Appendix G: Selected International Profiles

NATIONAL WATER REUSE
ACTION PLAN
DRAFT

Appendix G: Compilation of International Profiles

Every country faces a domestic responsibility to ensure that its population has access to water. This is especially important in arid regions and areas prone to drought. To help make sure that clean, safe water is available, many countries have developed comprehensive water management strategies that include water reuse. Australia, Israel, Namibia, Singapore, and South Africa incorporate water reuse into their water management programs to support water availability, security, and sustainability. These countries reuse wastewater that is treated to various levels for domestic, agricultural irrigation, and industrial water use. Some have developed guidelines to address the use of graywater, stormwater, and rooftop capture and reuse.

Countries on the leading edge of water reuse have experience with communication and outreach to the public to address the perception of water reuse applications. Regulations, economics, and sustainability are other barriers for reuse implementation that have been recognized and addressed. The summary table below and the country-specific write-ups in this appendix provide more detail on international experiences in implementing reuse.

Table G-1. Key International Leaders in Water Reuse

	Australia	Israel	Namibia	Singapore	South Africa
Drivers	Largely arid continent, population growth, vulnerable water supply, and drought	Arid region, population growth, and constrained systems	Arid country, drought-ravaged	Self-sufficiency	Arid country, population growth, severe and prolonged drought, and poor infrastructure
Reuse Applications	Groundwater replenishment	Agricultural irrigation	Potable water	Industry and reservoir augmentation	Potable water
Results	Established dedicated funding; set long-term groundwater replenishment and water reuse targets	Achieved water security; Israel can provide water and new water technologies	Pioneered potable reclaimed water and international benchmark for innovation	Developed overwhelming acceptance for potable reclaimed water	Successfully implemented potable reclaimed water; replicated the project model at other locations

Disclaimer

The international case studies included within this Appendix are included for illustrative purposes only and are not intended to be exhaustive. They were created to support development of the draft Action Plan and were not reviewed or approved by the applicable country. Each case study is unique and site-specific, and technology may not be as effective as demonstrated. Inclusion in this Appendix does not imply that the draft Action Plan endorses, approves, or supports these actions in this or any other location.

Leadership from Non-State Entities

The efforts of these pioneering nations are supplemented by many nongovernmental organizations. Large environmental and multinational entities are raising water scarcity awareness and promoting sustainable water management and reuse. Organizations that support water reuse efforts include the World Health Organization (WHO), the World Resources Institute (WRI) and the European Union (EU).

The **WHO** is an agency of the United Nations. Its role is to direct and facilitate global health. Safe water supplies are fundamental to global health as well as economic growth, education, and health care. The WHO has developed water quality guidelines that include the safe use of wastewater. These guidelines are just a sampling of the WHO's technical information and resources on water.

The **WRI** is a global research organization. Its work focuses on six issues (climate, energy, food, forests, water, and cities and transportation) and how they intersect with the environment and development. The WRI has complied current and future water stress rankings.

The **EU** is a political and economic union of 28 members states in Europe. Its water policy is to ensure water quality and quantity. Through policy, the EU is moving toward water efficiency and a water saving economy. Many EU studies, lesson learned, and actions are publicly available.

According to the WHO: By 2025, half of the world's population will face water stress.

According to the WRI: More than a billion people face water scarcity. The WRI projects that 3.5 billion people could face water scarcity by 2025.

According to the EU: As of 2007, 11 percent of Europe's population and 17 percent of its territory has been affected by either water scarcity or drought with further deterioration of the water situation expected.

International Profiles

International profiles were created to support development of the draft Action Plan. Reuse activities for the following countries are described below:

- Australia
- Israel
- Namibia
- Singapore
- South Africa

International Profile: Australia

Australia is the driest inhabited continent in the world, with the country's main water supply coming from rivers and surface reservoirs that are vulnerable to evaporation and drought.[1] The recognition of water resource vulnerability prompted a review of water sources, water usage, and consideration of alternate supply options.

Background

The climate in Australia varies significantly; the north is characterized as tropical (hot and humid) in the summer and warm and dry in the winter, and the south is characterized as hot and dry in the summer and cool/mild and wet in the winter.[2] Some areas receive over 100 inches of rainfall annually, while others go years without rainfall. For water resources, Australia relies on rivers, surface reservoirs, and non-conventional water sources such as seawater desalination. Australia's "millennium drought" lasting from 1996 to mid-2010 triggered major reform in water management throughout Australia.

Setting the Table

Australia is separated into six states: New South Wales, Victoria, Queensland, Western Australia, South Australia, and Tasmania. Water in Australia is managed by state and local governments. The Australian state governments have worked together to develop and implement the National Water Quality Management Strategy (NWQMS) to manage water quality within their jurisdiction. The strategy seeks to protect the nation's water resources by maintaining and improving water quality while supporting dependent ecosystems, agricultural and urban communities, and industry. The NWQMS comprises 24 technical and guidance documents and is being rolled out in two separate phases. The Phase 1 Guidelines cover graywater and treated sewage reuse (residential garden watering, car washing, toilet flushing, and clothes washing), irrigation (recreational and open space, agriculture, and horticulture), fire protection and firefighting, and industrial uses, including cooling water. The Phase 2 Guidelines cover recycled water to augment drinking water supplies, storm and roof water for purposes such as irrigation, and managed aquifer recharge.

The states have shown desire and willingness to manage their water resources to better prepare for the future. Queensland has developed a water security program to help manage its water resources and growing population demands until 2040.[3] In 2016, Victoria planned to invest over $370 million (USD) toward its Water for Victoria Program. The program includes the integration of multiple water resource projects including waterway and catchment health improvements, agriculture water efficiency projects, and rural water system upgrades.[4]

Turning Vision into Action

Water recycling varies significantly between the states. South Australia recycles the largest volume of water while the Northern Territories recycles the lowest volume of water. Western Water (a water

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[1] Australias Guide. (2019). Australia facts, just the facts. Accessed on 9 July 2019. https://www.australias.guide/facts/

[2] WeatherOnline. (2019). Australia. Accessed on 9 July 2019. https://www.weatheronline.co.uk/reports/climate/Australia.htm

[3] Australian Water Association. (2017). Queensland explores solutions to future water security issues. Accessed on 10 July 2019. https://www.awa.asn.au/AWA_MBRR/Publications/Latest_News/Queensland_explores_solutions_to_future_water_security_issues.aspx

[4] Victoria State Government. (2016). Water for Victoria: Summary. Accessed on 10 July 2019. https://www.water.vic.gov.au/__data/assets/pdf_file/0034/58849/Water-Plan-summary.pdf

authority in Victoria) recycles between 90 and 100 percent of its wastewater.[5] The South Australia Water Corporation has initiated a project titled the Northern Adelaide Irrigation Scheme (NAIS) to deliver up to 3.7 billion gallons of reclaimed water suitable for commercial food production.[6] The NAIS infrastructure will treat, store, and transport climate and season independent water to the farm gate.

Australia's major capital cities have set water recycling objectives. The city of Perth (Western Australia's capital) has set a 33 percent water recycling goal by 2025[7] and is working to diversify its water supply. Perth gets its water from desalination in combination with potable reuse or groundwater replenishment. More specifically, the Beenyup groundwater replenishment plant in Perth is operated by the state-owned Water Corporation. The plant features a groundwater environmental buffer and incorporates ultrafiltration, reverse osmosis, and ultraviolet treatment processes.[8] After successful completion of the trial phase, the Stage 1 construction for the full-scale plant started in 2014 and operations commenced in 2016. Stage 2 is now underway, with the goal of doubling the plant's capacity. A key factor in the scheme's success was the early engagement of the community and key stakeholders. Australia's use of advanced water recycling serves as leading example of indirect potable reuse through these groundwater replenishment efforts.

> **Weather in Perth:** Summers are warm and dry, and the winters are long, cool, and wet. It is windy and clear year-round.

In contrast with Perth, the city of Toowoomba (Queensland) has said "no" to water recycling by abandoning a potable reuse proposal in 2006. Communications and public acceptance were noted as major barriers to the proposal that could not be resolved; the community believed they were experiencing short-term water supply issues rather than long-term issues.

> **Weather in Toowoomba:** Summers are long, warm, and cloudy; winters are short, cold, and clear. Rain typically falls throughout the year.

Australians have also embraced water conservation. In Sydney, smart meters were piloted to track domestic water use and help consumers better manage their conservations practices as well as their water purchases.[9]

Key Outcomes

Coming out of Australia's "millennium drought," the government invested over $12 billion (USD) over a 10-year period in water management through the Water for the Future Program.[10] Other outcomes

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[5] Recycled Water in Australia. (no date). How much water is recycled in Australia? Accessed on 18 July 2019. http://www.recycledwater.com.au/index.php?id=62

[6] Southern Australian Water Corporation. (no date). Northern Adelaide Irrigation Scheme (NAIS). Accessed on 8 July 2019. https://www.sawater.com.au/current-projects/nais

[7] Recycled Water in Australia. (no date). How much water is recycled in Australia? Accessed on 8 July 2019. http://www.recycledwater.com.au/index.php?id=1

8 World Health Organization. (2017). Potable reuse: Guidance for producing safe drinking-water. Accessed on 8 July 2019. https://apps.who.int/iris/bitstream/handle/10665/258715/9789241512770-eng.pdf;jsessionid=B63AC513250D43CDD3A0D7368BB40F10?sequence=1

[9] Wallis-Lage, C. (2010, 1 September). Overcoming the global barriers to water reuse. WaterWorld. Accessed on 27 June 2019. https://www.waterworld.com/international/article/16201890/overcoming-the-global-barriers-to-water-reuse

[10] Murray–Darling Basin Authority. (2016). Since the Millennium Drought—The River Murray System: Lessons learnt and changes made. Accessed on 8 July 2019. https://www.mdba.gov.au/sites/default/files/pubs/Since-millennium-drought-report_0.pdf

included development of potable reuse regulations including the Commonwealth Water Act 2007 and the Basin Plan 2012.

Australians recognize the importance of behavior with respect to water usage. Every third week of October is National Water Week, coordinated by the Australian Water Association. The theme for 2019 is “It’s time to change the world.” The goal is to introduce sustainable water-related practices to children and get them to act. National Water Week includes events and competitions around the country.

Looking Ahead

Groundwater replenishment is one of the many solutions that will help Perth and the Water Corporation become more climate resilient and secure future water supply. Accordingly, the Water Corporation has set a goal to recycle 30 percent of wastewater by 2030 and 60 percent by 2060, meaning up to 20 percent of Perth’s drinking water needs could be supplied by groundwater replenishment by 2060.[11]

[11] Water Corporation. (2019). Groundwater replenishment. Accessed on 8 July 2019. https://www.watercorporation.com.au/-/media/files/residential/water-supply/gwrt/gwr%20brochure_february%202019.pdf

International Profile: Israel

Israel, on the arid east coast of the Mediterranean Sea, has historically faced challenges with water availability. As of 2015, the country now reclaims 87 percent of collected wastewater, up from 10 percent in the 1960s.[13] Israel's evolving water reuse strategy, driven by careful planning and efficient distribution, offers an example of how thoughtful decision-making can lead to successful water reuse.

> **Water Reuse for Agricultural and Other Purposes:** Reclaimed wastewater is primarily used for agricultural irrigation. It accounts for 37 percent of the water provided for agriculture and 7 percent of water provided for all uses.[12] Israel is aiming to treat all wastewater to allow unrestricted agricultural irrigation.

Background

The dry climate gives Israel unequal and seasonal variability of rainfall, with its modestly wetter north to a drier center and south, which include the main agricultural areas. In the mid-20th century, Israel primarily relied on groundwater as its chief water supply. Increased immigration in the 1980s strained existing water supplies and wastewater treatment infrastructure. The increases in demand were further stressed by several consecutive years of drought. After several outbreaks of infectious diseases were attributed to pollution from wastewater, public pressure increased on improving wastewater treatment and better monitoring the quality of reclaimed water.

> **Leader in Water Reuse:** "Today, nearly 90 percent of our waste water is recycled. That's around four times higher than any other country in the world. It is a remarkable achievement and this benefits not only Israel. Israeli companies are helping save water around the world, from Africa to California to India."
>
> —From the 2016 Israeli Corporate Social Responsibility Conference, opening remarks

Setting the Table

Israel's water policy history combines infrastructure development and regulatory reform. In the early 1950s, Israel enacted a national Water Law, rendering all water sources as public property. Along with its small geographic size, this enabled Israel to adopt centralized, integrated planning across its water sector.

In the early 2000s, Israel established a national Water Authority to integrate water management throughout the country. Its national master plan encouraged changing public perceptions to view effluent as a legitimate water resource. In essence, water reuse became an inextricable part of the nation's water policy.

The plan further called for increasing water efficiency, including by reducing losses in municipal systems, enhancing efficiency for irrigating public and private gardens, and using runoff to improve the urban landscape. Treated wastewater was also widely used for agriculture. In addition, the plan addresses Israel's potable water sources, and intentionally includes both traditional (surface water and groundwater) and alternative sources (reclaimed water and seawater desalination).

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[12] Israel Water Authority. (2015). The wastewater and treated effluents infrastructure development in Israel. 7th World Water Forum, Korea, 12-17 April 2015. Accessed on 26 June 2019. http://www.water.gov.il/Hebrew/ProfessionalInfoAndData/2012/03-The%20Wastewater%20and%20Treated%20Effluents%20Infrastructure%20Development%20in%20Israel.pdf

[13] Marin, P; Tal, S; Yeres, J; Ringskog, K. (2017). Water management in Israel: Key innovations and lessons learned for water-scarce countries. Washington, DC: World Bank.

Case Example: Shafdan Treatment Plant

The Shafdan wastewater treatment plant (WWTP) is the largest water treatment facility in Israel and considered a model plant by the United Nations. The plant currently treats 97 million gallons per day of municipal wastewater. Shafdan's main goals are to minimize environmental pollution and avoid health risks, prevent discharges of raw sewage, and treat wastewater for agricultural reuse. Sewage from Tel Aviv and the surrounding area undergoes secondary biological and tertiary soil aquifer treatment before being piped to the Negev Desert. More than 60 percent of the agriculture in Negev is irrigated by water from the Shafdan facility.[14]

Turning Vision into Action

Israel employed integrated water resources management planning across the country, creating a national water plan benefiting its citizens and its neighbors. The national policies called for replacement of freshwater allocations to agriculture by reclaimed effluent. To facilitate the use of effluent, Israel built a national water conveyance infrastructure that connected different water supplies (e.g., aquifers, desalination, reclaimed water) with potential end users. Much like an energy grid, this national infrastructure allowed Israel to convey water surpluses and address demand more flexibly.

Complementing improvements to its water infrastructure, Israel simultaneously increased the standards for treating wastewater (see inset box). The latest 2010 water quality standards for effluents specify 37 different parameters that are implemented to avoid potential adverse environmental consequences. These standards facilitate use of reclaimed water for a broad set of end uses. Israel's approach reflects the interconnectivity of its water infrastructure and the need to be able to move reclaimed effluent to a whole host of potential end uses.

This broad-scale integration of water management practices also leaned heavily on innovative approaches to treating water. For instance, Israel recharges aquifers with treated wastewater during low-demand months, capture of occasional flash floods, and comprehensive monitoring and control.

Timeline of WWTP Standards in Israel

Pre-1992: Primary treatment only
1992: Secondary quality standards for biochemical oxygen demand and total suspended solids
2010: Tertiary standards for nitrogen, phosphorus, filtration, disinfection
Reclaimed water from WWTPs came at no cost to users if it only received primary or secondary treatment. A small fee is charged for reclaimed water that receives tertiary treatment.[15]

Israel implemented supportive communications and outreach programs to educate its citizens on the importance of water conservation. This messaging is reinforced by pricing water at its actual cost. For instance, drinking water supplies to residents are priced at an order of magnitude higher than the reclaimed water used by farmers.[16] The infrastructure and water management reforms have improved Israel's own water security and allowed the country to provide water to the Palestinians and the Kingdom of Jordan, as well as export water-intensive produce.

[14] Marin, P; Tal, S; Yeres, J; Ringskog, K. (2017). Water management in Israel: Key innovations and lessons learned for water-scarce countries. Washington, DC: World Bank.

[15] A Zask, Israel Ministry of Environmental Protection, personal communication, 2019.

[16] A Zask, Israel Ministry of Environmental Protection, personal communication, 2019.

Key Outcomes

Since the 2000, Israel has invested over $750 million (USD) in large-scale reclamation efforts, which added 37 billion gallons per year in capacity.[17] It now has 67 large WWTPs, with the 10 largest WWTPs treating more than 56 percent of the total wastewater generated.[18] The nationwide piping infrastructure has connected various parts of the country, allowing surplus water to be easily conveyed as needed. To complement this connectivity, most wastewater has been undergoing tertiary treatment since the 2010 standards have been in place. Additional requirements for treated wastewater quality apply when there is a known agricultural irrigation use. The 2010 standards include, for the first time, requirements for salinity and concentrations of toxic metals.[19] These collective efforts have caused Israel's reused treated sewage rate to rise from 10 percent of collected wastewater the early 1960s to 87 percent in 2015.[20]

By increasing the amount of reclaimed water, Israel has reduced its dependency on limited natural water supplies and droughts have had little impact on end users. Wastewater reclamation replaces fresh water draws for domestic and industrial purposes. About 85 percent of reclaimed effluent is used for agricultural irrigation because it is more cost effective than desalinated water.[21] Small amounts are used for gardening and industry. As a result, Israel recognized treated wastewater as a resource and has subsequently become a leader in water reuse.

Looking Ahead

Israel aims to continue the development of its water reuse infrastructure and the successful momentum of the last two decades. The Water Authority's master plan targets reusing 100 percent of wastewater. By emphasizing both treatment technologies and connectivity of water infrastructure, the nation is well positioned to achieve that goal.

Israel's ability to efficiently reuse effluent anywhere across the country also increases the impact of otherwise small-scale projects. For instance, Israel now has several initiatives to capture and reuse rain water that would otherwise runoff to the sea. One such example is the Rainwater Harvesting Program. This program focuses on capturing rain from school rooftops for reuse onsite in toilets and watering gardens. This has resulted in a freshwater avoidance of more than 75 percent for participating schools.[22] This program has a secondary benefit by fostering an awareness of water resources and water scarcity in children. The program administrators seek to implement this approach more broadly across Israel.

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[17] Israel Water Authority. (2015). The wastewater and treated effluents infrastructure development in Israel. 7th World Water Forum, Korea, 12-17 April 2015. Accessed on 26 June 2019. http://www.water.gov.il/Hebrew/ProfessionalInfoAndData/2012/03-The%20Wastewater%20and%20Treated%20Effluents%20Infrastructure%20Development%20in%20Israel.pdf

[18] Marin, P; Tal, S; Yeres, J; Ringskog, K. (2017). Water management in Israel: Key innovations and lessons learned for water-scarce countries. Washington, DC: World Bank.

[19] A Zask, Israel Ministry of Environmental Protection, personal communication, 2019.

[20] Marin, P; Tal, S; Yeres, J; Ringskog, K. (2017). Water management in Israel: Key innovations and lessons learned for water-scarce countries. Washington, DC: World Bank.

[21] A Zask, Israel Ministry of Environmental Protection, personal communication, 2019.

[22] Vered, A. (2011, 26 January). Teaching water conservation to Israel's next generation. Jewish National Fund (press release). Accessed on 27 June 2019. http://usa.jnf.org/about-jnf/news/press-releases/teaching-water-conservation.html.

International Profile: Namibia

Namibia is one of the most arid countries in Africa: the average rainfall is about 10 inches per year, but the heat causes 83 percent to evaporate and only 1 percent of rainwater infiltrates into the ground.[23] The country has experienced water stress and shortages throughout its history but has used water reuse approaches to improve its water security.

Background[24]

Namibia's climate is characterized by hot and dry conditions and sparse and erratic rainfall. Namibia is one of the world's most sparsely populated countries. It is highly dependent on neighbors South Africa and Angola to sustain its water supply, as a large portion of its population lives near or along the banks of rivers shared with these countries.

The current demographic explosion in Africa is projected to exacerbate water needs. By 2030, about 80 percent of the world's population will live on the African and Asian continents, regions likely to experience continued water stress.[25]

Setting the Table

Namibia is a young country, having gained independence in March of 1990, and has inherited water management policies that were designed before independence. Namibia has drinking water guidelines but no comprehensive policy for treated wastewater.

Turning Vision into Action[26]

Before the 1960s, Namibia's capital city of Windhoek received its water from local springs. After the springs dried up, though, Windhoek became the first city in the world to reuse wastewater. It quickly became known as a pioneer in implementing this water management strategy. The city's Goreangab water reclamation plant commenced operation in 1969. The plant was upgraded five times over its lifetime; in 2002, a new plant began operation. The New Goreangab Water Reclamation Plant (NGWRP) uses treatment technologies with selected combinations of oxidation processes, activated carbon filtration, biofiltration, and membrane filtration to transform secondary domestic effluent into high-quality drinking water.

> "Water should be judged by its quality, not by its history."
> —Dr. Lukas van Vuuren, a pioneer associated with the Windhoek reclamation plant[27]

Absent standards for reusing treated wastewater, the plant has adopted its own water quality standards, which are largely based on existing guidance and standards including those from the World Health Organization and the U.S. EPA. The standards are enforceable per the plant's operating agreement. Today, the NGWRP meets 35 percent of the city

[23] Food and Agricultural Organization of the United Nations. (2005). Namibia. Accessed on 9 July 2019. http://www.fao.org/nr/water/aquastat/countries_regions/NAM/

[24] Food and Agricultural Organization of the United Nations. (2016). Namibia. Accessed on 9 July 2019. http://www.fao.org/nr/water/aquastat/countries_regions/NAM/

[25] Haushofer, C. (2019, 6 April). Africa: The reuse of treated wastewater for drinking water. Afrik 21. Accessed on 10 July 2019. https://www.afrik21.africa/en/africa-the-reuse-of-treated-wastewater-for-drinking-water/

[27] World Health Organization. (2017). Potable reuse: Guidance for producing safe drinking-water. Accessed on 8 July 2019. https://apps.who.int/iris/bitstream/handle/10665/258715/9789241512770-eng.pdf;jsessionid=B63AC513250D43CDD3A0D7368BB40F10?sequence=1

and its metropolitan area's drinking water needs, supplying high-quality drinking water for nearly 400,000 people.[28]

Key Outcomes and Looking Ahead

Windhoek has been relying on reused water to augment its drinking water supply for 50 years, and has a record of delivering safe, clean water even during multi-year droughts. The NGWRP is considered a model for reuse operations and is consistently studied/visited by experts, governmental personnel, and foreign mission personnel. It is considered an international benchmark for water and reclamation program innovation.

[27] World Health Organization. (2017). Potable reuse: Guidance for producing safe drinking-water. Accessed on 8 July 2019. https://apps.who.int/iris/bitstream/handle/10665/258715/9789241512770-eng.pdf;jsessionid=B63AC513250D43CDD3A0D7368BB40F10?sequence=1

[28] Haushofer, C. (2019, 6 April). Africa: The reuse of treated wastewater for drinking water. Afrik 21. Accessed on 10 July 2019. https://www.afrik21.africa/en/africa-the-reuse-of-treated-wastewater-for-drinking-water/

International Profile: Singapore

Singapore, the island city-state at the southern tip of the Malay Penninsula, currently imports about 40 percent of its water. Its current water supply agreements with neighboring Malaysia are set to expire in 2061. Singapore is investing in technology and water management to meet its goal of water self-sufficiency before the water agreements expire. To do this, Singapore's Public Utilities Board (PUB), the national water authority, uses an integrated approach to manage water supply, water catchment, and water use.[29] PUB's overarching strategy is to collect every drop of water, reuse water endlessly, and desalinate seawater.

Timeline of Water Management in Singapore
1961: PUB is formed to manage Singapore's water, electric and gas
2001: PUB created as a board under the Ministry of the Environment and Water, managing water supply; Singapore opens its first production plant for recycled water
2005: First desalination plant constructed
2008: Marina Bay reservoir constructed

Background

Singapore is one of the world's most "water-stressed" cities: though it is on the Equator in a tropical environment, it has no freshwater lakes or aquifers to help supply fresh water.[30] In 2014, Singapore experienced record-breaking dry spells. A steady increase in population has only exacerbated the strain on water resources. It is estimated that by 2060, two-thirds of Singapore's water demand will be industrial. These factors have driven Singapore to invest in alternative and innovative water supply solutions.

Setting the Table

Since restructuring and consolidating its water authorities in 2001, Singapore has integrated its water management to focus on its current four sources of water, also called the "Four National Taps":[31]

- **Locally managed catchment areas.** Singapore's activities in this area include expansive rainwater capture efforts and reservoir maintenance. Singapore's Active, Beautiful, Clean Waters (ABC Waters) program uses "natural systems consisting of plants and soil" to hold and treat rainwater runoff, and manage peak flow events.[32]
- **Imported water.** In 1962, Singapore signed the Johor Water Agreement, enabling it to draw and import up to 250 million gallons per day from the Johor River until 2061.[33]

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[29] Singapore Public Utilities Board. (2018). Our water, our future. Accessed on 8 July 2019. https://www.pub.gov.sg/Documents/PUBOurWaterOurFuture.pdf

[30] Reig, P; Maddocks, A; Gassert, F. (2013, 12 December). World's 36 most water-stressed countries. World Resources Institute. Accessed on 8 July 2019. https://www.wri.org/blog/2013/12/world-s-36-most-water-stressed-countries

[31] Singapore Public Utilities Board. (2019). Singapore water story. Accessed on 8 July 2019. https://www.pub.gov.sg/watersupply/singaporewaterstory

[32] Yau, WK; Radhakrishnan, M; Liong, S-Y; Zevenbergen, C; Pathirana, A. (2017). Effectiveness of ABC Waters design features for runoff quantity control in urban Singapore. Water 9(8): 577. Accessed on 9 July 2019. https://www.mdpi.com/2073-4441/9/8/577/htm

[33] Singapore Public Utilities Board. (2019). Singapore water story. Accessed on 8 July 2019. https://www.pub.gov.sg/watersupply/singaporewaterstory

- **Potable reclaimed water.** Singapore uses the term "NEWater" to describe potable water that comes from reclaimed wastewater. It undergoes "a four-stage treatment process (conventional treatment, micro-filtration, reverse osmosis, and UV treatment)" in order to meet drinking standards.[34]
- **Seawater desalination to produce potable water.**

Engagement Case Study: NEWater is potable (making up about 40 percent of Singapore's water needs with plans to increase to 55 percent by 2060), but mostly used in industrial applications. NEWater is also used to supplement reservoirs. The blended water is subsequently treated prior to distribution.

Turning Vision into Action

Foreseeing water availability challenges, Singapore has devoted resources to maximizing the potential of the "Four National Taps." Today, two-thirds of Singapore is served by a network of rivers, canals, and drains that convey rainwater to reservoirs. NEWater serves as the main water reuse application. The country has five water reclamation plants producing recycled water for potable and industrial applications. Combined, the plants treat about 157 billion gallons of water each year certified to the U.S. EPA and World Health Organization drinking water standards.[36] To supplement that supply, Singapore currently manages three water desalination plants that can meet up to 30 percent of the total water demand.

Key Outcomes and Looking Ahead

Singapore's desire is to rely less on imported water and become more self-sufficient with its water resources—but, by 2060, Singapore's water use is expected to more than double due to population and economic growth. Singapore expects to meet the majority of this future demand using NEWater and desalination. Accordingly, it has devoted $493 million (USD) in public funds to research and integrate water management technologies over 15-years.

Leader in Water Reuse: "Singapore has become a world leader in water management firstly because of its location as a densely populated city-state on an island lacking freshwater lakes. Thanks to the award-winning holistic work of its public utilities agency, the city currently receives more than half of its water supply from the unorthodox sources of rainwater collection (20%), recycled water (30%) and desalination (10%)."[35]

Singapore recognizes its largest current user of water is industrial. By finding ways to reduce the water needed for industrial operations, Singapore can reduce the increasing demand in that sector. Programs are already in place to incentivize and educate firms on the importance of water reuse and water reduction.

An ongoing challenge for Singapore is to ensure that water demand does not rise at an unsustainable rate. PUB has developed several outreach programs to foster conservation support in homes, schools, and workplaces. The programs include water efficiency labeling, toilet replacements, and recognition for individuals and organizations that champion water efficiency. A key outcome of this outreach is that per capita household water consumption has gone from 43.5 gallons per day in 2003 to 38 gallons per day in 2017. Singapore has a household water consumption goal of less than 34.3 gallons per day by 2030.[37]

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[34] Jacobson, M. (2012). Singapore water management. World Wide Fund for Nature. Accessed on 8 July 2019. https://wwf.panda.org/?204587/Singapore

[35] Jacobson, M. (2012). Singapore water management. World Wide Fund for Nature. Accessed on 8 July 2019. https://wwf.panda.org/?204587/Singapore

[36] World Health Organization. (2017). Potable reuse: Guidance for producing safe drinking-water. Accessed on 8 July 2019. https://apps.who.int/iris/bitstream/handle/10665/258715/9789241512770-eng.pdf;jsessionid=B63AC513250D43CDD3A0D7368BB40F10?sequence=1

[37] Singapore Public Utilities Board. (2019). Singapore water story. Accessed on 8 July 2019. https://www.pub.gov.sg/watersupply/singaporewaterstory

International Profile: South Africa

South Africa, an arid country that relies mainly on surface water supplies, has suffered severe droughts during its history. The Western Cape Province continues to experience the worst drought in 400 years; without intervention, South Africa's national water deficit will likely be around 17 percent by 2030.[38] Cape Town's water crisis in 2018, dubbed "Day Zero," threatened to turn off customer taps from the municipal water supply. Water scarcity not only threatens drinking water supplies but ecological conditions, the manufacturing sector, and the agricultural sector. South Africa has engaged in some water reuse efforts and aims to include water reuse applications in its overarching strategy for water security.

Background

The majority of South Africa's water and wastewater infrastructure is in poor or critical condition. Though the National Water Act says that water is a natural resource that belongs to all people of South Africa, many South Africans do not have access to fresh water and sanitary conditions. Formed in 2014, South Africa's Department of Water and Sanitation manages the country's water resources and has developed a master plan for water resources and infrastructure through 2030 and beyond.

Setting the Table

The country's water and sanitation master plan is built on five pillars of transformation (operational, institutional, structural, systemic, and delivery model). Water sustainability for South Africa will require moving from current water supplies—largely surface water—to increased groundwater use, reuse of effluent from wastewater treatment plants, water reclamation, desalination, and treated acid mine drainage.

Turning Vision into Action[39,40]

Direct potable reuse schemes are on the increase in South Africa. A leading example is the eMalahleni water reclamation plant. eMalahleni is an industrial town with coal-producing mines, steel manufacturing, and coal-fired power stations. The municipality, Anglo American Thermal Coal, and BHP Billiton entered into a partnership agreement to build the eMalahleni water reclamation plant. Under the agreement, the plant is owned by Anglo American Thermal Coal and the eMalahleni Municipality in turn buys the water from the plant for use in its distribution network. The plant was built to reduce acid mine drainage, so its source water comes from four different local mines, Greenside, Kleinkopje, South Witbank, and Landa.

After evaluating various technologies as part of pilot studies, project leaders decided to use a high-recovery precipitating reverse osmosis treatment process. The entire plant treatment system is controlled using a Supervisory Control and Data Acquisition (SCADA) system that allows the plant to operate automatically. Plant personnel are trained to operate all aspects of the plant if the SCADA

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[38] Water and Sanitation. (2018). National water and sanitation master plan. Volume 1: Call to action. Version 10.1. http://www.dwa.gov.za/National%20Water%20and%20Sanitation%20Master%20Plan/Documents/NWSMP%20Call%20to%20Action%20v10.1.pdf

[39] World Health Organization. (2017). Potable reuse: Guidance for producing safe drinking-water. Accessed on 8 July 2019. https://apps.who.int/iris/bitstream/handle/10665/258715/9789241512770-eng.pdf;jsessionid=B63AC513250D43CDD3A0D7368BB40F10?sequence=1

[40] United Nations Framework Convention on Climate Change. (2012). eMalahleni: Water Reclamation Plant | South Africa. Accessed on 9 July 2019. https://unfccc.int/climate-action/momentum-for-change/lighthouse-activities/emalahleni-water-reclamation-plant

system fails and are also responsible for taking and analyzing samples to verify the online sensor and probe measurements. The plant was commissioned in 2007 and continues to produce potable water for eMalahleni as well as reduce environmental risk from uncontrolled discharges of acid mine drainage.

Key Outcomes and Looking Ahead

South Africans recognize the importance of a talented workforce. Their plant operators must be familiar with specific plant activities and functions and overall operations, and (according to the National Water Act) must be certified.

While the government has a formal water management plan that includes water reuse, it is not yet being applied on a national or regional level. This has led to opportunities for the private sector. For example, the eMalahleni water reclamation project is being considered for replication by Anglo American at six of its other operations and has been replicated by other mining companies. The eMalahleni model is also being considered for mines other than coal.

> The South African insurance company Old Mutual, based in Cape Town, is no longer getting its drinking water from the city's water supply system and is providing potable water to its employees through an "off grid" system that recycles wastewater. As a corollary effort, the company has reduced its water consumption by 30 percent using electronic monitoring of flows and consumption, installation of aerators on taps, and savings on toilet flushing.[41]

[41] Haushofer, C. (2019, 6 April). Africa: The reuse of treated wastewater for drinking water. Afrik 21. Accessed on 10 July 2019. https://www.afrik21.africa/en/africa-the-reuse-of-treated-wastewater-for-drinking-water/