Executive summary

i The proposition

Desalination and water reuse in industry has emerged as one of the most important themes in the water sector over the past five years. Over the next five years the technologies associated with salt removal and the reuse of wastewater will become an essential part of sustainable economic growth and profitability for the following reasons:

- **Global economic growth is increasingly coming up against environmental restraints:** These constraints include water scarcity, the growing challenge of developing new sources of energy and mineral resources, growing pressures on agricultural productivity, and the need to manage carbon emissions within the context of global warming.
- **Freshwater availability is both a resource constraint in itself, and part of the solution to other resource constraints:** For example, water plays an increasingly important role in the extraction of marginal natural resources, optimising the efficiency of power generation, and addressing pollution. As the model for global economic growth moves away from extraction, production and disposal towards a circular model in which waste is recycled as the raw material for new products, the role of water becomes more important because it provides the vector for energy and materials recovery.
- **Corporate water users are being forced to take notice of water:** Whether it is because of investor concerns about operational risks, branding and commitment to corporate social responsibility or direct impacts on the profit and loss account, water has become a boardroom issue for the overwhelming majority of large companies (87% of annual filings to the SEC now include water risk assessments according to Ceres, the investor advocacy group). It means that businesses are more ready to invest in water technology than ever before.
- **Desalination and water reuse technologies are the main beneficiaries of these trends:** Removing salt from water, and other technologies which turn low quality wastewater and raw water sources into high quality process water, is the key driver of the water efficiency of the global economy. Whether it is delivering higher specifications of ultrapure water to guarantee the profitability of the microelectronics industry, facilitating the recycling of heavily contaminated produced water using evaporators and crystallisers in the Canadian oil sands, or enabling the expansion of the downstream oil and gas industry in the Arabian Gulf by using seawater as a feedwater source, desalination and water reuse technologies are unlocking the potential for growth.

The report focuses on the demands of the eight most water intensive industries:

- Oil and gas
- Refining and petrochemicals
- Power generation
- Food and beverage
- Pharmaceutical
- Microelectronics
- Pulp and paper
- Mining

Within these industries, our market forecast focuses on three principal areas where desalination/demineralisation technologies are employed:

- Ultrapure water (UPW)
- Seawater desalination
- Wastewater desalination

Our overall market forecast for these areas is as follows:

Figure i UPW, seawater desalination and wastewater desalination by industrial segment, 2011-2025

UPW, seawater desal and wastewater desal by industrial segment	2011	2012	2013	2014	2015	2016	2017	CAGR 2011-17	2025
Oil and gas									
Refining and petrochemicals									
Power generation									
Food and beverage									
Pharmaceutical									
Microelectronics									
Pulp and paper									
Mining									
Co-lo power / desalination									
Total (ex co-lo)									

Source: GWI

ii Oil and gas

There are four key growth markets for desalination and water reuse technologies within the upstream energy sector:

1. **Produced water management in the unconventional gas sector:** Shale gas and coalbed methane (CBM) production have the potential to rewrite the future of the fossil fuel industry – as long as the related water issues can be addressed effectively. The potential for shale gas production in many regions is limited by the disposal options for the flowback water from hydraulic fracturing. CBM production is challenged by the huge volumes of water that are brought to the surface. Desalination and water reuse technologies are potential solutions. This report argues, however, that the low price of gas in the U.S. in comparison to Europe and the Far East will hold back the development of a strong market for water technology in the North American shale plays until 2015. Instead the most immediate opportunities are in the Australian CBM sector.

2. **Low salinity water and sulphate removal for water flood:** In order to meet the world's continuing need for oil, producers are developing new deep sea resources, and looking to squeeze more oil out of existing reservoirs. It turns out that water quality holds the key to both. In the deepwater off-shore industry, around the Atlantic rim, there is growing demand for sulphate removal technology to ensure that when seawater is injected into the wells, it does not scale or sour the reservoir, damaging the profitability of the well. At the same time the industry is beginning to understand how the salt chemistry of water can alter the wettability of the sandstone in which the oil is held. By treating the injection water with a combination of reverse osmosis (RO) and nanofiltration (NF), it is possible to increase the amount of oil recovered from a reservoir by up to 15% or even more if used in conjunction with a chemical flood. The report suggests that this is a potential game changer: NF and RO for seawater flood could be the fastest growing sector of the desalination market in the oil and gas industry.

3. **Recycling produced water for steam enhanced oil recovery (EOR) in the heavy oil sector:** Outside the Arabian peninsula, Canada's oil sands represent the largest oil reserve in the world. Exploiting the oil sands increasingly relies on steam assisted gravity drainage, and that in turn increasingly relies on water recycling systems in general

and evaporation technology in particular. But it is not just Canada which needs to invest in water recycling systems to unlock production. Steam EOR is also becoming a feature of production in the Arabian Peninsula. The report suggests that Oman, and the Wafra field between Kuwait and Saudi Arabia, as well as new resources in Latin America will be strong markets for high recovery water desalination systems.

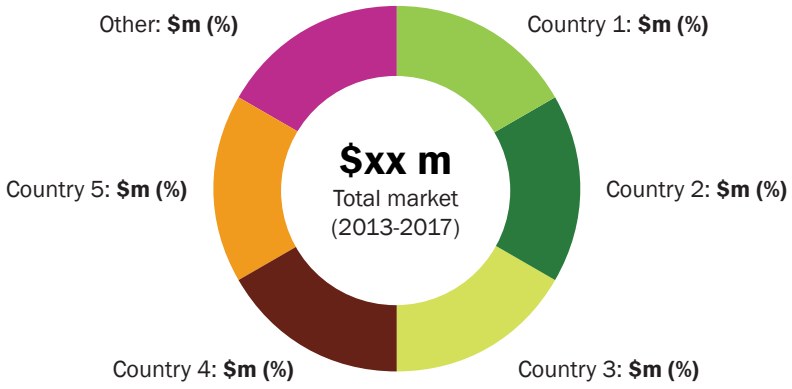
4. **Beneficial reuse of produced water in the conventional oil sector:** The oil industry produces 39 million m³/d of water – far more than the oil it brings to the surface. The vast majority of this is reinjected straight back into the ground, but a small amount (around 3%) is reused for beneficial purposes. The report argues that this proportion will increase to 7% by 2020, and that brackish water desalination systems will have a role in this evolving opportunity.

Figure ii Oil and gas industry market forecast, 2011-2025

Oil and gas ($ million)	2011	2012	2013	2014	2015	2016	2017	CAGR 2011-17	2025
Shale gas: conventional treatment									
Shale gas high recovery desal									
CBM high recovery desal [a]									
SRP/Low salinity systems [b]									
Water recycling systems for steam EOR [c]									
High recovery desal for steam EOR [d]									
Produced water polishing [e]									
Produced water RO/evaporation [f]									
Total									

Source: GWI; see chapter 2 for footnotes and additional detail.
For further information about the oil and gas market in North America, see GWI's Produced Water Market primary research report

Figure iii Oil and gas industry, top country markets, 2013–2017



Source: GWI

iii Refining and petrochemicals

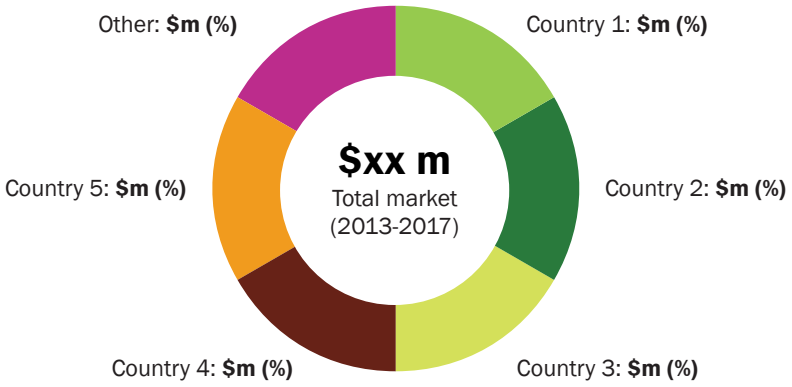
Refineries typically consume more water than crude oil. The specifications of the water used for steam, cooling and process applications are high, but the raw water sources are becoming more challenging as the locus of growth in the downstream sector moves away from the Atlantic rim and towards emerging markets such as India and China, and towards upstream producers such as the Gulf countries. The report argues that this means that seawater desalination is going to be an increasingly important technology for the refinery sector, and that greater emphasis will be put on reuse technologies.

Figure iv Refining and petrochemicals industry market forecast, 2011–2025

Refineries ($ million)	2011	2012	2013	2014	2015	2016	2017	CAGR 2011-17	2025
Pretreatment systems [a]									
Ultrapure water systems									
Wastewater treatment systems [b]									
Seawater desalination plants [c]									
ZLD systems									
Total [d]									

Source: GWI; see chapter 3 for footnotes and additional detail

Figure v Refining and petrochemicals industry, top country markets, 2013–2017



Source: GWI

iv Power

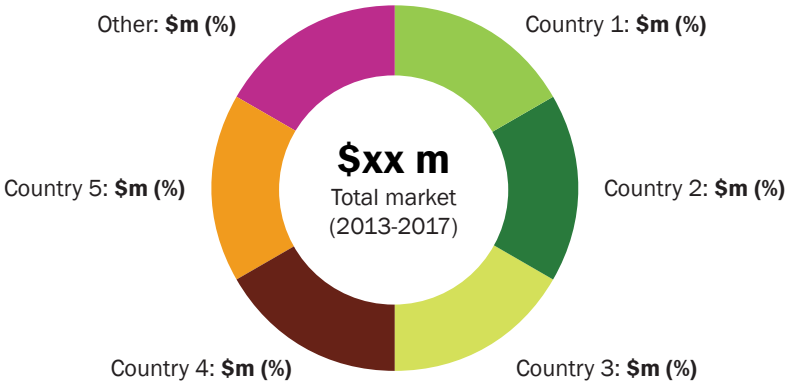
Power generation is the largest industrial user of water, and as with the refining and petrochemical industry, much of the growth is taking place in areas which have limited natural endowment. At the same time as requiring greater water efficiency, customers are putting a growing emphasis on the consistency, reliability and specification of their ultrapure water systems. The report argues that a combination of tighter regulation of coal emissions, ageing infrastructure, lower gas costs and the switch away from nuclear power looks set to lead to accelerated investment in new and upgraded gas power stations. Although coal is unlikely to increase its market share of the power sector, investment in wet scrubber systems for flue gas desulphurisation will lead to heavy investment in wastewater treatment systems. Overall there is a strong outlook for desalination and water reuse technologies including reverse osmosis, ion exchange (IX), low pressure membranes, electrodeionisation (EDI) and evaporators.

Figure vi Power industry market forecast, 2011–2025

Power ($ million)	2011	2012	2013	2014	2015	2016	2017	CAGR 2011-17	2025
Pretreatment systems [a]									
Boiler feedwater systems									
Condensate polishing systems									
Wastewater treatment systems (exc. ZLD)									
Seawater desalination [b]									
Co-located power/desal [c]									
ZLD/high recovery desalination systems									
Total [d]									

Source: GWI; see chapter 4 for footnotes and additional detail

Figure vii Power industry, top country markets, 2013–2017



Source: GWI

v Food and beverage

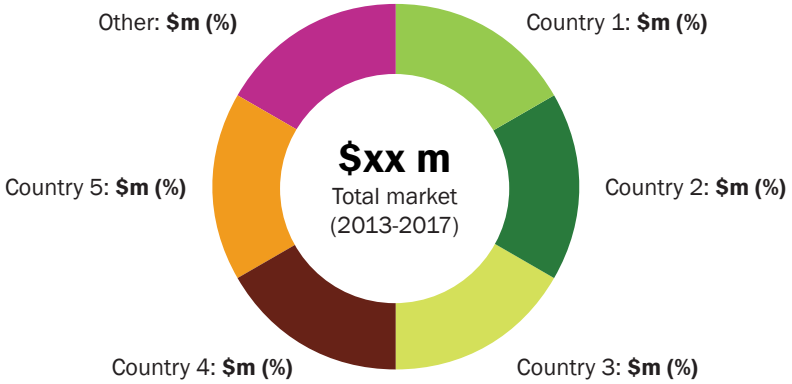
Direct reuse of wastewater in the product is not on the menu in the food and beverage industry, but the reuse of water for other purposes (e.g. washing) is now a priority. Most major food and beverage companies have made commitments to reduce their water consumption per unit of product, and reuse is an important part of the strategy for achieving this. Furthermore much of the growth of the industry is in emerging markets which typically have more limited, lower quality water resources than developed countries, creating water treatment challenges. In developed markets, emerging concerns about pharmaceutical by-products and other trace contaminants making their way into the product have lead to greater use of desalination technologies on the process water side.

Figure viii Food and beverage industry market forecast, 2011–2025

Food & Beverage ($ million)	2011	2012	2013	2014	2015	2016	2017	CAGR 2011-17	2025
Pretreatment systems									
Polishing systems									
Wastewater treatment systems									
Total									

Source: GWI. For further information about the Food & Beverage market, see GWI's Water for Food & Beverage primary research report

Figure ix Food and beverage industry, top country markets, 2013–2017



Source: GWI

vi Pharmaceutical

Water reuse is not on the agenda for process water in the pharmaceutical industry. However, drug companies remain a significant market for specialist desalination systems as they look to produce ultrapure and infection-free water for medicine manufacture, and there is interest in reducing water usage through recycling water for utilities and other less critical purposes. The highest quality water is for injections, and may be treated with activated carbon, ion exchange, electrodeionisation, UV disinfection, ultrafiltration (UF), reverse osmosis and distillation before it is used in the product. Such is the conservative nature of the customer base that many will ask for distilled water for processes even though the regulations do not require it.

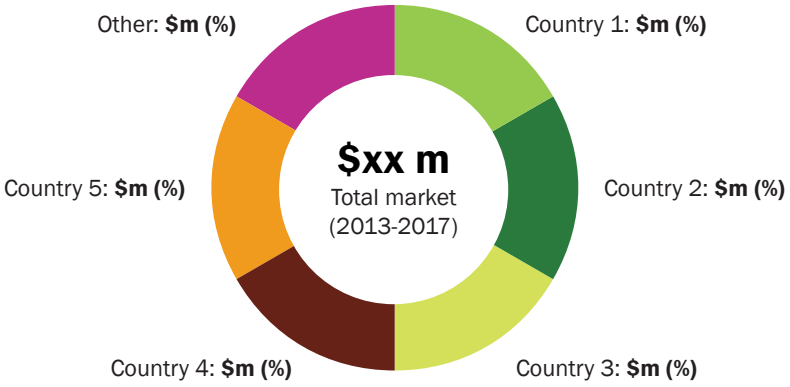
The report suggests that the main geographical areas of market growth are in the BRIC countries. The main technological opportunities are on the wastewater side, where regulatory concerns about micropollutants are opening up the market for effluent polishing using desalination technologies.

Figure x Pharmaceutical industry market forecast, 2011–2025

Pharmaceutical ($ million)	2011	2012	2013	2014	2015	2016	2017	CAGR 2011-7	2025
Pretreatment systems									
Ultrapure water systems									
Disinfection systems									
Wastewater treatment systems									
Wastewater polishing technologies [a]									
Total									

Source: GWI; see chapter 6 for footnotes and additional detail

Figure xi Pharmaceutical industry, top country markets, 2013–2017



Source: GWI

vii Microelectronics

Microelectronics is an important market for ultrapure water systems and the challenges are getting greater. As devices get smaller and the fabrication plants get larger, the purity of the water required increases. In terms of water reuse, the industry has relatively conservative attitudes towards recycling water for ultrapure water applications, but wastewater is treated and reused for cooling and other less critical purposes. This may be insufficient in the longer term: in Taiwan drought has twice threatened to close down the semiconductor industry in the past decade, and maximising reuse has become imperative. Learning from the Taiwanese experience, other chip makers are making commitments to reduce their water footprints.

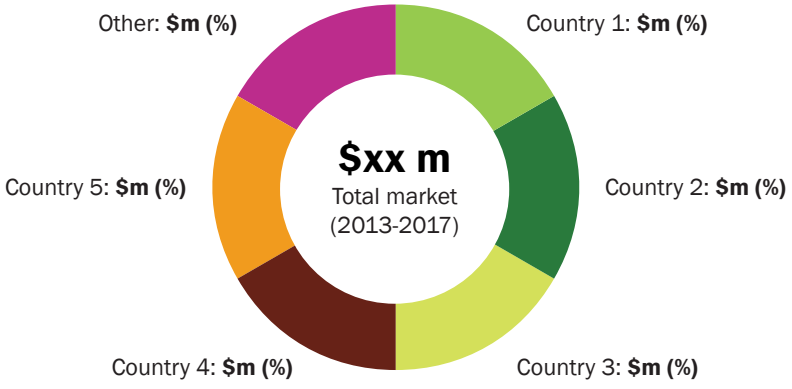
Besides semiconductors, two other silicon-based sectors of the microelectronics industry need large volumes of highly pure water: flat panel displays (FPD) and photovoltaics (PV). Both sectors enjoyed dramatic growth at the end of the 2000s and into the 2010s, but are in the process of maturing. Current water quality requirements are similar to those of the semiconductor industry 20 years ago. However, the report suggests that the increasing complexity of FPD and PV devices will create demand for even higher purity water. Short product cycles, together with the pressures on water resources in the key manufacturing markets will ensure strong demand for ultrapure water and water reuse technologies.

Figure xii Microelectronics industry market forecast, 2011–2025

Microelectronics ($ million)	2011	2012	2013	2014	2015	2016	2017	CAGR 2011-7	2025
Pretreatment systems									
Ultrapure water systems									
Wastewater treatment systems									
Total									

Source: GWI

Figure xiii Microelectronics industry, top country markets, 2013–2017



Source: GWI

viii Pulp and paper

Historically the pulp and paper industry has had little need for desalination and reuse – not least because the majority of production is located near water sources. Four things are changing this state of affairs, the report suggests.

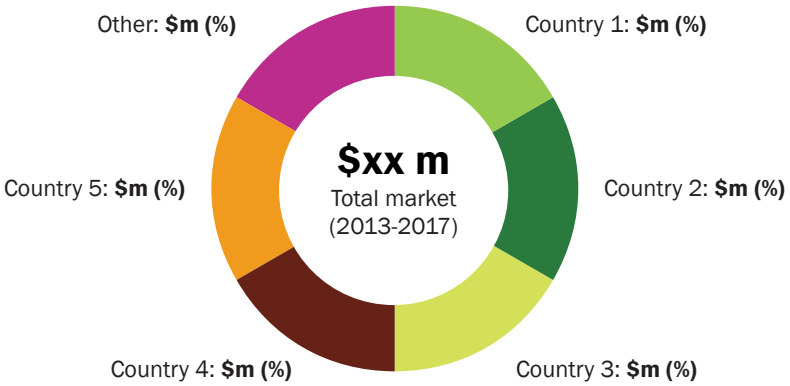
- The move towards recycling means that production in mills located in "urban forest" areas is rising. These facilities face higher water costs than green forest located mills, and have a greater interest in water efficiency.
- The fastest growing market for pulp and paper is in China, where raw water sources are both limited and impaired, and water technologies which can address these challenges are at a premium.
- The new generation of efficient boilers used in the industry require higher quality feedwater than the traditional boilers, and as existing production facilities are refitted, there will be greater demand for ultrapure water treatment lines than have historically been the case.
- Regulators are becoming more proactive about controlling effluent from the pulp and paper industry: this is especially true in the case of China, where environmental protection has not been a priority.

Figure xiv Pulp and paper industry market forecast, 2011–2025

Pulp and paper ($ million)	2011	2012	2013	2014	2015	2016	2017	CAGR 2011-17	2025
Process water systems (excl.UPW) [a]									
Boiler feedwater systems [b]									
Wastewater treatment systems [c]									
Total [d]									

Source: GWI; see chapter 8 for footnotes and additional detail

Figure xv Pulp and paper industry, top country markets, 2013–2017



Source: GWI

ix Mining

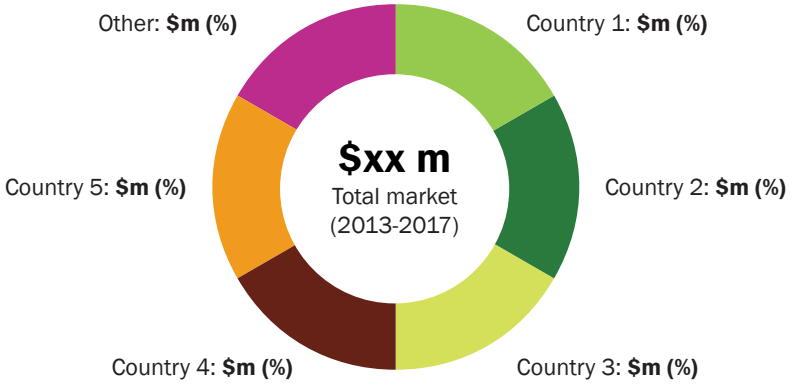
Water is becoming a significant licence to operate issue for the mining industry. Companies now realise that unless they can reduce their water footprint by minimising the amount of freshwater they draw from local resources, and ensure that the effluent they discharge is treated to the highest standard, they may be removed from projects and be blacklisted by governments. The result is that international mining companies are prepared to invest proactively in water technology, going beyond the basic regulatory requirements. At the same time strong mineral prices are drawing miners to work on projects in areas such as Western Australia, Chile and Peru where water represents a major logistical challenge. It all makes for an attractive market for desalination and water reuse technologies, the report concludes, with the proviso that a fall in mineral prices would bring many mining projects to a standstill. The only protection there is against the innate cyclicity of the mining market are sales tied to legally mandated acid rock drainage projects.

Figure xvi Mining industry market forecast, 2011-2025

Mining ($ million)	2011	2012	2013	2014	2015	2016	2017	CAGR 2011-17	2025
Process water treatment systems									
Wastewater treatment systems									
Seawater desalination systems									
Total									

Source: GWI. For further information about the mining market, see GWI's Water for Mining primary research report

Figure xvii Mining industry, top country markets, 2013–2017



Source: GWI

x Technologies

The core desalination and water reuse technologies covered by the report are reverse osmosis (RO), ultrafiltration (UF) and microfiltration (MF), ion exchange, electrodeionisation (EDI), and evaporation. Adsorption, physical/chemical separation systems, biological treatment, media filtration and disinfection are also covered, but with less specific detail. The main technology trends observed by the report are as follows:

- **The challenge of salt waste disposal:** Salty wastewater is a fundamental challenge. It is both messy and expensive to treat, and the end result is usually a sludge or brine, which is difficult to dispose of. Membrane-based approaches are defined by scaling problems, while thermal approaches are expensive and often have chemistry problems of their own. The ideal solution would be a low cost salt separation technology which salvaged other value beyond brine from the waste stream. Short of that, a membrane-based treatment which can handle concentrations of more than 100,000 mg/l salinity would be a useful addition to the technology portfolio.
- **Six sigma reliability and scale in ultrapure water:** Historically the boiler feedwater market has been a fragmented low margin systems business, served by a small number of higher margin chemicals companies supplying the resins. As customers have started to require higher specification water, with greater consistency and fewer waste problems, so the technology train has evolved from IX, to RO-IX, to UF-RO-IX and possibly UF-RO-EDI. It means that there is more value in the systems, relative to the resins, especially when sensing and control systems are incorporated, and lean manufacturing techniques are used to mass produce modular units. The resin manufacturers have responded to falling volume demand for the basic product by concentrating on mixed bed and specialist resins which remove specific impurities.
- **Fundamental water challenges remain in most industries:** While technology for municipal water treatment is largely settled, there are few industries which have the perfect water technology. In the paper industry, fibre and organic material are the challenges. In the Canadian oil sands it is silica. In the microelectronics industry the problem is with sensors which are no longer sensitive enough to measure the level of quality which is required. It means that the demand for innovation in water technology is strong enough to overcome the innate conservatism of the customer base.