DESALINATION IN SOUTH AFRICA: PANACEA OR PERIL FOR INDUSTRIAL DEVELOPMENT?

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Trade & Industrial Policy Strategies (TIPS) is a research organisation that facilitates policy development and dialogue across three focus areas: trade and industrial policy, inequality and economic inclusion, and sustainable growth

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Key findings

1) Desalination is a costly technology with high capital and operational costs. Desalination via reverse osmosis (membrane separation) is the leading desalination technology in the world today.
2) The desalination market is a small portion of the world water market (1.7% of capital expenditure) but is expected to grow at a relatively high rate (15% a year over the period 2015-2022)
3) The implementation of seawater desalination in South Africa has been limited, with a few small-scale desalination projects in the country. While future plans for desalination in South Africa were ambitious, there is a high chance that many projects will not materialise. This is already evidenced by moves away from the technology in KwaZulu-Natal and the Western Cape.
4) Local producers of desalination technology include international firms with local branches and purely local firms. Local desalination firms cater primarily for foreign markets.
5) The primary drivers for desalination are the need for water supply and socio-economic development. The primary barriers are environmental sustainability, being fit-for-purpose, ease of implementation, cost savings and energy security.
6) Desalination faces techno-economic risks related to high capital costs, energy costs, uncertain future rainfall, and environmental costs. Socio-political risks are also expected if water tariffs prevail to be high, and projects are not structured appropriately.
7) Local research and development (R&D) activities are generally carried out by water specialist companies, research organisations, and academics.

Key policy implications for South Africa

1) The local desalination industry is small, consisting of export-orientated firms, such as Grahamtek and Membratek. Large-scale industrialisation investments and efforts would not be appropriate, and existing support measures should be continued. Appropriate R&D funding should be designated to grow the industry and spur innovation.
2) Increased demand for desalination of brackish industrial water can be driven in key water-intensive sectors, such as mining, through encouraging smaller-scale desalination activities to recover spent water that has been processed in industrial processes. This can be done through mining licences.
3) Due to the export-orientation of local firms, incentives and subsidies to procure local goods and services for the export market, where possible, can serve as mechanisms to support adjacent manufacturers in the desalination market. These markets include the supply of integral desalination elements, such as membranes, chemicals and pumps, and general water-related components such as valves and piping.

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ABBREVIATIONS

dti (the)	Department of Trade and Industry
BWRO	Brackish Water Reverse Osmosis
ERD	Electrodialysis Reversal
DEA	Department of Environmental Affairs
DWS	Department of Water and Sanitation
GWI	Global Water Intelligence
MF	Microfiltration
ML	Megalitres
O&M	Operations and Maintenance
PPP	Public-Private Partnership
R&D	Research and Development
RE	Renewable Energy
RO	Reverse Osmosis
SWRO	Seawater Reverse Osmosis
TIPS	Trade & Industrial Policy
UCT	University of Cape Town
UF	Pore ultrafiltration
US	United States
WRC	Water Research Commission

1. INTRODUCTION

Water is a precious resource that underpins a successful economy. It is an essential input into numerous industries, and lack of water can wreak havoc on an economy. The recent water crisis in South Africa is testament to this. The desalination of water has been identified as a potential source for water in the country. Many voices have hailed desalination as the country's cure to water security woes, while critics have cited its high cost and potential environmental harm as rendering the technology unfit.

This paper seeks to contribute to the debate by examining two fundamental issues related to desalination. First, it examines whether desalination is appropriate for the South African context. This involves looking at how the technology is implemented, what the principal cost drivers are and the key trends in the technology. Then, it investigates the potential business model considerations that have to be borne in mind when thinking about adopting the technology for the country.

Second, it investigates whether South Africa could play an active role in providing desalination solutions to global markets. This is congruent with supporting the local industry and identifying a role for industrial policy to play a part in advancing the industry. To see what policy measures are appropriate, both the local and foreign markets for desalination are analysed.

The paper proceeds as follows. Section 2 outlines the technology and looks at the key international trends driving the desalination market.

Section 3 analyses the demand-side factors, shedding light on the international and South African desalination markets.

Section 4 looks at the business model considerations with desalination, specifically analysing the techno-economic risks, funding, socio-political risks, and drivers of desalination.

Section 5 considers the supply-side factors, honing in on the main players in the local and global manufacturing and R&D space.

Section 6 formulates key policy implications and Section 7 concludes.

2. PAST, PRESENT, FUTURE OF DESALINATION TECHNOLOGIES

Outline of technology

Over the past 30 years, desalination technology has evolved as a viable, albeit costly means of producing water, opening up non-traditional sources of water such as brackish water[1] and seawater (Voutchkov, 2016). The desalination process can occur at the origin of the water value chain when applied to seawater or aquifers, and at the wastewater treatment stage when applied to water that has been consumed, such as in the case of effluent mine water. Desalination of seawater is most ideal for supply to coastal regions that are close to the sources, while the desalination of water from industrial processes can be used for inland areas, which may be distant from the sea.

Desalination of water from any source takes place broadly via two processes: thermal evaporation and membrane separation (Voutchkov, 2016). *Thermal evaporation* involves the evaporation and condensation of saline water to purify it, and is most prevalent in the Middle East due to the access to cheap fuel and the historic use of facilities which co-generate energy and water (IDE-tech, n.d.; Voutchkov, 2016). Since heat is a vital input in thermal desalination, the process is typically coupled with power plants and refineries that discharge significant quantities of waste heat (IDE-tech, n.d.). *Desalination via reverse osmosis (RO)* is the prevalent membrane separation process in which pressure is applied to saline water, forcing it through a selectively permeable membrane, which purifies the water and removes the salt (Parise, 2012).

Thermal desalination processes are substantially more energy intensive compared to RO (Banat, 2007, p. 12). This is owing to the thermal processes requiring direct heat to evaporate saline water, in addition to electricity to drive pumps and electrical components, while RO desalination only requires the latter (Al-Karaghouli and Kazmerski, 2012, p. 1; Banat, 2007, p. 12). In addition, thermal desalination can only be used to purify sea water, and is only viable for large plant capacities, while RO plants can purify seawater and brackish water from mines and other industrial processes, and can be built for small- and large-scale plant capacities (Al-Karaghouli and Kazmerski, 2012, p. 1; Banat, 2007, p. 12). RO desalination also compares favourably to thermal desalination in that RO plants cost comparatively less to build, are simpler to operate, have a higher production-to-space ratio, and are easier to maintain[2] (Al-Karaghouli and Kazmerski, 2012, p. 1; Banat, 2007, p. 12). Thermal desalination as a process costs about four times that of desalination via RO (Laubscher, 2017).

Owing to the differences between the two types of desalination, thermal processes are favoured in locations only where energy costs are low (and possibly subsidised), and where waste heat is available (Banat, 2007, p. 12). Conversely, RO is favoured in other locations and has been the most predominant technology used in desalination globally (Banat, 2007, p. 12).

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[1] Brackish waters can be found in natural sources like aquifers and inland lakes, or from industrial sources like mines (World Bank, 2004, p. 32).

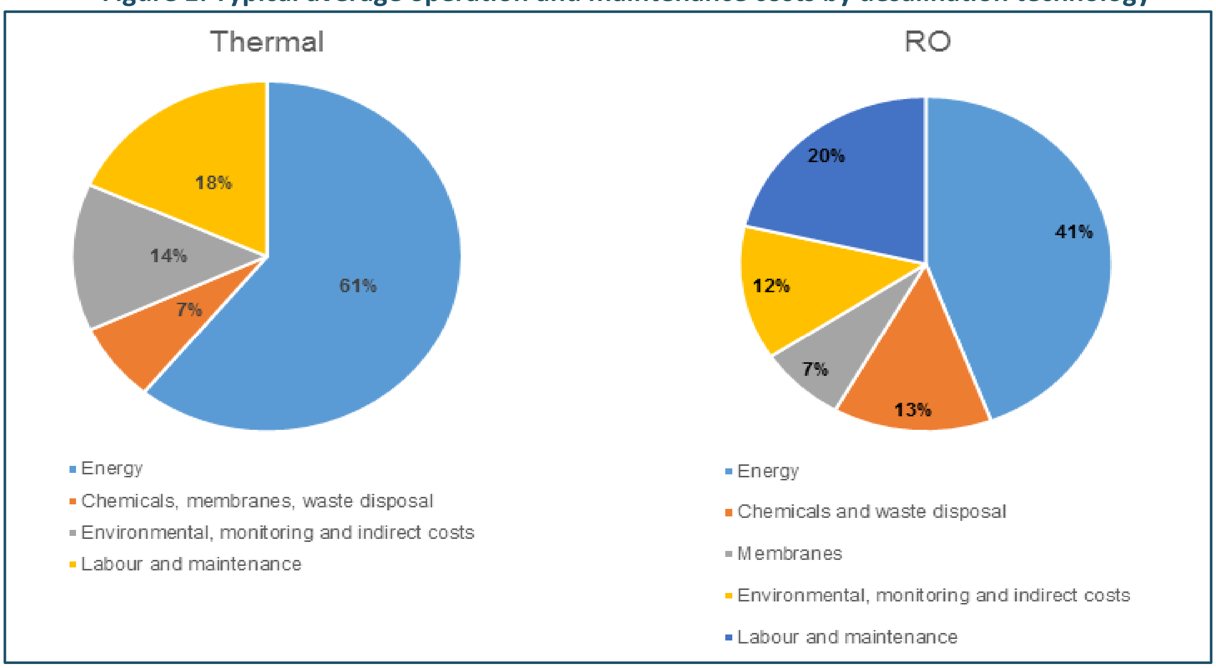
[2] With RO desalination, the entire plant does not have to be shut down when there is problem on a unit, or for routine maintenance.

An RO desalination plant is built on four integral systems: pre-treatment, high-pressure pumps, membrane systems, and post-treatment. Before water can be introduced to membrane, it undergoes pre-treatment to render it to the correct water quality, where processes remove suspended solids and prevent salt precipitation and microbial growth. High-pressure pumps then apply the correct amount of pressure to force the water through the membrane system, which separate out the salt from the water (Krishna, n.d., p. 5). At this point, water may be suitable for industrial use and pumped directly to industrial users. Such is the case, for example, at the Veolia-operated Mossel Bay desalination plant, which supplies five megalitres (ML) of desalinated water a day to PetroSA (Veolia, n.d., p. 2). Finally, the desalinated water can undergo post-treatment to render it to a potable standard where the water is stabilised and prepared for bulk distribution (Krishna, n.d., p. 5).

Key technological trends

The key cost drivers of desalination technologies relate to their high-energy intensity and associated energy cost; the high cost of membrane maintenance due to their cost and short lives; the high risk of failure of the pumping systems due to their high pressure operation; the growth of bacteria on membranes affecting the quality of desalinated water (also known as fouling) (Al-Karaghouli and Kazmerski, 2012, p. 1; Banat, 2007, p. 12); and the chemicals required in various parts of the system. Major developments in RO technology have assisted to mitigate against these challenges and lower the costs associated with this technology over time, however, relative to other water technologies, desalination remains highly costly. In a typical desalination plant, energy is the most substantial contributor to operational costs. Energy alone can account for between 37% and 55% of costs in the operation, depending on technology (CMI and Almar Water Solutions, 2016, p. 15).

Figure 1: Typical average operation and maintenance costs by desalination technology



Source: Author’s adaptation of CMI and Almar Water Solutions, 2016, p. 15; Advisian, n.d.; WRC, 2015a, p. 25

The development of energy recovery systems has contributed to the decline in energy costs associated with the technology. Energy recovery systems allow for the production of energy through high-pressure steam that is connected to desalination pressure systems. These recovery systems reduce the energy costs associated with RO desalination and have been a major contributor to declining costs, increasing the growth of RO plants worldwide (Al-Karaghouli and Kazmerski, 2012, p. 3; Krishna, n.d., p. 5).

Another significant cost driver in desalination systems are chemicals, which can account for up to 13% of operations and maintenance (O&M) costs in a typical RO system, the most common type of desalination (see Figure 1). Chemicals are used throughout the entire desalination system. These chemicals serve the following functions: adjusting pH, controlling scale, removing particulates, preventing biological fouling of membranes, and cleaning and remineralising the highly purified product streams (ICIS, 2010).

For a list of typical chemicals used in desalination, see the Appendix. In the pre-treatment phase, chemicals are used to ensure efficient operation of the membrane, as water that is not treated leads to the fouling of the membrane with particulate matter, organic/inorganic compounds, and biological growth (Valavala et al., 2011, p. 205). Chemicals used in pre-treatment processes include aluminium and iron salts, ferric chloride sulfate, sodium hydrogen sulfite, calcium carbonate (calcite), calcium sulfate, and gypsum (Valavala et al., 2011, p. 206-207). Chemicals are also used to clean membranes to increase their efficiency (Garcia-Fayos et al., 2014).

Recent advances in desalination technology have seen reductions in the use of chemicals. One example is the substitution of pre-treatment chemicals with membrane-based pre-treatment prior to water passing through the RO membrane. This involves the use of large pore ultrafiltration (UF) and microfiltration (MF) membranes to filter out solids before treatment with conventional chemical methods or to completely replace chemical methods (Valavala et al., 2011, p. 207-210). This reduces or completely eliminates the need for chemicals at the pre-treatment stage, thereby reduce ng chemical costs. Innovative firms such as IDE Technologies, for example, have developed their IDE PROGREEN™ system, which eliminates chemicals entirely from the desalination system at both the pre-treatment and membrane cleaning stages (IDE-tech, n.d.). Veolia also has its range of Hydrex™ 3000 and Hydrex™ 4000 desalination chemicals tailored to the desalination process, which aims to reduce operations costs (Veolia, n.d.).

The final notable cost component relates to the cost of membranes used in desalination, which can account for up to 7% of operations costs in a RO desalination plant. With membrane technology, newer membranes have been developed to last longer; allow more water to pass through; remove salt more efficiently; and are priced more competitively (Krishna, n.d., p. 5). These innovations have filtered into the South African market to some degree. For example, Veolia, the largest operator of desalination plants in South Africa, incorporated energy recovery systems and the latest membrane technology in their plants in the country in order to conserve energy and reduce costs in the desalination process (Veolia, n.d., p. 2).

In the face of growing water demand globally, the expected scarcity of traditional water resources, and the global shift towards reducing the dependence on fossil fuels, desalination powered by renewable energy (RE) sources has attracted a lot of attention.

There are numerous RE sources that can technically be coupled with desalination, however, the most common combination is solar photovoltaic (PV) systems with RO desalination (Mahmoudi et al., 2017, p. 1). At present, the technology supporting RE-powered desalination has not advanced to a level where it is viable for wide-scale operation, and the cost of water produced still remains significantly higher than conventional technologies (Mahmoudi et al., 2017, p. 1). Despite these barriers, a notable success for RE desalination in South Africa has been the setting up of a demonstration solar PV plant in Witsand in the Western Cape.

It is expected that by 2030, for example, RE-powered seawater RO plants will be able to produce water at a cost comparable to conventional technologies (Mahmoudi et al., 2017, p. 1).

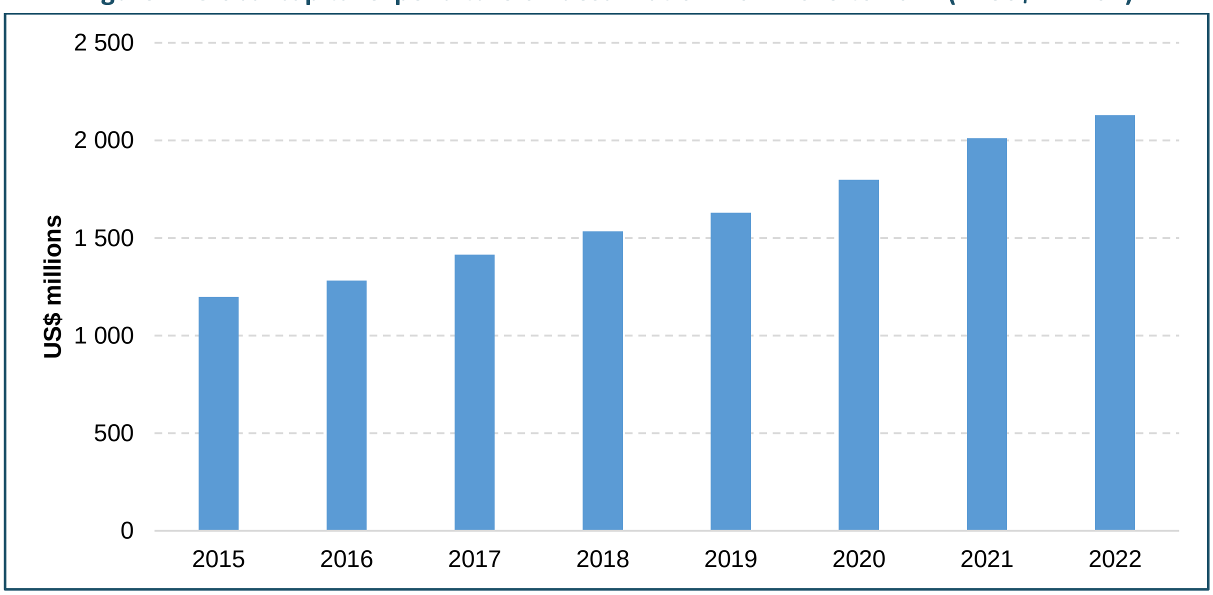
3. DEMAND-SIDE DYNAMICS: GLOBAL AND LOCAL TRENDS

Global dynamics

Currently, desalination accounts for only 1% of the world supply, with expectations of this proportion to double by 2030 (Voutchkov, 2016). Desalination of seawater is particularly promising because of the relative abundance of seawater, which accounts for 97.2% of the world's water resources (Voutchkov, 2016). Further, using seawater has the advantage of a water source which is resistant to drought and essentially unlimited (Voutchkov, 2016).

While desalination accounts for a small proportion of the total capital expenditure in the water market, the technology faces strong growth prospects over the near future, as indicated in Figure 2.

Figure 2: Global capital expenditure on desalination from 2015 to 2022 (in US$ million)

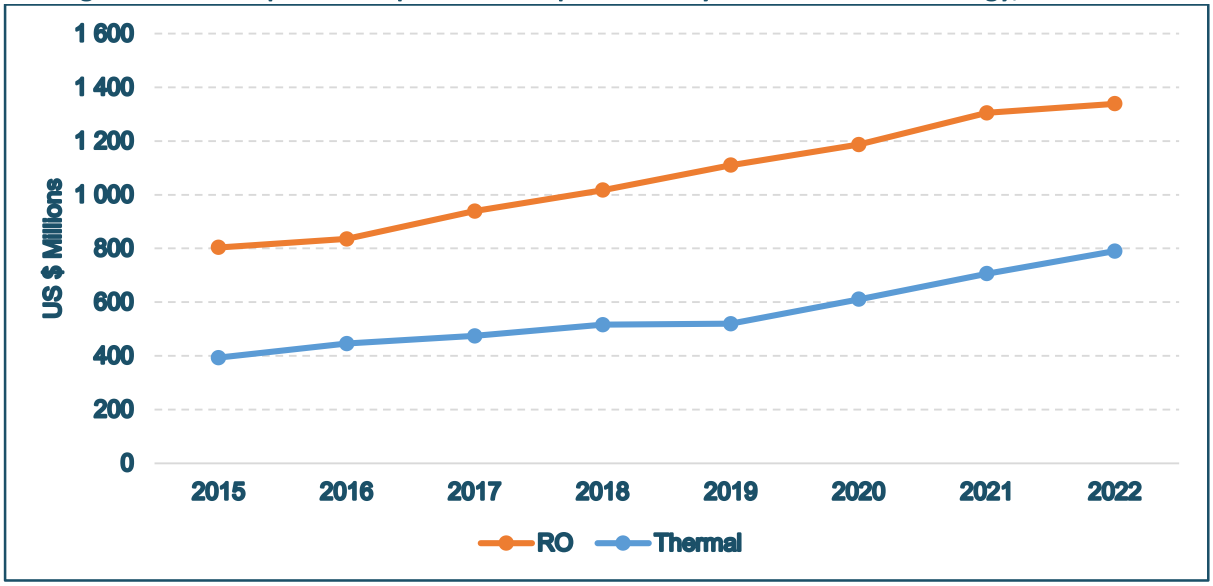


Source: Author, based on data from Global Water Intelligence (GWI)

Despite its small proportion of total capital expenditure (1.7%), desalination is set to be a fast-growing element of future capital expenditure, expected to grow at a rate of 15% a year over the period 2015-2022, exceeding the growth in total capital expenditure of approximately 5% a year.

RO desalination dominates the market globally, and this is reflected by the larger and rising capital expenditure on membrane-based desalination projects in Figure 3.

Figure 3: Total capital and operational expenditure by desalination technology, 2015-2022



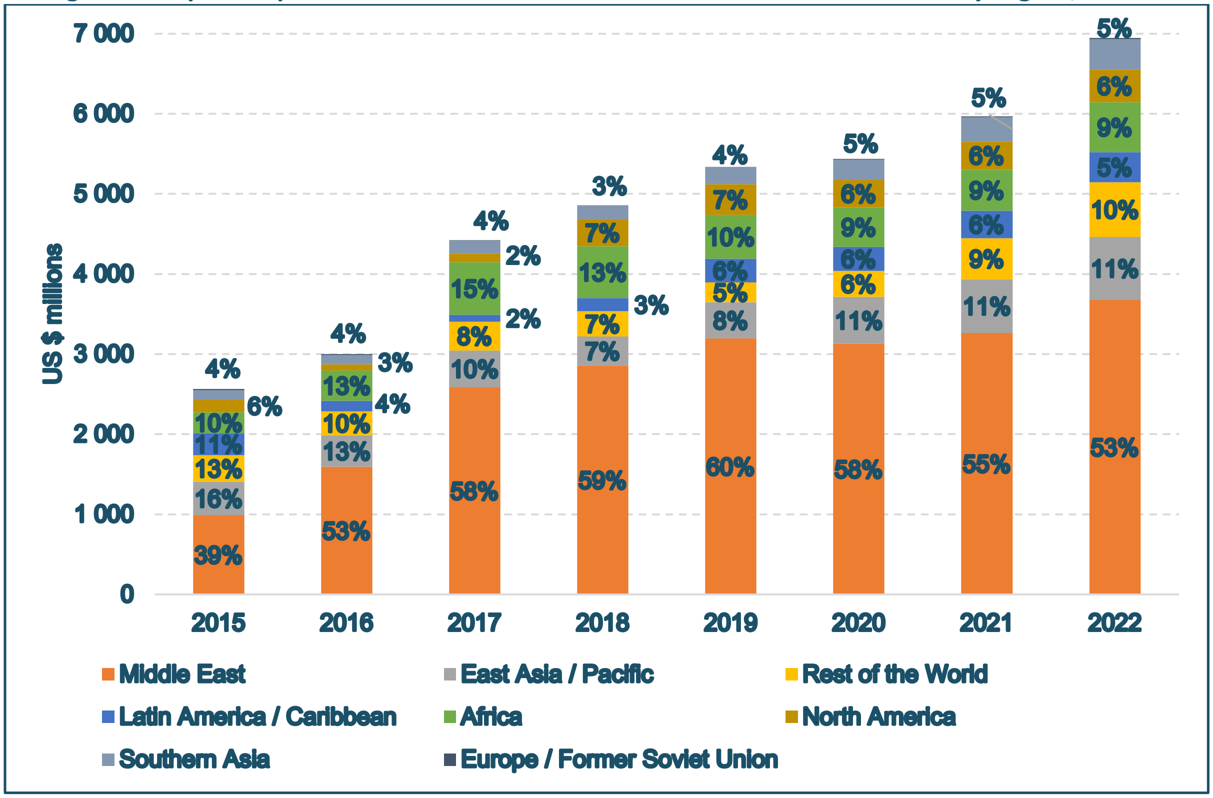
Source: Author, based on data from GWI

Historically, desalination plants have been employed in water-scarce countries in the Middle East and North Africa, however, promising developments in the technology are expected to take place outside of this region. There are approximately 18 000 desalination plants worldwide and around 56% of current capacity is accounted for by countries outside of the Middle East and North Africa regions (Voutchkov, 2016). Accelerated desalination developments are expected in Asia, the United States of America and Latin America over the next decade (Voutchkov, 2016).

The capital expenditure on desalination plants is distinguished by region in Figure 4. The Middle East and North African countries account for almost all of the new capital expenditure in the period. Out of that categorisation, the only African country outside of North Africa with planned desalination expenditure is South Africa, which accounts for less than 1% of the desalination capital expenditure over the period.

Figure 4 further points to the centres of demand for desalination technology and services as being chiefly the North African/Middle Eastern countries, with smaller investments in North America, East Asia, Latin America, Southern Asia, and European countries.

Figure 4: Capital expenditure on seawater and brackish water desalination by region, 2015-2022



Source: Author, based on data from GWI

Desalination in South Africa

To date, the implementation of seawater desalination in South Africa has been limited, with a few small-scale desalination projects. While thermal desalination has been considered for the Koeberg nuclear power station, owing to its discharged coolant water, desalination via RO has been the main method of implementation (Slater, 2017).

With the exception of the Koeberg power station, thermal desalination is inappropriate in the South African context due to high energy consumption in an environment with a constrained electricity provider and rising electricity prices, and thermal desalination requiring a higher capital expenditure (Laubscher, 2017; Slater, 2017).

Two types of desalination models have been in operation in South Africa: mobile packaged plants and fixed infrastructure plants (Le Guern, 2016). South African desalination projects include:

- A R20 million, 15 ML/day plant in Mossel Bay operated by Veolia, which is the largest in the country, and has been moth-balled due to adequate water in the region (Cloete, 2017, WRC, 2015a, p. 4);
- A 2 ML/day seawater desalination plant in Knysna operated by Veolia which incorporates an energy recovery system to save on energy costs (Veolia, n.d.; WRC, 2015a, p. 4);

- A 2 ML/day seawater desalination plant operated by Veolia in Plettenberg Bay (Veolia, n.d.; WRC, 2015a, p. 4);
- A 1.7 ML/day seawater desalination plant for the Cederberg Municipality in the Western Cape, with the option to upgrade to 5 ML/day (Veolia, n.d.; WRC, 2015a, p. 4);
- A desalination plant located in Sedgefield, owned and operated by the Knysna Municipality, and maintained by Grahamtek (WRC, 2015b, p. 4);
- The Cannon Rocks & Boknes Communities desalination plant which produces 750 m^3 of water per day from groundwater (Veolia, n.d.); and
- A mobile desalination plant in Richard's Bay providing 10 000 m^3 of water per day and supplying approximately 150 000 people (GWI, 2018, p. 30).

The high energy costs associated with seawater desalination have served as a barrier to its implementation thus far. For example, the largest desalination plant in the country, operated by Veolia, was mothballed due to the high cost of producing water (Cloete, 2017; WRC, 2015a, p. 4). In that case, the cost of water was approximately double that of water sourced from a dam: R16 per kilolitre for desalinated water as compared R9 per kilolitre (eNCA, 2017). More recent emergency disaster-relief plants have been estimated to cost up to R40 per kilolitre, the kind which have been installed in the Western Cape (Cloete, 2018).

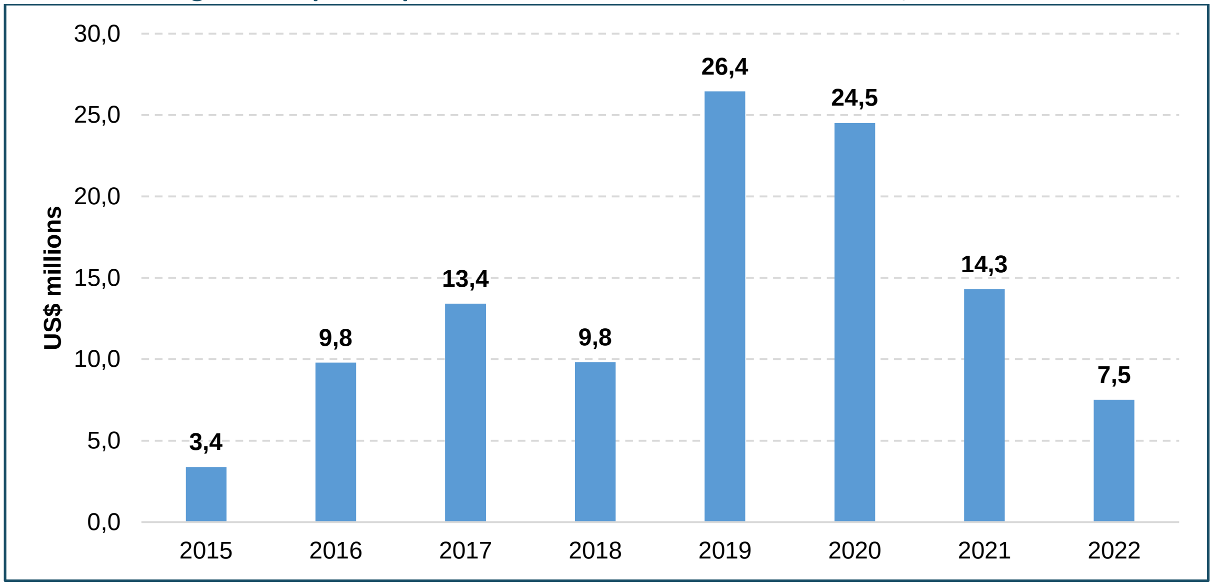
Desalination processes are also used to treat effluent water from industrial processes in addition, as indicated, and constitute a type of wastewater treatment. Such applications typically occur in the coal, phosphate, steel, and other mining industries that discharge acidic water as effluent (Veolia, 2012, p. 2). Anglo American was the first mining company in South Africa to process effluent mine water into drinkable water at its Witbank plant, which provides 30 million litres of water a day (approximately 12% of the area's municipal drinking water needs), recovering almost all of the wastewater produced (IOL, 2014; Tancott, 2014). In this case, the municipality is unable to fully supply its residents and relies on purchases from Anglo American to meet some of its water supply needs (South African Cities Network and University of the Free State, 2014, p. 30). Similarly, Glencore owns a 15 million litre per day desalination plant started in 2010, which supplies 20% of the Hendrina population with drinking water (Tancott, 2014). Sasol's Secunda Synfuels operations combine two forms of desalination, electrodialysis reversal (ERD) and RO desalination to purify acidic mine water that is discharged from coal mining activities (Sasol, 2014, p. 1).

As the water situation in South Africa worsens, anticipated demand for desalination was expected to pick up in the short to medium term. This demand was initially expected to be for small-scale disaster relief plants, while longer-term demand was expected for large infrastructure projects. These demand patterns were reflected in the project opportunities in certain regions of the country.

In the water-stricken Western Cape, 17 sites were identified for potential seawater desalination plants (Deklerk and Collins, 2017), with the City of Cape Town issuing tenders for short-term disaster relief desalination projects (Deklerk and Collins, 2017). Three seawater desalination plants, which cost R250 million each, were expected to be running by March 2018 (the Monwabisi, Strandfontein and V&A Waterfront desalination projects, with the first two producing seven million litres of water a day, and the latter producing two million litres) (Brandt, 2017; Palm, 2018). The city required some plants to be operational for a period of up to two years (Claymore, 2017).

As of May 2018, none of these three plants were providing water into the reticulation system. The V&A Waterfront plant was dealing with issues around water quality, while the start dates for the Monwabisi and Strandfontein facilities were delayed, without notice as to for how long (Palm, 2018). Further, the eThekwini municipality was considering the construction of a 100 million litre per day plant combining seawater with wastewater (Laubscher, 2017).

Figure 5: Capital expenditure on desalination in South Africa, 2015-2022



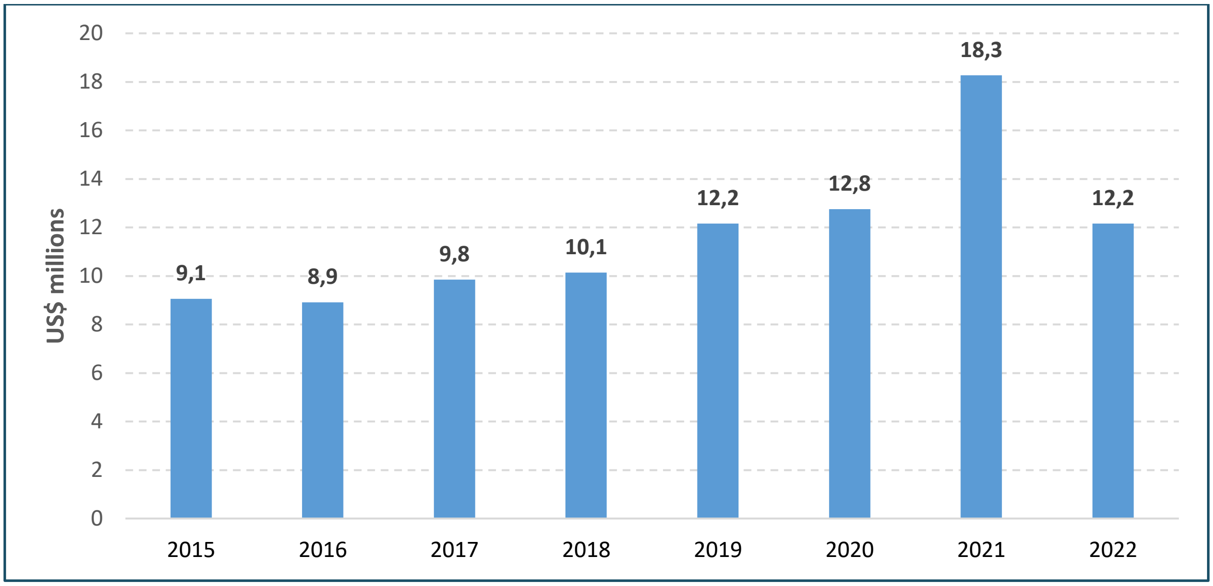
Source: Author, based on data from GWI

Figure 5 indicates the expected capital expenditure over the near future on desalination. While capital expenditure is less than US$15 million between 2015 and 2018, this expenditure rises to approximately US$26 million in 2019. It is not clear from the GWI data what accounts for this dramatic increase in spend, however, it is suspected this increase is due to the R1 billion eThekwini desalination costs being apportioned to 2019 onwards. Even accounting for this increase in capital expenditure in 2019, the overall capital expenditure expected is a very small component of expected capital expenditure over the near future. In terms of the total capital expenditure over the near future, this capital spend does not exceed 2% of total expected capital expenditure in the water sector.

It is also important to consider the cost of equipment which is explicitly associated with desalination technology. As identified, equipment, such as membranes, are vital for the operation of a RO desalination plant and can be a key cost component. Membranes account for up to 9% of operational costs at a desalination plant and represent a key cost factor (Advisian, n.d.).

Figure 6 indicates the total capital and operational expenditure for desalination equipment in South Africa. Desalination equipment, such as membranes, account for less than 1% of total equipment costs in the water sector over the period.

Figure 6: Capital and operational expenditure on desalination-related equipment, in South Africa from 2015 to 2022



Source: Author, based on data from GWI

Notes: 1. Desalination equipment includes high pressure membranes, low pressure membranes and thermal desalination equipment

What began as ambitious plans for future desalination projects in South Africa have evolved into an environment with a high probability that many projects will not come to fruition.

Table 1 provides an indication of the expected desalination plants to be installed in the country in the short to medium term. These planned projects may not materialise as desalination projects are already being halted. For example, investments in desalination by Umgeni Water have been temporarily deferred due to rising electricity costs, in favour of investments in the Lower uMkhomazi bulk water supply scheme dam (Pillay, 2017). This assumedly includes R1 billion to be spent on the Durban seawater reverse osmosis (SWRO), the Umgeni Water East Coast Desalination project, and the Elysium SWRO. In all likelihood, desalination expenditure will be lower than expected.

Further, the City of Cape Town has recently shifted its focus away from desalination to more cost-effective measures, with some desalination projects being halted due to other projects exceeding the budget (Pillay, 2017; Whittles, 2018)

Table 1: Planned desalination projects in South Africa

Project name	Client	Expected cost	Project description
Amtola Water BWROs	Amatola Water	R60 million (US$6.6 million)	Construction of three brackish water reverse osmosis (BWRO) plants as part of the Ndlambe Bulk Water Supply Scheme. The existing 750 m^3/day BWRO plant at Cannon Rocks will be enlarged and upgraded to a new capacity of 6 000 – 6 500 m^3/day, while a new 5 000 m^3/day BWRO facility is planned for Port Alfred, and a new 7 000 m^3/day BWRO facility at Dabi.
Saldanha Bay	West Coast District Municipality	R500 million (US$46 million)	To construct a 25 500 m^3/day desalination plant to supply 22 towns in the West Coast Region. The plant will be built in three phases of 8 500 m^3/day each, depending on demand, although the supporting infrastructure, including as the intake and outfall, will be designed to handle the full capacity from the outset.
Durban SWRO	Umgeni Water	R5.1 billion (US$382 million)	Up to two SWRO plants of 150 000 m^3/day each to serve Durban and Pietermaritzburg. Two potential sites have been identified: one near the Lovu River on the south coast and another near the Mdloti River to the north of the city. Indications are that this investment will be deferred due to escalating electricity costs (Pillay, 2017)
Cape Town SWRO	City of Cape Town	n/d	To construct a desalination plant with an initial capacity of 150 000 m^3/day, expandable to 450,000 m^3/day, to serve the municipality of Cape Town. The final capacity and technology still have to be determined, but it is likely to be an SWRO plant.
Zandkopsdrift rare earths project SWRO	Sedex Desalination	n/d	A new SWRO plant with a capacity of up to 8 million m^3/year (22 000 m^3/day) to supply process and potable water to the Zandkopsdrift rare earths project in the Northern Cape. The plant would employ dissolved air flotation (DAF)/dual media filtration (DMF) pre-treatment steps, and is scheduled to employ an open water intake incorporating coarse and fine screens.
Kouga desalination plant	Kouga Local Municipality	n/d	The municipality of Kouga is investigating the possibility of building a desalination plant, and is looking to undertake a feasibility study as the first step. The study will compare the feasibility of a desalination plant to various alternatives, including a recycling plant which would treat sewage effluent to potable standards, and the development of a new wellfield to supplement existing groundwater resources.
Elysium SWRO	Umgeni Water	n/d	To build a 2 500 m^3/day SWRO plant to provide potable water for pumping to the Elysium Reservoir south of Durban. The plant would be expandable to 10 000 m^3/day in future.

Project name	Client	Expected cost	Project description
Umgeni Water East Coast Desalination	Umgeni Water / eThekwini Municipality	n/d	To build two East Coast 150 000 m^3/day seawater desalination plants. An official tender was issued on 25 June 2012 for the appointment of a professional service provider to undertake the environmental impact assessment study.
Lucky Star (St. Helena Bay) and Amawandle (Laaiplek) fish factories	Oceana Group	R22 million (US$2.4 million)	Two canned pilchards and fishmeal processing plants are expected to have two desalination plants installed. Phase one of a R2 million desalination project is expected to be completed over the next few months at Amawandle, while phase one of a R20 million desalination plant is expected to be completed in the near future at Lucky Star (Buckle, 2018).
Hessequa hybrid solar desalination plant	Municipality of Hessequa	ZAR 9 million ($0.9 million)	Co-funded by the Western Cape Government and the French Treasury, a hybrid solar-powered desalination plant will be commissioned by the end of October 2018. The plant is planned to produce 100 kilolitres of water per day powered by the solar energy only, to address the normal local water requirement. Outside of daylight hours, grid electricity can be used to produce up to 300 kilolitres of water per day (Liedtke, 2018).

Source: Author, based on data from GWI

4. BUSINESS MODEL CONSIDERATIONS

Techno-economic risks

Desalination is technically possible in South Africa, and its operation has already been proven in the country. However, getting the economics right is an absolute imperative. Producing water at an affordable cost is the primary barrier to implementation and is contingent on a number of factors.

First, seawater desalination is only appropriate in coastal towns (proximal to the sea) and infrastructure needs to be present to transport water to areas of high demand. Further, desalination plants are best located in light industrial areas, ports, or harbours due to their space requirements. Desalination plants also need to be proximal to bulk water distribution systems, and in cases where this is not true, substantial civil works are required to connect plants to the reticulation system (Maytham and Callaghan, 2017). In the cases of regions where mines are prevalent, desalinated water from mines may be an option to mitigate against the high transmission costs from coastal regions.

Second, the high costs of energy associated with desalination also make the cost of producing potable water high. Due to this energy intensity, the cost of electricity inputs impacts on the costs and hence the viability of desalination projects. It is therefore important that desalination plants are located close to a source of adequate and affordable power to meet their high energy needs (Grahamtek, 2017, p. 7). From a climate perspective, the energy intensity of desalination also presents a conundrum as South Africa's electricity is primarily dependent on coal.

Third, uncertainty around future rainfall presents risks to the implementation of desalination. For example, if adequate rainfall were to be experienced in the future, the cost of producing water from desalination could far exceed existing traditional water sources. Thus, desalination plants have to be flexible, either to lower/cease production or be converted to a larger long-term asset (Grahamtek, 2017, p. 7). Planning for this is vital to avoid economic risks as is already being experienced by Veolia with the Mossel Bay plant which, as mentioned, is currently operating on zero-mode, and costs R200 000 a month to remain operational at a future date (eNCA, 2017). Experience from Australia's drought response is indicative of the scale of financial risk inherent in the risk of future rainfall. Australia invested US $10 billion in the early 2000s to build the 400-megalitre Victorian desalination plant in Melbourne. The project was completed only in 2013, after the drought subsided, and the plant was no longer required. The maintenance of the plant has cost the country US$200 million a year, despite no water being produced. The first water from the plant was produced in 2017, and maintenance costs are expected to rise markedly in the coming years (Ferguson, 2014).

Fourth, if not considered carefully, the location of desalination plants can have detrimental effects on the environment (Grahamtek, 2017, p. 7). Two points of contact are important: the intake of seawater and the discharge of brine and chemicals at the end of the process. When seawater is taken in, fish and other marine organisms can be killed on the filters and smaller organisms that pass through are killed during processing of the salt water (Cooley et al., 2013, p. 3). The discharge of brine and chemicals at the end of the desalination process may result in marine biological changes if this discharge occurs in shallow and/or semi-enclosed bays (Cooley et al., 2013, p. 14).

In summary, the techno-economic analysis of desalination points to substantial economic risks associated with desalination and, as a result, limited techno-economic potential in South Africa. Affordability and the price of water are prime determinants of whether the technology will succeed in providing the country with water security, and the experience thus far is that funding and affordability will constrain its successful rollout.

Experience in other countries, such as Australia, has proven the immense financial burden that the technology can place on the fiscus and taxpayers. In worst cases, such countries were left with white elephant projects providing no water, while draining away limited tax revenues. This burden has already been seen in the Western Cape where plans for desalination have been curtailed in favour of more cost-effective projects, such as tapping into aquifers. Besides the high capital and operating costs of the plant itself, civil works to accommodate connections to the reticulation system add high costs to an already expensive technology. The threat to marine life and ecosystems is also a concern, which may be somewhat mitigated against, but is unavoidable.

Who will fund desalination?

The reality of the South African context is such that resources are constrained, like many countries throughout the world. Internationally, as many nations' water utilities face financial constraints, a notable shift towards greater private sector participation has been noted (Montmasson-Clair, 2018). Involving the private sector in public projects can take on many forms, which include a sharing of risks and rewards. These risks and rewards in desalination projects will primarily depend on the type of institutional structure adopted for the technology. Table 2 presents a non-exhaustive set of typical options that have been adopted internationally, for consideration in the implementation of desalination plants in South Africa.

One institutional option is for the public sector to entirely finance, construct, operate and maintain desalination plants in South Africa. While the public sector gains from full oversight of these projects, this option is challenged by the lack of public funds available for very costly desalination projects, and the limited technical skills in the public sector to maintain and operate desalination plants. While certain public sector institutions, such as Amatola Water and the Knysna Municipality, operate desalination plants currently, most of the technical knowledge for the design, construction, technology, operation and maintenance of desalination plants rests in the private sector. Other existing institutional options include a myriad of public-private partnerships which confer different degrees of control to the public sector and various allocations of risk.

Table 2: Institutional options for desalination in South Africa

Options	Explanation	Risk/Benefit	Contract types	Capital expenditure by private partner	Degree of control by private partner
Public sector funds and operates desalination plants	Public sector is responsible for entire financing, building, operation and maintenance of desalination plants.	Risks: 1. Substantial burden on the national fiscus for upfront capital expenditure and operation and maintenance costs. 2. Lack of substantial technical knowledge in the public sector. Benefits: 1. Public sector has full oversight and control of operations.	N/A	N/A	N/A
Public-private partnership (PPP)	Public sector finances desalination plants and the private sector builds, operates and maintains desalination plants.	Risks: 1. Substantial burden on the national fiscus for upfront capital expenditure. Benefits: 1. Benefits from private sector technical expertise and efficiencies.	***Performance/ Management Contracts:*** private operator takes management responsibility for the utility for a period of time, to achieve some transformational objectives.	Low/Low	Low/Medium-low

Options	Explanation	Risk/Benefit	Contract types	Capital expenditure by private partner	Degree of control by private partner
			Operations and maintenance Contracts/ Affermage-type contracts: private contractor concentrates on O&M without taking risk on capital expenditure.	Low/Low	Medium/Medium-high
	Public sector allows private sector to finance, build, operate and maintain desalination plants and purchases water from the private sector at a price which covers costs and a reasonable return.	Risks: 1. Public sector is distant from operations and loses out on gaining technical expertise. 2. A lack of proper regulation can lead to unexpected costs on public sector and final consumers.	***Concessions and canon contracts:*** concessionaire has direct control over capital spending, but with increased focus on performance.	Medium	High

Options	Explanation	Risk/Benefit	Contract types	Capital expenditure by private partner	Degree of control by private partner
		Benefits: 1. Benefits from private sector technical expertise and efficiencies. 2. Risk is shifted to the private sector.	***Utility leases:*** equity sold to private sector from public water assets on the basis of long-term utility leases.	Medium	High
Investor-owned Utilities	Private utilities construct their own projects, generally with regulation of prices and service quality): rare and the result of privatisation (UK, Chile) or historical quirks (US)	Risks: 1. Public sector not involved in the provision of a public good. 2. A lack of proper regulation can lead to unexpected costs on public sector and final consumers. Benefits: 1. None	N/A	High	High

Source: Author's adaptation of (Montmasson-Clair, 2018, pp. 11–12)

A number of factors have been raised around desalination projects and their financial viability in South Africa:

- The penalties and overly-ambitious time frames of plant construction in the City of Cape Town have been criticised as ignoring the time associated with erecting large structures (Maytham and Callaghan, 2017). Ignoring this reality can result in financial risk for the plant operator (Hasenfuss, 2017).
- Small-scale emergency projects (e.g. 14 million litres per day) tend to be high risk and costly, implying a high water price and long-term utility-scale projects (e.g. 50 million litres per day) are more attractive from a long-term water security point of view, and to the private sector (Maytham and Callaghan, 2017).
- Due to the Municipal Finance Management Act, it is difficult for municipalities to commit to projects longer than three years. This constrain significantly ramps up the unit price of water, well in excess of R12 per kilolitre and presents an affordability challenge (Hasenfuss, 2017).
- Small-scale projects as a form of disaster relief, ignoring long-term water needs, may result in high debt consequences (GreenCape, 2017, p. 23).

Given the budget constraints faced by the public sector, a fully government-funded desalination strategy which sees the public sector build, finance, maintain and operate desalination projects throughout the country is highly improbable and likely inefficient due to the deep technical skills and knowledge that is present in the private sector. On the flip-side, entire private desalination projects absent of any public sector involvement places the management of the nation's key resource and public good in the hands of the private sector, which is undesirable.

A likely business model, if desalination is to be implemented, would be some form of PPP arrangement as has already implemented with the small-scale projects in the country. This arrangement sees risks and rewards shared between the public and private sector, and will have to be tailored to each project, which will depend on the project size and cost, among other factors.

Socio-political acceptability

From a socio-political perspective, a number of stakeholders stand to be affected by the rollout of desalination projects. Table 3 presents the principal stakeholders, the actions required by these stakeholders to push forward desalination, the positive and negative impacts on stakeholders, and the actions which can be taken to mitigate against negative impacts.

Table 3: Socio-Political Stakeholder Analysis

Stakeholder	Action required by stakeholder	Positive/Negative impacts	Mitigation actions
Department of Water and Sanitation (DWS) and other water departments	Detailed study of feasibility of desalination in South Africa, through the identification of locations for potential plants and how to connect these plants to centres of demand. A comprehensive plan of how rollout is going to occur, and the expected costs and benefits for the country. DWS should be aware of who the private sector specialists in desalination are and should correctly advise the entity that is awarding contracts.	Positive: DWS has adopted a proactive approach to desalination through the publication of the National Desalination Strategy in 2011, the Water Resource Reconciliation Strategy for the Western Cape, and the recent launch of the Richard's Bay desalination plant by the Minister. No resistance is expected from the department. If a thorough approach is adopted, DWS will win political and popular support. Also, DWS and other water departments will face reduced strain on traditional resources. Negative: If desalination plans are not implemented correctly, high costs may have to be borne by the fiscus and consumers, leading to a loss of confidence in the department. Further, depending on the project structure, the private sector could face high risks deterring them from investing. Depending on which public sector entities engage with projects, subsidiary water departments such as water boards and schemes could face reduced demand for their water supply by consumers shifting to desalination. High tariffs could result in public backlash.	DWS has to engage with all stakeholders in planning the rollout of desalination if this technology is seen as an important component of the water mix. Through thorough engagement with other departments, private sector specialists, and consumers, risks of planning and implementation can be identified and resolved.
Department of Environmental Affairs (DEA)	Ensure the environmental risks associated with desalination are clearly defined and mitigation	Positive: DEA has adopted a proactive approach to desalination through the publication of Guidelines for the Evaluation of Possible Environmental Impacts for seawater desalination. No resistance is	DEA has already published guidelines concerning the environmental impacts of seawater desalination, which

Stakeholder	Action required by stakeholder	Positive/Negative impacts	Mitigation actions
	options are presented by developers of each planned project. Ensure that projects are properly managed from an environmental perspective and regular monitoring takes place.	expected. If managed correctly, the department can ensure no harm to ecosystems and the environment. Negative: If projects are not properly managed from an environmental perspective, this can wreak havoc on biological ecosystems, which can be further worsened by pollution of seawater with discharged chemicals. This can impact agricultural and other food-dependent industries.	is a positive step. The department has to ensure that all projects adhere strictly to defined criteria concerning he environmental harm of desalination and that mitigation options are implemented and adhered to.
Municipalities	Municipalities have to engage with DWS to thoroughly understand the technology. Municipalities have to ensure that they are purchasing water at the correct price. This involves a detailed understanding of the likely costs of water through desalination and an understanding of the elasticity of demand of water consumers. If consumers do not accept higher water prices, municipalities will be forced into bankruptcy as has been evidenced recently.	Positive: Municipalities have access to a consistent security of water supply. Negative: Potential risk of higher costs of water as desalination is costly. This is compounded by the fact that consumers face affordability constraints and can only absorb limited price increases.	Municipalities require correct contracts in place to ensure they purchase water at the correct price and that erratic price rises are protected against. This ensures the liquidity of municipalities. Desalination is not a core competency for municipalities. The skills and capacity to develop, project manage and oversee the delivery of this technology are not likely to be available within all municipal structures and would have to be developed over time.

Stakeholder	Action required by stakeholder	Positive/Negative impacts	Mitigation actions
Water consumers	Consumers have to engage with the technology and decide if they are willing to pay a potentially higher price for water security.	Positive: Consumers have a consistent security of water supply. Negative: Higher municipal water tariffs due to the high energy costs of desalination should water be unable to be sourced from traditional sources.	Consumers have to lobby for the correct price control mechanisms to be in place to prevent excessive tariffs.
Private sector	Private sector specialists that have the technical know-how should engage with the public sector to provide solutions and proper mechanisms to move the technology forward.	Positive: If a PPP structure is adopted, the private sector can earn a reasonable return in exchange for imparting skills and a crucial service to the public sector. Negative: If projects are not structured correctly, the private sector could face high risks and run into profitability issues. This could hurt investor sentiment deterring the private sector from investing.	Ensure that projects are structured accurately to reward the private sector for the risk taken while ensuring that public funds are not exploited.
National Treasury	Treasury has to ensure that all desalination projects are financially viable and pose no risks of draining the fiscus.	Positive: In the long run, desalination would constitute a cost-saving initiative by diversifying the water mix and could be beneficial to the municipality finances and the fiscus. Negative: Desalination projects that are entirely government-funded place a sizeable burden on the fiscus, and desalination projects tend to be capital-intensive. This presents substantial opportunity costs, as money is diverted away from other priorities like healthcare, education and poverty alleviation.	Treasury has to decide if desalination is feasible in the current fiscal situation, and if it is, place limits on the amount of funds available for such investments.

Source: Author

Desalination as a technology for wider-scale application does face some risks from a socio-political perspective. Thus far, risks and resistance from the technology have been limited as projects have been implemented on a small scale. If substantial investments are made in the technology, there are likely risks faced by numerous stakeholders, as detailed in Table 3. Consumers and municipalities will eventually bear the burden of higher tariffs since desalination is a costly technology. A lack of proper long-term planning for projects can also lead to a lack of water as is evident currently in the City of Cape Town. The knee-jerk reaction to the water crisis and a lack of proper planning has resulted in the short-term disaster relief desalination plants being non-operational past their planned start date (Palm, 2018). Further, depending on the arrangement of projects, the Treasury may face increased pressures to invest in the technology placing strain on the national coffers.

Drivers and barriers

The primary drivers for desalination are the need for water supply and socio-economic development. Seawater desalination presents the advantages of a potentially unlimited supply of water resources that is unsusceptible to environmental factors like drought. Desalination may allow the country to diversify its water resources away from traditional, depleting water resources. The technology can also be scaled allowing systems to be initiated at a small-scale and ramped up should capacity need to be increased. Food security is also high on the agenda as water is a key input into the agricultural sector, which is the largest consumer of water in South Africa.

The drivers for desalination are overshadowed by the large barriers accompanied by the technology. These barriers relate to water quality, environmental sustainability, being fit-for-purpose, ease of implementation, cost savings and energy security. Desalination is a highly energy-intensive process requiring a large quantity of electricity. In South Africa, where most of the electricity is sourced from coal generation, this means increased greenhouse gas emissions. Further, desalination of seawater is associated with harm to marine biology and ecosystems through the intake of water and the discharge of chemicals and brine. Further, desalination is a high-cost technology from a capital and operations perspective. This translates into expensive projects and relatively high water tariffs. Finally, desalination is highly energy-intensive requiring a constant supply of electricity.

Table 4: Assessment of drivers for desalination

Factors	Explanation
Water supply	Desalination provides security of supply for water. In the case of seawater, desalination provides access to an essentially unlimited source of water.
Water efficiency	If desalination is available at higher than average prices, this may force users to reduce demand and become water efficient in use. Desalination, inherently, however, does not hinge on water efficient use.
Water quality	To ensure the right water quality is a costly process, primarily depending on chemical treatment in the desalination process. The cost of this treatment depends on the quality of the intake water and its source. Costs vary depending on whether seawater or brackish water is used.

Environmental sustainability	Desalination is a highly energy-intensive process requiring a large quantity of coal-based electricity translating into increased CO_2 emissions. Desalination of seawater is associated with harm to marine biology and ecosystems.
Socio-economic development	Given the correct planning, desalination may increase water access to vulnerable regions of the population.
Food security	Through security of supply, desalination provides constant water supply to agricultural industries, protecting against risks such as drought.
Fit-for-purpose	Building desalination projects to the appropriate scale is imperative to ensure long-term viability, supply and price of water. Small-scale projects tend to be high cost and of little utility in contributing to total water demand. Large-scale projects are highly capital-intensive and have high operational costs.
Ease of implementation	Desalination projects are highly capital intensive and require large amounts of space and civil works. Depending on the scale of the project, construction can vary from months to years. Longer than expected construction has become the norm in South Africa, as evidenced by the delays in the emergency disaster relief plants in Cape Town.
Cost savings	Desalination is a high-cost technology translating into expensive projects and relatively high water tariffs. Costs can vary from multiples of two to four depending on the scale of the project.
Energy security	Desalination is highly energy-intensive requiring a constant supply of electricity. The inherent energy intensity of the process does not render it suitable for meeting energy efficiency goals, particularly in South Africa, which relies of coal for electricity.

Source: Author's assessment

Notes: For each technology, drivers are considered a primary driving force (green coding), a secondary driving force (orange coding), a secondary barrier (yellow coding) or a primary barrier (red coding).

5. SUPPLY-SIDE CONSIDERATIONS: MANUFACTURING AND R&D

Manufacturing

Globally, large specialist multinational firms lead large-capacity desalination infrastructure projects. These projects include operations in Middle Eastern and North African countries (such as Saudi Arabia, Oman, Israel, Algeria, and Iraq), India, Spain and the United States. Table 5 lists leading global desalination firms.

It is not uncommon for projects to include joint ventures between large global firms and local firms, or global firms with different niche expertise. The 624 000 m^3/day Sorek plant in Israel, which is one of the largest seawater desalination plants in the world, for example, was financed, planned, built and is currently operated by a joint venture between IDE Technologies and Hutchison Water (IDE-tech, n.d.; Water Technology, n.d.).

Table 5: Leading global desalination firms

Firm	Head Office	Notable projects
IDE Technologies	Israel	Sorek Plant (Israel), Santa Barbara Plant (US), Carlsbad Plant (US), Tianjin Plant (China)
Hutchison Water	Singapore	Sorek Desalination Plant (Israel)
Doosan	South Korea	Ras Al Khair Plant (Saudi Arabia), Shuaibah Plant (Saudi Arabia), Busan Gijang Plant (South Korea)
Fedco	US	Jeddah III Plant (Saudi Arabia)
Veolia Group	France	Basra (Iraq), Jubail I and II Plants (Saudi Arabia), Sur Plant (Oman)
IVRCL	India	Minjur Plant (India)
Abengoa Water	Spain	Carboneras Plant (Spain), Chennai Plant (India), Ténès Plant (Algeria)

Source: Author

The South African market for desalination products and services also includes a number of local producers of desalination technology. Local producers include international firms with local branches and purely local firms. These firms are involved in the design, commissioning, operation and decommissioning of desalination plants.

Some of the principal firms in the South African desalination space are listed in Table 6.

Table 6: Principal desalination firms in South Africa

Firm	Ownership	Products/Services	Notable desalination projects
Veolia	Foreign	Designs, constructs, commissions and operates desalination plants through its association with the parent company, the Veolia Group in France.	Operates five desalination plants throughout the country including the large Mossel Bay plant.
Grahamtek	Local	Designs, constructs, commissions and operates desalination plants in South Africa and abroad.	Operates the desalination plant in Knysna.
Proxa	Foreign	Designs, develops, engineers and constructs reverse osmosis systems for a range of specifications.	Was awarded the tender for the supply, establishment, and operation of the City of Cape Town, Strandfontein and Monwabisi desalination plants in the Western Cape in a joint venture with Water Solutions.
Quality Filtration Systems	Local	Designs, develops, engineers and constructs RO systems in South Africa.	Was commissioned by City of Cape Town to design, supply, establish, commission, and operate the V&A Waterfront seawater RO desalination plant.

Firm	Ownership	Products/Services	Notable desalination projects
Energy Partners Holdings	Local	Energy Partners Holdings is a new entrant into the desalination space.	Was commissioned by the City of Cape Town to supply, establish, and operate a seawater RO Plant in Harmony Park Strand.
Water Solutions	Local	A partnership between Water and Sanitation Services South Africa (WSSA) and Sikhulakahle Water Services cc which supplies water services in South Africa.	Was awarded the tender for the supply, establishment, and operation of the City of Cape Town, Strandfontein and Monwabisi desalination plants in the Western Cape in a joint venture with Proxa.
Water Skills	Local	Conception, equipment manufacturing, commissioning and operation of reverse osmosis products.	N/A
Aveng Water	Local	Design, construction, and operation of desalination plants.	Designed, constructed, and operates the largest seawater desalination plant in Southern Africa, the Erongo Desalination Plant in Namibia.
Water Purification Chemicals & Plant	Local	Design, supply and installation of desalination plants.	N/A
EPF Systems	Local	Provides engineering, pumping and filtration services.	N/A
Nanotech	Local	Designs, manufacture and marketing of reverse osmosis membrane systems.	N/A
Aquamat	Local	Developing, manufacturing and distribution of reverse osmosis products	N/A

Source: Author

A crucial component of the RO desalination plant are the membranes which are used to separate out the salt from water. As illustrated in Table 7, the number of membrane manufacturers is limited to a small number of global firms. Local membrane manufacturing has been small to date due to the sophistication and capital requirements involved in manufacturing (GreenCape, 2017, p. 53). While a number of local distributors for foreign-made membranes exist, one company, i.e. Membratek, a subsidiary of Veolia Group, manufacturers membranes in the country (Table 7).

Table 7: Leading membrane manufacturers

Firm	Parent company	Location
Dow Filmtec	Dow Chemical	US
Fluid Systems	Koch	US
Hydranautics	Nitto Denko	USA and Japan
Toray	Toray	Japan
Osmonics	General Electric Power	US
Rochem	PALL	Germany and US
Toyobo	Toyobo	Japan
Vontron	South Huiton	China
Yarn-Home	Yarn-Home	China
Kent	Kent	US
LG Water Solutions	LG Chem	US and South Korea
Membratek	Veolia Water Technologies South Africa / Veolia Group	South Africa

Source: Author

Membrane manufacturers produce a number of membranes with different applications. Among the high-pressure membranes, desalination accounted for approximately 13% of membrane sales in 2017. The other categories of membrane sales were industrial water and wastewater treatment applications (70%), utility wastewater treatment applications (8%), and utility water treatment applications (15%).

With the chemicals that are necessary for membrane systems, a number of local and international firms manufacture chemicals for water treatment and desalination in particular. These firms are listed in Table 8. It may be noted that chemicals produced for desalination are largely universal to water treatment as they relate to broader water treatment processes like coagulation and flocculation. Firms which produce chemicals for desalination produce the same chemicals for a variety of other water treatment processes.

Table 8: Leading chemicals manufacturers

Firm	Location
Protea Chemicals	South Africa
Veolia Water Technologies South Africa	South Africa
Water Purification Chemical & Plant cc	South Africa
Zetachem	South Africa
ECM Chemicals	South Africa
Lonza Water Treatment	South Africa
Nanotech Water Solutions	South Africa

Curechem	South Africa
NCP Chlorchem	South Africa
Ecolab/Nalco	Global
GE Water	Global
Solenis	Global
BASF Water Solutions	Global
Kemira	Global
SNF Floerger	Global
Dow	Global

Source: Author

Research and development

Two principal trends in desalination have informed the direction in which the technology is evolving internationally: the preference of RO (membrane-based) desalination over thermal desalination; and the increased efficiency and cost-effectiveness of membranes.

On the first trend, RO desalination began to surpass thermal desalination in the mid-1990s and the gap between the technologies has been growing ever since. Three elements inherent to RO have driven this: lower capital costs, lower energy requirements, and greater operating efficiency, relative to thermal desalination (GWI, 2017, p. 145)

The greater operating efficiency is linked to the second trend, which has been the development of membrane construction, in addition to the incorporation of energy recovery devices (GWI, 2017, p. 145). After the global financial crisis and low oil prices, even Middle Eastern countries that have historically used thermal desalination, have switched new plants to RO processes, as is evidenced by plants in Qatar, the UAE and Oman after 2010 (GWI, 2017, p. 145).

The second trend, as noted above, is advances in membrane construction. Desalination via RO is still costlier than traditional sources of water, such as ground and surface water, and operators value any savings that can be conferred by membranes. The following developments have occurred in membrane technology: allowing more water to pass through membranes (increasing flux), allowing more salt to be removed (increasing salt rejection), and increasing the resistance of membranes to fouling[3] (GWI, 2017, p. 202).

Innovators, such as LG Chem, Aquaporin A/S and Applied Biomimetic A/S, have also developed membranes from new materials, such as nanocomposite materials, or improved the performance of aquaporin embedded membranes, which improves membrane performance and increases membrane life (GWI, 2017, p. 202).

[3] Fouling refers to the contamination of a membrane decreasing the amount of water which passes through and the quality of the water.

Local R&D activities are generally carried out by water specialist companies, research organisations, and academics. Some of the notable R&D activity in the country is outlined below.

The Water Research Council is deeply embedded in the desalination R&D space, having conducted research on the technology for some time. Notably, the WRC recently conducted an investigation into desalination in South Africa, exploring the background, current status, and costs of desalination plants in South Africa (WRC, 2015c). More recently, the WRC looked at the factors impacting the choice of desalination locations in South Africa (WRC, 2018).

At the School of Chemical Engineering at the University of Cape Town (UCT), a project is underway to increase the recovery yields from mine waste water using RO followed by a process known as eutectic freeze crystallization. *Eutectic freeze crystallisation* refers to a process which freezes the water in wastewater and crystallises the salt in the water into a solid state, allowing the salt to be removed (Swingler, 2018). The process, at the pilot stage, is able to recover 89% of water from seawater when combined with RO as compared to a 24% recovery from RO alone (Swingler, 2018). It is expected that a full-scale unit will be operational at the Tweefontein colliery in Mpumalanga in the near future (Swingler, 2018).

Private sector firms, like Grahamtek, also conduct R&D activities. Grahamtek, through its Innovation Hub, partners with Tier 1 global companies, explores new technologies, or new applications of existing technologies in the desalination space. The ultimate aim is to commercialise technologies, with the view of sharing intellectual property with the partnered firms. A current project Grahamtek is involved with looks at decreasing the energy intensity and dependence of RO desalination by incorporating waste-to-energy technology with efficient RO technology to provide off-grid desalination solutions (Grahamtek, n.d.). Grahamtek is also involved in the development of barge-based mobile sea desalination plants for emergency disaster relief providing water supply of between 5 000 and 20 000 m^3/day (Grahamtek, n.d.).

6. POLICY IMPLICATIONS

On the face of it, desalination presents as an attractive technology with which to relieve South Africa of its water challenges. However, on deeper inspection, the technology is not fit for wide scale rollout in the country. Lessons from the small-scale rollout of desalination in South Africa are also indicative of this.

First, the technology is highly capital-intensive, requiring substantial investments to erect plants that are able to supply adequate water. If a meaningful stance of diversifying the water mix to include desalination is made, large plants are vital as scale is required to ensure that the price of water being provided is affordable to consumers. This is particularly important in South Africa, where a large proportion of the country lives in poverty. Small-scale plants are very costly and work only to relieve temporary disasters with very little scope to meet systemic high water demands. Currently, small-scale disaster relief plants provide water at about four times the costs of the average municipal water supply. The costly nature of desalination has been recognised through recent ambitious projects that have been scaled back or cancelled in the country.

- A R1 billion desalination project planned for eThekwini was discarded in favour of building larger dam capacity.
- Further, in the drought-stricken Western Cape, the City of Cape Town has recently changed its focus away from temporary desalination plants due to it being less cost-effective and longer to construct as compared to other options like aquifers (Neilson et al., 2018).

Second, once plants are erected, the operating costs constitute another high cost component. High maintenance costs are a crucial contributor to the final cost of water. Specifically, the energy, membrane and chemicals costs prevent water from being provided at relatively lower levels. Membranes have to be regularly inspected and treated to prevent fouling. Membranes further cannot stand idle, as they begin to deteriorate. Chemicals are required across all levels of the process, from pre-treatment to the final water product. Once a plant is erected, it cannot be switched on and off without substantial cost implications, and construction has to be thought of very carefully when planning to add on capacity.

These high capital and operational costs pose a huge risk to the implementation of desalination technology as, if consumers are unable to afford water that is provided through desalination or if water is available from other sources, a dormant plant becomes a huge cost. By way of example, the relatively small Mossel Bay plant, which is currently dormant, costs R200 000 a month to maintain while not supplying a single drop of water into the system. For large desalination plants, these maintenance costs would be tremendous and would be an inefficient use of resources, particularly if they are not required to be operational.

While the hype of desalination has been presented as a solution to South Africa's water woes, it is prudent to direct resources to addressing challenges which can be targeted with lower costs, such as reducing water losses in the system, addressing maintenance of existing infrastructure, and demand management. As a result, desalination is not fit for the current South African context in a large and meaningful way. Existing small-scale projects should be maintained where feasible, however, further rollout should be examined very carefully.

With the desalination of brackish industrial water, key water-intensive sectors such as mining should be encouraged to engage in smaller-scale desalination activities to recover spent water that has been processed in industrial processes. As mentioned earlier, firms that have mining operations such as Anglo American, Glencore and Sasol have already installed desalination capacity at some of their operations, and in some cases supply water to adjacent communities. Such encouragement could take the form of recommending wastewater treatment technologies such as desalination in the mining licences that are awarded for new mining projects. Currently, applications for mining rights are made through the Department of Minerals and Resources, and this would be the principal avenue for policymakers to institute such a requirement. Other public sector institutions that would leverage their expertise would include the Departments of Environmental Affairs and of Water and Sanitation since wastewater treatment falls within the scope of these departments as well. If viable, firms should be encouraged to engage in these investments as part of a sustainable mining operation and also to assist in providing a source of potable water.

The next aspect to consider is whether there is the potential for industrial policy measures to support local manufacturing of desalination technologies. On the available evidence, desalination appears to be falling out of favour to local public entities to some degree, and desalination is not expected to form a substantial component of the water mix moving forward in South Africa.

The market for desalination services in South Africa is relatively small and not expected to grow substantially over the near future given the trends and investment environment. While local manufacturers of desalination technologies are present in the country, they are few and much of their expertise and services are exported to the centres of demand for desalination services, such as the Middle East. For example, Grahamtek, a local desalination firm, has a history of constructing large-scale plants in the Middle East. Recently, the firm won a R5 billion contract to build its sixth plant in Saudi Arabia. Further, Grahamtek is involved in the construction of the world's four largest desalination plants and has a presence in India and Ghana. Thus, most of its expertise are being exported and tuned for the international market. The handful of specialist desalination firms in South Africa are already proven on the international market, which is where their opportunities lie. Given the local context, current support measures geared towards supporting these firms should be maintained, however, it would be a waste of resources to mobilise substantial funds and support to attempt to create a local desalination industry when there is a limited local market.

A potential avenue for policy support to explore is to encourage firms like Grahamtek to support local industries in their foreign projects. While large desalination-reliant foreign countries like Saudi Arabia and Israel might have their own respective local or preferred procurement policies, where flexibility is allowed to project-implementing firms like Grahamtek to procure their own supply, incentives to support South African manufacturers of desalination-related equipment should be encouraged. This can take the form of subsidies or other support measures that make South African-produced products or services attractive, thereby drawing in adjacent South African manufacturers into such foreign desalination markets. These manufacturers can include the suppliers of integral desalination elements, such as membranes, chemicals and pumps, as well as general water-related components like valves and piping. In this way firms with an established foreign presence like Grahamtek can cluster in local manufacturers which are either not present in foreign markets, or have a limited involvement, supporting the growth of these industries.

While the technology continues to fall in price, R&D funding should be maintained to seek technological advances and potential cost-savings. In the South African context, the setting of priority themes in desalination R&D can include energy efficiency, non-renewable energy use, and the use of affordable solutions, and funding can be directed towards these initiatives.

7. CONCLUSION

Water is a precious resource that underpins a successful economy. It is an essential input into numerous industries, and lack of water can wreak havoc on an economy. The desalination of water has been identified as a potential solution for South Africa's water concerns. This paper has sought to evaluate two aspects related to desalination. First, whether desalination is an appropriate technology for South Africa. Second, whether desalination presents as an opportunity for industrial development in the country.

Analysis of the technology has brought to the fore key factors that have to be borne in mind when considering the rollout of the technology. The principal cost drivers associated with the technology have been identified as energy, chemicals and membrane costs. Together, these costs account for about 60% of operations costs in a typical desalination system. In addition, substantial capital outlay is required to construct desalination plants, implying a huge burden on the fiscus.

Analysis of the technology globally has indicated that the market for desalination comprises a small percentage of the total water market, however, it represents a growing international market. While many ambitious desalination projects have been planned for South Africa, the current fiscal climate has forced policymakers to seriously consider whether desalination is the appropriate technology for South Africa. Recent delays in temporary disaster relief plants in the Western Cape combined with the high costs of produced water have prompted moves away from desalination in the Western Cape and in KwaZulu Natal. The analysis of this paper reveals that, while desalination appears attractive from a water security perspective, it faces barriers from environmental sustainability, fit-for-purpose, ease of implementation, cost savings, and energy security perspectives. These barriers render desalination as unsuitable to meaningfully impact favourably on South Africa's water mix and development.

A second important aspect considered in this paper has been whether any industrial opportunities exist for policy to support in desalination in the country. South Africa's desalination market is minute compared to the international market and a handful of local capacity exists, which chiefly provides services and expertise to international clients. The restricted local market provides limited scope for widescale industrialisation, and policy should focus on existing tools being levered to local firms, supporting manufacturing and R&D activity.

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APPENDIX: CHEMICALS USED IN DESALINATION

Stage of process	Chemical	Function
Pre-treatment	Chlorine	Biocide
	Ferric Chloride	Flocculation
	Anionic polymer	Flocculation
	Sulphuric acid	Flocculation
	Sodium Metabisulphite	Reducing agent
	Phosphonate	Antiscalant
RO permeate	Soda ash	pH correction
	Carbon dioxide	pH correction
	Calcium carbonate	Stabilisation
Final product water	Chlorine	Disinfection

Source: Frontier Rare Earths and Royal HaskoningDHV, 2013, p. 2