الهيئة السعودية للمياه
Saudi Water Authority

WATER HORIZONS

Exploring the Future of Infrastructure, Digital Transformation, and Circularity

In partnership with

OliverWyman

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Summary

The global water sector is under increasing pressure. Climate change, population growth, and rapid urbanization are intensifying demand, exposing gaps in infrastructure, and driving the need for more resilient and efficient water systems.

Many countries are now confronting the limitations of aging water infrastructure. Upgrades are essential to reduce losses, enhance reliability. In addition, further infrastructure is needed to meet the rising demand for safe and reliable water supply services. Additional infrastructure is also needed to ensure equitable access by populations. At the same time, utilities are adopting advanced digital technologies, ranging from AI-driven analytics systems to smart networks, to improve operational efficiency, reduce costs, and anticipate system stress. These technologies are becoming key to how utilities manage assets, detect inefficiencies and losses, and engage with customers. The move towards sustainability and circularity is also gaining momentum. There is an increased focus on energy efficiency and on closed-loop models that recover materials and elements previously discarded.

This report examines eight structural shifts reshaping water management worldwide and addresses the three interconnected forces that are driving those changes: infrastructure, digital and AI, and circularity and sustainability. As demand rises and constraints tighten, stakeholders across the water sector face critical choices. This report provides policymakers, investors, industry leaders, and other stakeholders with insights to help them navigate the complex changes sweeping the global water sector. It encourages the development of informed and far-sighted strategies that strengthen the resilience and sustainability of water resources.

Infrastructure

Expanding Desalination

Desalination has become a crucial solution in addressing global water scarcity, especially in arid regions and rapidly growing economies. The sector is dominated by reverse osmosis (RO) technology. It has overtaken thermal processes because of its greater efficiency and lower cost and has become increasing viable and sustainable in applications across the world. Industrial sectors, including high-tech industries like data centers and semiconductor manufacturing, are rapidly increasing water demand, placing further emphasis on desalination solutions.

The global desalination capacity is projected to expand by 7.1% a year until 2030. Seawater desalination will constitute 89% of this capacity, with the Middle East and North Africa (MENA) region expected to lead the expansion with over 65% of new capacity by 2030.

Advancements in RO membrane technologies and energy recovery systems offer promising routes to further reduce costs, improve environmental sustainability, and enhance resilience.

Advancing Water Transmission

Water transmission infrastructure plays a pivotal role in ensuring secure and resilient water supply systems by connecting diverse water sources, including desalination, to distant demand centers. Across the world, water authorities are embarking on projects to enable alternative water sources and to connect different basins for water transfers. Efficient transmission networks mitigate risks from drought and supply disruptions, and boost water availability.

Opportunities to transfer water across national borders are increasing and such initiatives will provide many countries with additional, economically viable sources of water. Despite financial and operational complexities, expanding water transmission infrastructure not only strengthens supply security but also supports the integration of decentralized systems. As climate pressures intensify and urban populations grow, these investments present vital opportunities to enhance sustainable water management in arid and water-stressed regions.

Upgrading Network

Expansion and modernization of water and wastewater networks are critical to meeting growing urban demands and addressing aging infrastructure challenges globally. These networks form the backbone of water delivery and sanitation systems, impacting public health, environmental sustainability, and economic efficiency.

Access to water and wastewater networks varies internationally. Many developed countries have achieved almost complete service coverage. However, in countries with lower population density, notable gaps in coverage remain, particularly outside major urban centers.

A key metric highlighting systemic inefficiencies in water networks is non-revenue water, the volume of treated water not billed due to leaks, inaccuracies, and other wastage. Leading countries have successfully achieved and maintained levels of non-revenue water at 5% to 15%.

Globally, investment in water networks is expected to grow 2% to 3% a year through 2030. The United States, China, Japan, France, and Germany will account for over half of the global market share. For wastewater networks, growth is slightly faster at 3% to 4% a year, with the same countries leading investment. Investment focus for the water networks market targets physical infrastructure components (pipes, valves, pumps), with pipes representing the largest share with around 20%.

EXECUTIVE SUMMARY

Digital and AI

Digitizing Operations and Services

The digital transformation of water management is accelerating across the world. It is being driven by advanced technologies such as artificial intelligence (AI), Internet of Things (IoT), and data analytics. These innovations enable utilities to gain real-time visibility and control over water systems (during predictive maintenance, for example), significantly enhancing operational efficiency and sustainability.

Investments in digital water technologies worldwide are projected to reach US$72 billion by 2030, growing at around 7% a year, with major spending concentrated in the U.S., China, India, the UK, and Japan. Data management and analysis technologies account for the most spending, around 35%, and sales are expected to grow at 10% a year. Smart meter deployment represents over 30% of the digital water market with a stable 5% annual growth rate.

The digital revolution in water management unlocks significant opportunities to minimize water loss, enhance decision-making, and foster sustainable water systems. Continued innovation and investment will be critical to expanding digital adoption, strengthening utility resilience, and improving customer experience. Still, challenges remain, including legacy infrastructure, fragmented data systems, and the exclusion of certain customer groups.

Enhancing Cybersecurity

As digital technologies become integral to water management, cybersecurity risks have escalated, posing significant threats to critical infrastructure worldwide. Rising cyberattacks target water utilities' operational systems and sensitive data. They originate from a range of sources that include rival nations and organized crime syndicates. These threats jeopardize water supply continuity, water quality integrity, and customer privacy, thereby undermining public trust and operational resilience.

The global financial impact of cybercrime is substantial, incentivizing heightened government and regulatory focus on protecting critical infrastructure. Water utilities are responding by developing comprehensive cybersecurity frameworks, upgrading legacy systems, and deploying advanced intrusion detection and prevention technologies. However, a critical gap remains, as many utilities lack sufficient internal expertise—only about 20% of US water utilities expect to fully manage cybersecurity independently.

Human error remains a prevalent vulnerability, accounting for roughly 90% of security breaches, underscoring the importance of robust staff training programs in cybersecurity protocols. Recommended best practices include identifying and prioritizing critical infrastructure, performing regular risk assessments, establishing stringent cybersecurity standards, and engaging external expertise.

Circularity and Sustainability

Adopting Renewable Energy

Renewable energy integration is an increasingly vital strategy in water management. It offers considerable reductions in operating costs, carbon emissions, and enhances energy efficiency and security, especially for energy-intensive processes like desalination and wastewater treatment. For desalination solutions, key benefits include the potential to cut energy expenses, up to 30% of total operational costs, and to reduce greenhouse gas emissions by as much as 80%. This transition also enables improved water access in remote or off-grid locations through renewable-powered solutions.

Despite these advantages, challenges persist. The often intermittent power delivered by renewable sources requires hybrid systems to be connected to local grids to ensure reliability. High upfront capital investments and current technological limitations (in solar photovoltaic systems, for example) remain significant barriers. Emerging opportunities involve exploring alternative energy sources, including nuclear power. Small modular reactors (SMRs) are being assessed as a promising low-carbon energy source for water applications.

Ambitious targets have been set for the renewable energy contribution in desalination worldwide, with 40% of power for new desalination plants by 2030, rising to 60% for plants commissioned by 2035. While the operational savings are promising, widespread adoption hinges on overcoming financial and grid access challenges.

Mining Desalination Brine

The global deployment of desalination plants is generating significant volumes of brine discharge, posing environmental risks to marine ecosystems and coastal aquifers. However, the emerging trend of zero-liquid discharge and brine mining turns this challenge into an economic and sustainability opportunity by recovering valuable minerals from brine streams.

The economic prospects are substantial given the rising demand globally for minerals like lithium, potassium, sodium, magnesium, and bromine. These minerals are key components for industries ranging from agriculture to clean energy technology. Lithium, in particular, presents a market expected to exceed US$13 billion by 2030, driven primarily by electric vehicle battery needs. Additionally, the demand for potassium is increasing due to agricultural needs, expected to value the market at US$28 billion by 2030.

Still, economic challenges persist, especially with energy-intensive processes. Nevertheless, as desalination capacity expands globally, brine valorization offers water utilities potential new revenue streams and environmental benefits, advancing sustainability goals and transforming the brine from waste into a resource. This is expected to drive the global demand for brine mining technologies, particularly evaporators and crystallizers, over the coming decade.

EXECUTIVE SUMMARY

Valorizing Wastewater

Wastewater treatment is gaining recognition as a cornerstone of water sustainability, transforming wastewater from merely a waste product into a valuable resource. This shift is critical for protecting public health and ecosystems by preventing contamination of water bodies. Treatment capacity worldwide must be expanded by 160 billion cubic meters of annual capacity to meet Sustainable Development Goal 6.3 by 2030. Investments in the sector are forecasted to grow 3% to 4% annually, reaching approximately US$110 billion in capital expenditure and US$185 billion in operational expenditure.

Water reuse capacity is also expanding rapidly, particularly in regions suffering from acute water scarcity such as the MENA. The global reuse capacity is expected to grow 25% by 2028. Technological advancements like reverse osmosis, membrane bioreactors, and advanced oxidation processes have elevated treatment quality and efficiency, enabling reuse at scale.

Besides water reuse, wastewater presents additional value through recovery of energy, nutrients, and material present in wastewater. Anaerobic digestion and other technologies help recover energy, a proven approach with net-zero energy in several treatment plants, and surplus production can be routed to the local power grid. Nutrients and other materials can be recovered, expanding markets and offering economic advantages over commercial alternatives for sectors such as agriculture and construction.

1.0

INTRODUCTION

Around the world, the water sector is undergoing a profound transformation, driven by the confluence of urgent global challenges. Climate change is amplifying hydrological extremes. More frequent droughts and shifting rainfall patterns are now threatening water security in both developed and emerging economies. Rapid population growth, particularly in urban centers and semi-arid regions, is placing unprecedented pressure on already scarce water resources. And demand from agriculture, which already accounts for 70% of global water use, is set to climb further as the need for food around the world continues to rise.[1]

1.0
Introduction

In this context, utilities, regulators, financiers, and other sector stakeholders are re-thinking how water is managed across its lifecycle. Investors are rewarding solutions that mitigate physical risk and deliver measurable environmental benefits (e.g., green bonds), while policy makers are tightening regulations on leakage, discharge quality, greenhouse-gas footprints, and customer service. At the same time, digital innovation, especially in artificial intelligence, advanced analytics, and sensors, is accelerating the pace at which transformation is happening in water globally.

Because the sector's challenges are multi-dimensional, no single approach can address them all and a variety of developments are currently happening. However, a coherent pattern is emerging around eight pivotal trends that, individually and in combination, are reshaping the resilience and economics of water systems worldwide. These major trends represent very consequential shifts observed across many markets, selected for their:

- Demonstrated impact on water-supply security and reliability
- Proven gain in operational efficiencies through the latest technological and AI developments
- Relevance to policy priorities such as net-zero, circular economy mandates, and climate-adaptation strategies

We grouped these eight trends into three overarching categories:

Infrastructure

Physical interventions that enhance supply capacity, flexibility, or robustness while addressing increasing needs from water users.

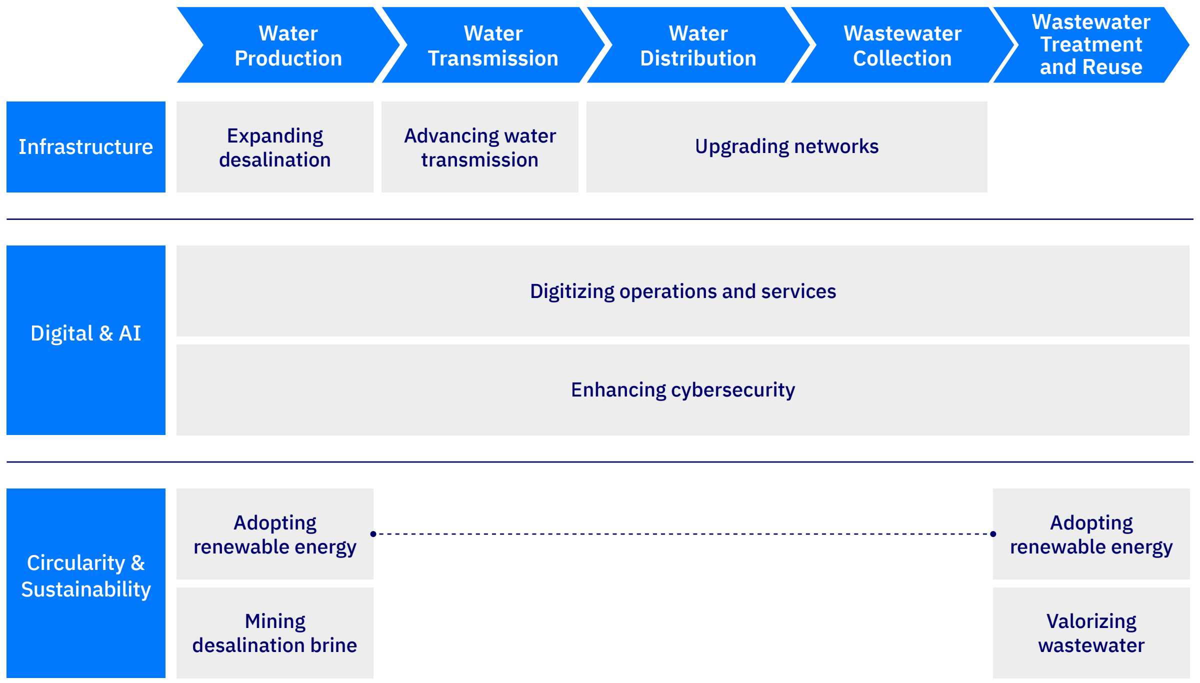
Digital and AI

Data-driven capabilities that unlock efficiency and predictive control for a more cost-efficient and customer-driven service.

Circularity and Sustainability

Systemic changes that close resource loops and reduce the footprint of water activities.

Figure 1. Mapping of major trends



Source: Oliver Wyman analysis

By framing the discussion around these categories, we can more effectively map how physical assets, digital intelligence, and circular principles intersect — creating integrated pathways to a more secure, climate-resilient, and economically viable water future. The sections that follow will examine each trend in turn, highlighting the underlying drivers, leading examples, and the outlook.

Additionally, the report will explore how these trends are expected to impact the global water markets, underscoring the importance of funding for sustainable and innovative water management practices. The report will also provide a deeper assessment on how these trends are expected to impact the MENA region, particularly in the Kingdom of Saudi Arabia.

By synthesizing these key trends, this report will provide stakeholders with actionable insights to navigate the evolving landscape of the water sector globally and ensure sustainable water management for future generations.

2.0

INFRASTRUCTURE

Utilities and governments around the world are increasing investment in modernizing water and wastewater infrastructure. Growing concerns about water scarcity and security are also pushing up spending on enabling infrastructure for alternative water sources such as desalination.

2.1
Infrastructure

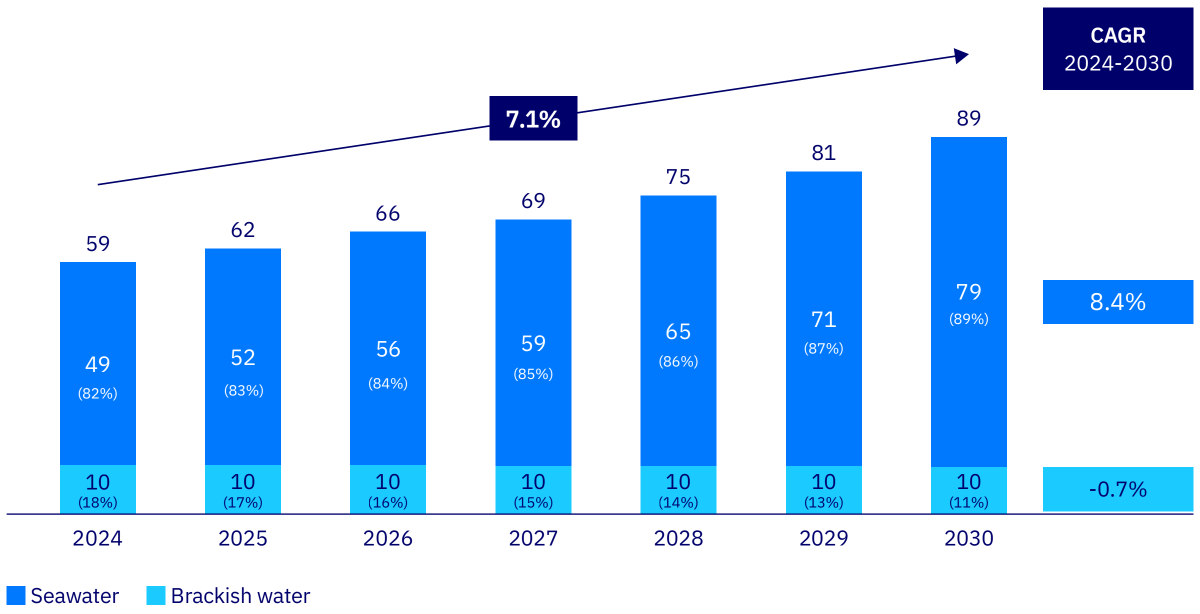
Expanding Desalination

Desalination is a key component of global water supply strategies, especially in arid regions that have low rainfall and little groundwater. It has risen in prominence as climate change, population growth, and new industrial demands put further pressure on water resources.

Reverse osmosis (RO) is now the dominant desalination technology and has overtaken older, energy-intensive, thermal processes such as multi-stage flash (MSF) and multi-effect distillation (MED).

Global operating capacity of seawater and brackish water desalination is projected to grow by 7.1% a year between 2024 and 2030, reaching approximately 89 million cubic meters a day by 2030.[2, 7]

Figure 2. Global seawater and brackish water desalination operating capacity[1] by feedwater
2024-2030, in million m³/day



1. Operating capacity = Current capacity + Capacity addition — Decommissioned
Source: GWI DesalData, SWPC, Oliver Wyman analysis

Several factors are driving this expansion:

- Population growth of close to 1% a year, combined with rapid urbanization, is increasing the need for reliable water sources.[3]
- Water scarcity and depletion of non-renewable sources remain critical concerns. Close to 25% of the global population faces extremely high water stress each year. By 2050, a further one billion people are expected to be living in such conditions.[4]
- Advances in membrane technology, plant design, and operational efficiency have reduced desalination costs by around 50% in the past 15 years.[5]
- Industrial demand continues to rise. Growing industries such as data centers and the production of semiconductors and solar cells will put further strain on scarce water resources. Currently, the global water consumption for data centers is approximately 560 million cubic meters a year, potentially rising to around 1,200 million cubic meters a year in 2030. The water consumption for chip manufacturing globally is expected to grow by more than 50% until 2030, reaching 70 million cubic meters a year.[6]
- Agricultural demand for water will continue to rise as food production is expected to climb 60% by 2025 to support a growing global population. However, agriculture's need for additional water could be limited to just a 10% increase if irrigation practices are improved and crop yields increased.[1]

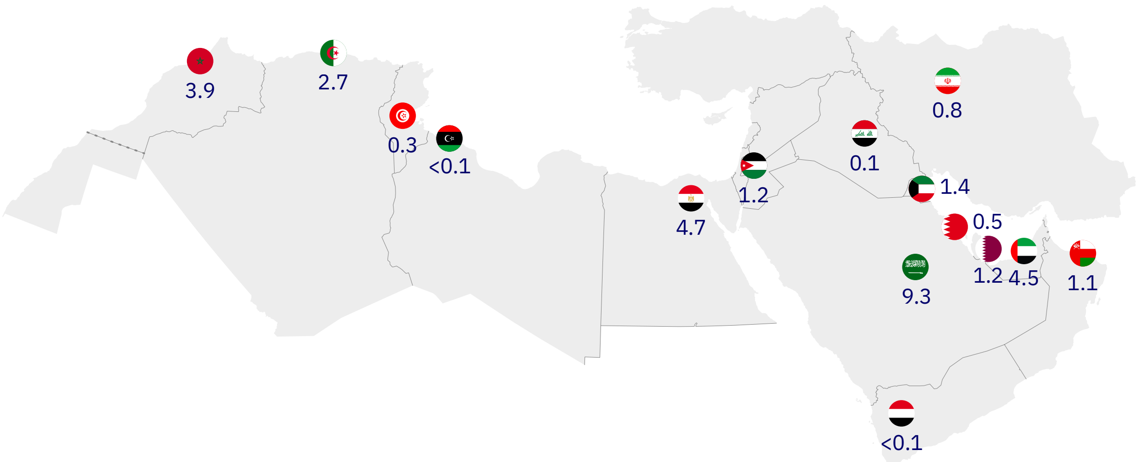
Most new desalination capacity uses seawater as its water source. It is abundant and can be readily accessed in large volumes. By 2030, seawater sources will account for 89% of global desalination capacity.[2, 7]

Regional trends[2, 7]

The MENA* region is at the forefront of the rise in desalination capacity. The region is projected to account for over 65% of new capacity by 2030, reaching an output capacity of 56 million cubic meters a day.

Saudi Arabia, Egypt, the United Arab Emirates, and Morocco are forecasted to account for 67% of new desalination capacity in the MENA region. Saudi Arabia alone is expected to deliver 28% of this increase.

Figure 3. MENA seawater and brackish water desalination capacity additions
2024-2030, in million m³/day



Total capacity additions 2024-2030 MENA
31.6 million m³/day

Note: Total capacity additions calculated considering an average rate of 5% of current capacity decommissioned per year until 2030

Source: GWI DesalData, SWPC, Oliver Wyman analysis

Outside MENA, key growth markets include China, India, the United States, Chile, Spain, Taiwan, South Africa, Australia, Singapore, and Brazil. These countries are expected to add 15 million cubic meters a day in extra capacity, bringing their total capacity to 33 million cubic meters a day by 2030.

*The data utilized in this analysis of the MENA region covers the following countries: Algeria, Bahrain, Egypt, Iran, Iraq, Jordan, Kuwait, Libya, Morocco, Oman, Qatar, Saudi Arabia, Tunisia, United Arab Emirates, and Yemen

Case study: Hsinchu, Taiwan[8, 9]

Taiwan is striving for greater water resilience through its "Enhancement of Water Production by Technology" strategy. In Hsinchu, the first large-scale municipal desalination plant, with a daily capacity of 100,000 cubic meters, is under construction. The region previously sourced all its water from reservoirs fed by rainfall.

The new plant will help address climate-related supply risks and support the growing water needs of local semiconductor and high-tech industries. It will also supply water to 1.6 million people. The plant will use RO technology together with energy-efficient processes, integrated solar power, and a compact design that will lower operating costs and reduce its environmental impact.

Developed through a public-private partnership (PPP) valued at NT$17.7 billion (which, at the time of publishing, was approximately US$560 million), the project is the first collaboration between Taiwan's Water Resources Agency and an international desalination provider. It is scheduled to be completed in 2028 and will operate under a design, build, operate (DBO) model with a 15-year operation and maintenance agreement.

Market investment outlook

Rising demand for desalination is spurring significant investment.[2]

- Global capital expenditure (CapEx) is forecast to reach over US$12.5 billion by 2030, growing at approximately 12% a year between 2024 and 2030
- Global operational expenditure (OpEx) is forecast to total US$15 billion by 2030, growing at around 7% a year over the same period

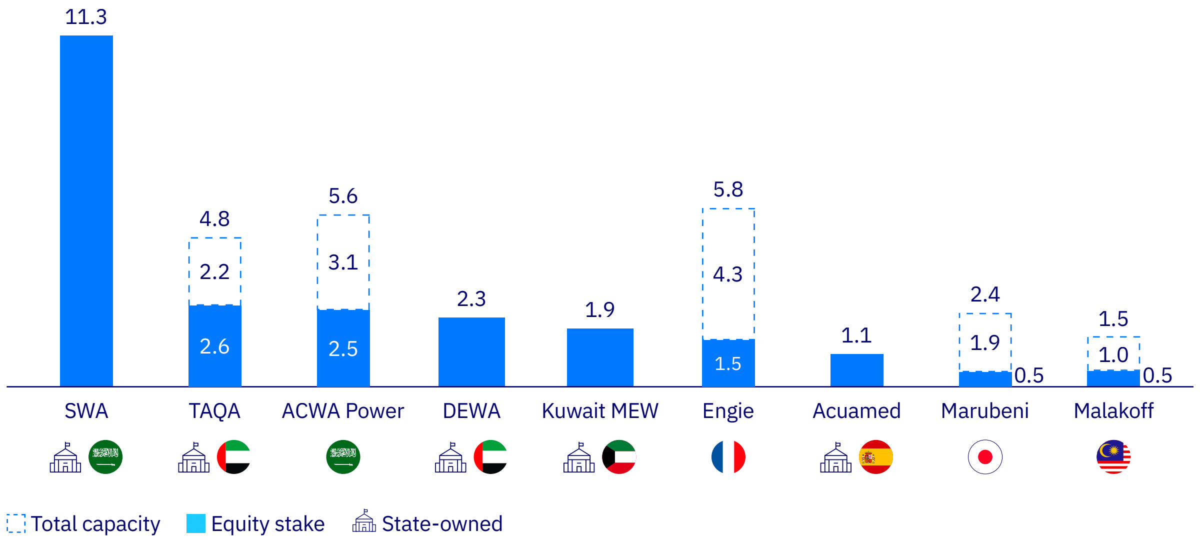
Saudi Arabia, Egypt, and UAE rank alongside China and the United States as global leaders in investment in desalination facilities, infrastructure, and services.

Desalination market

The Saudi Water Authority (SWA) has the largest desalination capacity in the world. It can produce more than 11 million cubic meters of desalinated water a day.[10]

The desalination engineering, procurement, and construction (EPC) market is a highly competitive environment in which Veolia, Acciona, and Metito are the main providers. Since 2014, each of these companies has supplied desalination capacity of up to 4 million cubic meters a day.[11]

Figure 4. Top 10 desalination capacity owners[1]
2024-2030, in million m3/day



Note: Taqa = Abu Dhabi National Energy Company; Kuwait MEW = Kuwait Ministry of Electricity & Water; DEWA = Dubai Electricity & Water Authority; Desalination plants only (excl. water treatment plants);
1. Owned capacity based on equity stake owned
Source: GWI DesalData, company websites and annual reports, Oliver Wyman analysis

Technology trends

RO is now the dominant technology among desalination plant operators and developers, having replaced older thermal methods such as MSF and MED. Typical costs range from US$0.52 to US$1.75 a cubic meter.[12]

RO is more efficient than MSF and MED technologies, with costs of up to US$0.56 a cubic meter. It is electrically powered, which typically results in lower greenhouse gas emissions compared to the heat-driven processes used in thermal desalination.[12]

Between 2020 and 2024, RO capacity grew by 5.4% a year, while thermal capacity declined by 3.4%. RO accounted for 97% of the top 50 desalination projects awarded during this period.[10]

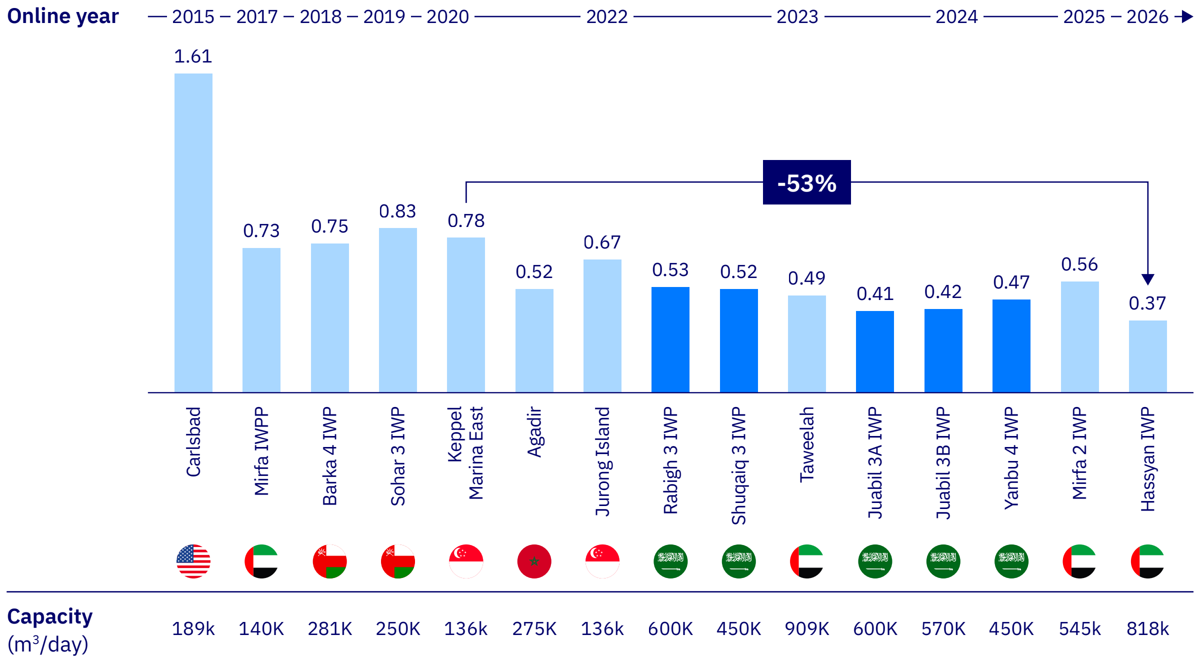
Growth is expected to continue with RO capacity projected to rise to 9% a year through to 2030 while thermal capacity will continue to decline.[10]

Cost trends[10]

The shift to RO by utilities and private plant developers has significantly reduced desalination costs. Over the past five years, prices for independent water projects and independent water and power projects have fallen by close to 50%.

Saudi Arabia and the United Arab Emirates have attained some of the lowest desalination costs in the world, with prices below US$0.50 a cubic meter.

Figure 5. Levelized price of water in selected independent desalination projects
In US$/m³



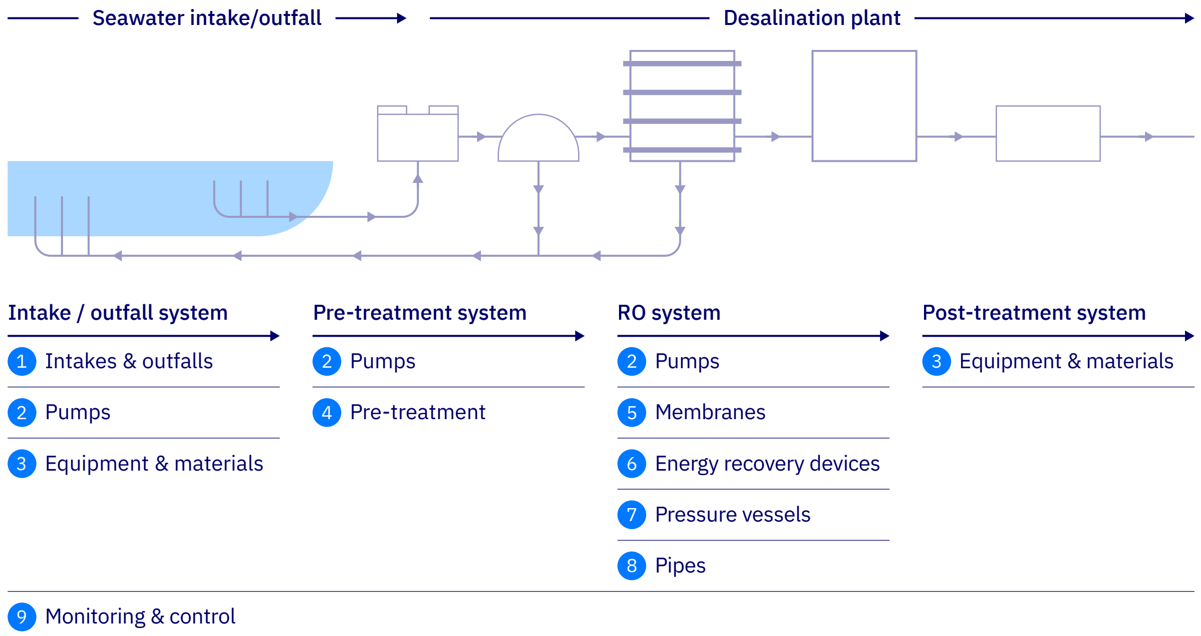
Note: All selected independent desalination projects are RO
Source: GWI DesalData, SWPC, ACWA Power

Supporting technologies

The transition to RO is also fueling investment in supporting technologies.

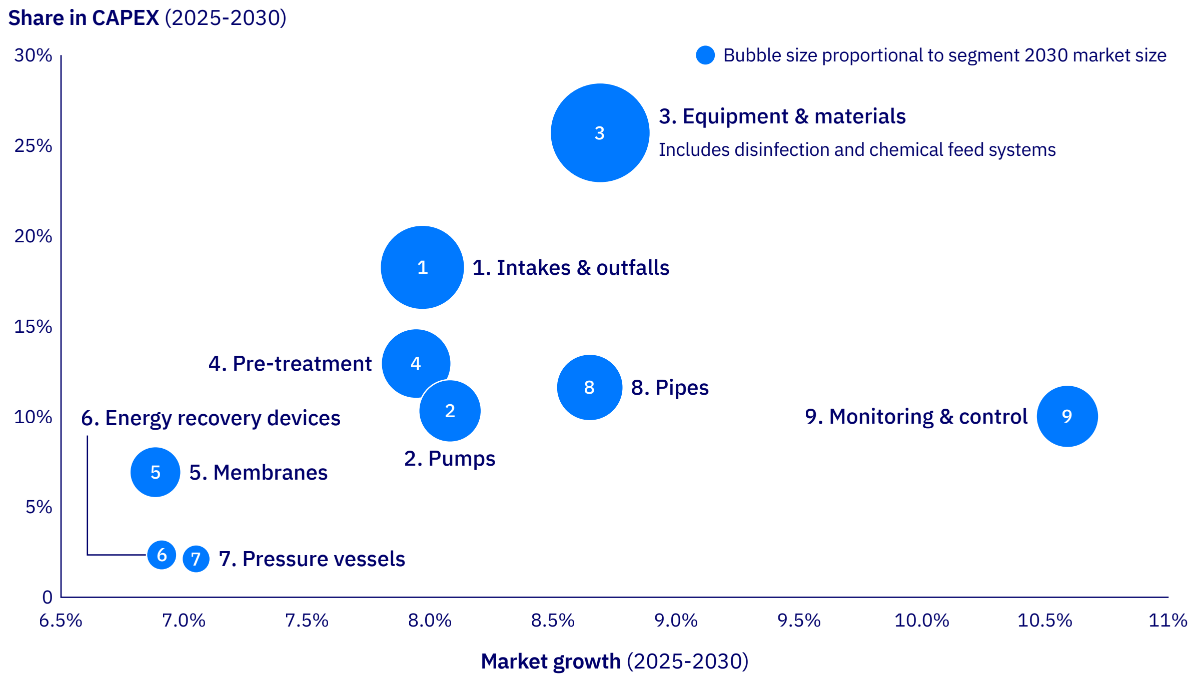
The market for monitoring and control equipment is expected to grow the fastest at more than 10% a year until 2030. Sales of energy recovery devices, by contrast, are forecast to grow by less than 7% a year.[2]

Figure 6. RO desalination process and main systems/components



Source: GWI WaterData, Lenntech, Oliver Wyman analysis

Figure 7. RO desalination technology market assessment



Source: GWI DesalData, Oliver Wyman analysis

The table below also shows key providers of leakage management solutions that are represented in the sensors and the data management and analytics categories.[13]

Other equipment and materials, including disinfection and chemical feed systems, are expected to hold the largest share of the desalination equipment market by 2030.

Table 1. Key providers of monitoring and control equipment

Company	Communications	Smart fluid control	Sensors	Automation & control	Data management & analytics
Itron	√		√		√
Sensus	√		√		√
Xylem	√	√	√	√	√
Mueller Water Products	√		√	√	√
Emerson		√	√	√	√
Grundfos		√	√	√	√
Talis		√	√		√
ABB			√	√	√
Ecolab			√		√
Hitachi			√	√	√
Schneider			√	√	√
Suez			√	√	√
Veolia				√	√
Ovarro			√	√	√
Siemens			√	√	√

Source: GWI WaterData

Challenges and opportunities

Water-scarce regions such as MENA require major investments to expand desalination capacity, placing heavy pressure on both capital and operational expenditure requirements. Attracting and retaining skilled technical talent is also a major challenge.

Advances in reverse osmosis membranes and other technologies are reducing the cost and environmental impact of desalination. Ongoing innovation can further lower capital and operating costs, improve sustainability, and increase system resilience.

Summary

The global increase in desalination capacity is a strategic response by utilities and government agencies to growing water scarcity. Supported by advances in RO technology, falling costs, and big investments, especially in the MENA region, desalination will be a key element in ensuring future water security.

2.2
Infrastructure

Advancing Water Transmission

Water transmission systems are becoming essential for nations looking to ensure long-term water security and resilience of water supply. The continuous search for alternative sources of water will result in greater distances between water supply and demand. This is particularly evident in seawater desalination-dependent countries, where transmission lines play a strategic role in connecting coastal desalination plants with inland areas. Water demand in those countries is growing fast, particularly in urban centers.

Water transmission systems also play a central role in connecting different basins, allowing the transfer of water to help distribute resources. Such capabilities boost water supply resilience during droughts, seasonal fluctuations, and other disruptions.

The transmission of water is an energy-intensive activity due to the need for continuous pumping. Moving water over long distances requires significant amounts of energy. Additional energy is often needed to move water over higher altitudes.

Global benchmarks in transmission energy efficiency

Leading transmission systems achieve pumping efficiencies of approximately 0.3 to 0.4 kilowatt hours per cubic meter per 100 meters (kWh/m³/100m). Examples include:

- Ras Al-Khair, Saudi Arabia: 0.30 kWh/m³/100m
- Shuqaiq, Saudi Arabia: 0.32 kWh/m³/100m
- California State Water Project, United States: 0.32 kWh/m³/100m[14]
- Aguas do Douro e Paiva, Portugal: 0.37 kWh/m³/100m[15]

There has been an increasing focus in Saudi Arabia on improving the operational efficiency and reducing specific energy consumption of water transmission systems. These efforts have been been spearheaded since 2022 by the Water Transmission Company (WTCO) and have achieved particular success at the Ras Al-Khair and Shuqaiq systems. Work is currently underway to improve the energy efficiency of other systems.

International transmission projects

Major transmission projects are underway throughout much of the world. Concerns about water security are prompting a significant rise in infrastructure investment. The table below shows some of the key projects under construction.[16, 17, 18]

Table 2. Key projects under construction

Name	Country	Owner/Developer	Length (km)	Cost (US$ million)
Barranqueras to Saenz Pena Potable Water Pipeline Project		Supercemento, OAS Empreendimentos SA, Rovella Carranza SA	512	378
Northern Water Supply Project		Government Of South Australia	600	-
Dingley Recycled Water Scheme Project		KBR Inc, Abergeldie Complex Infrastructure Pty Ltd, BMD Constructions Pty Ltd, South East Water Corporation	42	54
Agreste Water Supply Project		Estado de Alagoas	95	81
Radomiro Tomic Sulfuros Water Pipeline		Saipem SpA	160	560
Centinela Mine Water System Expansion Project		Transelec SA, Antofagasta Minerals SA, Almar Water Solutions BV	144	-
Mancheng 2021-2022 Rural Domestic Water Source River Water Replacement Project		Water Conservancy Bureau of Mancheng	23	-
South-North Water Transfer		Various	>2,400	US$ 62 bn
Canal del Dique Rehabilitation PPP Project		Sacyr Concesiones SL, Govenrment of Colombia, Agencia Nacional de Infraestructura	116	827
Fresh Water Pipeline from the Abdullah Water Distribution Complex		Ministry of Electricity, Water and Renewable Energy	94	150
Fresh Water Line from Wafra to Sixth Ring Road		Ministry of Electricity, Water and Renewable Energy	87	84
Water Pipeline from Duba to Sharma		Saudi Water Authority (SWA)	100	75
Transmission Scheme: Lot 1 and Lot 2		TAQA Transmission	306	130

Source: LSEG Workspace, MEED, Rogers et al., 2019, Oliver Wyman analysis

Case study: China's South-North Water Transfer, Middle Route[18]

The South-North Water Transfer project in China is the world's largest interbasin water transfer scheme. Composed of two main routes, it has a total capacity of 4.5 billion cubic meters a year. Freshwater from the Yangtze River in Southern China is diverted, through two main routes, to the industrialized municipalities of Beijing and Tianjin, as well as the provinces of Shandong, Jiangsu, Hebei, Henan, and Anhui.

The Middle Route is a diversion of more than 1,250 km, connecting the elevated Danjiangkou Reservoir in the Han River to Beijing and Tianjin. Because of the Danjiangkou Reservoir's elevation, water transfer through the Middle Route is driven by gravity. The construction of the Middle Route was started in 2004 and completed in 2014, and required the relocation of approximately 400,000 people from six counties in Hubei and Henan.

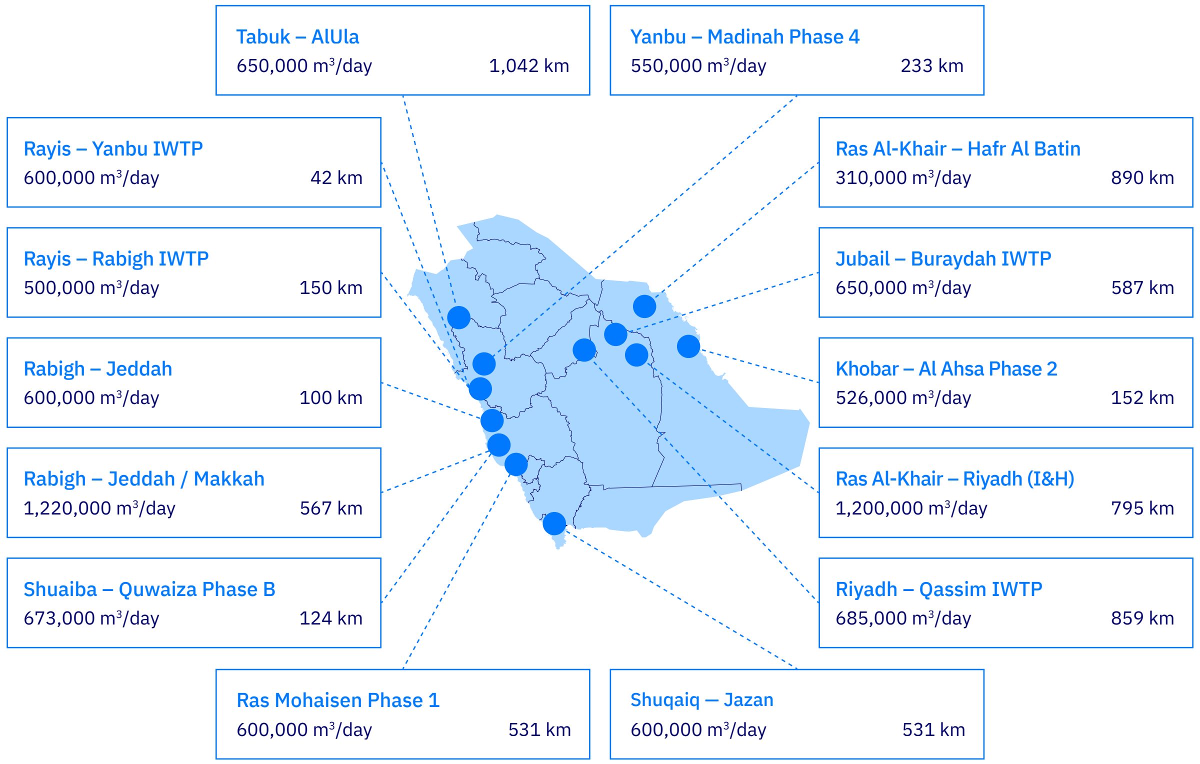
Before the project, industries that required a lot of water were discouraged from setting up in northern China. Now, industries and farmers are able to consider economic development more freely. The project also enables groundwater in northern China to be replenished and that reduced pollution. However, some pollution incidents have been reported in the Middle Route from chemical spills into the main canal.

Saudi Arabia

In Saudi Arabia, water transmission is critical to supply security. It links inland cities, such as Riyadh, to their main source of water more than 400 km away.

More than 10,000 km of new water transmission pipelines are set to be built by 2030, with investment totaling close to US$30 billion. This is expected to account for approximately 90% of the region's transmission investment.[17] Main projects are being developed by WTCO and ENOWA, and are contracted through the Saudi Water Partnership Company (SWPC) under public-private partnerships (PPPs).

Figure 8. Key future water transmission projects (under construction and planned) in KSA



IWTP: Independent water transmission pipeline
Source: MEED, SWPC, Oliver Wyman analysis

MAJOR TRENDS IN INFRASTRUCTURE

Other key GCC markets[17]

Besides Saudi Arabia, water transmission pipelines are also common in other Gulf Cooperation Council (GCC) markets.

Oman (500 km), Kuwait (200 km), and the United Arab Emirates (100 km) are all expected to extend their water transmission pipelines in the next five years. These extensions will require a total investment US$2.3 billion.

Cross-border opportunities in the GCC

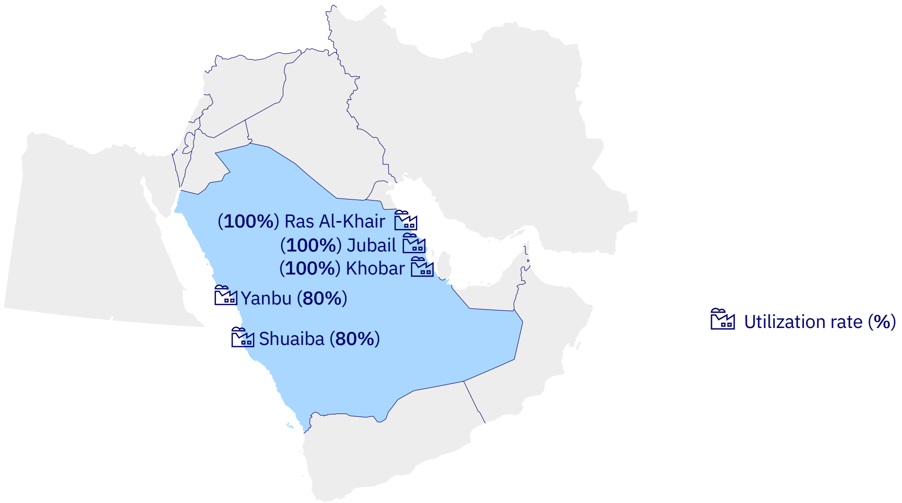
As the regional leader in water transmission, Saudi Arabia is well positioned to champion the development of a cross-border water market that connects its pipeline networks with neighboring GCC countries. Spare desalination capacity at plants in Yanbu, Shuaibah, and Khobar could support this opportunity. The plants operate in an area of the Gulf where cross-border transmission would be economically viable.

The feasibility of cross-border transmission, which is currently being evaluated by utilities and policymakers, depends on two factors:

1. The cost gap between Saudi Arabia’s lower production costs (driven by lower energy costs) and the receiving country’s local production costs.
2. The additional pipeline costs per kilometer required for interconnection.

Bahrain and Kuwait currently offer the strongest potential for cross-border transmission, with projected cost gaps between 10% and 25%.

Figure 9. Economic assessment for transmission desalinated water from KSA to MENA countries



In SAR/m³										
Cost for transmitted water	1.95	2.82	3.14	2.31	2.19	3.21	2.60	2.82	3.63	3.38
Cost for locally desalinated water	2.66	2.97	3.22	2.58	2.21	2.19	2.32	2.67	2.40	2.37
	24%	5%	3%	10%	1%					

Opportunistic cross-border transmission play

(xx%) Gap between cost of transmitted desalinated water and locally desalinated water

Note: Assumption of 50 years transmission lifetime, 0.25 MN m³/day transmission volume, CapEx of US$2 million km transmission line, OpEx of US$100 a year per km³ transmitted, 1.5 SAR/m³ desalination cost in KSA

Source: GWI DesalData, Oliver Wyman analysis

Challenges and opportunities

Developing water transmission systems adds complexity to water supply planning and infrastructure integration. Furthermore, it has a significant impact on capital requirements and operational costs in a sector already struggling to secure funding.

Nevertheless, water transmission expands the possibilities for water supply, enabling alternatives sources of water. It enables the interconnection of basins and the decentralization of supply sources. This would improve the resilience of water supply systems and strengthen water security.

Summary

Water transmission networks are essential for enhancing water supply resilience, especially in water-scarce regions. As urban populations grow and climate variability intensifies, the ability to efficiently transport water from source to demand centers is becoming critical. This is particularly true in the GCC region, where significant investment has already been committed to expanding and modernizing the transmission infrastructure. Cross-border transmission could provide new opportunities for regional water markets while strengthening the region's supply resilience.

2.3
Infrastructure

Upgrading Network

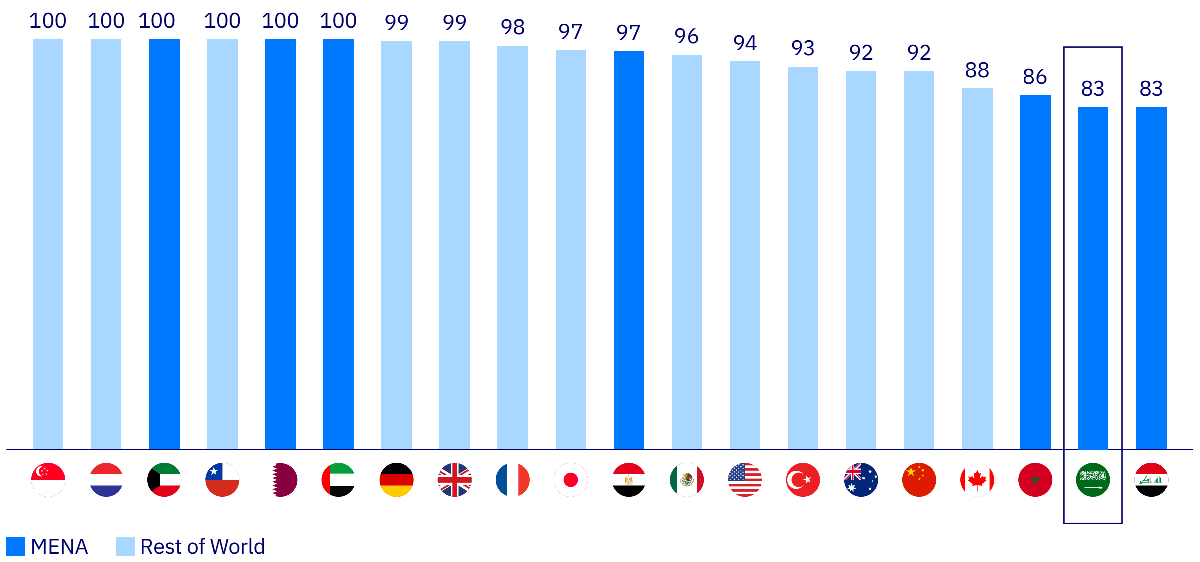
Expanding and modernizing water and wastewater networks has become a priority across the global water industry. Many countries have already achieved high levels of population coverage, but aging infrastructure, uneven access, and efficiency challenges continue to spur new investment in network replacement and expansion.

Access to potable tap water

Access to safe drinking water varies widely across the world. Many European countries maintain high safety standards and reliable access to potable tap water.[19]

Water networks in many European countries have achieved extensive population coverage. And Small, high-density nations such as Singapore, Kuwait, and Qatar have already attained complete or close to complete coverage.[20, 21]

Figure 10. Population connected to water supply network
%, in selected countries



Source: GWI WaterData, EurEau, MEWA, Oliver Wyman analysis

In the MENA region, there is still scope for improving network coverage, especially outside the highly populated urbanized states.

Modernizing aging infrastructure is a priority for many utilities around the world. Many water networks in developed countries, for example, were built in the previous century and their aging infrastructure is inefficient, increasingly expensive to maintain, and vulnerable to service disruptions. The American Society of Civil Engineers (ASCE), for example, estimates that more than US$1 trillion will be needed to repair and upgrade the country's water infrastructure over the next two decades.[22]

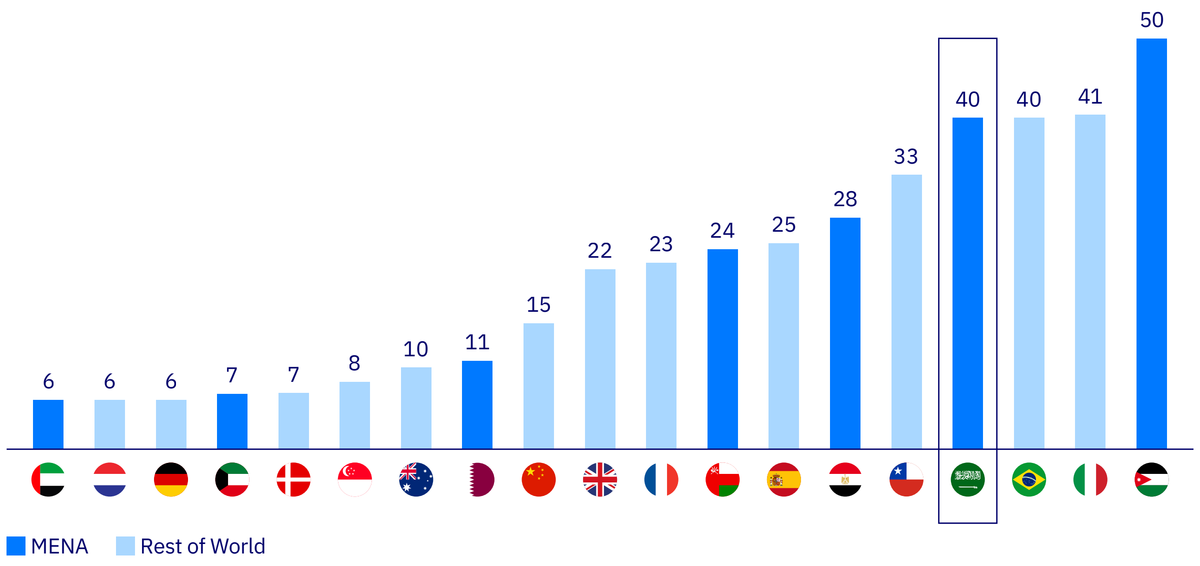
Non-revenue water

Non-revenue water is treated water that is authorized for consumption but is not billed or is lost. It is measured by determining the difference between a system's input volume of water, and the authorized water consumption that is billed. It comprises water losses from leakages, metering inaccuracies, and illegal connections.[23]

High levels of non-revenue water remain a major challenge for utilities around the world. The significant economic losses that result from non-revenue water highlight the need for targeted investment in network efficiency. Such investment will reduce financial losses and also improve service performance.

The best-performing countries maintain non-revenue water levels between 5% and 15%. MENA countries such as the United Arab Emirates, Kuwait, and Qatar, rank among such leading performers together with other small, high-density nations such as Singapore, the Netherlands, and Denmark.[20, 24]

Figure 11. Non-revenue water
%, in selected countries



Source: GWI WaterData, EurEau, MEWA, Oliver Wyman analysis

Coverage levels of wastewater services

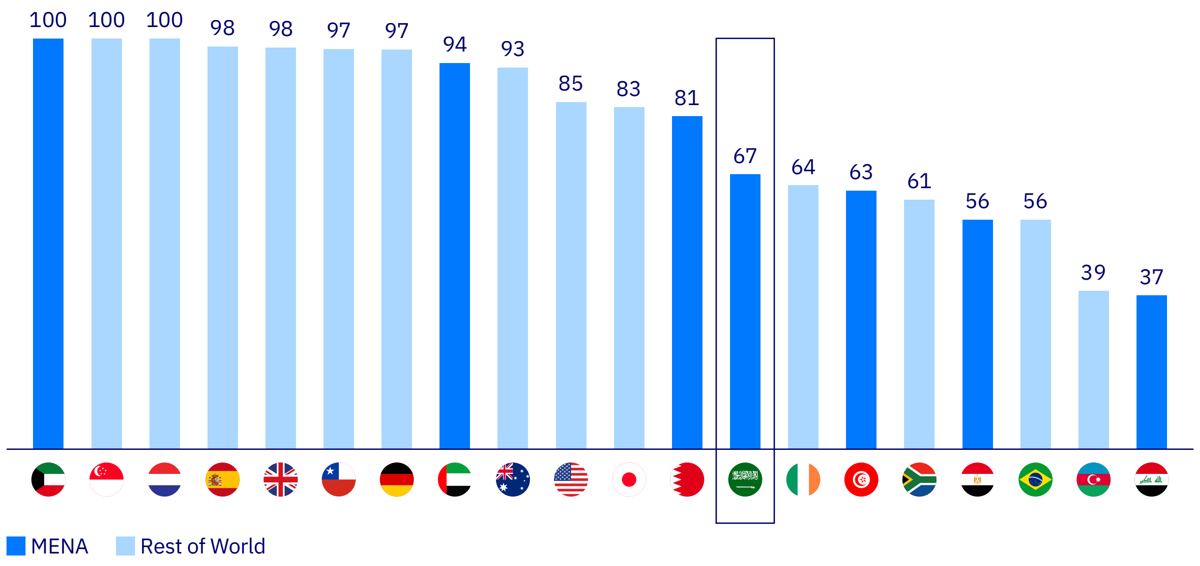
European countries tend to have extensive wastewater network coverage. Small, population-dense nations such as Kuwait and Singapore have also achieved full or near-full coverage.[20, 25, 26]

Yet many developing countries still need to expand their wastewater networks. Modernizing waterways and wastewater networks delivers substantial public health benefits. Such benefits include a reduction in waterborne diseases, improved sanitation, and more hygienic living conditions. In addition, it is critical to enhance environmental sustainability by reducing pollution incidents from wastewater.

Parts of the MENA region, including Saudi Arabia, Tunisia, Egypt, and Iraq, are among the countries that need to significantly extend their wastewater networks.[20, 26]

MAJOR TRENDS IN INFRASTRUCTURE

Figure 12. Population connected to wastewater collection network
%, in selected countries



Source: GWI WaterData, EurEau, UN Statistics Division, MEWA, Oliver Wyman analysis

Public health impacts

Modernizing water systems and wastewater networks delivers substantial public health benefits. They include a reduction in waterborne diseases, improved sanitation, and more hygienic living conditions.

Case study: Sharjah network replacement[27]

The Sharjah Electricity and Water Authority (SEWA) is replacing aging asbestos pipes with modern glass-fiber reinforced epoxy resin (GRE) pipes to improve system reliability and public safety.

In 2024, SEWA replaced 25 km of asbestos pipes at a cost of US$6 million. This year it plans to replace a further 40 km of asbestos pipes and expand the network by 60 km with new GRE pipes, with projected costs of more than US$11 million.

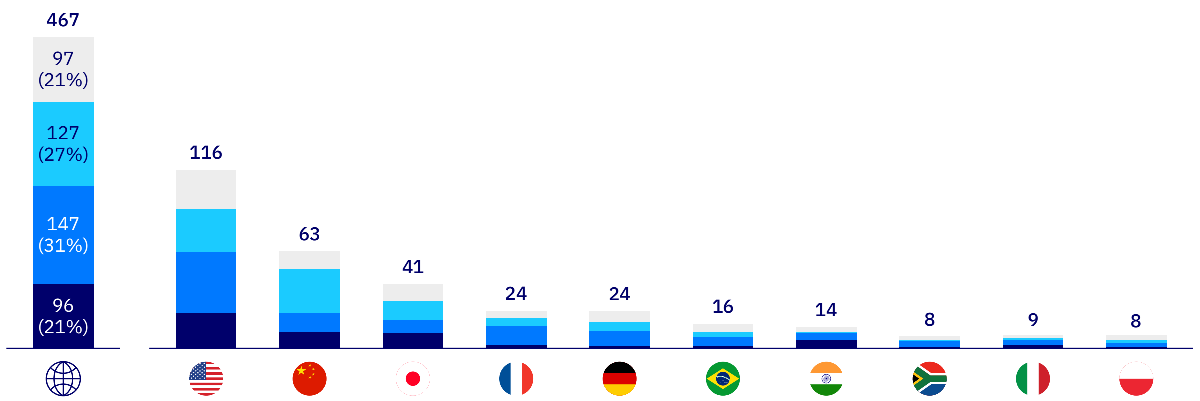
Global investment outlook[28]

Global investment in water networks, including both capital expenditure (CapEx) and operational expenditure (OpEx), is projected to grow by 2% to 3% a year until 2030. The United States, China, Japan, France, and Germany are expected to account for about 55% of the global market during that period. The top 10 countries will account for around 70% of total investment.

Most expenditure will focus on existing infrastructure, with OpEx projected to make up to 60% of the total market by 2030.

For wastewater networks, global investment is expected to grow by 3% to 4% a year to 2030. The United States, China, Japan, France, and Germany will again lead the market. They are expected to account for over 60% of global investment. The top 10 countries are projected to be responsible for 75% of total spending.

Figure 13. Water and wastewater network market size – Globally and top 10 countries
%, globally and top 10 countries in 2030



Source: GWI WaterData, Oliver Wyman analysis

In contrast to water networks, wastewater network investment will focus more on new infrastructure, with CapEx accounting for between 55% and 60% of the market by 2030.

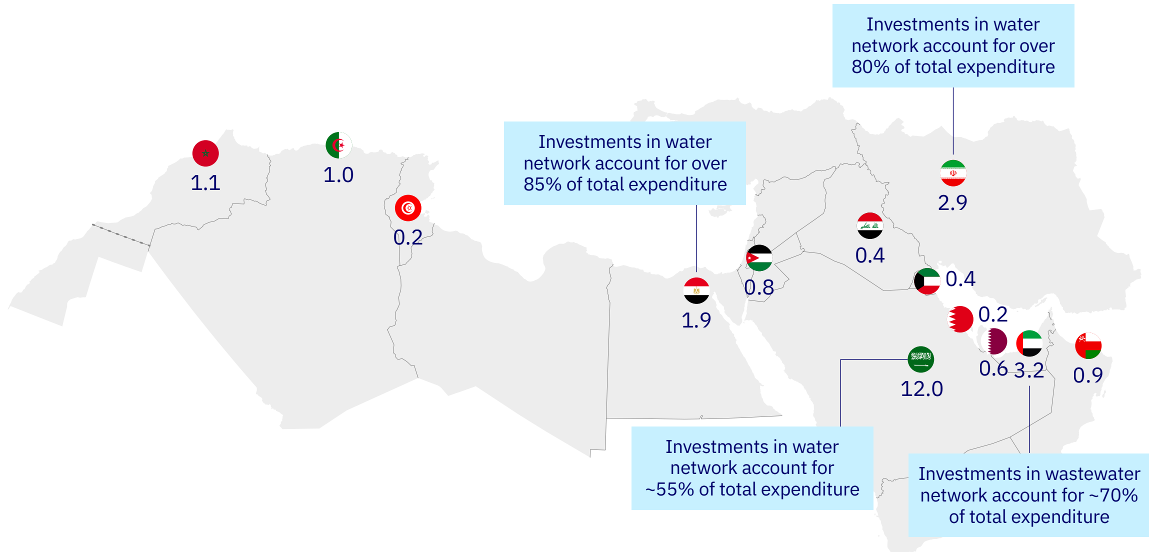
Investment trends in MENA* networks[28, 87]

Saudi Arabia, the United Arab Emirates, Iran, Egypt, and Morocco are likely to account for over 80% of the US$25.8 billion slated to be invested in water and wastewater networks in the MENA region by 2030.

Investment patterns vary across the region:

- In Saudi Arabia, about 65% of network investment is allocated to water networks, with CapEx representing around 80% of that total.
- In the United Arab Emirates, about 70% of network investment focuses on wastewater, with more than 90% of that spending allocated to CapEx.
- In Iran, more than 80% of network investment is directed toward water networks, with around 90% of that outlay going

Figure 14. MENA water and wastewater networks markets
2030, in US$ billion



Total market size 2030 MENA
US$25.8 billion

Source: GWI WaterData, SWA, Oliver Wyman analysis

*The data utilized in this analysis of the MENA region covers the following countries: Algeria, Bahrain, Egypt, Iran, Iraq, Jordan, Kuwait, Morocco, Oman, Qatar, Saudi Arabia, Tunisia, and United Arab Emirates to OpEx.

Physical infrastructure, particularly components such as pipes, valves, and pumps, will be the main focus of forthcoming network investment. The market for such components is expected to grow by 3% to 4% a year to 2030, reaching around 25% of total CapEx and OpEx.

Pipes alone will account for the largest share and comprise about 20% of the total networks market by 2030. This segment is projected to grow by 3.5% a year and will total close to US$97 billion by the end of the decade.

Within the pipe market, the split between plastic and metal components is expected to be fairly even. Each will represent

Table 3. Major suppliers in the pipe market and the types of products they provide

Company	Ductile Iron	Steel	Polyvinyl Chloride (PVC)	Polyethylene (PE)	Glass Reinforced
Xinxing Ductile Iron Pipes	★				
Saint-Gobain PAM	√				
Welspun Group	√	√			
Tenaris		√			
JM Eagle			★		
Advanced Drainage Systems				★	
Sekisui Chemical			√	√	★
Wienerberger			√	√	
Amiblu					√
Geberit		★			

★ Leader in the market segment √ Major player in the market segment

Source: GWI WaterData

more than 40% of the value of the total pipe market at around US$42 billion by 2030.

The table above shows some of the major suppliers in the pipe market and the types of products they provide.[29]

Challenges and opportunities

In many mature economies, existing water networks face increasing failures, leaks, and inefficiencies. Modernization is now essential, as simple repairs are no longer sufficient. At the same time, emerging markets must scale up network capacity to meet rapid urban growth and rising service expectations. This creates a dual challenge for utilities and national planners.

Advances in pipe materials deliver cost savings in network projects and improvements in water quality. Investment in networks is essential to achieve Sustainable Development Goal (SDG) 6 which aims to ensure the availability and sustainable management of water and sanitation for all.

Summary

Network expansion and replacement is a critical element of the global water industry’s evolution. Investment in water and wastewater networks to replace aging infrastructure and improve efficiency will help ensure sustainable, resilient water management and better public health.

3.0

DIGITAL AND AI

Recent innovation in digital and artificial intelligence (AI) is changing how utilities approach operations and decision-making. Smart sensors, IoT, data analytics, AI, and other technological advancements are enabling real-time decisions and predictive maintenance, resulting in operational efficiencies and cost reduction. However, the digitization of water services raises safety concerns that utilities must address by improving their cybersecurity.

3.1
Digital and AI

Digitizing Operations and Services

The rise of digital technologies is transforming water management operations across the world. Utilities are employing advanced digital technologies, such as the Internet of Things (IoT), artificial intelligence (AI), and data analytics, to create smarter, more efficient water management systems.[30]

Smart water management aims to bring data-driven intelligence to the traditionally analog physical layer of water infrastructure.[34] By integrating IoT devices and sensors throughout water networks, utilities can monitor and control a wide range of processes, including flow management, water quality monitoring, valve and pump control, and transient monitoring.[31]

In smart water management solutions, data collected by sensors is transmitted to centralized systems, where AI and machine learning algorithms analyze it to optimize performance and predict potential problems.[31] This also enabled utilities to greatly improve their engagement with customers. Utilities are using advanced digital technologies to enhance client service, encourage water conservation, and increase customer satisfaction. Digital technologies such as mobile applications, customer relationship management (CRM) systems, and a growing selection of AI-powered tools are enabling utilities to offer more personalized and proactive services.

Digital engagement benefits

Digitizing customer engagement offers a range of benefits for both utilities and their customers. They include:

- Platforms that improve the management of customer complaints and detection of customer violations[32]
- Behavioral analytics that generate personalized insights and recommendations to help customers reduce water use[33, 34]
- Water conservation programs that use gamification and social comparison to encourage sustainable consumption[35]
- Multi-channel platforms, including AI-powered chatbots, virtual assistants, and smart messaging services, which improve communications between utilities and their customers[34]
- Lower maintenance costs for utilities and less reliance on call centers[36]
- Personalized customer experiences that improve client satisfaction[36]
- New engagement channels, including video links and voice assistants, which enhance the customer experience delivered by utilities[36]
- Data-driven marketing systems that give utilities more accurate customer insights and support better decision-making[36]

Water Utilities are using digital technologies to boost customer engagement in a variety of ways. The widespread roll-out of smart meters enables real-time water usage data to both utilities and customers, which combined with the use of AI, allows for personalization of customer experience. Customers can easily monitor consumption, pay bills, and report service issues from a mobile application. CRM systems are tailored for water utilities' needs, efficiently managing data and customer interactions.

Case study: Yarra Valley Water, Australia[37]

Yarra Valley Water, which serves more than two million customers in Melbourne, is rising to the challenge of meeting the needs of a rapidly growing population while also contending with the effects of frequent droughts.

Yarra Valley Water conducted a pilot program with the aim to prove the potential of digital metering in unlocking large amounts of data and providing opportunities to optimize water resources management. It created personalized customer experience to help customers track water usage through Advizzo's software-as-a-service (SaaS) platform. Through the platform, digital tools would provide individual information to customers to encourage them to change their consumption behaviors.

- An average 6% reduction in water use between the summer of 2020 and the following summer, with savings of up to 11% among highly engaged customers.
- Sustained reductions in water consumption, with average annual savings exceeding 49 billion liters.
- 15% increase in online account sign-ups.
- Around 70% of engaged customers returned to online platforms.
- Half of the engaged customers shared additional data to support further insights.

The pilot program at Yarra Valley Water delivered cost savings for customers and resulted in a significant reduction in carbon emissions from the utilities' water operations.

Operational benefits

Smart water technologies provide a range of operational and financial benefits. They include:[31]

- Optimizing capital expenditure (CapEx)
- Reducing operational expenditure (OpEx) through improved efficiency
- Limiting water losses
- Real-time water usage monitoring and automated billing
- Enhancing service quality through real-time performance monitoring and control
- Improving customer service through personalized usage insights, faster issue resolution, and more responsive service delivery

Utilities are also using AI-powered analytics to improve predictive maintenance, anticipate equipment failures, reduce downtime, and extend asset life.[31]

Water management specialists have mainly adopted AI technologies related to machine learning models, AI computer vision, and GenAI-powered chatbots. They have pioneered the adoption of AI technologies in the water sector because of the cost benefits achieved by reducing non-revenue water.[38]

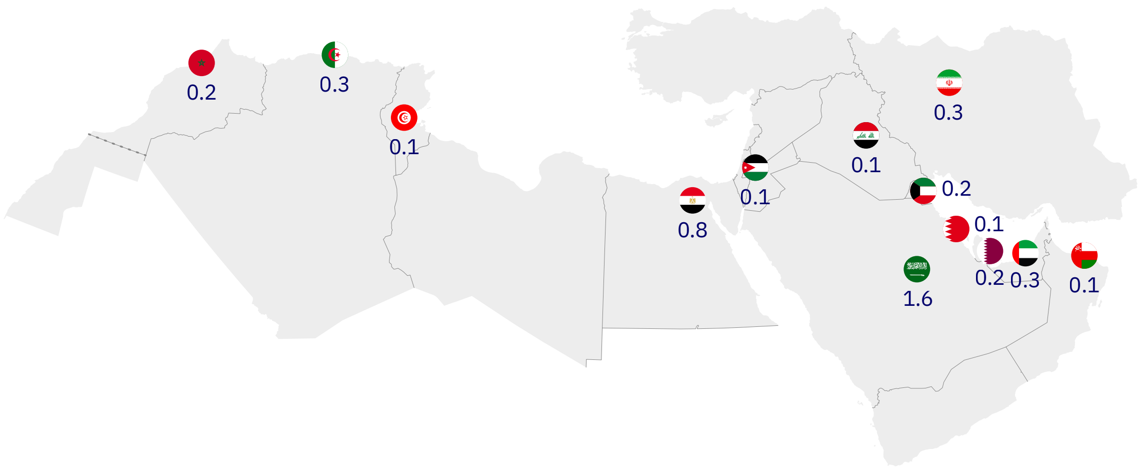
The increasing application of AI technologies in water management and operations is fueling a surge in investment in such solutions. In 2022 the year in which ChatGPT was launch, funding to AI-powered water solutions was about US$30 million. In 2023 and 2024, more than US$210 million investment in similar solutions was raised. A further US$30 million was invested AI-powered water solutions in just the first two months of 2025.[38]

Market outlook

Spending on smart water technologies through digitization is expected to grow significantly:[28]

- Global digital expenditure is forecast to reach US$72 billion by 2030, growing at about 7% a year. The United States, China, India, the United Kingdom, and Japan will account for around 55% of total expenditure between 2024 and 2030.
- In the MENA* region, Saudi Arabia, Egypt, and the United Arab Emirates are expected to be responsible for about 60% of digital expenditure with their spending topping US$4 billion by 2030.

Figure 15. MENA digital and smart solutions markets
2030, in US$ billion



Total market size 2030 MENA
US$4.3 billion

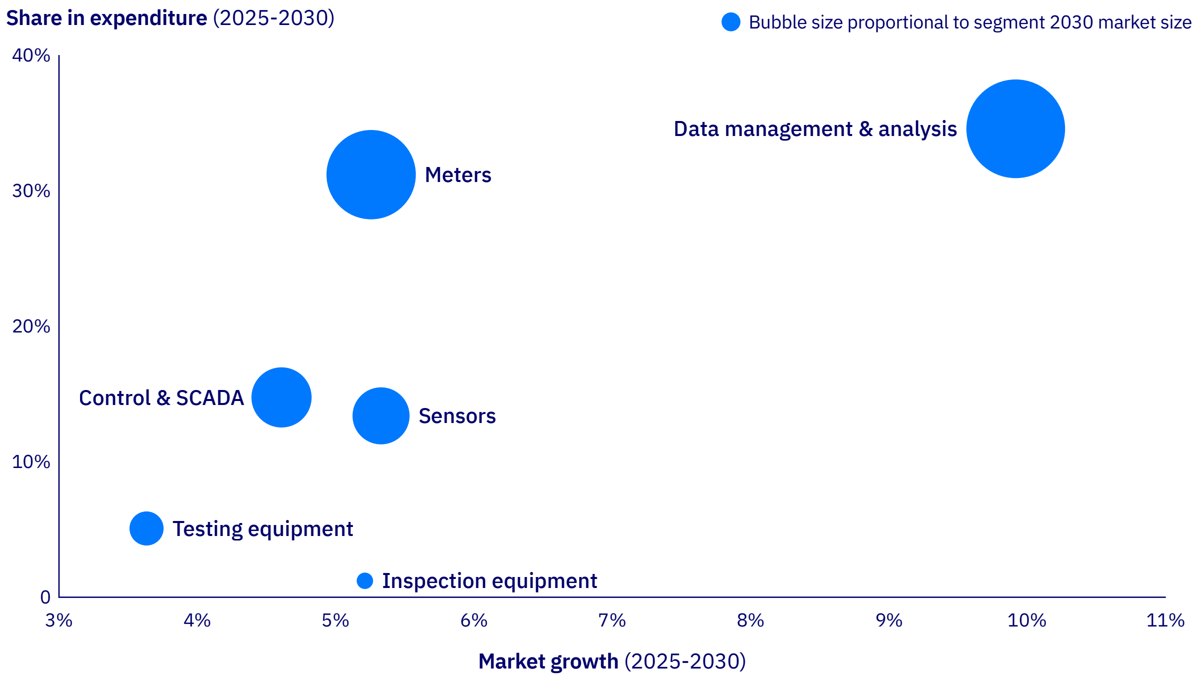
Source: GWI WaterData, Oliver Wyman analysis

* The data utilized in this analysis of the MENA region covers the following countries: Algeria, Bahrain, Egypt, Iran, Iraq, Jordan, Kuwait, Morocco, Oman, Qatar, Saudi Arabia, Tunisia, and United Arab Emirates

Market segmentation

Data management and analysis products are expected to dominate the market for digital and smart water technologies. They will account for 35% of total spending by 2030 and grow at 10% a year. The market for meters is forecast to be the next largest. It is expected to grow at 5% a year and account for more than 30% of the total digital and smart technologies market.[28]

Figure 16. Smart water and wastewater management products market assessment



Source: GWI DesalData, Oliver Wyman analysis

Key players

The market for digital water solutions is diverse, with many providers offering a wide range of technologies. Major providers and their product categories are shown in the following table.[13]

Table 4. Key providers of monitoring and control equipment

Company	Communications	Smart fluid control	Sensors	Automation & control	Data management & analytics
Itron	√	√	√		√
Sensus	√	√			√
Xylem	√	√	√	√	√
ABB		√	√	√	√
Grundfos				√	√
NIVUS		√		√	√
Ovarro		√		√	√
Schneider		√		√	√
Siemens		√	√	√	√
Badger Meter		√	√		√
Diehl			√		√
Endress + Hauser		√	√		√
Mueller		√	√	√	√
Emerson		√		√	√
Hitachi		√	√	√	√

Source: GWI WaterData

Challenges and opportunities

Many utilities remain hindered by legacy systems and low digital maturity. Siloed data and incompatible platforms continue to slow the adoption of smart solutions such as IoT, AI, and predictive analytics. Additionally, digital transformation risks excluding customer segments with limited access to digital services or connectivity.

However, the potential for utilities to reduce water losses and enhance operational efficiency has been demonstrated by utilities that have already adopted IoT, AI, and big data solutions. Digital technologies can deliver major gains through agile decision-making processes, especially those that address predictive maintenance. Digital tools that provide real-time feedback and advanced customer relationship management can improve customer satisfaction, drive conservation, and enhance revenue collection.

Summary

Digitization is changing the management of water resources throughout the world. By integrating digital technologies such as IoT, AI, and data analytics, utilities can optimize performance, improve efficiency, and enhance service quality. Ongoing investment will help utilities enhance operational resilience, sustainability, and customer service. Furthermore, customer experience is augmented through digital technology, playing an important role in reducing consumption and expenditure while improving service delivery.

3.2
Digital and AI

Enhancing Cybersecurity

With water utilities expanding their use of digital technologies in all aspects of their business, cybersecurity is looming as a major threat. The convergence of information technology (IT) and operational technology (OT) has exposed water infrastructure to a host of new and evolving cyber threats.[39]

Cyberattacks targeting water utilities are increasing. Threats extend beyond internal actors to include rival governments, organized crime groups, and independent hackers.[40]

Cyber risks pose serious threats to water service continuity, public health, and financial stability. Attacks can disrupt water supply, compromise water quality, and expose sensitive customer data. Ensuring the integrity, availability, and confidentiality of water systems data is essential for maintaining public trust and operational resilience.[40]

The urgency of this challenge is widely recognized. Water industry representatives in the United States this year ranked cybersecurity as one of their most pressing issues.[41]

Evolving threats

Water utilities are now regular targets of cyberattacks. Common incidents include:[41]

- Disrupting operations through malicious valve closures or alarm overrides.
- Theft of customer data, including payment information.
- Ransomware attacks targeting operational systems.

The global cost of cybercrime is projected to climb to US$10.5 trillion this year, up from US$3 trillion a decade ago.[42]

Governments and regulators are placing greater emphasis on cybersecurity as part of broader critical infrastructure protection initiatives.

Actions and investment trends

To address these risks, water utilities are taking action in several areas:[40, 42]

- Developing comprehensive cybersecurity strategies, including risk assessments, security frameworks, and incident response plans.
- Upgrading legacy systems and installing advanced cybersecurity technologies, such as intrusion detection systems (IDS), encryption, and access controls.

Cyber-attacks can be very expensive, with each data breach costing water utilities an average of US$4.9 million.[43] To better protect themselves, close to 80% of United States utilities plan to up their investment in cybersecurity over the next five years.[44]

However, many utilities lack the in-house resources to manage cybersecurity independently. Only 20% of water utilities in the United States expect to fully manage cybersecurity themselves.[42]

Human error is the main weakness that undermines an organization's data security. In the UK, an estimated 90% of data breaches are caused by human error.[45] To mitigate this risk, utilities are increasing their investment in staff training. The United States water sector ranks such training as the single most important activity that improves cybersecurity.[42]

Strengthening water sector cybersecurity

Best practices include:[40, 42]

- Identifying critical water infrastructure and OT response capabilities.
- Conducting comprehensive risk assessments.
- Establishing cybersecurity standards and controls.
- Implementing continuous monitoring and rapid detection capabilities.
- Engaging external cybersecurity experts for strategy, governance, and implementation support.
- Investing in staff training and certification programs.

Case study: Oldsmar Water Treatment Facility[46, 47]

In 2021, a hacker successfully connected to an engineer workstation at the Oldsmar water treatment plant, which provides water for approximately 15,000 people in Tampa Bay, Florida.

Although an alert employee was aware that someone had connected to the computer through TeamViewer, he was not initially alarmed because it was typical for managers and other engineers to connect remotely to check the water plant's operational condition.

However, the attacker started making changes to critical functions and controlling the amount of sodium hydroxide present in the water treatment process, from 100 parts per million to 11,100 parts per million.

Sodium hydroxide is a chemical used to remove metals from the water in the treatment process. With the high concentration instigated by the hacker, water would be unsafe for human consumption, potentially resulting in severe burns to the skin, nausea, damage to the mouth, throat, and digestive system. The changes made to the system would have taken from 24 to 36 hours to take effect. The rapid intervention of the employee at the plant ensured that no one was placed in danger by the hacker's actions.

Cybersecurity market[41]

A wide range of solution providers offer cybersecurity products and services to water utilities. Prominent cybersecurity firms include Nozomi Networks, Dragos, Darktrace, Fortinet, and IronTech Security.

Some participants in the water industry also offer cybersecurity services. They include Xylem, Badger Meter, Emerson, and Siemens.

Challenges and opportunities

The growing use of digital and remotely controlled systems increases vulnerability to cyberattacks. Recent high-profile intrusions underscore the need for robust, continuously updated cybersecurity. Both legacy installations and new systems must be protected to ensure public health, service continuity, and data security.

Water utilities need to ensure their cybersecurity can safeguard their business continuity and protect their water supplies.

Summary

Cybersecurity is essential for the protection of critical water resources and infrastructure. As utilities deploy more digital technologies, including IoT, AI, and advanced analytics, their exposure to cyber threats will inevitably increase. To safeguard service continuity, public health, and operational resilience, water utilities will need to invest in modern cybersecurity capabilities, strengthen workforce training, and embed cybersecurity into their broader digital transformation strategies.

4.0

CIRCULARITY AND SUSTAINABILITY

Sustainability and circularity practices have become especially important in the water industry. Utilities have set targets for the reduction of carbon emissions and water facilities are increasingly being designed to accommodate energy generated by renewable sources. Furthermore, circularity concepts such as zero-liquid discharge are now receiving greater attention from decision-makers who recognize the environmental and economic gains that can be achieved by recovering the full value of the sector's waste.

4.1

Circularity and Sustainability

Adopting Renewable Energy

Utilities and plant developers are increasingly shifting to renewable energy to power their water management solutions. It reduces operating costs, curbs carbon emissions, and improves energy security. Energy-intensive processes such as desalination and wastewater treatment offer some of the biggest opportunities for the integration of renewable energy sources into water management. Energy is one of the main costs in these processes and can reach more than 30% of total plant expenditure.[48] At the Rabigh 3 Independent Water Project (IWP) and Shuqaiq 3 IWP, for example, energy costs are close to 30%.

Integrating renewable energy into processes, such as desalination and wastewater treatment, can help utilities reduce reliance on fossil fuels, improve cost efficiency, ensure water and energy access in remote areas, and cut greenhouse gas emissions by up to 80%.[49, 50]

Although renewable energy is most often integrated with the electricity grid, it can also be used to support services in isolated areas. Dedicated systems, for example, can be set up to supply quality water to off-grid populations.

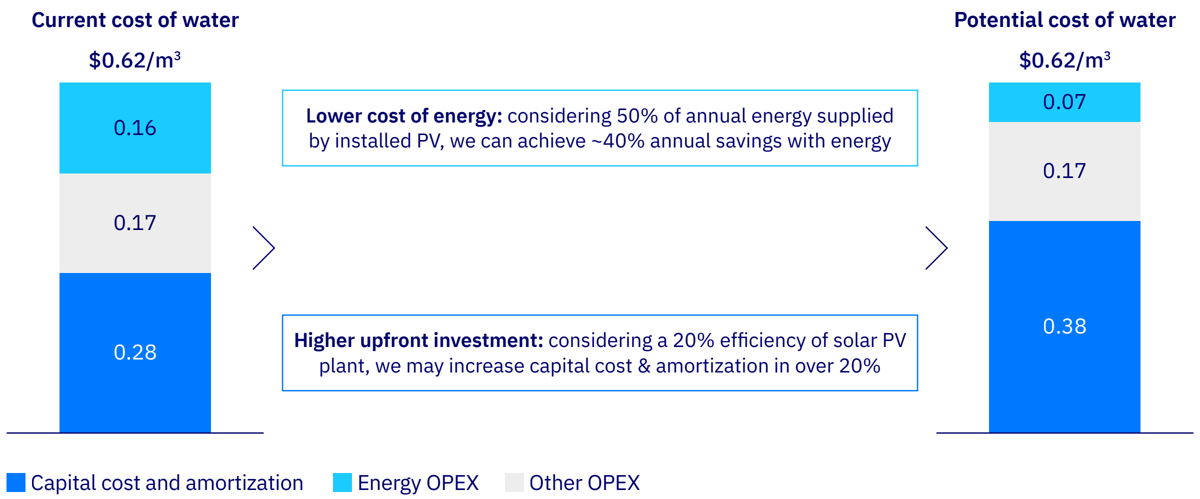
Challenges to integration

To successfully integrate renewable energy into their water infrastructure, utilities must overcome several barriers:

- The intermittent nature of most renewable energy sources requires hybrid systems that maintain a connection to local electricity grids.[49, 51]
- Significant upfront capital investment is needed to install renewable energy infrastructure.[52]
- Current technologies, particularly solar photovoltaic (PV) solutions, have low nominal efficiency and high investment costs which limit their suitability for desalination projects. Even when renewables supply up to half of energy needs, the unit cost of desalination may remain unchanged after accounting for capital outlays.[52]

Solar PV and wind power are currently the most common renewable energy sources integrated into desalination plants.[12] In wastewater treatment, biogas generation from anaerobic digestion of sludge is widely used, with PV and wind also increasingly contributing to plant energy supplies.

Figure 17. Water desalination with integrated renewable energy — potential for cost reduction
In US$/m³



Source: GWI DesalData, Janowitz et al., 2025, Oliver Wyman analysis

Case study: Pau-Lescar Biofactory, France[53]

The Pau Béarn Pyrénées metropolitan area aims to become carbon neutral by 2040 and is looking to renewable energy to help it achieve that goal.

Its Lescar wastewater treatment plant has been transformed into an energy-positive “biofactory,” developing 10 renewable energy and resource streams. The project features two major technology innovations:

Catalytic methanation

This process converts carbon dioxide emissions into synthetic methane, a renewable green gas. The plant converts all of its carbon dioxide emissions into synthetic methane.

Ultra-dewatering by hydrothermal carbonization

This process reduces treatment sludge by 75% and consumes less than 30% of the energy required for conventional thermal drying. It also increases biomethane production and creates a new resource, Biocoal, which can be used to enrich soil or as a fuel.

The Lescar facility now produces more energy than it consumes and maintains an exceptionally low carbon footprint. It produces 13,000 megawatt-hours (MWh) of biomethane and synthetic methane a year. The facility’s innovative wastewater processing technologies have avoided the production of an estimated 5,000 tons of carbon dioxide emissions a year.

Emerging opportunities

Utilities and policy-makers are evaluating new options for sourcing renewable energy to power water processes. Nuclear energy is already being used to power desalination, in countries such as Japan, India, and Kazakhstan. Other countries, including Egypt, are also planning to integrate desalination facilities into their nuclear energy projects. Recently, there have been several assessments of the potential for small modular reactors (SMRs) as a potential source of reliable, low-carbon power for desalination. Pilots and even mid-size desalination plants have been developed in countries such as South Korea, China, and Russia.[54]

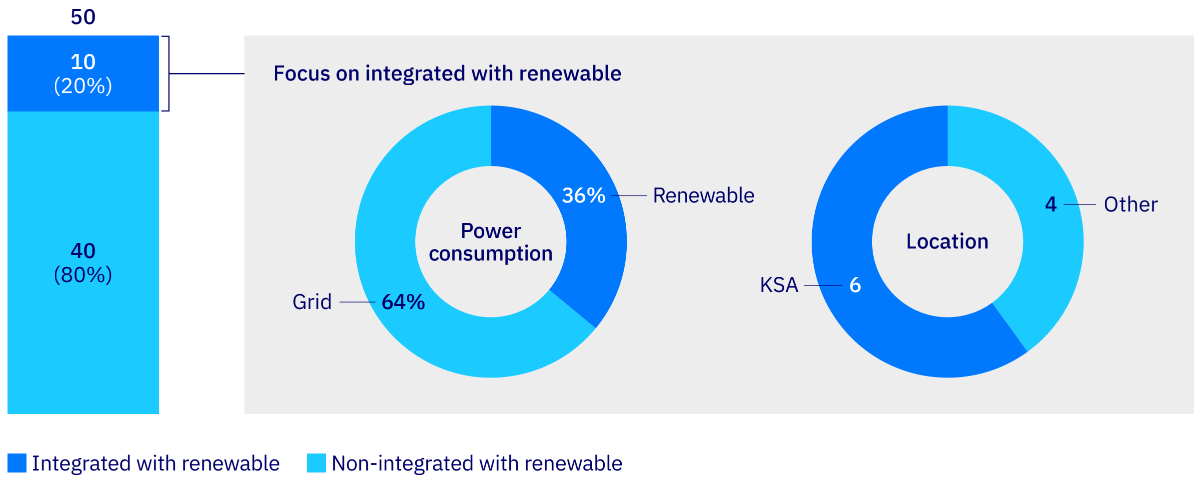
Another recent development is subsea desalination, where the natural pressure of the seawater is used as a free source of energy. The plant is installed at about 500 m below the sea surface, requiring 95% less land footprint. By eliminating high-pressure pumps, this solution requires 40% less energy. It also does not discharge toxic brine as a desalination byproduct. This results in a more environmentally-friendly desalination process.[55]

Current adoption levels

Despite growing interest, adoption of renewable energy in desalination remains modest:[10]

- Among the 50 largest desalination projects awarded in the past five years, only 10 have incorporated renewable energy as part of their power mix. In these projects, less than 36% of total power consumption is supplied by renewables.
- As much as 60% of these renewable-powered desalination projects are concentrated in Saudi Arabia, highlighting significant regional disparities in adoption.

Figure 18. Top 50 largest desalination projects by capacity awarded since 2018



Source: GWI DesalData, Oliver Wyman analysis

Outlook to 2030

Utilities are likely to increase their use of renewable energy in water management solutions as technologies mature and costs fall. The Global Clean Water Desalination Alliance, a global climate initiative launched at the UN Climate Change Conference during COP21, mandated that 40% the energy supplied to new desalination plants should be clean energy by 2030. For desalination plants to be commissioned between 2030 and 2035, the target is raised up to 60%.[56]

Challenges and opportunities

Capital requirements for renewable energy generation using technologies such as solar PV remain high. While desalination plants continue to have easy access to electrical supply grids, investments in facilities connected to renewable power are unlikely to yield significant savings.

Integrating renewable energy sources such as solar and wind into desalination and water operations can significantly reduce carbon emissions and lower long-term operating costs. It may also enable water supply solutions to be extended to communities in isolated areas.

Summary

Renewable energy sources offer utilities in the water industry an opportunity to advance their commitment to sustainability. Desalination and wastewater treatment are particularly well suited to using renewable power sources because of their high energy costs. Although several barriers currently hinder the switch to renewable energy sources, the pace of integration is expected to increase as technologies improve and costs fall. Renewable energy sources will play a key role in the global transition to more resilient and sustainable water management systems.

4.2

Circularity and Sustainability

Mining Desalination Brine

The mining of desalination brine is opening new opportunities for utilities and plant operators to turn an environmental challenge into an economic asset. By extracting valuable minerals from desalination byproducts, utilities can reduce the impact of brine discharge while creating new revenue streams.

As desalination increases around the world, particularly in arid regions, the volume of brine that utilities produce continues to grow. Traditional brine disposal can harm marine ecosystems by raising salinity levels, depleting dissolved oxygen, and introducing toxic chemicals. Brine can also contribute to saline intrusion in coastal aquifers.

Brine mining offers a sustainable alternative that recovers minerals for commercial applications. It also improves the desalination efficiency of utilities by increasing the recovery rate of freshwater.

Brine management solutions

Utilities are adopting a variety of brine management strategies that range from conventional disposal to advanced recovery and reuse.[11, 57]

Beneficial reuse

Brine is used in tolerant agricultural applications or industrial processes. This approach requires low energy and has moderate costs.

Membrane treatment

High-recovery membrane technologies reduce brine concentration and allow moderate water recovery. Energy use and process costs are moderate to high.

Membrane distillation

Hydrophobic membranes allow water vapor to pass through for recovery. This method achieves moderate water recovery but is energy-intensive and costly.

Evaporators and crystallizers

Thermal processes concentrate brine into solid or nearly solid products, achieving high water recovery. These solutions are energy-intensive and high-cost but dominate advanced brine management markets.

Minerals with commercial potential

Advanced brine mining enables the recovery of a range of valuable minerals. The type of minerals depends on the feedwater properties in the desalination location. Some of the most common minerals found in large water bodies, including the Red Sea and Arabian Gulf, are shown in the following table.[58, 59, 60, 61]

Figure 19. Potential brine mineral content

Mineral from Brine	Sodium (Na)[1]	Magnesium (Mg)	Calcium (Ca)[1]	Potassium (K)[1]	Bromine (Br)	Lithium (Li)
Application (examples)	Food Paper industry Road de-icing	Steel Construction materials Fertilizers	Construction materials Fertilizers	Fertilizers	Fire retardant Clear brine drilling fluids Agriculture	Batteries Lubricants Pharma products
Mining method	Solar evaporation Electrodialysis Evaporator / crystallizer	Ion exchange Membrane crystallizer	Evaporation / precipitation	Adsorption Flotation Dissolution-recrystallization Heavy Media Separation Solar Evaporation	Electrodialysis	Adsorption Membrane Precipitation Ion exchange
Market opportunities	Increasing use of sodium hydroxide by textile industry, driving demand Diverse applications of sodium hydroxide across other industries such as food and petroleum China presenting the largest market share, with ~30%, followed by US with ~19%	Global magnesium demand for clean energy technologies stood at over 4 thousand tons as of 2024 It is expected to reach almost 6 thousand tons by 2030 based on the current stated policies, growing at ~6% per year until 2030 Total demand globally for magnesium, including compounds, stood at 1 million tons in 2023; it is expected to reach 1.7 million tons by 2032, a ~6% per year growth	Increasing demand from construction industry due to higher binding and strengthening qualities Increase use in agriculture as fertilizer and soil enhancer US holds ~10% of global market, led by construction Growing Asia Pacific market, with India at ~6% p.a. and China at ~4% p.a.	Global market growth is primarily driven by agricultural fertilizers, which account for around 95% of total consumption Global potassium consumption is forecasted to reach over 83 million metric tons by 2030, growing at ~3.5% per year until 2030 Asia and South America remain the leading regions for the consumption of potassium and its compounds	In demand by construction and electronic industries as flame retardant Environmentally friendly material and compliant with stricter regulations Increasing demand also from oil & gas for drilling fluids US to be the largest market in 2033 (~28%), with largest growth in India (2.4% CAGR)	Global lithium consumption is forecasted to reach over 2.3 million metric tons LCE[2] by 2030, growing at ~14% per year until 2030 Growth is spearheaded by the EV sector However, lithium prices globally are decreasing, though demand is increasing Asia Pacific region to drive demand, with China as the largest producer of Li-ion batteries, and large demand also from Japan and South Korea

1. Including compounds; 2. Lithium Carbonate Equivalent

Source: USGS, S&P Global Market Intelligence, IEA, Lenntech, Latrobe Magnesium, Oliver Wyman analysis

With applications across multiple sectors, there is a huge opportunity for the commercialization of recovered minerals from desalination brine. Fueled by rising demand for batteries, the market for lithium is expected to grow at more than 14% a year, with a potential market size of more than 2.3 million metric tons by 2030. At a current price of approximately US$10 per kilogram,[62] this would correspond to a global market of over US$13 billion. Similarly, demand for potassium, which is in high demand for agriculture, is expected to grow at almost 4% a year, reaching a market size of over 83 million metric tons by 2030. With current potassium prices of around US$340 a metric ton, this would value the market at US$28 billion.[63]

Case study: Brine mining pilot at Haql RO plant[58]

The Water Technology Innovation and Research Development Institute (WTIIRA), an affiliate of the Saudi Water Authority (SWA), is developing a large-scale demonstration of brine mining at the Haql reverse osmosis (RO) plant on the Red Sea coast. The Haql RO plant, commissioned in 2020, has a desalination capacity of 17,000 cubic meters per day.

The demonstration will showcase two membrane-based brine concentration processes designed to enable low-energy production of sodium chloride. The project supports ongoing research at WTIIRA in advanced membrane technologies for nanofiltration and brine concentration, optimized membrane configurations, and enhanced techniques for brine polishing. These innovations will be demonstrated at the Haql brine valorization facility.

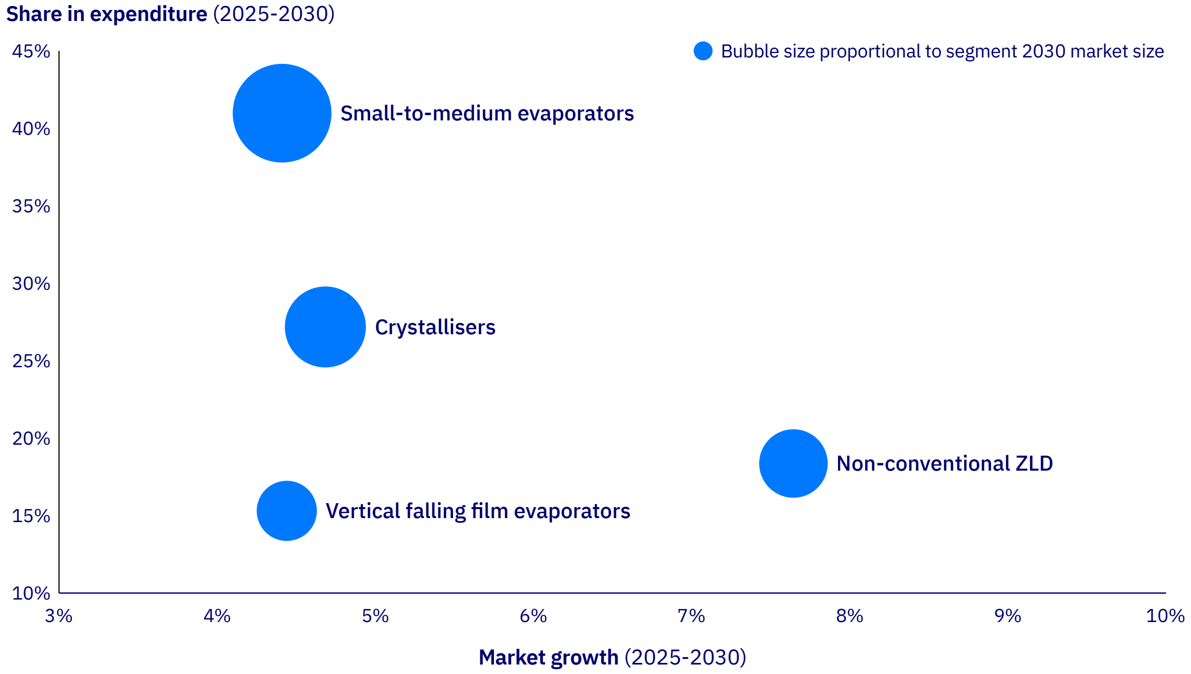
Following membrane filtration, a clarifier will extract magnesium hydroxide and calcium carbonate from the brine. Subsequent treatment through a crystallizer will recover sodium chloride, while a dedicated unit will enable bromine recovery. Through precipitation and dehydration of the RO reject, magnesium oxide will also be produced, with a portion further processed into magnesium.

Once operational, the pilot facility is expected to produce more than 2,000 tons of sodium chloride and 2 tons of bromine a year. In addition, approximately 500 tons of magnesium oxide and 20 tons of calcium carbonate will be recovered annually through the brine mining process.

Brine mining market

Evaporators and crystallizers are the top selling brine mining technologies. They are expected to maintain their market share for the rest of the decade with strong year-on-year sales.[28]

Figure 20. Brine concentration systems market assessment



Source: GWI WaterData, Oliver Wyman analysis

Table 5. Major players in the market for selected solutions

Company	Evaporators	Crystallizers	Other technology
Aquatech	√	√	VTFF brine concentrators
Veolia	√	√	VTFF brine concentrators
Alfa Laval	√	√	VTFF brine concentrators Humidification-dehumidification
Saltworks Tech.		√	Humidification-dehumidification
KMU LOFT Cleanwater	√	√	

Source: GWI WaterData

Challenges and opportunities

As desalination capacity grows, so does the challenge of managing brine byproducts. Brine mining and resource recovery hold promise, though costs remain high, and enabling technologies and regulatory frameworks are still being developed.

Extracting minerals and elements from desalination brine offers both environmental and commercial benefits. Increasing global demand for key minerals is driving the business case for brine mining in locations rich in such elements. Realizing this opportunity will require targeted investment and regulatory alignment.

Summary

Brine mining enhances the circularity and sustainability of desalination operations while creating new revenue opportunities. It is set to play an increasingly important role in the water industry's transition to more sustainable practices.

4.3

Circularity and Sustainability

Valorizing Wastewater

Wastewater treatment plays a critical role in protecting public health and ecosystems. Effective treatment prevents the release of harmful substances such as pathogens, heavy metals, and nutrients into water bodies, helping to reduce eutrophication, waterborne diseases, and ecosystem degradation.[64] It also reduces public exposure to contaminants and toxic substances.[65]

Water utilities and public authorities are increasingly recognizing that wastewater can be a valuable resource. Sludge, a by-product of wastewater treatment process, comprises a variety of organic and inorganic materials. It has long been viewed as a waste product that is expensive to dispose of and potentially damaging to the environment. However, advances in treatment technologies are enabling utilities to recover energy, nutrients, and materials from sludge.

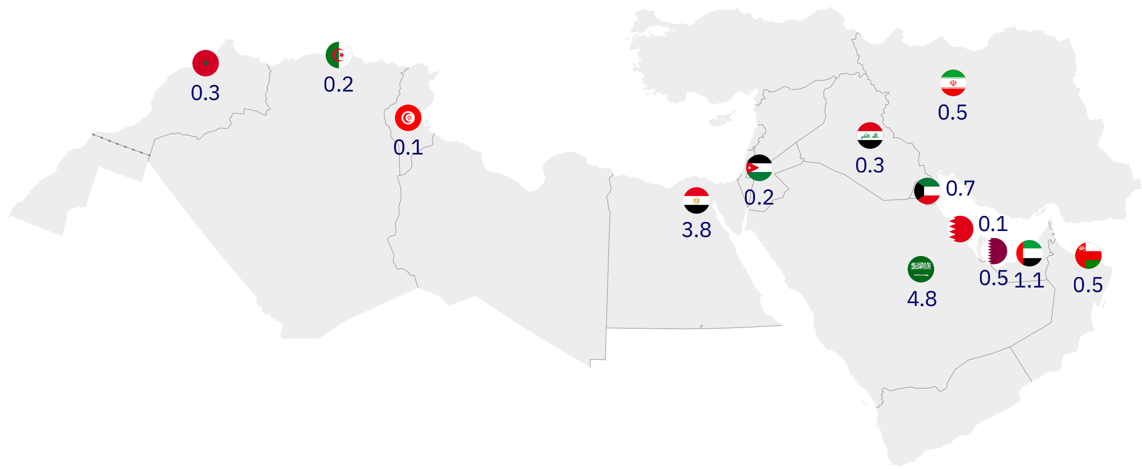
Globally, achieving the Sustainable Development Goal for wastewater treatment (SDG 6.3) by 2030 will require an additional 160 billion cubic meters of treatment capacity a year.[66, 67] The need is highly concentrated: China, the United States, and India together account for about 45% of the global requirement, while the top 10 countries represent around 70% of the required expansion.

In response, global investment in wastewater treatment is growing rapidly. Capital and operational expenditures are projected to grow at 3% to 4% a year through to 2030. By then, the United States, China, Japan, Germany, and the United Kingdom are expected to account for about 60% of global market value.[11]

Global capital expenditure is forecast to grow at over 4% a year, reaching around US$114 billion by 2030. The top five countries, China, the United States, the United Kingdom, Japan, and Germany, will account for 65% of this market. Operational expenditure is expected to grow at roughly 3% a year, reaching US$186 billion by 2030, with the top five countries responsible for around 60% of this total.[11]

Saudi Arabia, Egypt, and the United Arab Emirates are expected to account for approximately 75% of the market in the MENA* region, which is projected to reach US$13.1 billion by 2030. Investment profiles vary. More than 60% of investment in Saudi Arabia will be directed towards capital expenditure, with that number increasing to over 90% in the case of Egypt. In the UAE, over 60% of investment will be focused on operational expenditure.[28, 87]

Figure 21. MENA wastewater treatment markets
2030, in US$ billion



Total market size 2030 MENA
US$13.1 billion

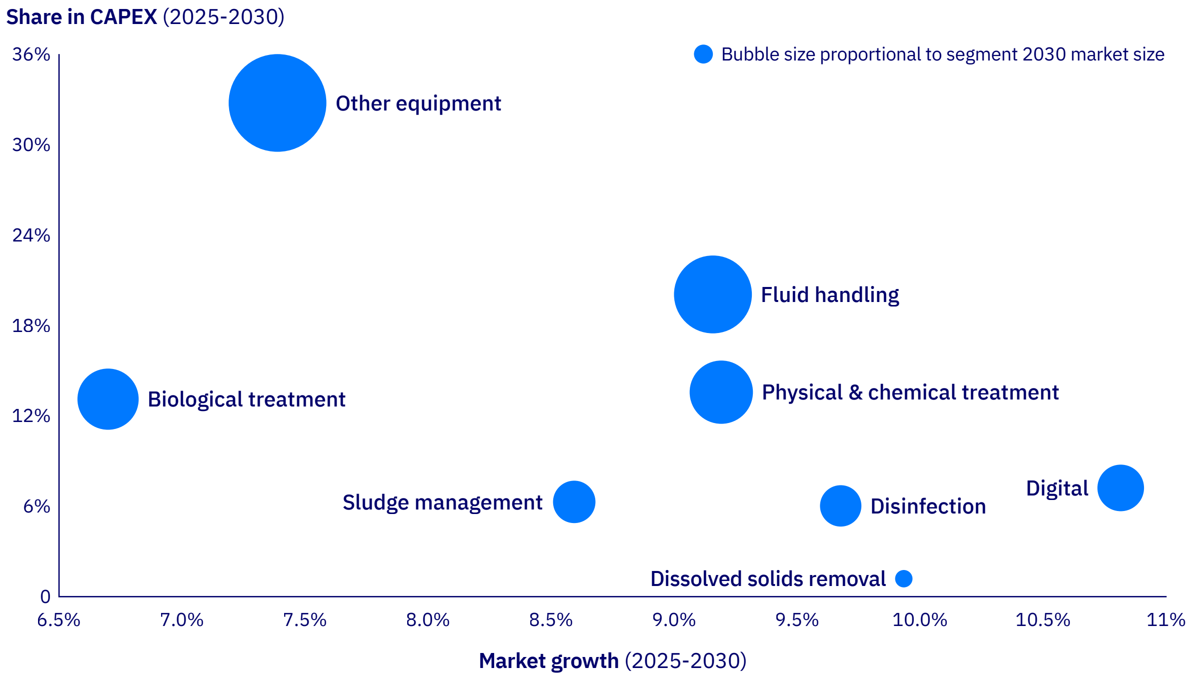
Source: GWI WaterData, SWA, Oliver Wyman analysis

At the component level, the largest share of wastewater treatment investment will remain in primary hydraulic equipment, such as pipes, valves, and pumps. This market segment is projected to grow at 4% a year and represent 20% of combined capital and operational expenditure by 2030.[28]

Sales of digital solutions, although currently representing less than 10% of total wastewater treatment investment, are expected to grow at more than 4.5% a year. Digital solutions will be the sector's fastest-growing segment.[28]

*The data utilized in this analysis of the MENA region covers the following countries: Algeria, Bahrain, Egypt, Iran, Iraq, Jordan, Kuwait, Morocco, Oman, Qatar, Saudi Arabia, Tunisia, and United Arab Emirates

Figure 22. Wastewater treatment technology market assessment



Source: GWI DesalData, Oliver Wyman analysis

Wastewater treatment has become an essential enabler of water reuse. Reusing treated water reduces demand for freshwater resources and helps alleviate water scarcity. Such scarcity has been exacerbated by climate change and rising demand from industrial and agricultural users.[11]

Water reuse also offers financial and operational benefits. It can lower costs for municipalities and industries, being more energy-efficient than alternatives (such as desalination), and delaying or eliminating the need for large new water infrastructure.[11,68] Regulatory measures are also driving adoption, combining requirements for direct reuse with restrictions on groundwater abstraction and wastewater discharges.[11]

Treated wastewater can be reused for both potable and non-potable purposes:[68]

Potable reuse

- Direct potable reuse: High-quality reclaimed water is injected directly into potable water distribution systems.
- Indirect potable reuse: Reclaimed water is released into natural sources such as rivers and aquifers for later abstraction and treatment.

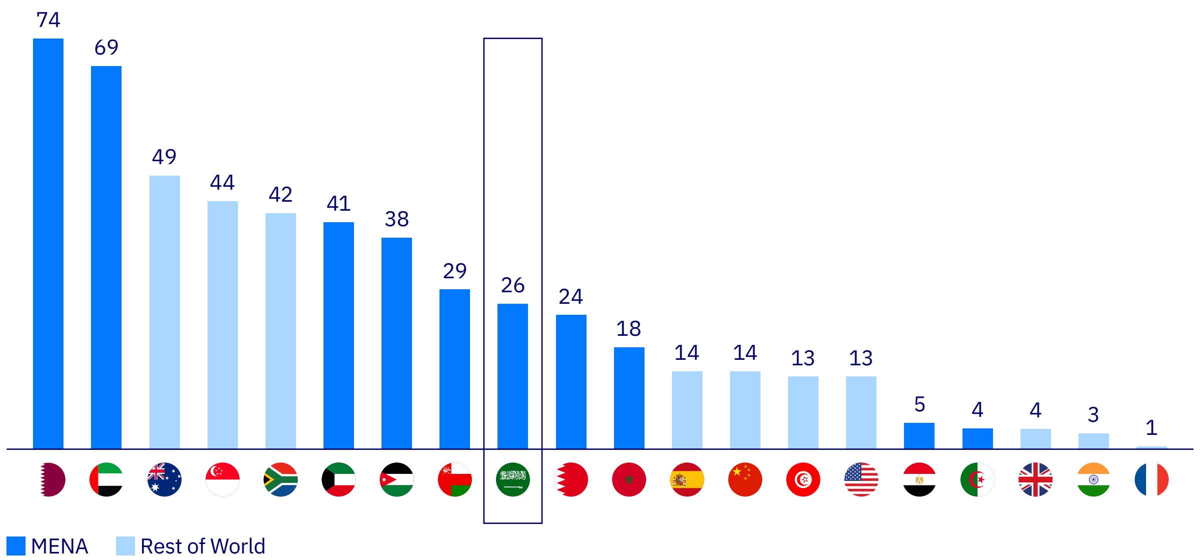
Non-potable reuse

- Agricultural reuse: Irrigation of crops, livestock supply, and aquaculture.
- Industrial reuse: Water for industrial processes including cooling, boiler feed, and washing.
- Environmental flows: Reclaimed water used to enhance flows in streams, rivers, lakes, and wetlands.
- Urban landscaping and other applications: Irrigation of parks, golf courses, and recreational areas.

While significant progress has been made, there is still considerable room for growth in global water reuse capacity.[67, 68, 69, 70] MENA countries are among the global leaders, driven by extreme water scarcity. Several countries have set ambitious national targets:

- Dubai aims for 100% reuse by 2030.[71]
- Saudi Arabia is targeting 70% to 100% reuse by 2030.[72]
- Morocco aims to increase its reuse capacity tenfold by 2050.[73]

Figure 23. Reused treated wastewater
%, in selected countries

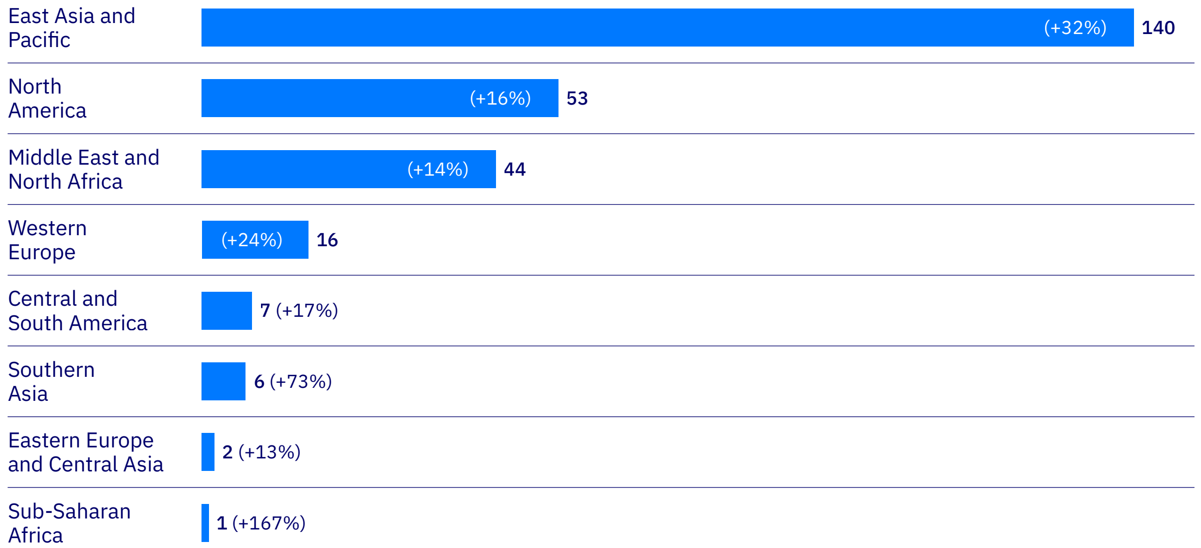


Source: Mateo-Sagasta et al., 2022, Jones et al., 2021, UN Environment Programme, Veolia, MEWA, Oliver Wyman analysis

Water reuse growth and investment trends[11]

Globally, water reuse capacity is projected to reach approximately 300 million cubic meters a day by 2028, an increase of 25% over 2023 levels. The Asia Pacific region will account for nearly 50% of this capacity, with China responsible for 40% of global reuse capacity. MENA will contribute more than 15%, led by Egypt, home to some of the world's largest reuse wastewater treatment plants.

Figure 24. Global treated water reuse capacity
2028, in Mn m^3/day



Note: Increase from 2023 capacity provided between brackets
Source: GWI Market Focus Deck: Desalination and Reuse, Oliver Wyman analysis

Water reuse serves many applications. Industrial reuse accounts for about 30% of current capacity, while agricultural reuse represents more than 25%. The fastest-growing segment is potable reuse, where capacity is expected to increase by 50% between 2023 and 2028.

New treatment technologies

Recent advances in treatment technologies are accelerating the adoption of water reuse. Reverse osmosis membranes now remove dissolved salts, micro-pollutants, pathogens, and viruses with improved durability and reduced energy use. Ultrafiltration and nanofiltration membranes provide high-efficiency pretreatment, while new materials such as graphene oxide and ceramics offer enhanced performance.[74, 75]

Advanced oxidation processes, such as ozonation, effectively remove trace organic contaminants, supporting potable reuse.[76] Membrane bioreactors, which combine biological treatment with membrane filtration, deliver high-quality effluent suitable for reuse, with improved energy efficiency and automation.[77]

Energy recovery

Energy can be produced from sludge, mostly through anaerobic digestion. Anaerobic digestion is a well-established method for converting organic matter in sludge into biogas, primarily composed of methane and carbon dioxide. Such biogas can be used to generate electricity, provide heating, or serve as a transport fuel.[68, 78]

Aside from anaerobic digestion, dried sludge can be used as a fuel, for example, in cement kilns. In such applications, dried sludge has an energy potential of 25 megajoules per kilogram (MJ/kg). This is an energy content similar to that of commercial charcoal briquettes.[68]

Nutrient recovery

Wastewater sludge is also rich in nitrogen, phosphorus, and potassium. Once recovered, these minerals can be used in agricultural fertilizers:[68, 79, 79]

Nitrogen

Municipal wastewater around the world contains about 16 million tons of nitrogen. Recovery rates from thermal hydrolysis range from 10% to 80%, which would yield two to 13 million tons of nitrogen a year.

Phosphorus

Around three million tons of phosphorus are present in the world's wastewater. Recovery technologies such as thermal hydrolysis and struvite precipitation can achieve recovery rates of 33% to 96%, enabling extraction of one to three million tons of phosphorus a year.

Potassium

About 6 million tons of potassium are in wastewater globally. With recovery rates similar to phosphorus, an estimated two to six million tons could be recovered each year.

Nutrient extraction from wastewater could in theory meet about 13% of global fertilizer demand. At current market rates this volume of fertilizer would cost around US$40 million.

Material recovery

In addition to energy and nutrients, sludge can yield other valuable materials. They include cellulose, bioplastics, volatile fatty acids, metals and extracellular polymeric substances. These materials are already being recovered and reused in various industrial applications around the world.[80, 81, 82, 83, 84]

Figure 25. Materials and other resources potentially recovered from wastewater

Material	Cellulose	Bioplastics	Metals	Volatile Fatty Acids	Extracellular Polymeric Substances
Application (examples)	Raw material for paper production Soil conditioner Material for asphalt and bio-composites Fuel for biomass combustion plants Feedstock for fermentation	Food packaging Hygiene products packaging Industrial packaging Composting bags	Fertilizers and pesticides (e.g., Boron) Batteries (e.g., cobalt) Pharmaceuticals (e.g., platinum) Electronics (e.g., rhodium) Jewellery (e.g., gold and silver)	Polymers production Solvents production Pesticides production Rubber production Paint production Biodiesel production	Printing paste production Fireproofing and waterproofing fabrics production Seed and concrete coating production Medical products Jewellery

Source: UN Environment Programme, Atasoy, M., 2020, Veluswamy et al., 2021, Staszak, K. and Wieszczycka, K., 2023, Adeeyo et al., 2023, Oliver Wyman analysis

For example, the global market for volatile fatty acids (VFA) has been growing over the recent years (demand for butyric acid, for instance, has grown at more than 8% a year). Because VFAs are produced from anaerobic digestion, wastewater treatment plants would need to stop biogas production to obtain such acids. However, there is an economic potential, because the cost to obtain propionic acid from wastewater treatment is 35% lower than the commercial selling value.[81, 82]

Case study: Green Riyadh project, Kingdom of Saudi Arabia[85, 86]

Green Riyadh is an ambitious urban forestation project, and is a milestone contributing to a key Vision 2030 goal in promoting Riyadh as one of the world's top 100 most livable cities. The project is contributing to the increase in green space share per capita, planting trees around the city, as well as in all its provinces. It will contribute to improving the air quality and reducing temperatures in Riyadh, encouraging Riyadh's inhabitants to follow a healthier lifestyle.

The project contemplates planting 7.5 million trees, covering 72 native shade species compatible with local environment, across several of city's facilities such as gardens, parks, and mosques. It is expected to increase the green coverage in Riyadh by 9.1%.

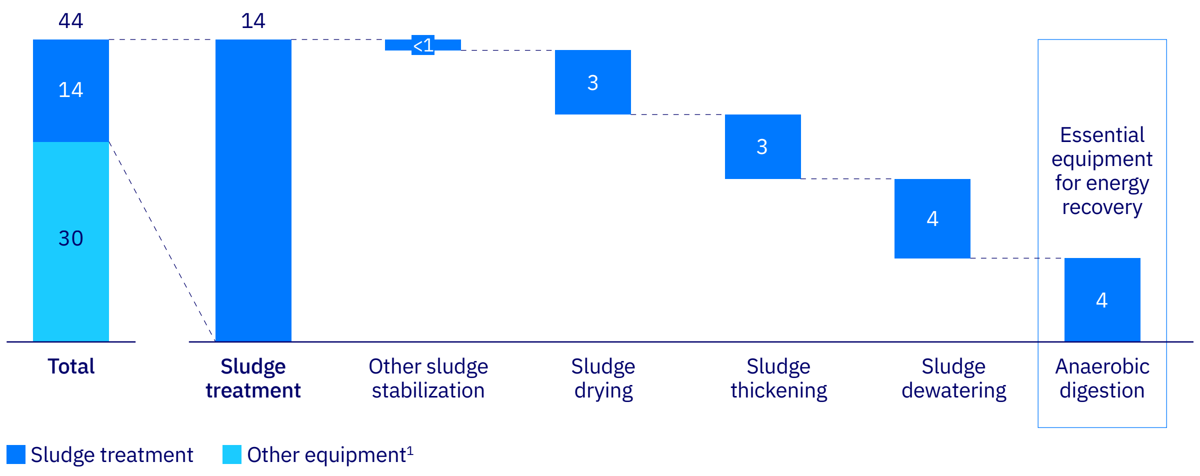
To secure the irrigation needs for such project, 1,350 km of water pipes with up to 2.4 m diameter are being installed for water reuse. While the water reuse is highly limited in Riyadh, the project will positively contribute to the city's sustainability with the use of 1.7 million cubic meters of reused water daily.

Amongst other, Green Riyadh is expected to offer benefits to the city such as ambient temperature reduction by 2 Celsius degrees, air quality improvement, and dust concentration in air reduction.

Market trends and investment outlook[28]

Global investment in sludge management (capital and operational expenditure) is projected to reach US$44 billion by 2030. About US$4 billion of this spending is expected to be directed toward anaerobic digestion technologies.

Figure 26. Global sludge management market
2030, in US$ billion



1. Including required pumps, valves, pipes, sensors, control equipment, and others
Source: GWI WaterData, Oliver Wyman analysis

The anaerobic digestion market is forecast to grow at more than 6% a year through to 2030. Top markets will be the United States, United Kingdom, Germany, Japan, and Canada. These countries are expected to account for around 55% of the global market. The United States alone will account for 30% of global expenditure.

In the MENA region, Egypt, the United Arab Emirates, and Saudi Arabia are projected to account for 75% of the anaerobic digestion market.

Veolia, LIPP, and Anaergia are currently the leading suppliers of digestion solutions. These companies offer advanced solutions for energy, nutrient, and material recovery across global markets.

Challenges and opportunities

Reusing and recovering from wastewater still requires significant capital investment. Moreover, regulatory frameworks must be established to allow for water reuse or nutrients recovery for purposes such as agriculture.

Recycled water presents a proven alternative source of water. With the increase in water availability challenges, the water reuse for multiple purposes has been a successful strategy globally. New technologies enable the recovery of valuable resources from wastewater, providing an opportunity for water utilities to move towards net-positive energy.

Summary

Utilities and policymakers are recognizing that water reuse is critical to their strategies for addressing global water scarcity, protecting public health, and supporting sustainable development. Also, sludge is now seen as a valuable resource.

Technological advances and increasing investments in treatment and associated infrastructure are enabling more efficient and safe recycling of water for a diverse range of applications. Policy initiatives and ambitious national targets are accelerating the adoption of water reuse, especially in water-stressed regions. With global investments in sludge management projected to reach US$44 billion by 2030, the sector is set to play a significant role in global efforts to build more sustainable and resilient water systems.

MAJOR TRENDS IN CIRCULARITY AND SUSTAINABILITY

5.0

CONCLUSION

The global water landscape is facing enduring and intensifying challenges that are reshaping how water resources are managed worldwide. Demand for secure, sustainable, and resilient water systems continues to rise. Climate change and the increasing unpredictability of precipitation patterns exacerbate water scarcity, placing additional pressure on already stressed systems. With a quarter of the world's population currently experiencing extreme water stress, and projections indicating that up to one billion more people will face such conditions by 2050, the magnitude and urgency of water challenges are clear and growing.[4]

This new reality requires new approaches to water management. The diversification of water supply portfolios, including expanded desalination, reuse and recycling of wastewater, and enhanced transmission networks, highlights the necessity for flexible, resilient, and integrated water management frameworks. Technological innovation is not merely complementary but transformative: digital technologies such as AI, IoT, and advanced data analytics allow utilities to optimize operations, reduce losses, predict failures, and engage consumers more effectively. Renewable energy integration is pivotal in addressing the carbon footprint of high-energy processes like desalination and wastewater treatment, paving the way toward sustainable water-energy nexus solutions.

The complexity and scale of global water issues underscore the imperative for broad-based collaboration among policymakers, regulators, utilities, investors, industries, and communities. Funding these massive water infrastructure needs requires innovative financing mechanisms, capable of closing the funding gap that has been widening in recent years. Green bonds and other impact investment instruments are gaining momentum, enabling dedicated capital flows towards sustainable water projects that offer measurable environmental and social returns. Such financial innovations align investor interests with sustainable water development goals, helping to bridge the global infrastructure financing gap.

Moreover, hydro-diplomacy is emerging as a vital instrument for managing shared transboundary water bodies peacefully and effectively. By fostering dialogue and cooperative frameworks between countries, hydro-diplomacy helps to mitigate conflicts, facilitate data sharing, and unlock cross-border initiatives such as water transmission and joint reuse projects. These multi-level cooperation efforts, locally, nationally, and internationally, are pivotal for building resilient water systems that adapt to shifting climatic and geopolitical dynamics.

The outlook for the water sector globally is both robust and diverse. It requires a holistic and integrated approach with strong governance, technological innovation, and sustainable financing. This approach will enable adaptive practices, responsive to climate variability and sociopolitical dynamics, while fostering sustainability. Still, robust policy frameworks are required to support sustained investment in infrastructure modernization, digital transformation, smart management practices, energy efficiency, and circularity.

The water challenges of today and tomorrow are intimidating, but with concerted efforts and innovative thinking, the sector can advance towards a more resilient, sustainable, and equitable water future for all.

LIST OF TABLES AND FIGURES

List of Tables and Figures

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