, or urine-diverting toilet.	Estimated Cost ($/users/day)	TBD

C. Switzerland

Helbling (with the Gates Foundation) 6 – Technology Demonstration			
Helbling has been engaged by the Gates Foundation to develop HTClean, a next-generation reinvented toilet based on a high temperature and high-pressure processing design. The toilet is being engineered specifically for the domestic household. Intuitive visual cues on operation, maintenance, status, and usability are integrated.			
Maintenance Requirements Life Expectancy	Non-hazardous, non-odorous, solid waste cakes and excess liquids to be regularly disposed by user. Life Expectancy: 20	Capacity (Users/day)	10
Segmentation	Multi-unit: Core processing technology could be scaled for schools or public/community application or by installing units in each stall Household: Designed as a self-contained household unit for up to 10 users per day	Estimated Cost ($/users/day)	TBD

D. Brazil

Brazil is one of the world's most water rich countries as it holds between 12-14% of the world's water, according to the World Bank. However, majority of its water resources can be found in the Amazon River, while Sao Paulo, which is home to over 12 million people, has access to less than 2% of its resources. Sao Paulo's water resources are badly affected by pollution and put under severe strain due to the increase in demand for water, resulting in its supply incapable of meeting the demand.

Ongoing pollution, overuse, and lack of water treatment has resulted in a lack of sufficient supply of potable water in the region. In response to this, the city of Sao Paulo introduced the Water Recovery Project which aimed at:

1. Increasing its recovery of water
2. Promoting the efficient use of water
3. Improving wastewater systems

Brazil's sanitation sector has improved since 2010 by increasing the percentage of its population that has access to clean water and safe sanitation. However, vast inequalities remain in the country as poorer, rural areas still lack access to basic sanitation. This is similar scenario to that of South Africa.

Brazil's government is responsible for sanitation services, but its infrastructure serves only roughly 50% of its 200 million inhabitants. The rural communities are often located near rivers, which serve as a source of drinking water, bathing water, as well as water for cooking. These rivers end up being severely polluted and, as a direct result, poses a serious health risk to those living in these areas and depending on this system as their source of water.

In order to combat this problem, politicians in Brazil are calling for the sector to be privatized. Private companies have already expressed a keen interest in investing into the sector. Privatisation of the sector will open it up for much needed competition, thereby drastically improving sanitation services and preventing any form of corruption.

The National Sanitation Information System reported that the size of the Water and Sanitation in Brazil was US$ 24.8 million (R$ 135 billion). It also reported an investment of US$ 1 million in water and US$ 0.8 million in sewage in 2018.

The country is home to 5,570 cities, of which 40% are serviced by approximately 25 state owned companies. These state-owned companies face financial issues resulting in low investment into the sector. The private sector services approximately 6% of the country's cities. The lack of a national framework and absence of a centralized regulatory body has discouraged private investment. For the private sector, investment into infrastructure projects is favourable because it results in a steady revenue stream from rate paying customers. Not only will privatizing the sector improve sanitation services, it will create thousands of jobs and boost the economy of Brazil.

Many schools in Brazil do not have access to basic sanitation facilities. The School Census of 2018 found that 4.3% of primary schools have no sanitation system (inside or outside school building), and that over 50% have a cesspit. Furthermore, only approximately 40% of schools are connected to the sewer network. The regulations for school toilet facilities states that there should be 1 toilet and 1 waste container for every 40 students. Yet, a study done on a school in Bahia, found that the school was not only not complying with these regulations, but the existing sanitation facilities in poorer regions were also insufficiently maintained and inadequately serviced. Numerous toilets were dirty, broken, inadequate in numbers, unlockable, and did not provide any soap and water for proper sanitary hygiene. Students were interviewed to gain insight into the situation, they reported that they often bring soap and toilet paper from home, or simply refrain from using the toilet throughout the school day, noting that the health risks from using the toilet may be higher than those associated with not passing waste at all. The study also noted how the lack of proper sanitation facilities affected the female students to an even greater effect than male students.

It is therefore not enough to only establish sanitation infrastructure, as they are not maintained, are inconsiderate of socio-cultural aspects and no education and training is carried out, which results in wasted government funds. The WASH project has been implemented in 12 public schools across Anapolis. The initiative is broken down into 4 phases:

1.To evaluate WASH services in the 12 schools

2. To improve the management of services

3. To train managers and teachers on the importance of basic hygiene

4. To educate the school on the environmental effects of poor sanitation

Investing in infrastructure without incorporating the above in public schools in general will likely lead to misuse of facilities or no use at all. Behavioural changes are important to ensure that projects of this nature are sustainable and will not result in sunk costs.

Biosaneamento was founded by the architect Luiz Alberto Altmann Fazio in 2017 to tackle the issue of absence of sanitation in Brazils poorest communities in Rio de Janeiro. The project is aimed at building low-cost biogas toilets in these communities by converting waste into fertilizer and capturing methane gas, which is then used by the local community. Many people cannot afford to purchase gas in these areas. Local materials are also used to construct the toilets, creating jobs for locals. Biosaneamento was able to use $18,000 prize money to build approximately 50 systems to serve over 600 people.

Source: World Bank, Recovering Water: A Results-Based Approach to Water Supply and Sanitation in Brazil's São Paulo State, 2018; German Development Institute, Katharina Stepping, Urban Sewage in Brazil: Drivers of and Obstacles to Wastewater Treatment and Reuse, 2016; Édila Dalmaso Coswosk, Priscila Neves-Silva, Celina Maria Modena & Léo Heller, Having a toilet is not enough: the limitations in fulfilling the human rights to water and sanitation in a municipal school in Bahia, Brazil, 2019; National Sanitation Information System, 24th Diagnosis of Water and Sewage Services, 2018; National Institute for Educational Studies and Research, Statistical Notes: School Census, 2018; United Nation Sustainable Development Goals, WASH in Schools in Brazil, 2019; We Work, Bringing Sanitation to Rio de Janeiro's poorest neighborhoods

E. Kenya

Kenya, unlike Brazil, is a country characterized with limited renewable water resources. To put this into context, the World Bank estimated Brazil's renewable internal freshwater resources at 28,000 cubic meters per capita, whereas Kenya has estimated resources of only 443 cubic meters per capita. Furthermore, like many African countries, areas in Kenya lack basic sanitation infrastructure, resulting in a large percentage of the population without basic sanitation services. The sanitation sector is poorly funded, and a result, solutions such as pit latrines are poorly built. As the country sees an increase in urbanization, the demand for sanitation services increases. The already stressed sector struggles to deal with the containment of waste, as well as its transport, treatment and disposal.

The Kenyan government has appointed the Ministry of Water and Sanitation to be responsible to enhance the accessibility of water and sewerage services. The ministry outlined a program-based budget with the purpose of sewerage infrastructure development. The ministry made KES 35.6 million in 2019/20 and a forecast KES 36.1 million for 2020/21. This budget funds several programs with the aim to increase the number of people accessing improved sanitation, develop the sewerage network and increase clean, potable water access for the population.

The government had limited success so far in providing basic sanitation to the population of Kenya. Only 27% of the population have access to basic sanitation in rural areas in 2017, and a mere 35% in urban areas. Open defecation continues to be a problem in rural areas (14%). Moreover, as of 2017, 41% of the population continues to rely on pit latrines while on 5% have toilet facilities with access to the sewer system. In schools, the available data is limited, but research conducted as part of the Joint Monitoring Programme (JMP) for water and sanitation by the WHO and UNICEF reported, that 100% of the interviewed schools have limited access to sanitation services

In rural areas, open defecation in common, due to lack of alternatives and access to open land. This results in the contamination of water resources which communities rely on for various activities such as cooking, bathing, and cleaning. Kenya wants to eradicate open defecation practices by 2030, in line with the Sustainable Development Goal Number 6, which is for all to have access to basic sanitation and water.

Only 59% of Kenyans access to basic water services and only 29% have access to sanitary services. KIWASH, a USD 51 million investment from USAID, has been working with 231 private sector enterprises to enable 119 307 people to gain access to clean and reliable water and a further 554 609 people with access to basic drinking water. Through combined work with the ministries of health at county level, the development bank eradicated open defecation in 1 147 villages and enabled 94 020 people to gain access to basic sanitation.

Kenya is facing several challenges in its sanitation industry:

1. Little focus on water infrastructure development as opposed to water resource and sanitation management
2. Increased peri-urban and satellite towns have led to increased demand for water and sanitation services

Many companies are however trying to combat this issue through innovation of new toilet technologies. These include Sanivation, which have designed toilets and convert waste into biomass fuel. The company provides an end-to-end solution for rural communities who do not have access to conventional sanitation infrastructure. The cost of the system is USD 7 a month, and waste is collected and processed, and converted into briquettes, which are then used for fuel. The waste collected from the toilets and from farms in the community is treated by harvesting solar power. The company has positively impacted over 200,000 people and sold over 1,500 tons of briquettes.

Other solutions include Ikotoilet, which is a system designed for low water consumption, rainwater collection, water recycling, and water purification. The Ikotoilet can withstand 100 uses per day, and also converts waste to fertilizer. The Ikotoilet is also designed for a second purpose, to be used as a meeting place for various activities surrounding sanitation. It hosts showers, provides sanitizing products, and personal healthcare products are sold onsite. The Ikotoilet also aims to create jobs in the communities they are situated in, by employing individuals to maintain the toilets. Ikotoilets works under a build-operate-transfer model.

Source: World Bank, Why Kenya's Sanitation Challenge Requires Urgent Attention, Water.org, Kenya's Water and Sanitation Crisis; World Bank, Kenya: Using Private Financing to Improve Water Services, 2018; John Njuguna, Progress in sanitation among poor households in Kenya: evidence from demographic and health surveys, 2019; UNICEF, Improving Water, Sanitation and Hygiene in Kenya, 2019;Kenyas Integrated Water, Sanitation and Hygiene Project, Factsheet,2019; National Government Estimates of Revenue and Expenditure for 2018/2019 Financial Year