WATER AND THE CIRCULAR ECONOMY

# Enabling South Africa's Water Security through a Circular Economy

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# EXECUTIVE SUMMARY


Economic development and population growth are giving rise to increasing demands on South Africa's water resources. A number of studies confirm that South Africa is already over-exploiting its renewable water resources, and without additional interventions, will continue to do so in future. A large portion of South Africa's gross domestic product (GDP) and jobs are directly dependent on water. Primary agriculture (including forestry) is the largest user of water, at 61% of the country's water resources, contributing ~3% to national (GDP) and 7% of formal employment; followed by municipal/domestic use (DWS, 2018).

According to the 2nd National Water Resources Strategy, proposed interventions to increase water supply and reduce demand are not enough to bring the South African water sector into balance. New approaches will have to be adopted to reconcile future national water withdrawals with supply. Therefore, there is a need for improving water systems by considering the whole water-use value chain and by identifying solutions that enhance both the economic and environmental performance of the system. A more sustainable, efficient, and sufficient approach to our limited water resources is needed to counteract water depletion and ecosystem pressures. A circular economy approach can help to address these challenges by decoupling development from water consumption, thereby addressing national resource security in support of socio-economic development through sustainable water resource use.

The methodology used in this study to explore a circular economy development path for the South African water sector, included a detailed meta-analysis of local and international circular economy approaches and interventions; and stakeholder engagement processes to collect the views and experiences of South African water sector stakeholders.

The study confirmed that most of the circular economy interventions (CEIs) evaluated for this report are not new to the South African water sector but have only been partly implemented to date. Many interventions are potentially mature and scalable solutions which merit further investigation for mainstreaming. There is overwhelming agreement (92% of respondents) that the South African water sector needs the circular economy to improve water sector resilience and enhance water security. Similarly, there was a high level of agreement (84% of respondents) that the implementation of CEIs in the South African water sector could lead to inclusive growth and (new) job creation, while also mitigating environmental pollution (74% of respondents).

There was a high level of support for established CEIs such as water conservation, water demand management, water reuse, and resource efficiency, and the benefits they provide the South African water sector. There was less support for circular design, 4IR technology application, and circular business models, and the potential benefits they can provide the water sector, possibly the result of less understanding of these CEIs. This is mirrored in the assessment of the level of readiness to implement CEIs in the South African water sector, and the current levels of implementation. Water conservation, water demand management, water reuse, and resource efficiency, were scored by respondents as having a higher level of readiness. Less familiar interventions such as circular design, circular business models, and 4IR technology application, having lower levels of readiness. Established practices such as water conservation, water demand management, water reuse, nature-based solutions, and water resource efficiency are considered to have some level of implementation already in South Africa, whereas circular design, circular business models, and 4IR technology application, lag behind in terms of their current level of implementation.

It was apparent that more needs to be done to raise awareness of CEIs and the potential benefits they can provide the sector. According to respondents (55%), the South African water sector (in general) does not have a good understanding of what the circular economy is and the potential benefits it can provide. Greater awareness around the circular economy and the benefits to the water sector, could help to fast-track circular economy implementation ambitions to ensure future national water security and manage supply and demand risks that could hamper the National Development Plan objectives of economic development and social prosperity.

A number of obstacles and challenges to scaling CEIs in the South African water sector were identified. These included, amongst others, financial constraints and the lack of incentives; lack of knowledge; lack of technical capacity; legislation; a lack of political will; a lack of collaboration between government, industry, and academia; low-priced water and attitude towards water; and public perceptions. Importantly, the identification of these challenges may have paved the way to institute a formal water sector programme and the demonstration of these CEIs.

In conclusion, key and strategic economic sectors should be incentivised to initiate upscaling and mainstreaming of CEIs. An initial focus should be the high water demand and pollution intensive economic sectors, such as agriculture and manufacturing; and the high water-loss (non-revenue water) areas such as cities and towns (human settlements). To achieve any meaningful impact, both the public and private sectors will need to invest in (i) the *replication* of current successful initiatives; (ii) the *localisation* of international best practice examples to local settings; and (iii) the *identification* of new opportunities through ongoing RDI investments.

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# ACRONYMS

| | |
|---|---|
| 4IR | Fourth industrial revolution |
| AFP | The African Future Project |
| CAGR | Compound annual growth rate |
| CE | Circular Economy |
| CEIs | Circular Economy Interventions |
| CEW | Circular economy in water |
| CSIR | Council for Scientific and Industrial Research |
| DEWATS | Decentralised wastewater treatment system |
| DWS | Department of Water and Sanitation |
| EMF | Ellen MacArthur Foundation |
| GDP | Gross Domestic Product |
| IAP | Invasive alien plants |
| IF | International Futures |
| IPAP | Industrial Policy Action Plan |
| IPCC | Intergovernmental Panel on Climate Change |
| IWE | Industrial Water Efficiency |
| NBS | Nature-based solutions |
| NCPC-SA | National Cleaner Production Centre |
| NDP | National Development Plan |
| NGO | Non-governmental organisation |
| NRW | Non-revenue water |
| NWA | National Water Act |
| NWRS | National Water Resource Strategy |
| NWSMP | National Water and Sanitation Master Plan |
| PPP | Public Private Partnership |
| RO | Reverse osmosis |
| SEA | Sustainable Energy Africa |
| SWPN | Strategic Water Partnerships Network |
| USD | US Dollar |
| WISA | Water Institute of Southern Africa |
| WRC | Water Research Commission |
| WRG | World Research Group |
| WSSLG | Water and Sanitation Sector Leadership Group |
| WWTW | Wastewater treatment works |
| WWTP | Wastewater treatment plant |

# 1 Introduction

## 1.1 Background

Water affects every aspect of societal development, it drives economic growth, supports healthy ecosystems, and is vital for life itself. Water and its related services are required across the whole economy, including critical areas of national economic activity such as cooling water for electricity generation and irrigation water for agriculture and food production (CIWEM, 2019).

Climate change has a measurable effect on the water cycle and is expected to reduce freshwater quality and availability. The IPCC (2022) projections indicate that changes in the water cycle will impact on agriculture, energy production, urban water uses and other ecosystem services, with water-related risks expected to increase with every increment in warming level. Population growth and urbanisation are also expected to increase the competition for water resources. These pressures have affected the sustainability of water resources, driving the need for increasingly efficient water use. Research indicates that the global demand for freshwater will exceed viable resources by 40% by 2030 if business-as-usual water management approaches continue (i.e., if we do not change the way water is used, managed and shared) (WRG, 2012, Tahir *et al*., 2019).

South Africa's growing economy and population is also giving rise to growing demands for water. According to the WWF (2017), South Africa is approaching physical water scarcity by 2025. Donnenfeld *et al*. (2018) reports that South Africa is already overexploiting its renewable water resources, and without additional interventions, will continue to do so for the near future. The main drivers of water demand in South Africa are agriculture (for irrigation of crops and sustaining livestock); industrial (for manufacturing applications such agro-processing and textiles; energy generation capacity from non-renewable sources); and municipal (due to the large number of piped water connections, urban population size and portion of population living in urban areas) (Donnenfeld *et al*., 2018; WWF, 2017). A large portion of South Africa's GDP and jobs are directly dependent on water. Primary agriculture (including forestry) contributes about 3% to South Africa's gross domestic product (GDP) and is responsible for 7% of formal employment. The energy sector contributes 15% towards GDP and is responsible for 250,000 jobs. The manufacturing sector contributes 15.5% towards GDP and is responsible for 13.3 % of total employment, while the mining sector contribute 8.8% directly and 10% indirectly towards GDP and is responsible for 1 million direct and indirect jobs (DWS, 2018).

The African Future Project (AFP), using the International Futures (IF) forecasting system predicts that water demand in South Africa will increase from 15.6 million $m^3$ in 2014 to 18.9 million $m^3$ by 2035 (Hedden, 2014).

When taking into consideration the water conservation and water demand management interventions identified by the Department of Water and Sanitation (DWS) in the National Water Reconciliation Strategies, the water withdrawals could be reduced from 18.9 million $m^3$ to 18.3 million $m^3$, but this is still above the expected available supply of 17.8 million $m^3$ as calculated for 2035 (Donnenfeld *et al*., 2018 ).

According to the second National Water Resources Strategy (NWRS 2) (2013) proposed interventions to increase water supply and reduce demand are not enough to bring the South African water sector into balance. New approaches will have to be adopted to reconcile future national water withdrawals with future national supply. Therefore, there is a need for improving water systems by considering the whole water-use value chain and by identifying solutions that enhance both the economic and environmental performance of the system. The draft NWRS 3, takes the above factors into consideration and emphasises the need for reducing water demand and increasing supply; management of water under a changing climate; improving raw water quality; and protecting and restoring ecological infrastructure (NWRS 3, 2021).

**According to the WWF (2017), South Africa is approaching physical water scarcity by 2025.**

A more sustainable, efficient, and sufficient approach to our limited water resources is needed to counteract water depletion and ecosystem pressures as a result of urbanisation, industrialisation and changing climate. A circular economy approach can help to address these challenges facing the country's water system. A circular economy transition provides South Africa with the opportunity to decouple development from water consumption, thereby addressing national resource-security in support of socio-economic development through sustainable water resource use.

When applied to water resources, the circular economy principles of eliminating waste and pollution; closing resource loops; and regenerating natural systems, provide a framework for South Africa to address water security (Godfrey, 2020; WRG, 2012) (Figure 1).

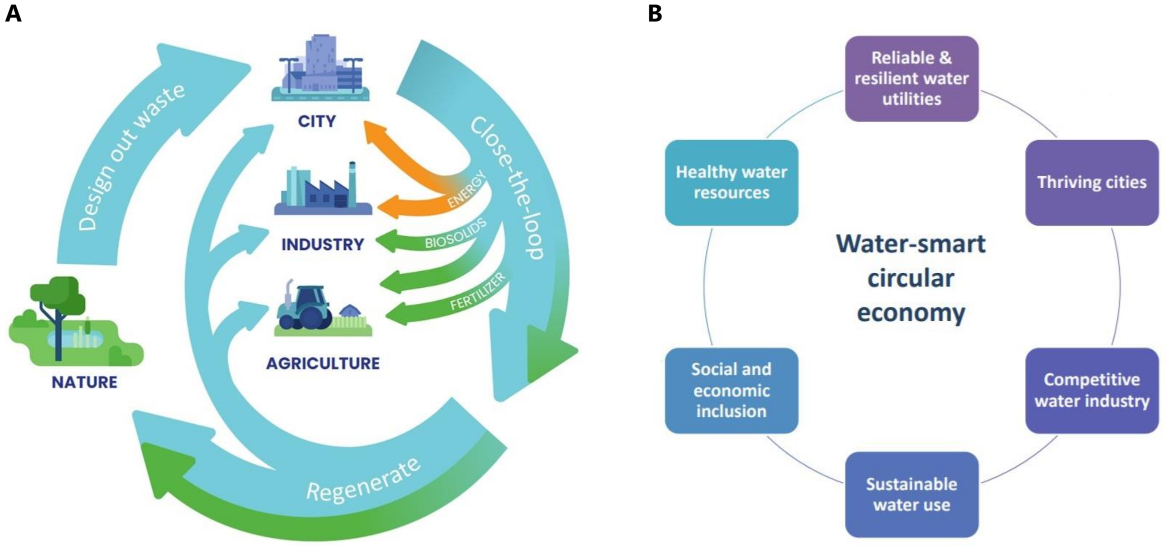


Figure 1. Circular water systems (adapted from Delgado *et al.*, 2021 and Zvimba, 2019)

Applying the three circular economy principles of the Ellen MacArthur Foundation (EMF, 2019) to the South African water sector, points to opportunities in:

1. *Designing out waste and pollution*: e.g., reducing water use and wastewater generation, improved water use efficiency, better water use practices.
2. *Keeping products and materials in use*: e.g., reuse and recycling of wastewater (return flows), reclamation and recovery of resources from water-based waste.
3. *Regenerating natural systems*: e.g., improving water flow and quality through the restoration of land by controlling invasive alien plants (IAP) and rehabilitating and protecting wetlands and riparian systems.

## 1.2 Objectives

As cities continue to grow rapidly and climate change alters the availability and distribution of water resources, meeting population (social) and economic water demands will become more challenging. There is a need to transition from the existing linear "*take, make, use, and waste*" economic model to a more circular one in order to ease the mounting pressure on resources such as water, energy, and materials. This study explores the opportunities for greater circularity in the South African water sector and is a component of a larger CSIR project titled '*Identifying opportunities for a more circular South African economy – A resource perspective*'.

The first phase of this project produced a series of short briefing notes, including one for the water sector, titled "*Decoupling South Africa's development from water demand through a circular economy*" (Seetal *et al.*, 2021). This second phase of the project undertakes a more comprehensive assessment of the circular economy in various sectors of the South African economy, including the water sector.

This report provides a deep dive into Circular Economy Interventions (CEIs) in the South African water sector. It seeks to provide further detail on the following:

a. The *current development path* of the South African water sector, including a high-level overview of the sector, an overview of the current availability and demand for resources, expected trends (assuming little to no major disruption), an analysis of potential resource constraints for future growth of the sector, and the identification of key economic and socio-economic gains and losses associated with the current path;
b. A *potential circular development path* for the South African water sector, including identifying circular economy interventions based on local and international examples; assessment of the appropriateness of these interventions for South Africa through engagement with key stakeholders; a critical assessment of the readiness (including potential obstacles and unintended consequences) to implement these CEIs in the South African context; an assessment of potential business opportunities with the implementation of certain circular economy solutions, including possible high-impact circular economy projects in the sector; and an analysis of how circular economy interventions could address resource constraints, while unlocking environmental, social, and economic opportunities.

Sections 1.2 and 1.3 outline the study objectives and methodology, respectively. Section 2 reviews the current development path for the South African water sector. Section 3 provides insights into the latest trends and circular economy interventions in the water sector. Section 4 explores a circular economy development path for the South African water sector, and Section 5 provides some conclusions and recommendations from the study.

### 1.3 Methodology

The methodology used in this study to explore the circular economy development path in the South African water sector was two-fold. These included:

- A detailed meta-analysis of local and international circular economy approaches and interventions; and,
- The collection of empirical data on the views and experiences of the circular economy by South African water user role-players through stakeholder engagement processes.

The primary purpose of the meta-analysis was to undertake a *status quo* assessment of documented South African circular economy research, practices and experiences and to identify those CEIs showing prospects for mainstreaming or upscaling. The same was done in the international environment for both developed and developing countries, to compare practices and experiences. A special focus was placed on international circular economy practices not yet used in South Africa, but that could have merit and potential for local adoption.

The methodology for stakeholder engagement included participation in an online survey, following an initial public event. The rationale for the stakeholder engagement approach considered that the water user sector is extensive, complex and different to other sectors. Hence, the approach to soliciting the South African circular economy views was designed as an open survey for all economic sub-sector groups / individuals / organisations to participate in, essentially designed as an open and inclusive survey. A key consideration in the stakeholder engagement component of the project design was to mitigate the potential risk of excluding any important circular economy role-players by not soliciting or inviting their direct inputs and also, that the feedback and results from the study needed to be as meaningful and representative of this wide range of water users and impactors in the South African water user sector as possible. This was essential to provide a sound empirical basis to enable continuity with any proposed recommendations for interventions from the project, whether on a policy or a more practical basis.

Some other survey methodological considerations included:

- No one sector individual or sub-sector role-player can articulate all its constituency issues definitively, although representative institutions / organisations can provide generic insights;
- Maximising participation in a screening / survey had to be tactical and appealing, therefore preceded by a public event facilitated by sector leader(s) in an open forum (e.g. DWS-National Water and Sanitation Sector Leadership Group (WSSLG) / Strategic Water Partnerships Network (SWPN) / Water Institute of Southern Africa (WISA); and
- The pockets of circular economy excellence in the water sector needed to be identified, acknowledged and highlighted following the survey.

The online survey was launched at the end of March 2023, during World Water Week. The event, which was jointly hosted by WISA, the CSIR and the SWPN, was titled "*Opportunities for Water Innovation in a Circular Economy*". The significance of WISA and SWPN as the joint event hosts was that:

- WISA is the largest and only multi-disciplinary representative organisation of all water sector professionals in Southern Africa with its membership being in excess of 3500, spanning a wide range of water sector disciplines; and,
- the SWPN represents more than 2000 organisational members across the various economic sectors in the country. The SWPN is an arm of the NEPAD Business Foundation which aims to mobilise businesses to promote sustainable socio-economic development in Africa. It serves to improve the state of the African continent and Southern African region through implementing sustainable business initiatives in trade facilitation, climate action or green transition and digital transition all of which are aligned to the circular economy. As a key role-player in the water sector, it is the only government and private sector co-led water partnership in South Africa, formally identified by the NWRS 2 as the key platform to facilitate water management partnerships between the DWS, the private sector, civil society and other key stakeholders. The SWPN is formally recognised in the National Water and Sanitation Masterplan (NWSMP). Its current main objective is to close a 17% gap between water supply and demand that is anticipated to manifest by the year 2030 in South Africa.

The survey questionnaire is shown in Appendix 1.

# 3 Current development path for South African water sector

## 3.1 Overview of the water sector

South Africa is a semi-arid, water scarce country with a climate characterized by periods of either wet or dry spells with droughts and floods. It is one of the thirty driest countries in the world with highly variable and unpredictable rainfall, and an average annual rainfall of approximately 460 mm, which is less than half that of the world average (DEA, 2011). As a consequence of variable rainfall, the associated rainfall run-off and high evaporation rates, water resources (availability) are unevenly distributed across the country.

Furthermore, human settlement patterns in the country followed historical pre-industrial economic activities of (predominantly) mining and agriculture, which were typically away from the larger watercourses. These areas of major urban and industrial development now have the highest water resources demands, which has necessitated large-scale transfers of water across catchments through inter-basin transfer infrastructure.

In addition, in order to manage the uneven distribution of water resources and to manage floods and drought, the country also invested in water resources infrastructure including dams with total storage capacity of 31 billion $m^3$ (Mwendera & Atyosi, 2018). The country's total annual runoff is estimated to be 49 billion $m^3$/annum, (which includes 10% from Lesotho). However, only a yield of about 14 billion $m^3$/annum of total surface runoff is available for use through dams, inter-basin transfers and other water resources available in the country.

South Africa shares four international river basins namely Orange, Limpopo, Pongola and Maputo rivers, with six (6) neighbouring countries. According to DWS (2018), 45% of the country's total river flow comes from these river basins. Because of these international obligations, South Africa's water availability is further constrained, necessitating an approach to water management that can optimise its use of the available resources. Currently, South Africa with its limited available water resources is using 98% of its available water supply of about 15 billion $m^3$/annum (DWS, 2015, GreenCape, 2021).

The IFC (2019) estimate the country's water consumption at approximately 16 billion $m^3$/ annum, or an estimated 237 litres per person per day, higher than the world average of 173 litres per person per day. Most of this water comes from surface water (68%), 13% ground water and 13% return flows (Figure 3). Other sources, such as desalination make up the remaining 6%. South Africa's water resources are under increasing pressure as the need for both development and socio-economic transformation increases.

Based on growth projections and current water use efficiency levels, the demand for water in South Africa is expected to increase significantly, exceeding supply by 17% by 2030 (Figure 2). Climate change, industrialisation, water-related environmental concerns such as the need to preserve ecosystems, population dynamics, and economic expansion are the primary factors influencing the availability and distribution of water resources (Mwendera & Atyosi, 2018).

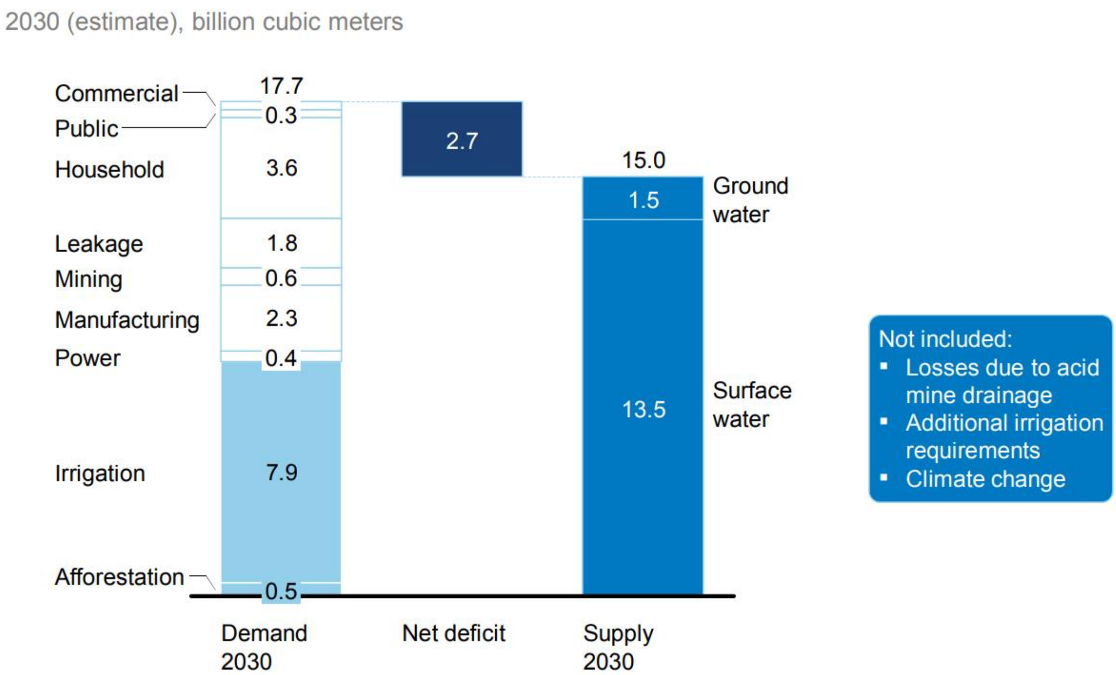


Figure 2. Water demand versus supply projections (figures are billion $m^3$) (WRG, 2012)

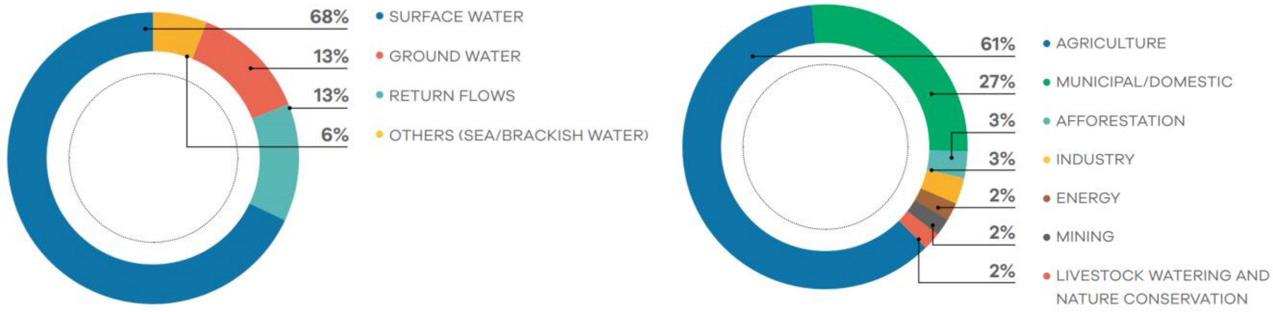


Figure 3. Water supply sources and allocations in South Africa (GreenCape, 2021)

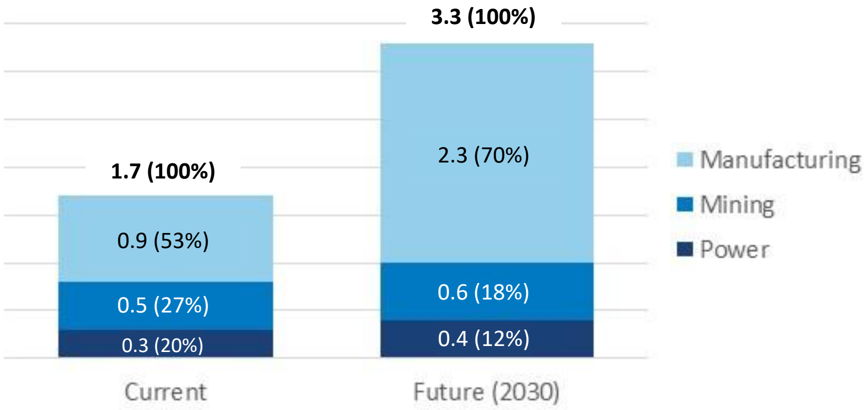


Figure 4. Water demand (billion m$^3$) in industrial sector (adapted from WWF, 2017)

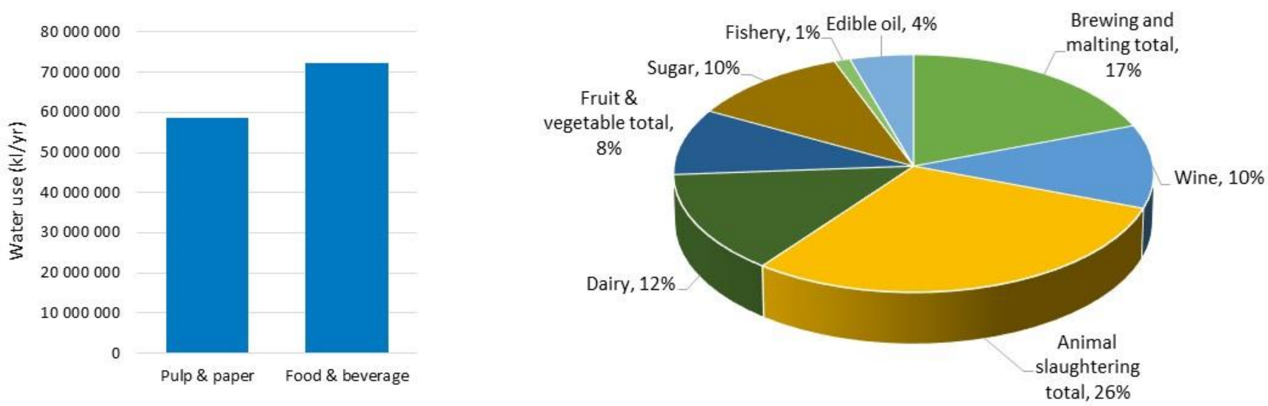


Figure 5. Water consumption in the agri-processing sector (adapted from IFC, 2019)

Direct use of water is concentrated in major sectors of the economy, which include agriculture, manufacturing, mining and energy production and public water supply (EPA, 2012). The sectoral allocations are shown in (Figure 3). Water requirements for irrigation in South Africa are significant, with agriculture representing 61% of total water allocations. Municipal or human settlements, and the industrial sector (including mining, manufacturing, and energy) accounts for 27% and 7% of total water use respectively. Within the industrial sector, manufacturing is the highest user of water and expected to grow by 2030. Figure 4 shows the current and expected demand for water in South Africa's industrial sector.

The Industrial Policy Action Plan (IPAP 2016/17 – 2018/19) sets out the intentions of South Africa to expand the manufacturing sector, in particular agro-processing which is earmarked for national growth and development (DWS, 2018). The National Development Plan (NDP) has also identified agro-processing, together with its upstream sectors as important for economic development, with a potential for creating significant jobs whilst contributing to an inclusive rural economy. The IFC (2019) estimates that in 2019, the agro-processing sector was a significant water user with estimated consumption of about 130 million m$^3$/year, divided between pulp and paper, and the food and beverage subsectors (Figure 5) (IFC, 2019).

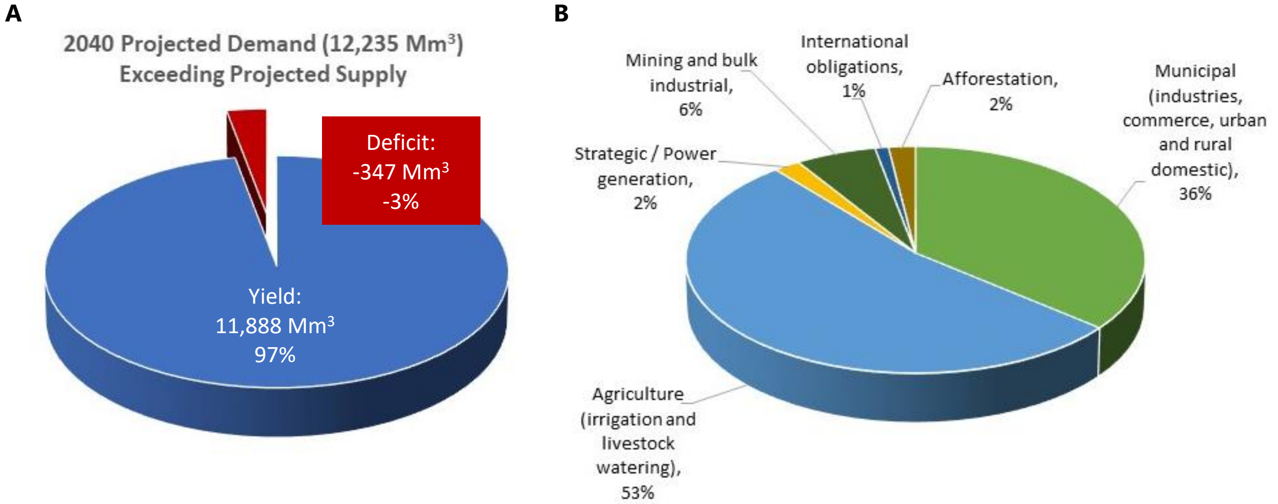


Figure 6. **[A]** Projected demand in comparison to the yield in large water supply systems and **[B]** 2040 Water use per sector projection (DWS, 2022)

Table 1. Provisional water balance with or without critical interventions (DWS, 2018)

| Water use sectors | 2030 water requirements projections (million m³) | | |
|---|---|---|---|
| | Without demand management interventions | With urban losses reduced from 35% to 15% | Reduce domestic demand from 237 l/c/d to 175 l/c/d |
| Agriculture (irrigation and livestock watering) | 9 700 | 9 700 | 9 700 |
| Municipal (industries, commerce, urban and rural domestic) | 5 800 | 4 941 | 3 696 |
| Strategic / Power generation | 430 | 430 | 430 |
| Mining and bulk industrial | 1 017 | 1 017 | 1 017 |
| International obligations | 178 | 178 | 178 |
| Afforestation | 434 | 434 | 434 |
| **Total water requirements (2030)** | **17 559** | **16 700** | **15 455** |
| Total water available (2015) | 13 949 | | |
| Increased surface water yield | 874 | | |
| Increased groundwater use | 405 | | |
| Desalination (including treated AMD) | 588 | | |
| Re-use | 110 | | |
| **Total water available (2030)** | **15 926** | **15 926** | **15 926** |
| Deficit / surplus | -1 633 | -763 | 527 |
| Deficit / surplus | -10% | -5% | 3% |

DWS developed water resource reconciliation strategies for the large water supply systems and metropolitan areas and for all other towns and villages in South Africa to reconcile future water demand and current supply. Identified interventions to improve water supply include water conservation/demand management; development of surface water infrastructure; inter-basin transfer schemes; reuse of effluent; groundwater development; improving existing infrastructure; and desalination of sea or brackish water. The DWS (2022) report shows that nationally, the water supply systems are at a deficit of 96 Mm³/year (1%), predicted to be 3.4% by 2040 (Figure 6).

Other growth projections show that water demand will increase in the agricultural sector by 0.5 million m³, the municipal sector by 1.3 million m³ and industry by 0.5 million m³ by 2030, when compared to the data observed for 2017. The municipal sectors projected increase is attributed to increasing urbanization and increase in the population with access to piped water (Donnenfeld, 2018).

The water balance with or without interventions is shown in Table 1. It must be noted that the differences in the water projections and predictions in different reports and at different time periods, referenced here, are based on two main factors:

- The availability and accuracy of water data as inputs into the models that generate the projections and predictions; and
- The assumptions made on the types of interventions and their respective successes / failures that affect the supply or augmentation of current water supplies, as well as the demand-side interventions and management actions which range from infrastructure maintenance, operations processes, through to user behaviour.

For example, once high confidence water use data becomes available following the completion of water use validation and verification projects in different areas across the country, these result in more accurate reconciliations of water resources availability and demands / requirements and associated projections for the affected areas.

Notwithstanding the above, and although none of the predictions and projections are definitive, the overall consensus is that there will be a water resources availability shortfall within the coming decade, based on the various envisaged socio-economic development scenarios.

With increasing pressure on our water resources, South Africa's water security is at risk.

### 3.2 Potential constraints in providing water for future socio-economic growth

South Africa's water sector is facing a number of challenges caused by insufficient water infrastructure maintenance and investment, recurrent droughts driven by climatic variability and change, growing water requirements driven by industrial and agricultural development, deteriorating water quality in rivers due to anthropogenic-related pollution, and increasing non-revenue water[1] (DWS, 2018; Kalebaila *et al*., 2020; Matumba, 2019; World Bank and IWA, 2016). Further deterioration will lead to system failures and the inability to maintain and manage water resources and provide required water services.

South Africa's surface water resources are highly developed, with limited options for further augmentation and construction or development of physical infrastructure (Moodley *et al*., 2021). Where the potential to build new infrastructure exists, the cost of construction and maintenance will likely affect it negatively because water infrastructure is typically capital intensive, requires a high initial investment and takes longer to recover the initial cost (OECD, 2016).

Changing climate is expected to raise temperatures and decrease rainfall, leading to severe impact on future water availability and contributing to an increasing number of droughts already experienced in the country (UNDP, 2023). Climate change poses a threat not only to the country's water resources, but also to food security, health, and infrastructure. Droughts and floods have had devastating effects in recent years, in various provinces of the country including the Western Cape, Eastern Cape, KwaZulu-Natal, Gauteng, Mpumalanga and North-West. According to King (2021),

> "*average global temperatures will continue to rise, and South Africa will experience more frequent and greater heat extremes*" and these extremes signify "*greatly extended periods of 'drought' (i.e., below historical annual average rainfall), with severe implications for agriculture and all social and economic activity*".

Water and energy are heavily dependent on each other and, if one fails, the other is severely affected. The water service cycle depends on energy for raw water abstraction from dams, rivers or ground water systems, reticulation systems, water treatment processes, and distribution, including wastewater treatment and sludge processing (SALGA, 2014; SEA, 2017). On average, water and wastewater infrastructure accounts for some 20-70% of energy consumption in a South African municipality (SALGA, 2014). This makes the water sector vulnerable to constraints on energy availability. The economic activity of the country is highly dependent on inter-basin transfers of water which requires electricity to work, especially for Gauteng province where several key economic sectors that require high levels of water security are located. Constant power cuts experienced in the country are already affecting treatment and distribution networks in most municipalities and in the absence of power backup, water supply within the country will reduce while demand increases.

### 3.3 Policies and strategies

There are several water- and associated (energy, mining, agriculture, municipal, etc.) sector policies that provide for a transition towards a circular economy. Some of the specific water sector legislation, strategies and policies include the National Water and Sanitation Master Plan (NWSMP, 2018), National Water Security Framework for South Africa (Nepfumbada & Seetal, 2020), National Water Act (NWA 36 of 1998), National Water Resource Strategy (NWRS 2, 2013), and draft NWRS 3.

The National Water Act (No.36 of 1998) provides the legal framework for the efficient and sustainable

[1] Non-revenue water is water that is pumped and then lost or unaccounted for.

management and use of the country's water resources. The National Development Plan (NDP) 2030 sets out the priorities for water demand management and projects the importance for a reduction in water demand by 2030. DWS developed the NWRS (reviewed every five (5) years) to address water resource management to meet the country's development goals. The NWRS 2 responds to priorities set in the NDP and NWA imperatives that support sustainable development. The NWRS 2 acknowledges that South Africa is a country with a water crisis and is dealing with several issues related to water, including supply security, resource pollution and environmental degradation, as well as wasteful water usage (Jordan *et al*., 2021). NWRS 2 aims to manage water effectively and efficiently for sustainable growth and development.  The DWS has developed a water reuse strategy to encourage informed decisions relating to water reuse. NWSMP 2018 details a plan on the priority actions that must be implemented in South Africa by 2030 to address the current water crisis, as well as future water challenges that may impact sustainable development in the country (DWS, 2018). It emphasizes the necessity of optimizing the water mix, which is currently heavily dominated by surface water, with some groundwater and return flows to a water mix that includes increased groundwater use, reusing effluent from wastewater treatment plants, water reclamation, as well as desalination and treated acid mine drainage on the supply side.

While current South African policy and regulation speak to many aspects of the circular economy, the concept has not (yet) been integrated into South Africa's water policy. In recent public stakeholder meetings to solicit inputs into the development of South Africa's NWRS 3, for the first time the circular economy has been formally proposed and tabled as an item for consideration and inclusion as a water sector regulatory instrument to enable and enhance current water use efficiency and sustainability practices in the sector.

# 4 The Circular Economy – A water perspective

## 4.1 Expected trends in water sector

Global water demand is expected to increase by 30% in 2050, influenced by growing population, urbanization, and severe climate changes. Changes in climate worsen water scarcity, lead to droughts and floods events, and affect all areas that are dependent on water (Idrica, 2023). There is a need for alternative water supply that will increase resilience to climate related disasters and ensure a reliable and sustainable water supply for the future. Globally, water utilities and municipalities are investing in innovative technological solutions that promise to improve water efficiency, reduce water wastage, and enhance the quality of water resources. Growing pressures on our water resources are expected to drive interest in digital technologies and non-traditional water sources such wastewater reuse, decentralization, and desalination to optimise water supply resources (StartUsInsight, 2023). Some of these trends are discussed in the following sections.

### 4.1.1 Demand management and water conservation measures

The following trends will play a major role in addressing growing challenges of freshwater availability:

- Efficient irrigation
- Efficient technology for NWR reduction
- Water reuse
- Desalination
- Decentralized recycling of greywater

#### *4.1.1.1 Efficient irrigation*

Water plays a vital role in food security and to achieve sustainable food production, water needs to be managed properly. South Africa's water resources are already under pressure with low levels of assurance for agricultural use. In 2015 the country extracted about 10 billion $m^3$ of water for agricultural use. Table 2 shows the estimated volumes of water wasted through different irrigation types in South Africa (WWF, 2014).

Considering the country's water scarcity, efficient irrigation is a cost-effective measure needed for South Africa to close the 2030 demand-and-supply gap (WRG 2030, 2009). Precision drip irrigation is one of the most water efficient solutions that can be used to optimize or increase agricultural production using the least amount of water. Precision irrigation delivers water and nutrients directly to the plant's roots when required and in the amount that meets the crop's needs. Increasing irrigation efficiency through reduction in water use while improving farming practices will help to relieve the pressure on water resource availability for agriculture and will also have significant effect on the total water requirements. According to a research market report (2019), the global precision agriculture market is expected to double, from USD 4.8 billion in 2018 to more than USD 10 billion by 2024 (DNV, 2021).

#### *4.1.1.2 Efficient technology for non-revenue water reduction*

Non-revenue water (NRW) losses in South Africa are a serious concern with average physical losses in municipal systems estimated to be around 35% (real losses), against a global best practice of 15%. The NWSMP priority action plan includes reducing non-revenue water and water loses in all municipalities to 15% (DWS, 2018). Reducing NRW is critically important to decoupling South Africa's development from water consumption, and in designing out pollution and waste to meet future water demand. Development of smart water monitoring systems that use sensors and algorithms to predict and monitor leaks is the latest trend, and is expected to grow in the future, driven by increased investment in infrastructural development (Research and Market, 2022). Implementing these technologies will help fix problems in the water network before they happen and eliminate water wastage. Reducing NRW will also result in increased municipal revenue, decreased costs, improved service delivery levels and preservation of our scarce water resources.

Table 2. Irrigation efficiency and irrigation water wastage (WWF, 2014)

| Irrigation method | Proportion of total use (%) | Efficiency (%) | Total area in use (ha) | Estimated water wastage ($mm^3$/annum) |
|---|---|---|---|---|
| Flood | 28.5 | 65 | 456 000 | 465 |
| Sprinkler | 25.5 | 75 | 848 000 | 235 |
| Centre pivot | 27.5 | 80 | - | 171 |
| Micro | 13.1 | 85 | 296 000 | 58 |
| Drip | 5.4 | 90 | - | - |
| **Total** | **100** | **-** | **1 600 000** | **929** |

#### *4.1.1.3 Water recycling and reuse*

Insufficient freshwater supply is a key driver for the implementation of water reuse. Water reuse is recognized as an intervention to augment water supply and address critical water shortages. Reusing water in a water scarce country like South Africa can provide a valuable water source for key industries, reducing the demand on limited water resources (Saporiti & Robins, 2021). Sources of water for reuse include municipal wastewater, industrial process and cooling water, and agricultural runoff (US EPA, 2022). Municipal wastewater can become an investment opportunity. Recovery of resources such as energy, reusable water, biosolids, and other resources from wastewater treatment facilities provides an economic and financial benefit that contributes to the sustainability of these wastewater treatment systems and the water utilities operating them (Rodriguez *et al*., 2020).

Instead of discharging wastewater to water streams, it can be treated to the level required by each consumer sector (e.g., crop or field irrigation, groundwater recharge, cooling water or process water for industries, drinking water, etc.) (Rodriguez *et al*., 2020). Reclaiming water for reuse for non-potable uses instead of using freshwater supply can be a water saving measure, saving potable water for drinking purposes. Some of the international and local reuse case studies are briefly discussed in the following sections:

Nestle South Africa (Mossel Bay dairy factory) implemented zero water technology where its wastewater is reused for other applications within the facility. The water is reused for various purposes such as cooling, garden watering and cleaning, eliminating the need for municipal water intake. The reduction of wastewater that needs to be disposed from the factory, frees the capacity at the municipality's wastewater treatment plant.

The Petrochemical Company Chevron, in the vicinity of Potsdam WWTW previously used about 7500 $m^3$/day of municipal water and in April 2006 it started a project to replace the municipal water with reclaimed wastewater to save water. Their water recycling plant draws treated wastewater from the Potsdam Wastewater Works and upgrades it for industrial use at the Chevron refinery. The wastewater is purified to near drinking water quality using clarification, ultra-filtration and reverse osmosis technology, and is then supplied to the refinery for use as steam, cooling water and firewater (Jemenez & Asano, 2008).

Israel is one of several countries facing high risks in water scarcity. As a result, many water reuse projects were started to use urban wastewater from major cities and towns to irrigate crops. Israel treats and reuses 75% of its municipal wastewater for irrigation (Friedler *et al*., 2006; Niekerk & Schneider, 2013).

The City of Cape Town in planning to implement the largest direct wastewater reuse plant to diversify water sources and address scarcity adding up to 100 million litres of water per day. The plant is expected to start operations in 2027 (Huisman of Mail and Guardian, 2022).

#### *4.1.1.4 Desalination*

Desalination is another alternative water source especially in coastal areas. The expected growth in desalination is attributed to technological improvements of reverse osmosis (RO) membranes, which is expected to lower the technology barrier, reduce costs and energy consumption. The water desalination equipment market is estimated to grow at a compound annual growth rate (CAGR) of 8.2% from 2022 to 2032 (FMI, 2022). The DWS estimate that up to 10% of the country's urban water supply could come from desalination plants by 2030 (Creamer Media, 2012).

#### *4.1.1.5 Decentralized recycling of greywater*

Decentralised wastewater treatment systems are considered key to cleaning up urban wastewater issues and providing an affordable and effective alternative to centralised sewage systems, taking pressure off ageing wastewater infrastructure. Their use is most common in less densely populated areas, treating lower volumes of wastewater and often applying low-cost technologies (e.g., stabilizing ponds, anaerobic filters and constructed wetlands). When properly designed and implemented, decentralized treatment systems can allow for the recovery of nutrients and energy, reduce freshwater demand, and help secure access to water in times of scarcity (WWDR, 2017). One local example is the decentralised wastewater treatment system (DEWATS) located in a community in Newlands East, north of central Durban (Newlands Mashu DEWATS project). The system was constructed in 2009, receiving wastewater from 84 households, treating up to 40 $m^3$/day of domestic wastewater. The aim was to assess the potential of DEWATS effluent as a source of nitrogen (N) and phosphorus (P) for a selected crop (banana/taro intercrop), closing the loop by recycling and returning nutrients to soil from a properly treated waste stream for use in agriculture (Musazura *et al*., 2018).

### 4.1.2 Industrial symbiosis

Industrial symbiosis allows industries to trade waste and resources. Sharing surplus water and wastewater resources can contribute to more resilient water systems, promote a circular economy, support net zero emission ambitions and aid positive environmental, economic and social outcomes (IWA, 2022). Collaboration between industries is key in the success of industrial symbiosis programmes.

Entities such as GreenCape and the NCPC-SA currently facilitate a number of successful industrial symbiosis programmes in the Western Cape, Gauteng, Limpopo, KwaZulu-Natal, Free State and Mpumalanga. Since inception, the NCPC programme, for example, has shown many successes including saving 1,030,500 $m^3$ of industrial water from 2015 to 2018 (NCPC-SA, 2018).

### 4.1.3 4IR Technology application (Digital water)

Smart water network is a fully integrated set of data-driven components (products, systems and solutions) that enables utilities to prioritize and manage maintenance concerns, remotely and continuously monitor and diagnose issues, and use data to optimize all aspects of the water distribution network, wastewater collection, and treatment system (SWAN, 2023; Water 20/20, 2021).

Smart water management tools such as smart meters, when driven by frequent real-time data that a smart water network provides, improvements in system performance, such as leakage and pressure management, network operations, and water quality monitoring, can result in significant capital savings (Water 20/20, 2021). Hence, increasing capital expenditure for future development and improving water systems resilient to issues associated with climate risks. According to the research commissioned by Sensus, smart water networks can reduce utility costs by up to $12.5 billion annually worldwide (Water 20/20, 2021).

### 4.1.4 Nature-based solutions

South Africa's water security depends not only on our built water infrastructure, but also on managed land (sustainable land-use) in our catchments. Globally, there is an interest in employing nature-based solutions to help reduce water risks to economies and society, including water pollution, floods, droughts, and water scarcity, that are likely to become worse under future climates. Nature-based solutions (NBS) offer a variety of social, environmental, and economic benefits, including increasing water yield, improving water quality, supporting food security, reducing flood damage, providing jobs for semi-skilled people, and developing rural economies. Ecological infrastructure includes healthy wetlands, rivers, and groundwater (Acreman *et al*., 2021; WWAP/UN-Water, 2018).

NBS approaches and activities include source water protection; watershed management; wetlands restoration, protection and construction; forest conservation; riparian buffers; water harvesting; agricultural best management practices; afforestation; sustainable drainage systems; and protecting mangroves, amongst others (Cooper, 2022). DWS established the 'Working for Water Programme' to remove invasive alien plants that were using large amounts of water resulting in reduced base flows to streams. The programme has contributed to job creation for local communities, which includes processing the plant material which has been harvested. It has been estimated that the clearing of invasive alien plants from riverbanks in riparian areas, has increased streamflow by nearly 46 million $m^3$ per annum (Green Economy Coalition, 2018; Marais & Wannenburgh, 2008).

# 5 Circular economy development path for the water sector

The traditional linear economy usually characterised by "take-make-use-dispose" has resulted in substantial depletion (and pollution) of water resources. Water is a unique element in the circular economy because it is a resource, a product, and a service and should be considered and valued as such (Morseletto *et al*., 2022). Morseletto *et al.* (2022) further defines circular economy in water (CEW) as an economic framework for reducing, preserving, and optimising the use of water through avoiding waste, efficient use of water and quality retention while ensuring environmental protection and conservation.

Since many industries depend on water, water management is an essential component of an economy. In addition, a lack of access to clean water supplies can reduce both production capacity and profits. Effective and efficient water management brings about benefits across a wide range of sectors and functions which depend on water, including ecosystems services (GWP, 2015). As discussed in the previous section, with increasing pressure on our water supplies, South Africa's water security is at risk. The DWS, in collaboration with the World Research Group (WRG), has identified water conservation and demand management, and diversification of water mix (which includes reuse of water and desalination) as priority areas that need to be addressed to close the gap between water demand and supply.

Circular economy principles have emerged as a response to the current unsustainable linear model and offers an opportunity to maximise the use of resources and reduce waste, capturing the full value of water (as a service, an input to processes, a source of energy, and a carrier of nutrients and other materials).

This section provides an overview of circular economy interventions in the water sector, and the findings from the detailed meta-analysis and water sector engagements, regarding the appropriateness, readiness to implement, and level of implementation of these interventions in South Africa, as well as the potential obstacles or challenges to their adoption.

## 5.1 Circular Economy Interventions

In South Africa's water sub-sectors, there are practices which already reflect circular economy principles. These interventions, which offer the potential to reduce or avoid freshwater extraction, reclaim resources, and reduce energy use (reduce greenhouse gas emissions) are a response to South Africa's known water scarcity and availability and its hydrological regime.

The selected priority CEIs, based on the findings of the literature review and an assessment of current circular water practices, are listed in Table 3, and discussed below.

Table 3. Proposed Circular Economy Interventions (CEIs) for the water sector

| CE interventions | Description and Benefits |
|---|---|
| 4IR Technology application | Use of new smart technologies and innovative systems that embrace the internet of things (IoT), machine learning, artificial intelligence (AI), etc– water saving technology, sensors, monitoring systems and networks, digital twinning, etc |
| Circular business models | Approach where all resources are recycled, reducing the use of new raw materials, limiting losses of raw materials and reusing materials wherever possible in the same product or related products and the business benefits of these are constantly monitored for further improvements and optimisation. |
| Circular design | An approach to production design and resource use that incorporates the three circular economy principles of designing out waste and pollution, keeping products and materials in use and regenerating natural systems |
| Industrial symbiosis | Processes and agreements between different production facilities where the by-product of an industry or industrial process become the raw material for another – waste to resource-sharing surplus water |
| Nature based solutions | Use of natural systems that deliver valuable services to people, such as water and climate regulation, soil formation and disaster risk reduction – ecosystem rehabilitation and conservation (wetlands, estuaries, grasslands, forests, etc) |
| Recycling / reuse | Process whereby wastewater is reclaimed from a variety of sources and treated to a standard appropriate for a second purpose – municipal, industrial and agricultural wastewater. |
| Resource efficiency processes | Process whereby limited resources are used in a sustainable manner while minimizing wastage and impacts on the environment. |
| Water conservation | The minimization of loss or waste, the care and protection of water resources and the efficient and effective use of water – Reducing NRW and drip or precision irrigation |
| Water demand management | Management approach and behavioural change that aims to conserve water by influencing demand – Rainwater harvesting |

## 5.2 Appropriateness of solutions

This section highlights the outcomes of the stakeholder engagement process which was aimed at assessing the appropriateness of the proposed CEIs for the South African water sector. Select comments and observations from stakeholders on the appropriateness of CEIs are also included below.

### 5.2.1 Stakeholder engagements

A total of 134 survey responses were received. Of these, there were 49 fully completed questionnaires and 85 partially completed questionnaires (i.e., not all questions completed). Incomplete surveys typically had one or more open-ended questions unanswered. This report presents the findings from all respondents to the survey. The number of responses varied for the different questions.

In terms of respondent profiles, the majority of respondents (59%) had generally high workplace authority (executive and senior managers) in both the public and private sectors, with considerable circular economy understanding. 83% of respondents had more than 10 years' experience in their respective sub-sector, with 12% having between 5-10 years' experience. 67% of respondents felt they were already involved in the circular economy, with 68% having an excellent or good knowledge of the topic. Experience with circular economy projects also ranked highly, with 59% of respondents having more than 10 years' experience in circular economy related projects, and 25% with 5-10 years experience.

The majority of respondents were from the domestic water supply and services sub-sector (15%), followed by mining (11%), energy (11%) and agriculture and forestry (10%) sub-sectors. Responses were received for all 17 different water user sub-sectors listed in the survey. Most respondents were from the private sector (46%), followed by 36% from government, with academia/research, NGO and other, making up the remaining numbers. 21% of respondents were in science/engineering/technical roles.

When asked to what extent stakeholders agreed that the proposed circular economy interventions could benefit the South African water sector, the results showed that more than 50% of participants strongly agreed with most interventions (Figure 7). There was a high level of support for water conservation, water demand management, water recycling/reuse, and resource efficiency processes. For industrial symbiosis, 4IR technology application, circular business models, and circular design, respondents were either neutral in their responses, or disagreed with the statement, which corresponds well with the level of familiarity with these particular circular economy interventions.

There was overwhelming agreement (80% of respondents agreed and strongly agreed) that the South African water sector needs the circular economy to improve water sector resilience and enhance water security. Similarly, a high level of agreement (84% of respondents) that the implementation of CEIs in the South African water sector could lead to inclusive growth and (new) job creation, while also mitigating environmental pollution (74% of respondents).

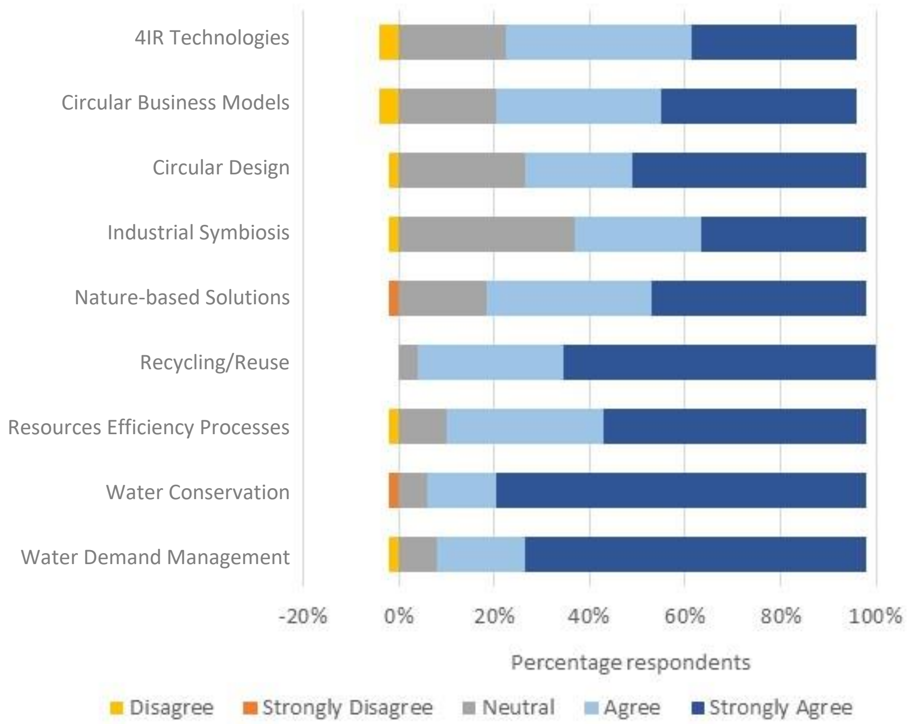


Figure 7. Extent to which circular economy interventions can benefit the South African water sector

According to 82% of respondents, the South African water sector is strongly dependent on the access to other resources (e.g., energy, chemicals, materials) that impact on its performance and management. There was a strong sense from sector stakeholders (74%), that the South African water sector is adversely affected by the export of un-beneficiated raw materials and products from water intensive economic sectors (e.g., agriculture, mining). Essentially, the lack of primary product beneficiation made the country less competitive in the global marketplace and the retention of wastes and waste products from primary production processes offset any potential economic benefit from their production and potential related investment into circular economy practices.

Although a slight majority of respondents (43%) disagreed that the strong dependence of the South African economy on the import of finished goods and high-value products had a positive impact on the water sector through reduced water demands and less pollution, there were mixed views on this issue with 22% in agreement and 35% remaining neutral. This view correlates very closely with that regarding the beneficiation of exported raw primary products.

## 5.3 Readiness to implement interventions

Many circular economy interventions have found application in the global north but are yet to find scale or application in developing countries that face their own unique circumstances. Stakeholders were asked to rate the sectoral readiness to implement these interventions (Figure 8) and the current level of implementation of the proposed CEIs in South Africa (Figure 9). With water reuse already making up a significant part of South Africa's water balance, and with the Western and Eastern Cape provinces experiencing debilitating droughts in recent years, there is an expectation that some circular interventions, e.g., water reuse and water demand management, will already have found scale in South Africa. There has been an ongoing "push" to escalate water and wastewater reuse and to implement more effective water demand management programmes across the country which contributes directly to the sector's circular economy implementation programme.

### 5.3.1 Stakeholder engagement

A high number of survey respondents indicated that the South African water sector is partly ready to implement all of the CEIs proposed (Figure 9).

As expected, given their practice in South Africa, water conservation, water demand management, water reuse, and water resource efficiency, were scored by respondents as having a higher level of readiness to implement. Less familiar interventions such as circular design, 4IR technology application, and circular business models, scored lower in terms of readiness. This may indicate the favouring of more conventional and familiar approaches, rather than any "newer" and unfamiliar ones.

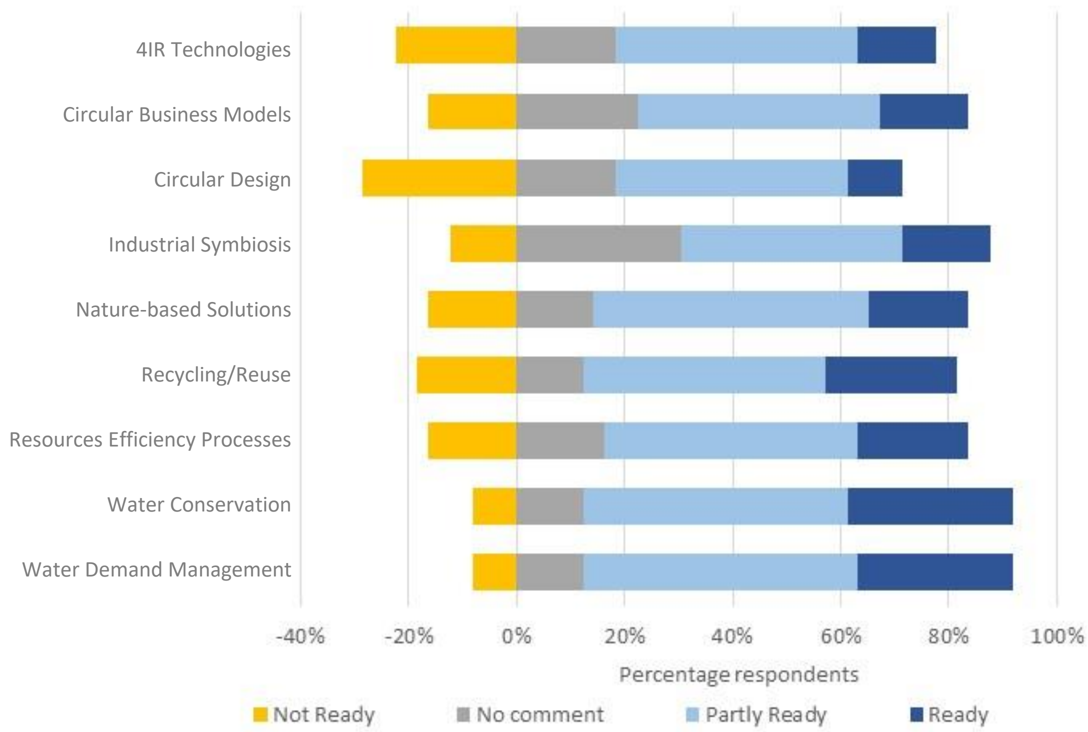


Figure 8. State of readiness to implement circular economy interventions in South African water sector

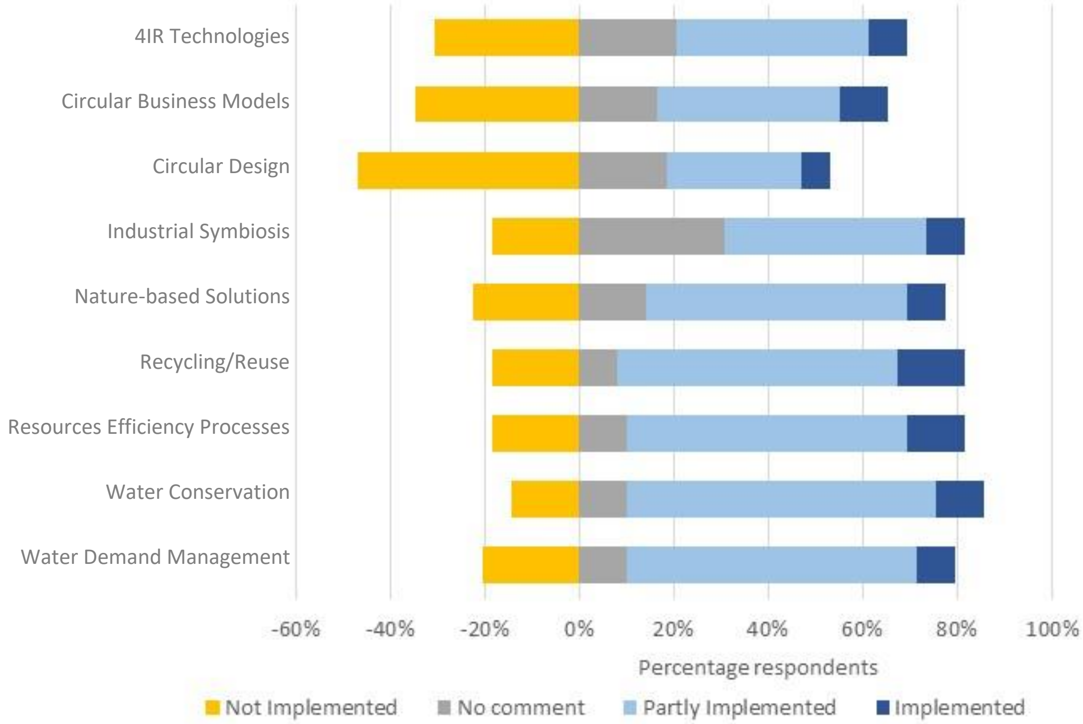


Figure 9. Level of implementation of circular economy interventions in South Africa.

When asked on the level of implementation of circular economy interventions in South Africa, a high number of respondents indicated that all CEIs are partly implemented. Established and conventional water sector practices such as water conservation, water demand management, water reuse, nature-based solution, and water resource efficiency processes are considered to have some level of implementation already in South Africa, whereas circular design, circular business models, and 4IR technology application, lag in terms of their current level of implementation. This may be due to a lack of awareness of the opportunities these interventions provide for the water sector, or the lack of a business case for their adoption.

### 5.4 Challenges and Obstacles to Implementation

Despite the overwhelming support for a greater uptake of circular economy interventions in the water sector, many respondents (55%) were of the view that the South African water sector does not have a good understanding of what the circular economy is and of the potential benefits it can provide the water sector.

Despite the existence of circular economy initiatives and research projects in the South African water sector, extensive implementation and scaling of CEIs is still lacking, with most interventions implemented in pilot or demonstration projects. While these implemented CEIs have the potential to offset and even prevent future water shortages, create new business opportunities, and progressively lead to sustainable water management, there is no concerted effort to encourage their uptake nor scaling.

The issue of the potential benefits associated with CEIs, financial incentives and a leadership compulsion was pointed out in the survey responses as being obstacles to circular economy implementation. Hughes & Lotti (2019) support these findings and have pointed out that even if there are drivers and opportunities that enable transitioning to circular economy practices, there are also barriers or obstacles which prevent wider adoption of these practices. Wastewater treatment plants present a significant opportunity to recover and reuse wastewater and other resource materials. However, there are barriers towards widespread adoption or implementation of wastewater reuse in practice. Barriers include public perception where society finds the water use undesirable, including safety concerns where direct reuse may pose environmental or health risks; high initial investment required with little ROI; and difficulty accessing capital. Other challenges also exist in reusing wastewater for irrigation purposes as the contaminants in the water may impact crops and soil quality, and be harmful to the people who eat the crops. Considering that agriculture is the largest consumer of water in South Africa, there is a need for clear policies that promote safe wastewater use to drive agricultural growth and public acceptance.

Kalebaile *et al.* (2020) have attributed the slow pace of water reuse implementation in South Africa to several complex interrelationships between technological, economic, and socio-political factors. And further highlight that socio-political factors play a far more important role in impeding the widescale implementation of planned water reuse.

Respondents identified a number of obstacles to implementing circular economy interventions in the South African water sector. The main obstacles constituting 70% of the responses, and ranked below in terms of the number of responses, were:

- financial constraints,
- a silo approach/no integration or partnerships,
- a lack of technical skills/capacity,
- lack of political will (coupled with leadership)
- absence of specific regulations/laws/policies and legislation), and
- awareness of the circular economy

Additional obstacles raised included – lack of prioritisation; limited (under) resources; public perception; rules/red tape; attitude towards water/behaviour; lack of incentives; no monitoring, compliance and enforcement; lack of government support; corruption; and resistance to change. These are very similar constraints to the implementation of circular economy interventions as found in the CSIR's other sector studies, including agriculture, energy and manufacturing.

***Lack of knowledge of the circular economy***
An overall lack of awareness of circular economy practices is a significant barrier to developing a circular economy. It is important to raise awareness of the need to reduce, reuse and recycle water throughout the water sector and make aware of the benefits especially in South Africa as a water-scarce country. As noted by one of the survey respondents –

> *"there is the need for human capital building to make people understand the importance of the circular economy and collaboration with the higher education sector to develop short learning programs to bridge the skills gap".*

***Lack of technical and technological capacity***
The lack of technical and technological capacity (uptake of developed technology) within the water sector is another obstacle in implementing CEIs. A number of medium- to large-scale municipal water reuse projects already exist in South Africa. Also, a wealth of literature and technological innovations already exist to support implementation of water and wastewater reuse interventions. Potable water reuse schemes have been implemented in eMalahleni, Durban, Beaufort West, etc., but wide-scale adoption of these developed technologies has always been a challenge and is still lagging. Interventions are mostly implemented as short-term and/or small-scale interventions in response to a need at a particular time.

***Financial constraints/economic issues***
The economic viability, either through a direct return on investment (ROI) or some other means of financial support, is vital to the transition from linear to circular in any sector – the environment must be right or conducive for long-term investment. Many CEIs require adequate investment to achieve widescale implementation. Research has shown that the biggest obstacles to the implementation of interventions such as water or wastewater reuse, is achieving the required return on investment and the lack of initial capital investment to fund infrastructure which requires high upfront investment costs (Kirchherr *et al*., 2018; Liu *et al*., 2021). Partnerships between the public and private sectors are needed to support implementation and scaling, as demonstrated at the Durban recycling plant where the private sector provided the capital needed to implement a wastewater reuse project for industrial purposes under a PPP agreement with the local water utility.

***Public perception***
A lack of public acceptance is also considered a barrier to water and wastewater reuse. The public often have misconceptions about the risks related to reusing reclaimed water (water recovered from wastewater). Engaging or educating the public on the importance and benefits of reclaimed water will avoid a repeat of the eThekwini situation, where the community initially resisted the proposal to recycle and reclaim wastewater for potable reuse (Carnie, 2012). Therefore, there is a need for public education regarding water and wastewater reuse opportunities and the benefits of reusing wastewater, so as to overcome resistance from the public. The public must be assured of the quality of the reclaimed water, so as to not negatively impact environmental and human health.

***Legislation/regulations (Lack of policies that support a circular economy transition)***
The lack of a supportive policy framework is another obstacle to water and wastewater reuse and can hinder the implementation of CEIs. Although South Africa has pockets of circularity within the water sector, it is a necessity to assess the current legal framework from a more circular perspective, to understand if it will support and facilitate the transition from a linear to a more circular water sector. Political will is another important factor needed in transitioning to a circular economy. This links closely to the need for improved awareness around CEIs and their potential benefits to South Africa. Obstructing laws (red tape) are also viewed as obstacles to the implementation of CEIs. There is a need for regulators to formulate policy frameworks that will promote circularity within the water sector in order to alleviate the pressure on surface and groundwater resources.

***Low-priced water and attitude towards water (considered infinite)***
Water is a free or a low-cost resource most of the time, which often makes water projects a low priority compared to other projects.

### 5.5 Business Opportunities to Implement CEIs

The current South African water sector, which is largely dominated by linear practices, needs to evolve into a more resilient, circular water economy, where waste and pollution are designed out, water is continuously reused, and natural systems are regenerated (Mauter & Fiske, 2020). To improve water security, it is important to scale up practices that reduce water demand, increase availability, and facilitate more efficient use of water. The benefits of CEIs in the South African water sector are overwhelmingly supported by stakeholders engaged during this study. Accordingly, there are a number of business benefits and opportunities that can be realised and expanded.

#### 5.5.1 Design out waste and pollution

The NWRS 2 recognises that the development of additional conventional surface water resources is limited and that other reconciliation options such as water conservation and demand management need to be implemented. As part of design-out-waste, addressing water conservation through minimising water losses and wastage (transmission losses and improved infrastructure maintenance) and improving water use efficiencies (technologies and water pinch interventions) are key interventions (Seetal *et al.*, 2021b).

The Industrial Water Efficiency (IWE) Project under the National Cleaner Production Centre (NCPC-SA) reviewed the potential water savings in agro-processing companies over the past three years. The study identified the food processing sub-sector as a focus for the development of a water efficiency guideline, which was subsequently developed in 2021. Implementation of the project resulted in measured water consumption savings of 33,448 $m^3$, with resulting cost savings of R1,087,864 at a food production and processing company which reduced its water consumption from 1316 $m^3$ in 2016 to 426 $m^3$ in 2019 (a 68% reduction) (NCPC, 2020-21). Scaling up water efficiency programmes across all sectors of the economy, has the potential to generate real savings for businesses.

In Monclova-Mexico, the city optimised its water distribution network by regulating water pressure and addressing non-revenue water which boosted the operations and water supply from 10 hours per day to 24. The city realised energy saving of 4.75 million kWh (27% reduction) and water savings of 1.94 million $m^3$ (WBG, 2020).

The need to improve water use efficiency in irrigated agriculture is crucial for sustainable agricultural production (Bwambale *et al.*, 2022). Precision irrigation provides an agricultural system which uses resources efficiently. Precision agriculture can reduce costs associated with water abstraction and increase yields by

means of more efficient and effective application of fertilizers, water and other agricultural inputs (Okole *et al*., 2022). It can also reduce environmental impacts by allowing farmers to apply required amounts of fertilizers, water and other agricultural inputs at the appropriate rate only (Bwambale *et.al*., 2022). Recycling irrigation water, where drainage and surplus irrigation are channelled back to the irrigation network, can be an important asset in water management and is also an integral element of circularity in the agricultural space. Recycling irrigation water can ease the upstream management problem by allowing less precision in distribution because no surplus is lost (Proaxxes, ND).

5.5.2 Keep products and material in use

The purification of wastewater and its subsequent reuse are fundamental to the circular economy and leads to more environmentally sustainable cities (Molina-Gimenez, 2018). Apart from reusing the wastewater, resources and energy can be extracted from the wastewater sludge, easing the stress of sludge treatment and disposal (Liu *et al*., 2021). By-products such as compost or biogas generated from wastewater treatment plants, can be recovered and developed into new markets, with value. The anaerobic processes in wastewater treatment plants generate biogas and a solid residual. Biogas is a source of energy which can be sold to a third party or can be utilized on-site to cogenerate electricity and heat for the wastewater treatment plant, improving the plant's energy efficiency, lowering costs, and enhancing the plant's reliability (Rodriguez *et al*., 2020). The compost or solid residual can be applied to land as a soil conditioner or fertilizer (EMF, 2013). Rodriguez *et al*., (2020) reported on the potential revenue streams and saving that can be achieved from resource recovery from wastewater treatment plants (Figure 10).

Singapore is another world leader in water reuse, recycling large volumes of effluent into high grade water for industrial use. Wastewater is treated using advanced filtration and ultraviolet rays to disinfect the water. The resultant water is known as NEWater. The treated water is mainly used in microchip manufacturing plants which are heavily water dependent. It is also used for cooling systems in buildings. Some of the treated water is used to top up drinking water reservoirs during the dry season and, following further treatment, flows to households. Their recycled wastewater can meet 40% of Singapore's water demand and is expected to rise to 55% by 2060 (WEF, 2022).

One international example is in San Luis Potosi, Mexico, where a thermal power plant (as a third party) uses treated effluent from the nearby wastewater treatment plant to cool its towers instead of using fresh water. The use of wastewater is 33% cheaper for the power plant than previously used groundwater and has resulted in savings of $18 million for the power utility in six years

Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB) in Chennai, a city on the southeastern coast of India has installed, and is operating, energy-recovery plants in seven of its twelve WWTPs to generate electricity from biogas. The approach reduces the energy drawn from the grid and improves the financial sustainability of its wastewater treatment operations.

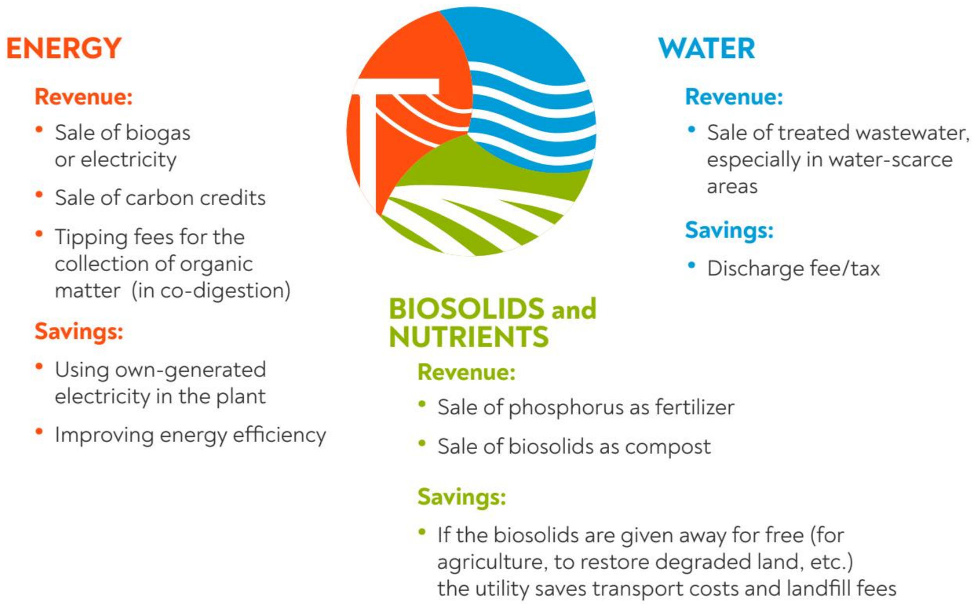


Figure 10. Potential revenue streams and savings from resource recovery for wastewater treatment (Rodriguez *et al*., 2020)

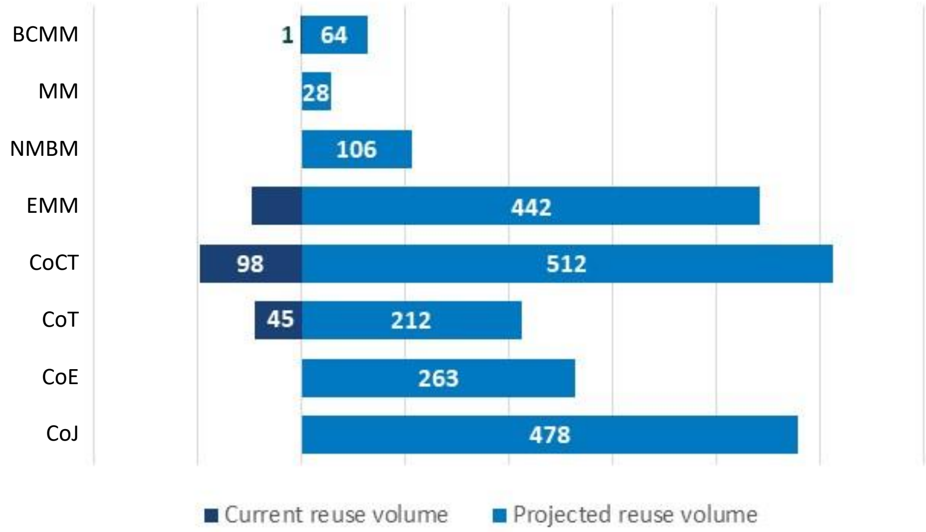


Figure 11. Current and projected water reuse volumes (Ml/d) (CSIR, 2019; Walters and Steyn, 2022)

The partnership between the Village of Ridgewood's water utility and a co-digestion technology provider and engineering company (Ridgewood Green) in the United States led to a successful co-digestion project where a wastewater treatment plant generates enough biogas to power the treatment plant, heat the digester to operating temperatures, thereby lowering their carbon footprint. In return, the Village of Ridgewood buys the electricity produced by Ridgewood Green for the operation of the plant at a lower price than it used to pay for electricity from the grid.

Even though the agricultural sector is the largest water consumer, only a small proportion of irrigated agriculture directly uses treated wastewater. Utilization of treated urban wastewater for urban and peri-urban agricultural irrigation is another important way of helping to conserve and expand available water supplies and reduce the impact of high nutrient levels on water bodies. The use of treated wastewater for urban irrigation and peri-urban agriculture has been used for many years in many countries (Rodriguez *et al.*, 2020). South Africa's water legislation does allow for treated wastewater to be used as a controlled activity for food crop and non-food crop irrigation, and for livestock drinking if it complies with the necessary and relevant health and agricultural standards. The agricultural sector remains the main potential user of treated wastewater.

South Africa has a potential to reuse wastewater for a variety of purposes. Current reuse versus projected water reuse volumes for each of South Africa's metropolitan municipalities are shown in Figure 11. It highlights the growing importance of water reuse as part of the water availability in large, urban metropolitan areas in South Africa.

### 5.5.3 Regenerate natural systems

A nature-based solution such as a constructed wetland offers a variety of benefits, including reduced downstream pollution, improved water quality (sediment trapping, nutrient removal and chemical detoxification) and flood and drought regulation (UN Environment-DHI, UN Environment and IUCN, 2018).

Dini & Bahadur (2018) reported on a case study in Krom River in the Eastern Cape where a rehabilitated wetland played an important role in reducing potential impacts of floods downstream of the wetland during 2006 floods. The rehabilitated wetland managed to slow the velocity and destructive potential of the floodwaters and trap the sediments.

### 5.5.4 Summary

From the foregoing it is evident that business opportunities may manifest in two broad categories – internal business benefits and external (outsourced) options. Whether the choice is a single preferred option or a combination of the two, there is clear evidence of the potential for financial and broader economic benefits where circular economy is implemented. Among the comments relating to circular economy opportunities from the survey, financial incentives from government were proposed to promote the mainstreaming of CEIs. From a number of case studies described, there is evidence to indicate that there are very direct and tangible benefits that can be realised through CEIs, as an incentive in itself as in internal business case and opportunity.

# 6 Conclusion

With expected economic development, most of South Africa's economic sectors are expected to grow, and with it, increasing demand for potable water. This study has provided evidence, supported by the views of water sector role-players, of the potential for the circular economy to be an enabler for a more water resource efficient, sufficient and sustainable growth path for South Africa. The opportunity for a more circular water sector to ensure greater water resource security was a view shared by most water sector stakeholders engaged during the study. Understanding the opportunity a circular economy provides the South African water sector has been facilitated through engagement with highly experienced, knowledgeable professionals, many in senior positions in the public and private sectors and who see the merits of circular economy interventions.

**The study has reconfirmed that most of the CEIs evaluated in this report are not new to the South African water sector but have only been partly implemented to date.**

Many CEIs are potentially mature and scalable solutions which merit further investigation for mainstreaming. There is overwhelming agreement (92% of respondents) that the South African water sector needs the circular economy to improve water sector resilience and enhance water security. Similarly, a high level of agreement (84% of respondents) that the implementation of CEIs in the South African water sector could lead to inclusive growth and (new) job creation, while also mitigating environmental pollution (74% of respondents).

There is a high level of support for, and understanding of, existing CEIs such as water conservation, water demand management, water reuse, and resource efficiency processes and the benefits they provide the water sector. With less support for 4IR technology application, circular business models, circular design and industrial symbiosis, possibly the result of a lack of awareness of the opportunities these interventions provide the water sector, or the lack of a business case for their adoption. This is mirrored in the assessment of the level of readiness to implement CEIs in the South African water sector, and the current levels of implementation. Water conservation, water demand management, water reuse, and resource efficiency were scored by respondents as having a higher level of readiness. Less familiar interventions such as circular design, 4IR technology application, and circular business models, having lower levels of readiness. Established practices such as water conservation, water demand management, water reuse, nature-based solutions, and water resource efficiency processes are considered to have some level of implementation already in South Africa, whereas circular design, circular business models, 4IR technology application, lag behind in terms of their current level of implementation.

More needs to be done to raise awareness of CEIs and the potential benefits they can provide the water sector. According to respondents (55%), the South African water sector (in general) does not have a good understanding of what the circular economy is and the potential benefits it can create for the sector. Greater awareness around the circular economy and the benefits to the water sector, could help to fast-track circular economy implementation ambitions to ensure future national water security and manage supply and demand risks that could hamper the National Development Plan objectives of economic development and social prosperity.

However, a number of obstacles and challenges to scaling CEIs in the water sector were identified. These included, amongst others, financial constraints and the lack of incentives; lack of technical and technological capacity; legislation; a lack of political will and leadership; lack of knowledge on the circular economy; a lack of collaboration between government, industry, and academia; low-priced water and attitude towards water; and public perceptions. Importantly, the identification of these challenges may have paved the way to institute a formal water sector programme and the demonstration of these CEIs. This could be included within any of the current and future governmental District Development Models, Industrial and Special Economic Development Zones, or in critical targeted areas nationally.

In addition, key and strategic economic sectors should be incentivised to upscale and mainstream CEIs within their sectors. An initial focus should be the high water demand and pollution intensive economic sectors, such as agriculture and manufacturing; and the high water-loss (non-revenue water) areas such as cities and towns (human settlements). To achieve any meaningful impact, both the public and private sectors will need to invest in (i) the *replication* of current successful initiatives; (ii) the *localisation* of international best practice examples to local settings; and (iii) the *identification* of new opportunities through ongoing RDI investments.

While the draft NWRS 3 does not make direct reference to the circular economy, it is heartening to note that there is a strong emphasis on the water sector CEIs described in this report. Particular attention is given to reducing water demand, increasing water supply, and protecting and restoring ecological infrastructure through the various mechanisms and interventions described here. Direct attention is also being given to managing water and sanitation under a changing climate. Finally, in whatever manner it is currently framed for formalisation and implementation, the circular economy in South Africa's water sector is its "*no option solution*" to avert a potential future national water crisis.

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## Appendix 1: Survey questionnaire

SURVEY QUESTIONNAIRE

**CIRCULAR ECONOMY INTERVENTIONS FOR THE SOUTH AFRICAN WATER SECTOR**

Dear Participant

You have been selected as a suitable candidate for this survey based on your current (or previous) role within the water sector. The selection process was based on your company / sector involvement in the areas of water conservation, water demand management, recycling, wastewater valorization, sustainability, life cycle assessments, or the circular economy. It would thus be appreciated if you would be willing to participate in this survey which should take about 15-20 minutes to complete.

**The aim of the survey is to assess the suitability of potential circular economy interventions for the South African Water Sector, and the readiness of the sector to adopt these interventions.**

The **information provided will remain completely confidential and the anonymity of respondents will be retained indefinitely**. Based on your specific response(s) and willingness to participate, we may contact you directly for further discussions and possible involvement in ongoing or future sustainability-related projects within the CSIR.

**Please click on the link below for more information on the CSIR-DSI Circular Economy Project as it relates to this survey.**

If required, you may contact any of the following representatives regarding the survey:

| Name | Role | Contact details |
|---|---|---|
| Ashwin Seetal | Project Lead | aseetal@csir.co.za |
| Matlhodi Mathye | Senior Researcher | mmathye@csir.co.za |

## PART 1: DEMOGRAPHICS/PROFILE

**In this section, we would like to request information about you and your company/organization.**

1.1. Please indicate which water user sub-sector(s) you are currently active in. You may select more than one.

| WATER USER SUB-SECTOR | Y | N |
|---|---|---|
| - Domestic Water Supply and Services (municipal, regional, private, etc) | | |
| - Agriculture and Forestry | | |
| - Town Planning / Property / Land Management | | |
| - Financial Services | | |
| - Mining | | |
| - Energy | | |
| - Food and Beverages | | |
| - Textiles and Clothing | | |
| - Wood, Paper, Printing | | |
| - Chemicals (petroleum, plastics) | | |
| - Glass and Non-Metallic Minerals | | |
| - Metals and Machinery | | |
| - Electrical Machinery and Equipment | | |
| - Telecommunications and Electronics | | |
| - Transport Equipment | | |
| - Furniture | | |
| - Other | | |

If other, please specify: ______________________________

1.2. Please select the category to which your organization belongs.

| Type of Organization | Private Sector | Government | NGO | Other |
|---|---|---|---|---|

If other, please specify: ______________________________

1.3. How many years of experience do you have working in your sub-sector?

| Sectoral Experience | < 1 year | 1 - 2 years | 3 - 4 years | 5 - 10 years | > 10 years |
|---|---|---|---|---|---|

1.4. Please indicate your main level of responsibility within your organisation? Note: only one selection.

| LEVEL OF RESPONSIBILITY | Y | N |
|---|---|---|
| Executive | | |
| Senior Management | | |
| Junior Management | | |
| Project Management | | |
| Science/Engineering/Technical | | |
| Research and Development | | |
| Finance | | |
| Extension and Support Services | | |
| - Other | | |

If other selected, please specify: ______________________________

## PART 2: CIRCULAR ECONOMY EXPERIENCE

Circular economy interventions can broadly be categorised under three principles:

(i) *designing out waste and pollution;*

(ii) *keeping materials and products in use, and*

(iii) *regenerating natural systems.*

This survey seeks to appraise a number of proposed circular economy interventions for the South African water sector.

2.1. Please rate your personal knowledge of the Circular Economy (CE).

| **CE Knowledge** | None | Novice | Working | Good | Excellent |
|---|---|---|---|---|---|

2.2. Are you currently (or have previously been) involved in Circular Economy related projects and/or interventions?

◻ Yes

◻ No*

** If your answer is No, then skip to Question 2.5*

2.3. How many years of experience do you have with Circular Economy (CE) related projects?

| **CE Involvement** | < 1 year | 1-2 years | 3-4 years | 5-10 years | > 10 years |
|---|---|---|---|---|---|

2.4. Please briefly describe the CE related projects you are or have been involved in.

1. ________________

2. ________________

2.5. Are you or your company affiliated with any Circular Economy related organisations, e.g. ACEN, Ellen McArthur Foundation, WEF, SWPN, etc?

◻ Yes

◻ No

If yes, please indicate the affiliations below.

1. ________________

2. ________________

## PART 3: PROPOSED CIRCULAR ECONOMY INTERVENTIONS

In this section, we would like to assess the following:

- whether you agree with the proposed Circular Economy interventions,
- your views regarding key interventions to be implemented or scaled, and
- some of the challenges/barriers to the implementation of Circular Economy activities within the South African water sector

Based on your knowledge and experience, please provide responses to the following questions or statements.

3.1. Which of the following Circular Economy Interventions are you familiar with?

| CIRCULAR ECONOMY INTERVENTION | Y | N |
|---|---|---|
| 1. Water Conservation | | |
| 2. Water Demand Management | | |
| 3. Circular Design | | |
| 4. Recycling / Reuse | | |
| 5. Resources Efficiency processes/systems/technologies | | |
| 6. 4IR Technology Application (smart meters, monitoring, remote controls, AI, etc) | | |
| 7. Industrial Symbiosis | | |
| 8. Circular Business Models (sharing economy, partnerships and agreements, etc) | | |
| 9. Nature-based Solutions | | |

3.2. To what extent do you agree that the following Circular Economy interventions can benefit the South African water sector?

| CIRCULAR ECONOMY INTERVENTION | Y | N |
|---|---|---|
| 1. Water Conservation | | |
| 2. Water Demand Management | | |
| 3. Circular Design | | |
| 4. Recycling / Reuse | | |
| 5. Resources Efficiency processes/systems/technologies | | |
| 6. 4IR Technology Application (smart meters, monitoring, remote controls, AI, etc) | | |
| 7. Industrial Symbiosis | | |
| 8. Circular Business Models (sharing economy, partnerships and agreements, etc) | | |
| 9. Nature-based Solutions | | |

3.3. The South African water sector is in need of Circular Economy interventions to improve resilience and water security.

| Your Rating | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|

3.4. The implementation of Circular Economy interventions within the South African water sector would lead to inclusive growth and (new?) jobs creation

| Your Rating | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|

3.5. The implementation of circular economy interventions within the South African water sector could mitigate environmental pollution

| Your Rating | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|

3.6. The South African water sector is strongly dependent on access to other resources (e.g. energy, chemicals, materials, etc) that impact on its performance and management

| Your Rating | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|

3.7. The South African water sector is adversely affected by the export of unbeneficiated raw materials and products from water intensive (water supply and wastewater discharge) economic sectors

| Your Rating | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|

3.8. The strong dependence of the South African economy on imports of finished goods and high value products has a positive impact on the water sector (reduced water demands and less pollution).

| Your Rating | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|

3.9. The SA water sector has a good understanding of what the Circular Economy is and the potential benefits for the sector.

| Your Rating | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|

3.10. How would you rate the South African water sector in terms of its readiness towards implementing the proposed Circular Economy interventions listed below.

| CIRCULAR ECONOMY INTERVENTION | Not Ready | Partly Ready | Ready | No Comment |
|---|---|---|---|---|
| 1. Water Conservation | | | | |
| 2. Water Demand Management | | | | |
| 3. Circular Design | | | | |
| 4. Recycling / Reuse | | | | |
| 5. Resources Efficiency processes/systems/technologies | | | | |
| 6. 4IR Technology Application (smart meters, monitoring, remote controls, AI, etc) | | | | |
| 7. Industrial Symbiosis | | | | |
| 8. Circular Business Models (sharing economy, partnerships and agreements, etc) | | | | |
| 9. Nature-based Solutions | | | | |

Please elaborate on your response above, particularly where you consider the sector is not ready

______________

3.11. Do you know of examples of Circular Economy interventions that are already implemented?

| CIRCULAR ECONOMY INTERVENTION | Not Implemented | Partially Implemented | Fully Implemented | No Comment |
|---|---|---|---|---|
| 1. Water Conservation | | | | |
| 2. Water Demand Management | | | | |
| 3. Circular Design | | | | |
| 4. Recycling / Reuse | | | | |
| 5. Resources Efficiency processes/systems/technologies | | | | |
| 6. 4IR Technology Application (smart meters, monitoring, remote controls, AI, etc) | | | | |
| 7. Industrial Symbiosis | | | | |
| 8. Circular Business Models (sharing economy, partnerships and agreements, etc) | | | | |
| 9. Nature-based Solutions | | | | |

3.12. Are there other interventions you consider important that may have been omitted?

Please elaborate ________________________

3.13. What would you consider are the main obstacles towards the implementation of the proposed Circular Economy interventions for the South African water sector?

Please list possible obstacles ______________________

3.14. Please provide any additional information you consider relevant to the implementation of the Circular Economy within the South African water sector

______________________________________________

3.15. Would you be willing to be interviewed (if needed) to discuss the above issues in further detail?

- ◻ Yes
- ◻ No

**Thank you for your participation in this survey, your time is appreciated and insights highly valued!**

## Appendix 2: Definition of Terms

| | |
|---|---|
| Water reuse | Utilization of treated or untreated wastewater for a process other than the one that generated it, i.e., it involves a change of user. For instance, the re-use of municipal wastewater for agricultural irrigation. |
| Wastewater use | Wastewater use is the intentional or unintentional use of untreated, partially treated, or mixed wastewater that is not practiced under a regulatory framework |
| Decentralized wastewater treatment system | Treatment of wastewater or water at point of supply or demand |
| Grey water reuse | Wastewater derived from the domestic and household use of water for washing, laundry, cleaning, food preparation etc. Grey water does not contain faecal matter |
| Groundwater-Aquifer recharge | Manmade processes or natural processes enhanced by humans that convey water underground. The processes replenish ground water stored in aquifers for beneficial purposes |
| Non-revenue water management | Water that is pumped and then lost or unaccounted for. |
| Precision agriculture | It is based on the optimized management of inputs (water) in a field according to actual crop needs. |
| Rainwater harvesting | Collection and storage of rainwater that runs off from roof tops and catchment areas (parks, roads or open ground). |
| Desalination | The removal of dissolved salts from water to make it fit for use. |