Business guide to circular water management: spotlight on reduce, reuse and recycle

Contents

Foreword

Securing water of sufficient quantity and quality is one of the most important challenges facing the world today. It affects present and future generations, and has significant implications for business, society and the environment.

Today, four billion people experience severe water scarcity over the course of a year. As climate change worsens, water scarcity will become even more common.

At the same time, population growth, urbanization and economic development will increase global demand for water by 50% by 2030* – demand will rise, but the amount of available water will not. If we don't change course, water demand will outstrip supply by 40% by 2030.

This issue is particularly relevant for businesses, as companies are likely to be last in line for water allocation in resource-constrained areas. As such, business has a key stake and an essential role to play in addressing water challenges.

In 2016, many of the world's largest companies reported USD 14 billion in water-related impacts including drought, flooding or water stress – five times more than the previous year.

It's time to act. And a paradigm shift in our understanding of wastewater is an urgent and necessary step.

Currently, over 80% of wastewater generated by society flows back into the environment without being treated or reused. This has serious implications for ecosystem health and will have a costly impact on society.

But it's not just about risks – transforming our understanding of wastewater will bring significant opportunities.

By pursuing the '5Rs' approach, and reducing, reusing and recycling water, while recovering resources and replenishing water ecosystems, companies can create win-wins for their own operations, other water users and the ecosystems they operate in and depend upon.

This Business Guide to Circular Water Management is designed to equip business decision-makers with the tools they need to understand how to overcome internal and external barriers to implementing circular water management solutions. It will also help businesses understand how and why water regulations matter, and what best practices already exist.

The aim is for this guide to kick-start company action, and to ensure business leadership on the paradigm shift. It also makes the case for taking the first step in valuing water as a precious natural resource, and in understanding wastewater as an asset to company resilience, continuity and growth.

We wish you an insightful read, and commend you on starting this journey.

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* UN-Habitat. (2016). *World Cities Report 2016: Urbanization and development.*

Acronyms and abbreviations

BIER	Beverage Industry Environmental Roundtable
CAPEX	capital expenditure
CAS	conventional activated sludge
C&S	cleaning and sanitization
CDP	Carbon Disclosure Project
CCGT	combined cycle gas turbine
CEDI/IX	continuous electrode ionization/ion exchange
CHP	combined heat and power
COD	chemical oxygen demand
CWSI	combined water-stress index
DAF	dissolved air flotation
DEG	Deutsche Investitions- und Entwicklungsgesellschaft (German Development Bank)
EDF	Electricité de France
EPA	Environmental Protection Agency
ES	environmental sustainability
GAC	granular activated carbon
GEMI	Global Environmental Management Initiative
HO	hydrogen oxide
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
IUCN	International Union for Conservation of Nature
IWA	International Water Association
KWRP	Kwinana Water Reclamation Project
MF	microfiltration
mg/L	milligram/liter
mL	milliliter
mS/cm	millisiemens/centimeter
NF	nanofiltration
OECD	Organisation for Economic Co-operation and Development
OPEX	operational expenditure
OWS	oil/water separator
PAC	powdered activated carbon
P&G	Procter & Gamble
RO	reverse osmosis
ROI	return on investment
SAM	Sustainable Asset Management (RobecoSAM)
SBR	sequence batch reactor
SOP	standard operating procedure
TDS	total dissolved solids
TEE	triple effect evaporator
TIRU	Traitement Industriel des Résidus Urbains
TP	total phosphorus
TPI	tilted plate interceptor
TSS	total suspended solids
UF	ultrafiltration
UNEP	United Nations Environment Programme
US	United States
UTE	Usina Termeléctrica Norte Fluminense
UV	ultra-violet
WBCSD	World Business Council for Sustainable Development
WHO	World Health Organization
WNF	Wereld Natuur Fonds (World Wide Fund for Nature, Netherlands)
WRI	World Resources Institute
WRM	Water Risk Monetizer
WWF	World Wildlife Fund for Nature
ZLD	zero liquid discharge

1 The importance of circular water management

1.1 Need for action

Based on current trends, water demand is projected to exceed sustainable supply by 40% in 2030[1]. Population and economic growth, urbanization, climate change and many other factors are adding pressure on sustainable water supplies. Businesses have built their strategies on natural resources that are changing. Changes in the availability of natural resources are affecting the day-to-day operations of many businesses and are creating challenges in value chains. For example, declining water reserves can create difficulties in securing water of appropriate quality (e.g., for agriculture) and/or in sufficient quantity (e.g., for cooling industrial processes), and can affect the efficiency of production. This may lead to competition for water among different users, such as communities, industries, agriculture and tourism.

Authorities in water-scarce countries are tightening regulations on water extraction and water discharge, making it harder for companies to comply. The extent to which businesses are affected differs from industry to industry and from location to location.

1.2 About this guide

This Business Guide aims to help companies in developing strategies to respond to these changes by implementing circular water management practices. Companies may be at the beginning of their water management journey or may already have a water management strategy in place. In either case, this Business Guide suggests ways to overcome common barriers encountered in framing or implementing a strategy for circular water management, focusing on the reduce, reuse and recycle steps in the 5Rs approach (reduce, reuse, recycle, restore and recover water resources). The practical advice on raising awareness and supporting dialogue aims to help companies engage stakeholders. Guidance on developing a solid business case for reducing water use, reusing or recycling water aims to help companies ensure an acceptable return on investment by taking account of the true cost of water, and to help them comply with regulations on water intake and discharge. The overview of practical tools, methodologies, examples and insights, draw on experiences in responding to risks. The case studies on reducing water use, reusing, recycling, restoring water reserves and recovering valuable resources from wastewater identify opportunities. Best practices drawn from these case studies and the distillation of key success factors show ways to overcome barriers.

Chapter 2 explains the 5Rs approach and how to use a risk-based method to develop a circular water management strategy. **Chapter 3** addresses regulatory frameworks, which are important drivers as well as barriers. This chapter provides an overview of regulatory approaches to initiate water reuse and recycling worldwide, and shows that water scarcity does not always lead to more stringent regulations.

Chapter 4 focuses on the main barriers companies encounter in water management and gives examples of ways to overcome them. **Chapter 5** stresses the importance of understanding the main drivers for developing and upholding water management plans. This chapter shows how companies have implemented the 5Rs approach, and the key success factors and enablers through case studies provided by WBCSD members. **Chapter 6** describes tools to help tackle barriers, for instance through a corporate water strategy, by identifying organizational risks or by prioritizing sites that need more sustainable water management plans.

There are many ways companies can reduce, reuse and recycle water. **Chapter 7** gives an overview of water-quality requirements for different uses and technologies to fulfill these requirements. **Chapter 8** explains the economics in building a business case for investment in water reduction, reuse and recycling projects. A viable business case can be built for recovering (one of the 5Rs) energy, resources and nutrients, or reducing energy consumption through a reduction in water usage (one of the 5Rs).

Chapter 9 provides a decision flow chart. The flow chart takes a 5Rs approach, first identifying the drivers for implementing circular water management, focusing on reduction, reuse, recycling and replenishment. Checklists provide guidance on what to consider and how to implement circular water management projects at the corporate and site level.

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[1] 2030 Water Resources Group. (2009). *The Water Resources Group. Background, Impact and the Way Forward.*

2 Water and industry

2.1 The global water cycle and the industrial water cycle

Water is present in many different forms, continually moving on, above and below the surface of the Earth (the 'water cycle'). The mass of water on Earth is constant over time but the partitioning of water into ice, fresh water, saline water and atmospheric water fluctuates, depending on a wide range of climatic variables.

Water moves by evaporation, condensation, precipitation, infiltration, runoff and subsurface flow **(Figure 1**). These processes involve the exchange of energy and are dependent on temperature. The Intergovernmental Panel on Climate Change (IPCC) shows that, if current trends continue, temperatures may increase between 3.7°C and 4.8°C by 2100[2]. Higher temperatures and changes in climate will have significant consequences on the water cycle, locally altering the availability of water in the ground and on the surface, and water storage.

Every business impacts and depends on natural capital, such as water, to some degree and faces risks and opportunities associated with these relationships. The effects of businesses on natural capital can be negative, for example through pollution, or positive, for example through better water quality. While impacts are often measured, some businesses do not recognize dependencies, for example that production processes depend on water. All impacts and dependencies have costs and benefits, not only for businesses, but also for society. Understanding the links between business and society and the associated risks and opportunities can enable better, more timely decision-making.

Industry is a major water user, accounting for between 10% (Asia) and 57% (Europe) of total water consumption[3] and, as such, has a huge impact on regional water consumption. Benchmarked data across industries indicate that there are opportunities to reduce industrial water consumption by up to 50%[4]. Addressing water use is an important way for business to contribute solutions to securing water in the watersheds in which they operate. Circular water management presents a variety of opportunities for doing so.

Industries take water from groundwater, surface water and (municipal) drinking-water systems. They subsequently treat this water as needed to bring it to the quality required for industrial processes and production (e.g., cooling water, boiler water, beverages, cosmetics). Wastewater is either discharged directly, after on-site treatment, or recycled after treatment.

Watersheds capture and store rainfall, sustain and regulate stream flows, recharge groundwater reservoirs and are essential to regional water supplies. Healthy watersheds provide reliable water supplies for industry, agriculture and communities. Companies that involve other water users in the watersheds in which they operate, and collaborate across sectors enhance water security and water management, and mitigate risks[5].

The way business deals with water not only has an impact on the local environment but also on the way society perceives business (e.g., reputation, employee satisfaction).

"Benchmarked data across industries indicate that there are opportunities to reduce industrial water consumption by up to 50%."

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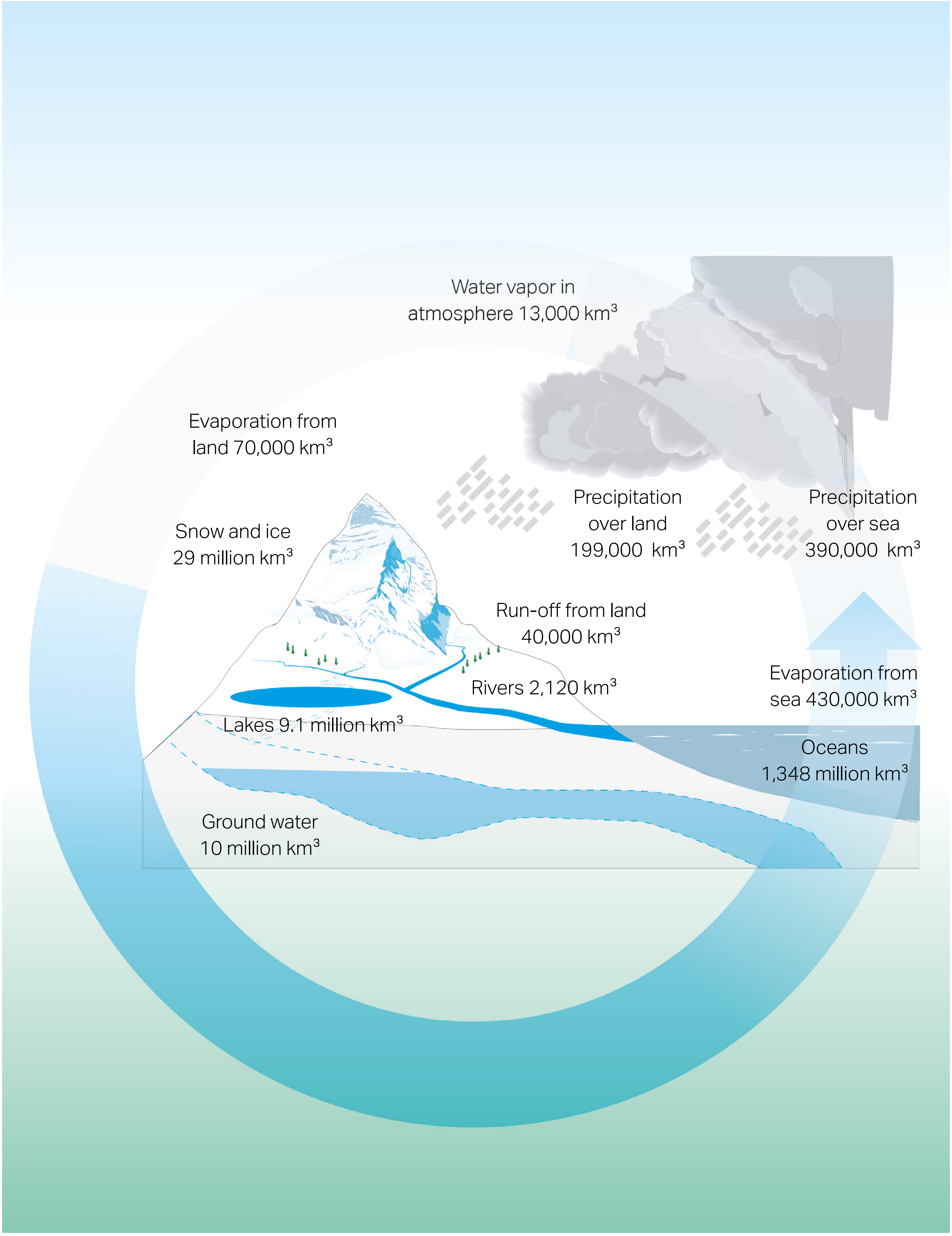
[2] Intergovernmental Panel on Climate Change. (2014). *Climate Change 2014: Synthesis Report.* Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. Geneva, Switzerland: Intergovernmental Panel on Climate Change (IPCC).
[3] Food and Agriculture Organization of the United Nations (FAO). Aquastat.
[4] Andrews, M., Berardo, P. and Foster, D. (2011). The sustainable industrial water cycle – a review of economics and approach. *Water Science and Technology: Water Supply*, v 11 (1).
[5] World Business Council for Sustainable Development. (2013). *Sharing water: Engaging business. Why watershed approaches are important to business sustainability.* World Business Council for Sustainable Development (WBCSD).

Figure 1. The water cycle depicting annual renewable water supply per person by basin (m³ per year). Adapted from *Water facts and trends. Version 2*, 2009, World Business Council for Sustainable Development (WBCSD)



2.2 Water management: a risk-based approach

Making effective policy decisions and improving water stewardship are essential in managing water risks for example, in minimizing risks to water supplies associated with the negative impacts of climate change. Countries can respond to current and future water shortages caused by climate change by encouraging efficient use of water, allocating water to high value uses, and by changing to more efficient industrial and agricultural practices[6].

Regions that are extremely dry require far-reaching policies to prevent inefficient use of water and to address the risks of water scarcity. The European Union, for example, incorporates water reuse into a Water Framework Directive. The Directive provides guidelines for integrating water reuse into water planning and management[7].

Policies and investments that can assist countries in developing water-secure and climate-resilient economies include:

- Planning allocation of water resources
- Providing clear guidelines on water quality
- Adopting incentives to increase water efficiency
- Investing in infrastructure to secure water supplies.

Reports of the US Environmental Protection Agency (EPA) show that water-related risks apply to all sectors of the economy. Every sector relies on water[8], either directly or indirectly. Since water is essential in manufacturing and delivering products, and for virtually all products, almost all companies are affected by water-scarcity risks. Securing business licenses, for example, depends on the availability of sufficient water of the required quality for the business to operate.

Water affects operational risks, reputational risks, regulatory risks and overall financial risk.

Businesses can mitigate risks related to water by taking the 5Rs approach – reduce, reuse, recycle, restore, recover – when developing a water management strategy. The 5Rs approach ensures that all opportunities to mitigate water-related risks are identified and acted upon.

2.3 The 5Rs approach to circular water management

European Union policy identifies the use of treated wastewater as one potential solution to water scarcity[9]. The International Water Association (IWA) developed the 5Rs approach to water management – reduce, reuse, recycle, restore and recover – for companies to consider and adopt as common practice. Many companies are already applying one or more of the 5Rs. The entire water value chain, from source, through supply to consumers, needs to embrace the 5Rs as an approach. This Business Guide uses the following definitions of the 5Rs:

- **Reduce**: reduce water losses and boost water efficiency
- **Reuse**: reuse water, with minimal or no treatment, within and outside the fence for the same or different processes
- **Recycle**: recycle resources and wastewater (treated by membrane or reverse osmosis to a very high quality) within and outside the fence
- **Restore**: return water of a specific quality to where it was taken from
- **Recover**: take resources (other than water) out of wastewater and put them to use.

This Business Guide focuses on the 'reduce, reuse, recycle' steps. Reducing water use, reusing water and recycling wastewater can help reduce water stress and can often result in lower investment and energy costs. Treated wastewater can also deliver significant environmental, social and economic benefits. Furthermore, treated wastewater can ensure a reliable water supply, independent of seasonal weather. National strategies increasingly acknowledge and embrace the potential of treated wastewater[10].

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[6] World Bank Group. (2016). *High and Dry: Climate Change, Water, and the Economy.* Washington, DC: World Bank.
[7] Communication from the Commission to the European Parliament and the Council – Addressing the challenge of water scarcity and droughts in the European Union COM (2007) 414. 19.
[8] Environmental Protection Agency. (2013). *The Importance of Water to the U.S. Economy.* November, 1–37. Environmental Protection Agency (EPA).
[9] Communication from the Commission to the European Parliament and the Council – Addressing the challenge of water scarcity and droughts in the European Union COM (2007) 414.
[10] European Commission. (2016). *Water Reuse – Background and policy context.*

The 5Rs approach to circular water management, rather than approaches that look at water, energy and waste systems individually, minimizes pressure on water resources in terms of both quality and quantity. Cross-sector collaboration, between industry, agriculture and government, and the recovery from wastewater of resources such as energy, nutrients and metals, are important aspects of the circular economy approach. Innovation in recovering resources such as energy, biomass, biosolids, char/ash and chemical nutrients in the water cycle is developing rapidly. But examples of large-scale, marketable applications are still limited.

Businesses need to do more research on up-scaling resource recovery systems, to develop a deeper understanding of viable policies and incentive schemes, and to promote innovations within their operations and across sectors.

Nevertheless, the potential for reusing water and recycling wastewater is significant. Inter-sector collaboration offers many possibilities, using treated urban wastewater to supplement or replace demand from industries for potable and fresh water in arid regions, for example. Treated urban wastewater could also supplement or replace potable and fresh water in expanding cities and contaminated environments, even in temperate regions. Not all processes and uses require potable water, for instance:

- **Cooling system make-up water, process water, wash-down water and miscellaneous uses, such as site irrigation, fire protection, road cleaning, dust suppression, construction aggregates, beautification**
- **Agricultural irrigation** (industrial crops, fodder and seed crops, orchards, forests, food crops)
- **Indirect potable reuse** (aquifer recharge, reservoir replenishment), **direct potable reuse** (extensive advanced treatment of municipal wastewater beyond conventional secondary and tertiary treatment directly into a water distribution system).

Chapter 7 provides examples of typical water-quality requirements for different uses.

Inter-sector collaboration for water reuse can respond both to water-risk exposure of a company and to water-risk sharing with other users in a watershed. Both dimensions are key to consider in developing appropriate strategic responses to corporate water risk over the long term[11].

[11] Kölbel, J., Fedotova, T. and Billstrand, J. (2016). *Realizing Water Stewardship: A simple framework for a complex journey*. Available upon request.

3 Regulatory framework

Regulatory frameworks can be important drivers but also significant barriers in reducing, reusing and recycling water.

In 2007, Footitt et al.[12] reviewed measures to control water consumption in European Union member states. Measures ranged from increasing efficiency and applying economic instruments to restricting use. In the last couple of years, reusing and recycling water has begun to be acknowledged and embedded in European and national strategies[13]. These strategies set out water-quality guidelines, standards and regulatory frameworks for different uses and geographical regions.

In December 2015, the European Commission presented a Circular Economy Action Plan[14]. The package of actions promotes further development of water reuse and recycling in the European Union. The focus is on overcoming barriers to water reuse and recycling wherever it is cost-efficient, and safe for human health and the environment. The action plan for water reuse aims for integrated water planning and management, water reuse in irrigation and aquifer recharge, water reuse in industrial activities, research and innovation in water reuse, and allocating European Union funds for investing in water reuse[15]. The plan also addresses the need for water-quality guidelines.

UN-Water, in collaboration with the International Water Association (IWA) and the United Nations Environment Programme (UNEP), addresses water-quality guidelines in the *Compendium of Water Quality Regulatory Frameworks*, which brings together standards and guidelines for managing water quality. The compendium is a living document that is continuously updated with information about policies, and legal instruments and their implementation[16].

The compendium is a useful reference on laws and policies regulating water quality for different uses at a variety of geographical scales. The information it provides constitutes useful guidance to ensuring water quality is fit-for-purpose.

The compendium provides a means whereby countries can make water-quality regulatory frameworks related to water reuse widely available. Global guidelines referring to water reuse are limited. In general, it is the regional and local frameworks that provide guidance on water quality for different uses. Nevertheless, global guidelines would be conducive to achieving coherence between sectors and geographical regions. At a global level, the World Health Organization sets standards for the quality of drinking water[17] and safe use of wastewater for agriculture irrigation and aquifer recharge[18]. However, no specific regulations for water reuse are available yet.

The overviews of how some European countries, India, Australia, the United States, and the United Arab Emirates address and regulate water reuse (**Figures 2–5**) are based on a literature search and information provided by local practitioners. They highlight differences rather than providing a comprehensive picture of existing regulatory frameworks.

The nature of regulation and extent to which it is encouraged depend on the specific region and country. The main drivers for regulating water reuse are water scarcity and the need to manage demand.

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[12] Footitt, A., McKenzie, M., Kristensen, P., Leipprand, A., Dworak, T., Wilby, R., Huntingdon, J., van Minnen, J. and Swart, R. (2007). *Climate change and water adaptation issues.* ISBN 978-92-9167-917-1.
[13] European Commission. (2016). *Water Reuse – Background and policy context.*
[14] European Commission. (2015). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. *Closing the Loop – An EU Action Plan for the Circular Economy.*
[15] European Commission. (2016). *Water Reuse – An Action Plan within the circular economy.*
[16] UN Water. (2015). *Compendium of Water Quality Regulatory Frameworks: Which Water for Which Use?*
[17] World Health Organization. (2011). *Guidelines for Drinking-water Quality. Fourth Edition.*
[18] World Health Organization and United Nations Environment Programme. (2006.) *WHO Guidelines for the Safe Use of Wastewater, Excreta and Greywater. Volume 1. Policy and Regulatory Aspects.*

Figure 2. Regulations and practices concerning water reuse in four European countries

United Kingdom

- Environmental Permitting Regulations require demonstrating best available technique (BAT) which includes water efficiency.
- Regulations with respect to water quality are captured in Water Supply – Water Quality and Water Fittings regulations.
- Water reuse is stipulated but no targets are set.

The Netherlands

- No specific legislation available on water reuse.
- Water prices are low.
- No active push for water reuse unless specified by the individual companies.

Spain

- First draft National Plan for Water Reuse published in 2010 and Guidelines on Reuse of Treated Wastewater in 2007.
- Goal was to increase reuse from 450 million m^3 in 2007 to 1.2 billion m^3 in 2015. Actual application was only 300 million m^3 in 2015.
- Water reuse is seen as expensive.

Poland

- Environmental law refers to 'adequate use of the environment'.
- No specific legislation available on water reuse.
- Only corporate requirements in place.
- Water prices are low.

Figure 3. Regulations and practices concerning water reuse in India and Australia

India

- Water reuse is regulated through the direction under section 18 (1) of the Water Prevention and Control of Pollution Act.
- Guidelines on techno-economic feasibility of implementation of Zero Liquid Discharge regulation for water polluting industries are available.
- Water reuse is required since any new expansion needs to consider zero liquid discharge.

Australia

- State Water Plan 2007 regulates water reuse.
- The water quality is regulated through National Water Quality Management Strategy Australian Guidelines for Water Recycling.
- Water recycling target is 30% of all wastewater by 2030.
- There is a need for water reuse/recycling since it is predicted that the demand will increase by 40% while it is already facing water stress.

Figure 4. Regulations and practices concerning water reuse in the United States

United States

- Regulations for water reuse are created at the state level, supported by two federal agencies: US Environmental Protection agency (USEPA) and the Bureau of Reclamation (USDOI).
- In the US Senate, the Committee on Energy and Natural Resources is responsible for federal laws governing water reuse.
- Rules to regulate and promote water reuse vary by state.
- Many states do not yet have regulations in place to allow for direct potable reuse.
- There are no targets around reuse.

Figure 5. Regulations and practices concerning water reuse in the United Arab Emirates

United Arab Emirates

- Collaboration between eight government agencies working under the Permanent Committee for Setting and Implementing Water and Agricultural Strategies in the Emirate of Abu Dhabi to preserve water resources.
- Regulation & Supervision Bureau has issued criteria for guidance on reuse (first step in direction of establishing legislation).
- About 60% of treated sewage effluent is used for landscaping irrigation.

As well as countries and regions, certain sectors apply water-quality, water-use and water-reuse regulations. Health and safety regulations, in the food and beverage sector for example, limit the possibilities for water reuse. Companies need to set standards for quality and management systems that do not conflict with local or regional regulations.

In general, industries and water users look for guidance on water-quality standards for different applications. Although the need for guidance is recognized by, for instance, the European Union, currently none is available. **Chapter 6** provides an overview of typical water-quality standards and how they may be applied.

4 Barriers to circular water management

In interviews with 25 people from 16 WBCSD member companies, the barriers to water reduction, reuse and recycling most frequently mentioned were:

1. Regulation and water quality
2. Resources (costs, value and human resources)
3. Lack of awareness
4. Lack of dialogue.

4.1 Regulation and water quality

Regulation can be a barrier to water reuse. Rules would need to change to enable a circular approach to water management. For example, in most cases, direct use of wastewater in producing consumer goods is currently banned. Likewise, reducing water use risks breaking regulations on the maximum concentrations of certain substances in effluents.

Another barrier frequently experienced is that people do not have confidence in the regulations specifying the quality of water from treated effluent. Negative public reactions to reusing and recycling water stem from a lack of knowledge, and cultural and religious beliefs. Public perceptions impact brand reputations and product sales (e.g., using purified wastewater to wash beverage containers). **Chapter 5** provides examples of best practices in complying with regulations and **Chapter 7** lists technologies for treating wastewater for various uses.

4.2 Resources

Achieving a return on investment (ROI) can be a barrier. Low prices for water and high infrastructure costs, or a combination of these factors, make it difficult to achieve a ROI in projects related to circular water management. The costs, economics and value (monetization) of reusing water can be barriers at several stages. **Figure 6**, from the Natural Capital Protocol[19], illustrates the costs and value of water. The Natural Capital Protocol is a framework for identifying, measuring (e.g., amounts, extent) and valuing (e.g., relative importance, worth) the direct and indirect impacts (negative or positive) on business activity and dependencies (reliance) of businesses on natural capital. In this Business Guide, the focus is on water as part of natural capital.

Understanding the true costs of water in business processes is fundamental to successfully reducing water use, reusing and recycling water. Taking the value of water and water risks into consideration increases the likelihood of success. Monetizing water as a resource for other users makes projects to recycle water more viable. **Chapter 8**, dealing with project economics, provides a detailed evaluation of opportunities.

Location with respect to a local water supply (upstream/downstream) affects the cost of water. **Figure 6** illustrates the interactions of water users with each other and with a company. When a company is one of the top water users drawing from a local water supply, water becomes an important issue to take into account when assessing the costs of water.

The costs of human resources and infrastructure may also be barriers:

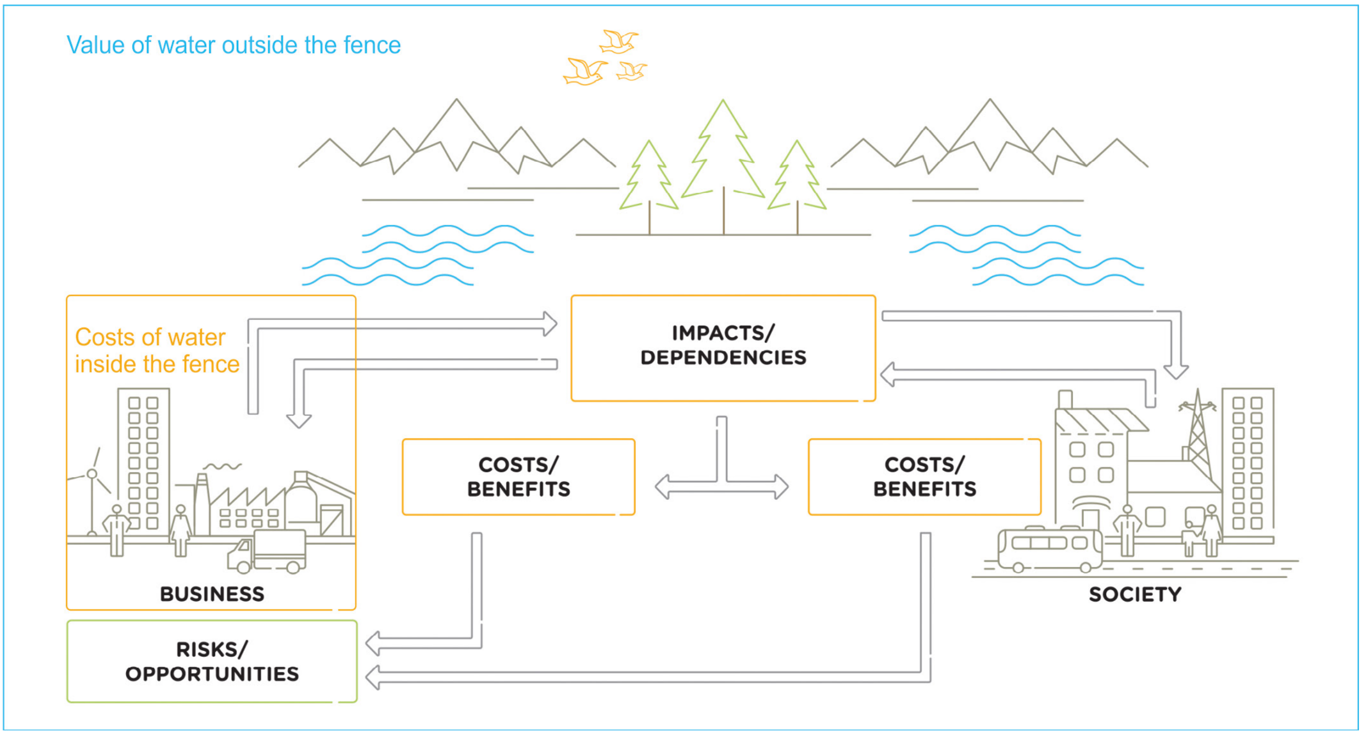
- Cost of infrastructure to reduce, reuse and recycle water
- Cost of operational controls to optimize water conservation
- Cost of maintenance of or changes in operations to sustain water reductions
- Cost of implementation and follow-up (including regulatory).

4.3 Lack of awareness

Lack of awareness can also be a barrier and can lead to missed opportunities. Building awareness on site of the benefits of reusing water, especially in water-scarce areas, is important. However, proposals to reduce, reuse and recycle water typically face conflicting priorities and resistance from key personnel, stakeholders and

[19] Natural Capital Protocol. (2016).

Figure 6. Costs of water inside the fence, value of water outside the fence (including externalities), based on the impacts and dependencies of water. Source: Natural Capital Protocol



decision-makers. A lack of data showing the need and opportunities to reduce, reuse and recycle water often makes this barrier more difficult to overcome.

Identifying the value of water can help establish the importance of water to a business.

Most company water strategies, often regarded as 'just another environmental sustainability scheme', are modeled on energy strategies. However, energy strategies overlook the fact that water is always a local matter, whereas energy is a global issue (greenhouse gas emissions). Risks related to water are linked to local water availability, local water quality and local stakeholders with a claim on local freshwater resources. The challenge is to raise awareness of water risks at all levels in an organization.

Raising awareness of the need to reduce, reuse and recycle water throughout an organization requires a knowledge of the barriers and drivers at each level. **Chapter 5** presents tools to raise awareness at corporate and site levels. The case studies describe opportunities for raising awareness of the value of reducing water use, and for reusing and recycling water.

4.4 Lack of dialogue

A lack of dialogue can be another barrier. Depending on the issue, collective action by local stakeholders might be required. Providing support to start a dialogue on a circular approach to water can help raise awareness of the need to reduce, reuse and recycle water both inside and outside the fence. Stakeholders and governance are important aspects of successful collaboration at the watershed level. Several reports[20 21 22] touch on the following principles for engagement and governance:

- The decision-making approach (stakeholder analysis)
- Clear goals, commitment and responsibilities
- Access to information, data and capacity
- Buy-in and agreement, learning, adjustment and improvement
- Legal, regulatory and policy frameworks
- Delivery of outcomes.

Chapter 5 provides guidance on how to implement collective action at watershed level based on best practices drawn from case studies.

[20] World Business Council for Sustainable Development. (2013). *Sharing water: Engaging Business.*
[21] The CEO Water Mandate. (2013). *Guide to Water-Related Collective Action.*
[22] Organisation for Economic Co-operation and Development. (2015). *Stakeholder Engagement for Inclusive Water Governance.* OECD Studies on Water. Paris: OECD Publishing.

Case study: **BP Australia**
Collective commitment overcomes financing barrier
Sector: **Oil and gas sector**

Although the BP refinery in Western Australia significantly reduced its demand for water, it still relied to a large extent on potable water. BP worked with the Water Corporation of Western Australia, the potable water supplier of most of the water for the refinery for drinking and industrial use, the local regulator, the Government of Western Australia and a number of companies to develop an alternative source of water for industrial use. The Kwinana Water Reclamation Project (KWRP) treats municipal wastewater for industrial purposes, reducing the demand for potable water from six industries.

One of the barriers to overcome was financing for pipelines and for a tertiary treatment plant to make the water suitable for industrial use. Between them, the industrial partners, the Water Corporation, and the Government of Western Australia agreed to finance the project, collectively committing to securing long-term water supplies and environmental sustainability over short-term financial gain. The treated water initially came at a significant premium of around 20% compared to the potable water it replaced. However, to meet long-term water security goals, the Government of Western Australia underwrote a discount on the price of the reclaimed water.

4.5 Overcoming barriers

The following chapters provide practical guidelines for overcoming these barriers. Theory and case studies show how barriers can be overcome, and refer to tools and technologies for implementing solutions. **Figure 7** shows the main barriers to circular water management and the 5Rs.

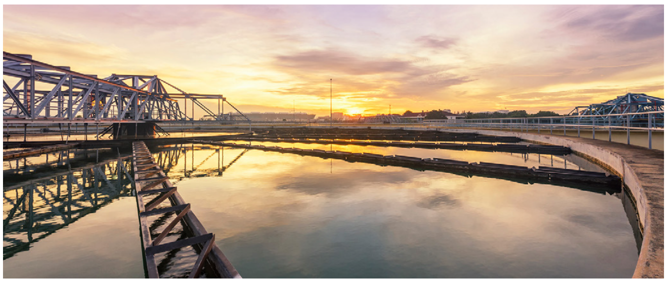
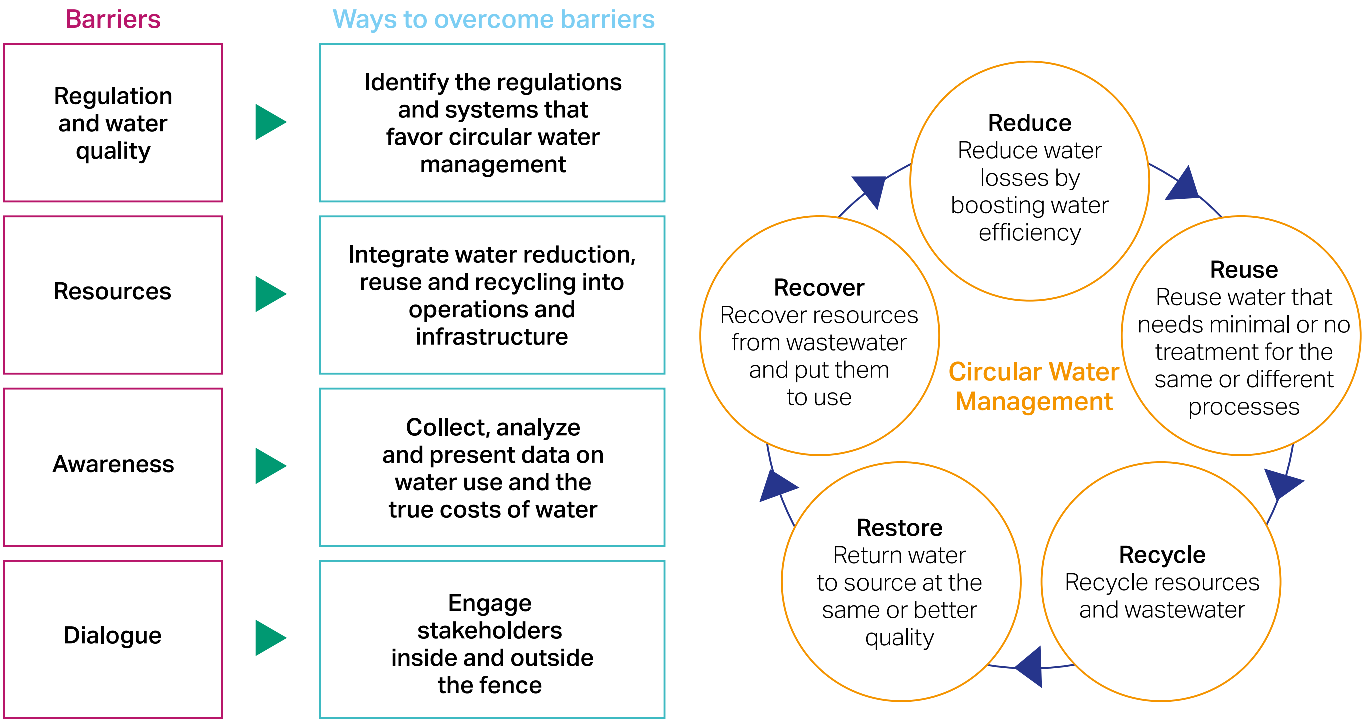


Figure 7. Barriers to circular water management and ways to overcome them



5 Drivers, key success factors and solutions

Identifying the drivers for circular water management is the first step in starting a conversation within a company. Conversations on the drivers help to create an enabling environment for the 5Rs approach to reducing, reusing and recycling water.

The questions that businesses need to ask are:

1. Is there enough water for the business to operate (now and in the future) and grow?
2. Do suppliers have enough water to operate and grow?
3. Is the license to operate secure if water is scarce?
4. Is productivity impacted by lack of access to safe water, sanitation and hygiene by employees?
5. Do customers have enough water to use products?
6. Is access to capital and insurance secure?

The tables in **Section 5.3** indicate barriers that may be encountered in reducing water use, and in reusing and recycling water, and describe solutions companies have developed to overcome barriers.

5.1 Drivers

Analysis of company case studies and a literature review identified the following main drivers for recycling water.

Emerging regulatory frameworks

- **Regulatory compliance (site level):** Some authorities are encouraging water reuse (e.g., India and Australia) through regulations requiring zero liquid discharge (ZLD). By optimizing their use of water and anticipating regulations, companies can maintain operations.
- **Internal compliance (corporate level, site level):** The global strategies of many companies set internal standards reflecting emerging issues (regulatory and social responsibility).

Risks to water supplies (now and in the future)

- **Securing license to operate (corporate, site):** Recycled water is an independent, secure resource that can replace or reduce the freshwater input needed for operations and can be used in several ways, for example, for cooling tower make-up water and boiler feed. Thus, recycled water reduces business risks associated with a lack of available water and strengthens resilience to disruptions in supplies (e.g., droughts) caused by climate change or geographical conditions (e.g., water scarcity). Using wastewater can minimize or eliminate the need to dispose of effluent. As manufacturing facilities grow, water scarcity is becoming a bigger risk. An increasing demand for water from industry can impact water availability and supply in some regions.
- **Opportunity for growth (site):** By becoming less dependent on a particular water supply, a business has more opportunities for growth. Access to reliable, affordable, appropriate quality water is key to the growth and continuity of industrial operations. Growth may generate more revenue (higher yields and productivity) and provide opportunities to further advance circular water management.
- **Reducing operating risks (corporate, site):** Pressure to shrink water footprints and an increasing awareness of the need to ensure sustainable water resources systems are drivers for industries to reduce operating risks by developing sustainable operations.

Costs and resources

- **Significant savings (site):** Reducing water use results in savings in energy and chemicals, and can reduce effluent discharge fees.

Corporate policy

- **Reputation enhancement (corporate, site):** It is important for businesses to maintain their reputation as responsible water users. By reducing their water footprints and enhancing collaboration with stakeholders at watershed level, communities and other water users may benefit. A reputation for responsible water use can indirectly enhance brand value and increase revenues or act as a differentiator between similar players in the industry.

Identifying the drivers for recycling water is the first step in the decision tree presented in **Chapter 8**. The decision tree takes businesses through the steps in evaluating the applicability of recycling water in their operations.

Case study: **Procter & Gamble (P&G)**
Recycling wastewater relieves water stress in China
Sector: **Consumer goods**

A P&G factory in a water-stressed region of China faced the challenge of needing to increase cleaning and sanitization washouts while at the same time reducing water use. In order to address this challenge, the approach was to optimize water use during product production and increase the amount of water recycled. The specific solutions were to treat washwater by dissolved air flotation (DAF), in biological tanks, by filtration and by reverse osmosis (RO) filtration. The wastewater RO permeate is sent directly to utilities (mainly cooling towers), while the wastewater RO concentrate goes into a mechanical vapor recompression evaporator to create condensate that is then used to run on-site utility systems. A storage tank balances the water streams. Optimizing the core production process by treating the washwater saved 40,000 m³ of water a year and using recycled water saved an additional 20,000 m³/year.

5.2 Key success factors

Input from WBCSD members and the results of an analysis of case studies identified key success factors in reducing, reusing and recycling water (see **Figure 8**).

5.2.1 Company culture and leadership

The support of top management is the primary factor in success. Effective communication with internal and external stakeholders, and convincing them of the need for recycling water, are also essential for the success of projects to reduce, reuse and recycle water.

5.2.2 Integration into project approach

Integrating circular water management (5Rs approach) and sustainability in the early phase of a project is also important. At that stage, all variables are open and sustainability-related changes can be incorporated in the most profitable way. Flexibility in considering alternatives is a starting point for securing a high return on investment (ROI) and minimizing operational expenditure (OPEX). Sustainability starts at the conceptual stage of a project rather than being an add-on to the design at the end. For example, from the start, a wastewater plant can be designed as a treatment facility for recycling water, or provided with bolt-on connections for future advanced effluent treatment modules.

5.2.3 Changing mindsets on the value of wastewater

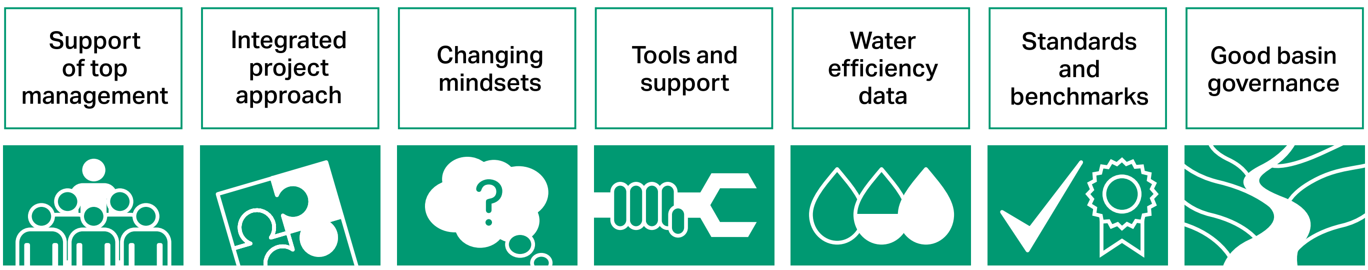
Success also lies in changing perceptions about the value of wastewater and water economics. Concerns regarding cost, value and human resources need to be replaced by recognizing potential value, savings and revenues. Recovering product energy and chemicals from wastewater also creates value.

5.2.4 Tools and support for monitoring performance

Due diligence in monitoring water-use-related performance at an early stage is also a key success factor in realizing effective, sustainable, wastewater recycling.

Tools such as water balances and water maps help in making decisions and designing systems. Key performance indicators support decision-making and deciding priorities by providing insights on the links between water and process economics. It is important to be aware of the existing water footprint, to recognize it and to act on it. It is also important to disseminate performance data both internally and externally.

Figure 8. Key success factors in reducing, reusing and recycling water



5.2.5 Benchmark fit-for-purpose technology

A critical factor of success is choosing a treatment that delivers water of a quality appropriate for the purpose for which it is to be used. Recycling projects need to adopt fit-for-purpose treatment guidelines. This means guidelines specifying the quality of water for each type of use and the technology mix that would achieve:

- Segregating wastewater streams and applying different treatments that meet the quality required for end uses
- Navigating regulations that specify fit-for-purpose water quality, support resource recovery and provide incentives to deploy technologies
- Efficiently using water and treating effluent effectively.

5.2.6 Good basin governance

Various users share regional water supplies. Industry is one of many users who depend on the same sources of water. Therefore, industry also shares the responsibility for protecting water resources. This means industries need to consider other users' objectives when evaluating where to retrieve water from a basin and when investigating sinks for recycled water (e.g., feeding recycled water into a river, reservoir or groundwater aquifer).

Good basin governance is only possible when good relationships have been established, for example with water boards and water companies. The knowledge and insights of other users regarding the water balance in a basin will help in developing a well-thought-out plan for local water management.

5.3 Solutions to barriers

The following tables present ways of overcoming barriers drawn from case studies described in **Appendix A**. The following barriers are discussed:

1. Regulatory and water quality
2. Resources (costs, value and human resources)
3. Lack of awareness
4. Lack of supporting dialogue.

5.3.1 Regulatory and water-quality barriers

Barriers in this category concern the regulatory requirements for the quality of effluent and public perceptions of reclaimed water. Gaining approval by a local regulatory agency for process changes related to water that affect the quality of a final product may also be a barrier.

Table 1. Regulatory and water-quality barriers to reducing water use, and reusing and recycling water

Regulatory and quality barriers

BARRIER	OVERCOMING BARRIERS	COMPANY APPLICATIONS (CASE STUDY #)*
Water quality does not meet process needs	• Understand the specific water-quality needs and determine whether the proposed project will pose a risk to the water quality required by the process. • Evaluate or draft a standard operating procedure (SOP) that specifies concentration limits for influent water. • Check whether there is expertise at other sites that can be leveraged to work on water-quality issues.	EDF Group (1) P&G (17, 18) Birla Cellulosic Kharach (BCK) (19)
Regulatory barriers to process change	• Incorporate the cost of the process change into the overall project capital expense (CAPEX) when developing a business case. • Understand the exact requirements of the regulating agency.	Nestlé (11) P&G (17, 18)
Water reduction will create regulatory risk for concentration-based effluent limits	• Negotiate with regulators to move away from concentration-based discharge requirements. Show the environmental community that the benefits outweigh the challenges of modifying permits. • Participate in the regulatory process to ensure that business concerns are considered. • Maintain a good relationship with the regulating agency to position the business to negotiate permit changes on effluent constituent levels that accommodate water conservation concerns.	Nestlé (9) P&G (17, 18)
Negative public reaction could impact branding and product sales (e.g., using purified wastewater to wash beverage containers)	• Confirm the exact specifications for water quality for the specific use and continuously monitor water quality to confirm that quality is maintained. • Discuss with marketing and sustainability leadership. Can this be branded or marketed in a favorable way? • Implement less controversial projects first.	
The project involves a technology that generates waste and residual streams. Handling residuals is a challenge (e.g., reverse osmosis brine)	• Clearly articulate the business case. Make stakeholders and decision-makers aware of the financial viability of the project (i.e., smart business not philanthropy). • [If barriers are with regulators.] Will the project increase the daily mass load from the plant? If not, consider opening a dialogue with the permitting agency to request a switch to mass-based limits. • Identify an alternative use for the waste stream (e.g., reverse osmosis (RO) reject can be used as cooling tower make-up).	P&G (17, 18)

* Case study numbers refer to the case studies in Appendix A, Table A.1

The below case study from Procter & Gamble (P&G), 'Towards 100% recycling of water and surfactants from washwater', describes measures that overcame regulatory and quality barriers transforming them into drivers for recycling.

Case study: **Procter & Gamble (P&G)**
Towards 100% recycling of water and surfactants from washwater
Sector: **Consumer goods**

Barrier: **The more water-efficient a site becomes, the more concentrated the wastewater and the more difficult and expensive it is to treat.**

Solution: *Recycle water and chemicals contained within the washwater.* **The washwater streams are a mixture of water and product. After investigating three innovation pathways, the final solution uses membrane technology to extract the raw materials (mainly surfactants) from the washwater thereby splitting the washwater into a water fraction and a concentrate. The concentrate is a mixture of surfactants and other raw materials and can be recycled for a variety of applications (e.g., low-grade surfactants for industrial use). The water stream is treated to legal discharge requirements or, ideally, for reuse in the production process after additional polishing.**

5.3.2 Resource barriers

Resource barriers such as a lack of ROI, a lack of infrastructure and insufficient human resources can build resistance to circular water management projects. Barriers related to resources also include inadequate business cases due to incomplete valuation of water. Water is a free or low-cost resource most of the time, which often makes water projects a low priority compared to other projects.

Table 2. Resource barriers to reducing water use, and reusing and recycling water

Lack of resources (funds, infrastructure, human resources)

BARRIER	OVERCOMING BARRIERS	COMPANY APPLICATIONS (CASE STUDY #)*
No funding for water reduction Or The return on investment (ROI) is too low	• Ensure evaluation takes account of the full cost of water. • Build a case around non-financial benefits (public perception, risk avoidance, benefits to community from reducing water use). • Consider developing an alternative ROI that reflects the intrinsic value and business risks associated with water. • Investigate whether there are government grants that could be leveraged.	Vale (2) EDF Group (3, 8, 14) P&G (4) L'Oréal (5, 6, 7, 16) Birla Cellulosic Kharach (BCK) (20, 21) Nestlé (22)
Lack of corporate infrastructure to reuse water	• Benchmark competitors to justify a culture of sustainability. • Identify personnel performance metrics that incentivize sustainable practices.	L'Oréal (5)
Lack of operational controls to optimize water conservation	• Develop specifications for operating equipment that incorporate controls. • Benchmark similar operations to identify and justify the most effective control strategies.	P&G (17)
Inability to sustain water reductions through lack of maintenance or change in operations	• Incorporate water use and conservation into commissioning practices. • Automate maintenance systems to ensure regular essential maintenance. Add maintenance to processes to ensure correct, water-efficient operations.	L'Oréal (5)
Lack of implementation and follow-up	• If not already part of business operations, implement a formal post-verification program for all water projects to confirm that they have met performance expectations. • Incorporate water savings from projects into future plant budgets.	EDF Group (3, 8, 14)

* Case study numbers refer to the case studies in Appendix A, Table A.1

No single case study addresses all the barriers stemming from lack of resources. However, a L'Oréal case study, 'Growing from reduction to recycling', shows how a global approach can encourage change at local level.

Case study: **L'Oréal**
Growing from reduction to recycling
Sector: **Cosmetics**

Barrier: **Water in cosmetic factories is mainly used in cleaning production equipment, which may account for 20%–70% of total consumption. L'Oréal uses mainly potable urban water for utilities. The group set an ambitious target of reducing total water consumption by 60% per finished cosmetic product by 2020 as measured from a 2005 baseline of water withdrawal in factories and distribution centers.**

Solution: **Following a program to reduce water use by optimizing production processes, L'Oréal is developing several projects to recycle wastewater. By the end of 2015, 10 projects were in place: in Karlsruhe (Germany), Rambouillet (France), Aulnay (France), Libramont (Belgium), Burgos (Spain), Settimo (Italy), Istanbul (Turkey), Pune (India), Suzhou (China) and Montreal (Canada). Projects involve further treatment of wastewater discharged from wastewater treatment plants to bring it up to the Group's quality standards, mainly using membrane technologies. The treated wastewater is then used to wash manufacturing tools and in cooling processes. Depending on site needs, up to 60% of all freshwater for utilities could be replaced by recycled water. The plan is now to implement similar measures at a number of other sites and to include the measures in the Group's industrial standards.**

5.3.3 Lack of awareness barriers

Lack of awareness can delay water-saving and recycling projects, and can even prevent them from getting off the ground. To raise awareness, water-use data and the costs of water for the entire process chain need to be collected, evaluated and presented to those responsible for making decisions. The costs of water – of energy to move water, of labor to operate water systems, of water for heating and cooling – need to be taken into account because they are often not recognized. Opportunities to reduce demand for water and to recycle water are thus overlooked because its costs are understated.

Table 3. Awareness barriers in reducing water use, and reusing and recycling water

Lack of awareness (perception, culture)

BARRIER	OVERCOMING BARRIERS	COMPANY APPLICATIONS (CASE STUDY #)*
Difficulty getting support because water is considered to be 'cheap' by decision-makers or key site personnel	• Develop charts of total water use or weighted water use (e.g., gallons of water per product made) showing where a site ranks in the business relative to other sites. Site leaders generally do not want their site to be an outlier on the high side. • Consider performing a total cost analysis. • Build a case around non-financial benefits (public perception, risk avoidance, community benefits from reduced water usage by facility, etc.).	EDF Group (1) Heidelberg (12) Shell (15)
Change in priority/not a priority	• Obtain high-level support for making the project a priority within the company or site.	Shell (15)
Resistance to change by key personnel, stakeholders or decision-makers	• Understand and address the concerns being raised. • Establish recognition awards (either at site level or for individual personnel). • Develop a business case to convey the financial value of the project.	
Misunderstanding of regional water supply and demand	• Use local information to calibrate water-stress models. • Participate in local water boards. • Incorporate regional water stresses in the business case. • Develop forecasts of the impact of water stress on the site.	
Lack of data	• Incorporate water meters into pre-planning and design. • Develop global or site strategies for installing water meters for new equipment that uses water. • Integrate water meters into data gathering systems (e.g., electronic data, operator log sheets, etc.).	

* Case study numbers refer to the case studies in Appendix A, Table A.1

"Opportunities to reduce demand for water and to recycle water are often overlooked because its costs are understated."

5.3.4 Lack of supporting dialogue barriers

Providing support for dialogue on recycling water and circular thinking is important to raise awareness both inside and outside the fence. **Table 4** suggests tactics for overcoming the lack of a supporting dialogue and engaging in collaboration at watershed level.

Table 4. Dialogue barriers in reducing water use, and reusing and recycling water

Lack of supporting dialogue

BARRIER	OVERCOMING BARRIERS	COMPANY APPLICATIONS (CASE STUDY #)*
Lack of stakeholder engagement	• Establish open dialogue and ensure stakeholders have the same end-goal in mind.	ENGIE (10) EDF Group (13) Shell (15) BP (23)
Misunderstandings about regional water supply	• Develop a regional water balance and identify water use on site. • Showcase opportunities for reusing water outside the fence.	Shell (15) EDF Group (13)

* Case study numbers refer to the case studies in Appendix A, Table A.1

No single case study addresses all or most of the barriers stemming from a lack of dialogue. However, an Electricité de France (EDF) Group case study shows how stakeholders working together can overcome these barriers and lead to water recycling locally.

Case study: **Electricité de France (EDF) Group**
An open dialogue with neighboring companies creates opportunities
Sector: **Energy production**

Barrier: **Electricité de France (EDF) Group uses hot water generated by a thermal power plant to heat a greenhouse for tropical plants. On one side of a road is Edison Candela's combined cycle gas turbine power station. On the other side are 90 hectares of greenhouses owned by Ciccolella, the world's largest grower of the tropical flower Anthurium. The win-win partnership conserves water, a scarce resource in the Italian region of Puglia.**

Solution: **The agreement between Edison and Ciccolella is simple: the hot water produced by the power station is used to heat greenhouses. In the mountainous region of Puglia, heating greenhouses is important as winters are bitter. The flower producer receives 20,000 m^3 of 37°C water an hour to run a heating system. Edison, in return, receives water cooled to 30°C to reinject into its steam production system. The sensible reuse of water is a win-win for all, and there are no CO_2 emissions. The total investment for Ciccolella was EUR 200 million but the grower buys hot water from Edison at a preferential rate, which helps minimize the risk of investment.**

6 Tools

6.1 Overview

Tools can provide useful information to build a business case and overcome barriers. However, given the variety of available tools, selecting the right fit-for-purpose tool can be a challenge. Researchers and institutes are working to provide an overview of the tools available, an effort which is ongoing as tools are constantly evolving. This chapter summarizes the range of tools described in reports such as the WBCSD *Water for Business* and the International Union for Conservation of Nature (IUCN) *Water Management and Stewardship*.

Figure 9 provides an overview of frequently used tools, discussion papers and general guidance that can help understand water-related risks, impacts and opportunities to overcome barriers related to reusing and recycling water, and reducing water use. This is not an exhaustive list of all the tools available. The purpose of this chapter is to provide a starting point for gaining insight into the tools available to address barriers.

WBCSD's *Water for Business Guide Version 3* [23] provides in-depth descriptions of the most commonly used tools.

6.2 User experiences

The most frequently mentioned tools in the case studies were water-balance tools to quantify current water use and identify opportunities for water savings.

Case study: **Procter & Gamble (P&G)**
Global approach, locally customized
Sector: **Fine chemicals**

The global Dry Laundry Team at P&G developed a tool for mapping all water use in dry laundry operations globally. The in-house tool can be customized with site-specific data and by activating/deactivating (if nonexistent) water streams unique to a specific site.

Figure 9. Tools, principles and guidelines to overcome barriers in reducing water use, and in reusing and recycling water

Risk assessment	Regulation and water quality	Resources	Awareness	Dialogue
GEMI Local Water Tool™	WRI Aqueduct	True Cost of Water Tool	WBCSD Global Water Tool	WBCSD Global Water Tool
Water Risk Monetizer		WRI Aqueduct	WFN Assessment Tool	WFN Assessment Tool
WFN Assessment Tool		WWF Water Risk Filter	WRI Aqueduct	OECD Principles on Water Governance
Growing Blue Water Impact Index		WFN Assessment Tool	WWF Water Risk Filter	
WWF Water Risk Filter		BIER 2015 True Cost of Water Toolkit	ISO 14046: Water Footprint – Principles, requirements, and guidelines	
WBCSD Global Water Tool		GEMI Local Water Tool™		
WRI Aqueduct		Water Impact Index		

[23] World Business Council for Sustainable Development. (2012). *Water for Business Guide Version 3.* Download information for these tools can be found in Chapter 13.

Case study: **Grasim Industries Limited, Chemicals Division, Renukoot Chemicals Unit**
Measuring and mapping reveals possibilities for reducing, reusing and recycling water
Sector: **Chemicals**

The Renukoot Chemicals Unit developed a sustainability road map to reduce freshwater consumption by 10% from a 2013–14 baseline and to meet global standards by 2017. The unit began by measuring effluent generated by each plant. Previously, the unit had no meters to measure freshwater consumption in individual process units. Mapping water consumption in terms of effluent quantity and quality showed the potential for saving in each process. The unit created a water-balance tool in Excel to assess water use and the potential for water savings across departments.

"In general, widely accepted assessment tools are used to develop corporate water policies, whereas tools developed in-house are usually used to implement corporate water policies."

"The choice of tool depends on the level of decision-making (operational level, maintenance level or board level), the level of knowledge of water issues and the goal of the assessment."

Case study: **L'Oréal**
Risk-assessment process global manufacturing sites
Sector: **Cosmetics**

L'Oréal uses a broad range of leading risk-assessment tools to comprehensively assess risks. In their yearly risk-assessment process, the World Resources Institute (WRI) Aqueduct and the WBCSD Global Water Tool are used as a first step in screening all manufacturing sites globally to identify those that are located in 'risk' or 'high risk' regions. The sites identified are then evaluated with the World Wildlife Fund for Nature (WWF) Deutsche Investitions- und Entwicklungsgesellschaft (DEG) Water Risk Filter in order to have a better understanding of the risks that facilities are exposed to. This method is also applied to evaluate the sites of strategic suppliers.

L'Oréal uses these methods to identify water-related risks that could have a major impact on cosmetics production at a global level. The significance of each identified risk is considered and relevant action plans are developed to address these risks. At L'Oréal, the strength of using both internal and external methods is leveraged by building on global water-risk understanding while applying it within the specific context of production. The different tools integrate different indicators that reflect quality, quantity and reputational water risk. The focus is on freshwater availability through measuring water-stress and water-scarcity indicators for the regions where manufacturing sites are located, taking into account natural stress factors and the impact of cosmetic industrial activity on water availability. This method allows L'Oréal to cover more regions and to get a better picture of local situations in terms of the severity and timeframes of water stress, thereby identifying critical hotspots.

Another example of user experience can be found in *Managing Water-Related Business Risks & Opportunities in the Beverage Sector*, a report published by the Beverage Industry Environmental Roundtable (BIER) in 2012[24].

[24] Beverage Industry Environmental Roundtable. (2012). *Managing Water-Related Business Risks & Opportunities in the Beverage Sector.* Beverage Industry Environmental Roundtable (BIER).

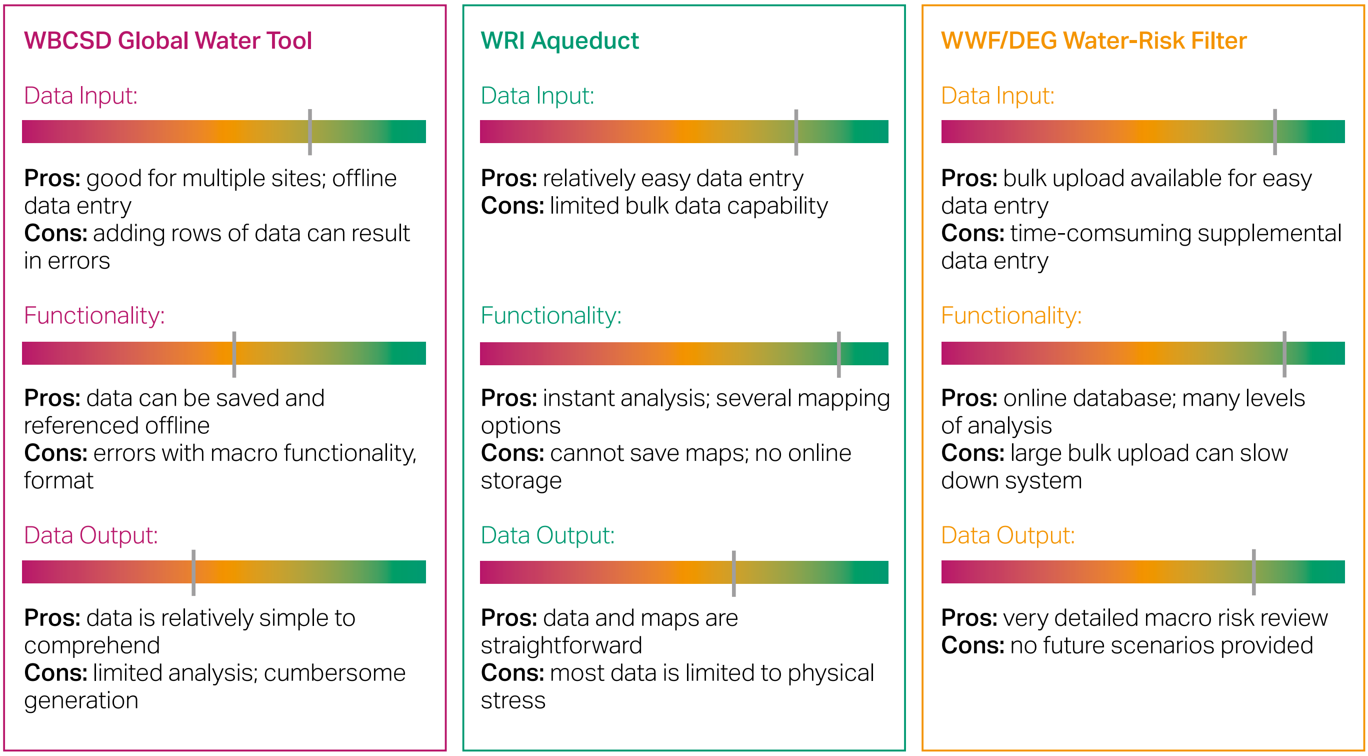
Case study: Beverage Industry Environmental Roundtable (BIER)
Managing Water-Related Business Risks & Opportunities in the Beverage Sector
Sector: **Consumer goods**

The Beverage Industry Environmental Roundtable (BIER) surveyed member experiences of tools for assessing water risks and opportunities in 2012. The results of the survey identified 'go-to' tools for BIER members. These were summarized by a dashboard capturing the ease of data-input, functionality of the tool and the user friendliness of the data output. The example that follows compares results from the WBCSD Global Water Tool, World Resources Institute (WRI) Aqueduct and World Wildlife Fund for Nature (WWF) Deutsche Investitions- und Entwicklungsgesellschaft (DEG) Water Risk Filter.

Tools can support growth in a company's understanding of freshwater (quality and quantity) process chains. Corporate or site-level tools can be used or developed as appropriate. In general, widely accepted assessment tools are used to *develop* corporate water policies, whereas tools developed in-house are usually used to *implement* corporate policies. In-house tools draw on local knowledge of water quality used in processes and water challenges within a particular water basin.

The choice of tool depends on the level of decision-making (operational level, maintenance level or board level), the level of knowledge of water issues and the goal of the assessment.

Figure 10. Analysis of three tools for assessing risk and opportunity. Adapted from *Managing Water-Related Business Risks & Opportunities in the Beverage Sector*, 2012, Beverage Industry Environmental Roundtable



7 Technologies

Several technologies for reusing and recycling water have been applied in the last few decades. Common treatment technologies include biological processes, membrane filtration and separation, and chemical oxidation processes – mostly continuous electro-deionization (CEDI), ultra-violet (UV) and ozone-based.

Advanced treatment technologies and their efficiency are discussed in the context of industrial water and recycling (e.g., recycled water for use in a cooling tower). The three main grades of industrial water are:

- **Low-grade** industrial water
- **Intermediate-grade** industrial water
- **High-grade** industrial water.

Table 5 presents typical water-quality parameters for the three grades of water.

Applications for recycled water of different grades differ widely. Recycling treated wastewater in the Food & Beverage sector is much more strictly regulated by legislation and public opinion than in the Oil & Gas sector. However, in general the following applications are possible:

- **Low-grade water**: use of reclaimed water for irrigation, flushing, cleaning (vehicles, non-production floors etc.) and dust control
- **Intermediate-grade water**: use of reclaimed water in cooling towers, as process water and for cleaning
- **High-grade water**: use of reclaimed water as boiler feed, demineralized water (water that has had all minerals, salts and ions removed) and condenser make-up water (water supplied for example to a steam boiler to compensate for loss by evaporation and leakage).

Table 5. Typical water-quality parameters for industrial water

Parameter	Unit	Low-grade	Intermediate-grade	High-grade
pH	–	6–9	6–9	>6
Biological oxygen demand (BOD)	mg/L	10–30	n.s.	n.d.
Chemical oxygen demand (COD)	mg/L	100–150	70–90	<2 mg/L for drinking water and <0.5 mg/L for process water measured as total organic carbon (TOC)
Total nitrogen (TN)	mg/L	10–20	1–5	n.d.
Total phosphorus (TP)	mg/L	1–10	2–5	n.d.
Total suspended solids	mg/L	10–25	5–15	0–1
Total dissolved solids	mg/L	500–2500	100–2500	<1–15
Conductivity	mS/cm	0.75–3.5	0.15–3.5	0.001–0.02
Alkalinity as $CaCO_3$	mg/L	n.s.	40–100	0–50
Calcium hardness as $CaCO_3$	mg/L	n.s.	50–750	1–5
Chlorides	mg/L	50–250	50–250	n.d.
Sulfates	mg/L	n.s.	0.35	n.d.
Iron (Fe)	mg/L	n.s.	0.2	0.01
Silica	mg/L	n.s.	<25	0–1
Dissolved oxygen	mg/L	n.s.	n.s.	<0.005
Fecal coliforms	number/100 mL	0	n.s.	n.s.

Note: mg/L: milligrams/liter; mS/cm: millisiemens/centimeter; mL: milliliter; n.s.: parameters not specified are low due to the treatment applied; n.d.: not detected since parameters must be lower than detection limits.

Figure 11 shows technologies for treating wastewater by sector. **Appendix B** provides detailed descriptions of technologies.

The list of technologies in **Figure 11** shows the effort necessary to achieve a required quality of recycled wastewater in different types of industries. Depending on the technology, the energy required ranges from energy to transport water (free-fall systems to low pumping energy) to energy for evaporating water.

The energy requirement influences the operational expenditure (OPEX) of a technology and, therefore, is one of the barriers to overcome along with chemical consumption.

Figure 11 shows that producing intermediate-grade industrial water requires most effort. Water authorities often demand that water discharged to surface water or into the ground meets intermediate-grade standards.

Figure 11. Overview of typical technologies by industrial sector (CAS: conventional activated sludge; CEDI/IX: continuous electrode ionization/ion exchange; COD: chemical oxygen demand; DAF: dissolved air flotation; GAC: granular activated carbon; SBR: sequence batch reactors; TPI: tilted plate interceptor; TSS: total suspended solids; UV: ultra-violet)

Type of industry	Preliminary treatment	Biological treatment	Low-grade water: indicators (mg/L) **COD** 100–150; **TSS** 10–25; **conductivity** (mS/cm) 0.75–3.5	Tertiary treatment	Salt & mineral removal		Intermediate-grade water: indicators (mg/L) **COD** 70–90; **TSS** 5–15; **conductivity** (mS/cm) 0.15–3.5	Polishing			High-grade water: indicators (mg/L) **COD** n.d.; **TSS** 1–5; **conductivity** (mS/cm) 0.001–0.02
Dairy	Physical/ chemical e.g., DAF	Aerobic treatment e.g., CAS		Ultrafiltration	Evaporation	Reverse osmosis		GAC	UV	Chlorine dioxide	
Food and beverage	Physical/ chemical e.g., DAF	Anaerobic/ aerobic e.g., SBR		Ultrafiltration		Reverse osmosis		UV	CEDI/IX		
Chemicals	Density-driven e.g., oil-water separation	Aerobic treatment e.g., CAS		Sand filtration		Reverse osmosis		CEDI/IX			
Pharmaceuticals and cosmetics	Physical/ chemical e.g., DAF	Aerobic treatment		Ultrafiltration		Reverse osmosis		GA	Ozonation	UV/ H_2O_2	
Pulp and paper		Anaerobic/ aerobic e.g., CAS		Ultrafiltration		Reverse osmosis		GAC	Ozonation		
Mining	Physical/ chemical e.g., coagulation	Constructed wetlands		Ultrafiltration	Reverse osmosis	Crystallization and evaporation		CEDI/IX			
				Ultrafiltration		Reverse osmosis		CEDI/IX			
Oil and gas	Density-driven e.g., TPI	Aerobic treatment e.g., CAS		Sand filtration		Reverse osmosis		CEDI/IX			
	Density-driven e.g., TPI	Constructed wetlands		Ultrafiltration	Reverse osmosis	Crystallization and evaporation		CEDI/IX			
Cement	Physical/ chemical e.g., coagulation			Ultrafiltration	Reverse osmosis	Crystallization and evaporation		CEDI/IX			
Electricity generation	Physical/ chemical e.g., coagulation					Crystallization and evaporation		Organic scavenger	CEDI/IX		
	Physical/ chemical e.g., coagulation			Ultrafiltration	Reverse osmosis			CEDI/IX			

8 Economics of circular water management

Water prices are 'cheap', resulting in a significant barrier to improving the efficient use of water across manufacturing lifecycles. When considering the cost of water throughout the whole water management cycle (intake, storage, transport, various treatments, disposal, energy, chemicals, etc.) then the total cost of water management is very different from the price of water. As a consequence, the return on investment (ROI) is often underestimated and does not justify investment. Evaluations of ROI need to consider (in order of implementation):

1. Costs of water inside the fence, including direct and indirect costs related to the handling of water
2. True value of water inside the fence, which includes taking into account associated risks related to water (e.g., the lack of sufficient water for production)
3. Value of water, all the above including monetization of water by other users in the catchment area.

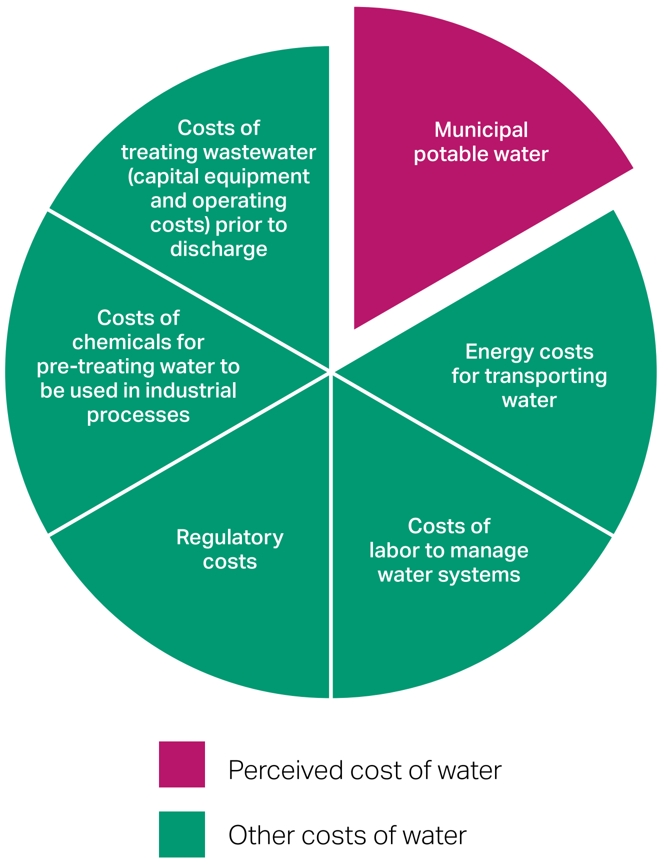
8.1 Costs of water inside the fence

Many companies pay very little for access to plentiful, high quality water. Although the cost of water has increased in recent years, water is still cheap compared to the cost of energy and raw materials. Evaluating the true cost of water is a first, essential step in justifying water reduction, reuse and recycling. Factors that affect the real costs of water include:

- Energy costs for transporting water
- Costs of labor to manage water systems
- Regulatory costs
- The costs of chemicals for pre-treating water to be used in industrial processes
- The costs of treating wastewater (capital equipment and operating costs) prior to discharge.

Companies seldom consider these costs in a holistic manner and, therefore, they underestimate the impact of the cost of water on their businesses. They also miss opportunities to lower operating costs by managing water carefully (**Figure 12**). When total water costs are considered, reducing water use, reusing water or recycling (waste) water become critical business decisions rather than optional voluntary activities.

Figure 12. Perceived and actual costs of water. The pie-chart shows the total actual water costs. The magenta slice of the pie is the perceived cost that most companies take into account when building a business case for water projects. The green slices are the other costs related to water use.



"When total water costs are considered, reducing water use, reusing water or recycling (waste) water become critical business decisions rather than optional voluntary activities."

8.2 True value of water at site level

The value of water for a production site expresses the actual costs and the costs of risks associated with water. Risks can be insufficient water for production, poor product quality as a result of insufficient water quality and regulatory issues related to discharge. Incorporating the costs of risks associated with water in proposals to reduce, reuse and recycle water boosts the potential return on investment (ROI) making those proposals more likely to go ahead.

An example is the Nestlé case study on prioritizing water recycling projects.

Case study: **Nestlé**
Prioritizing water recycling projects
Sector: **Food & Beverage**

Nestlé typically invests a certain amount each year in environmental sustainability (ES) projects. Traditionally, the company has chosen projects with a short payback period. Projects with over a five-year payback are usually not approved. Corporate engineering developed a methodology to evaluate water-saving projects that takes account of environmental and social benefits as well as financial benefits. The method involves applying a 'shadow' or 'notional' cost of water which increases in proportion to water scarcity in the area where a factory is located. This method helps Nestlé identify, prioritize and invest in projects with the most overall benefit.

Nestlé technical management started by accepting that water is undervalued. Water is a critical resource for Nestlé factories. In many cases, the cost of water covered only pumping and water-treatment costs. The engineering department experimented with a base cost of water of around one Swiss franc per cubic meter (~1 CHF/m^3) adjusted for water scarcity. For several years, Nestlé had assessed water risk based on three publicly available water-stress indices (Water Resources Institute Aqueduct, ETH Zurich Pfister Advanced Water-Stress Index, World Wildlife Fund for Nature (WWF) Deutsche Investitions- und Entwicklungsgesellschaft (DEG) Water Risk Filter) which gave a combined water-stress index (CWSI) risk score of between 1 and 5, depending on the availability of water.

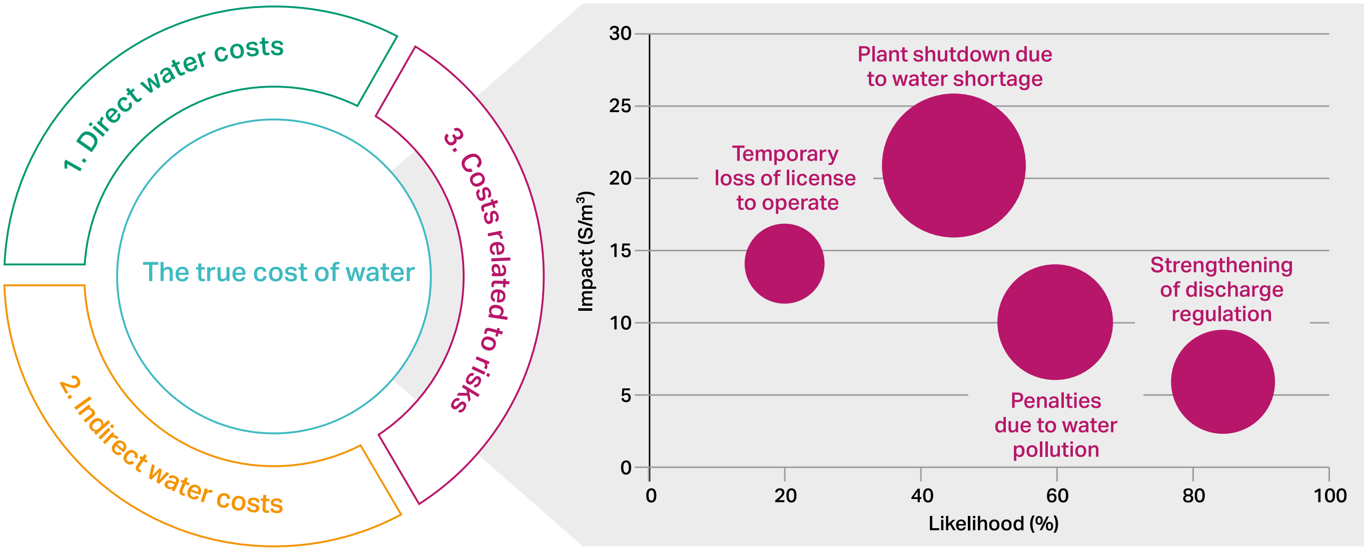
Aqueduct	Pfister	WWF	Normalized score	Water availability
1. Low risk (0–1)	<0.1	0.00–2.99	1	Abundant
2. Low to medium risk (1–2)	0.1–0.2		2	Sufficient
3. Medium risk (2–3)	0.2–0.4	3.00–3.99	3	Stress
4. High risk (3–4)	0.4–0.9	4.00–5.00	4	Scarcity
5. Extremely high risk (4–5)	>0.9		5	Extreme scarcity

Multiplying the base cost by the CWSI score raised the cost of water in areas where there was a high risk of water scarcity. Calculations comparing the locally adjusted 'notional cost' of projects in different locations indicated the payback. The method worked well, favoring water-saving projects in water-scarce areas while still allowing approval of beneficial projects in water-abundant areas.

Nestlé evaluated publicly available tools for calculating local water costs, the Veolia True Cost of Water and Ecolab Water Risk Monetizer (WRM). However, Nestlé felt that these tools did not have advantages over their own method and decided to continue the model based on CWSI.

Nestlé has used the 'notional cost' method for evaluating capital expenditure (CAPEX) in water projects since 2011. During this time, technical managers have approved many projects which would otherwise have been rejected because of a long payback period.

Figure 13. The True Cost of Water tool looks at the financial implications of water-related risks. Adapted from *The True Cost of Water,* 2014, Veolia



The graph represents an example of identified risks during the analysis. Each risk is plotted on a graph based on its probability and potential economic impact.

Besides solutions to quantify risks developed by companies, generic tools have been developed to quantify the value of water inside the fence. The Veolia 'True Cost of Water' tool is an example.

Veolia developed the 'The True Cost of Water', a tool for economic evaluation based on the risks and benefits of reducing, reusing and recycling water[25]. Besides direct and indirect costs, the tool incorporates costs associated with risks (**Figure 13**), specifically risks to operations (e.g., water shortages, flooding), financial and regulatory risks, and risks related to reputation (e.g., temporary loss of license to operate).

8.3 Value of water

Determining the 'value' of water goes further than determining the true cost of water. The concept of value looks at externalities in order to understand and manage impacts and dependencies on natural resources, and the way these impacts and dependencies interact with societies and economies. Water valuation assesses the worth of water to different stakeholders under specific circumstances. The WBCSD *Business Guide to Water Valuation*[26] determines prices, costs and values associated with six water-related dependencies and impacts. At present the methodology is complex and needs to be made more practical. Until then, tools for costing water can be used to evaluate the opportunities for reducing, reusing and recycling water.

"Determining the 'value' of water goes further than determining the true cost of water."

[25] Veolia. (2014). *The True Cost of Water.*
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9 Guidelines for tailor-made business approaches to reducing water use, reusing and recycling water

9.1 Evaluate the applicability of the 5Rs

This chapter summarizes the evaluation criteria required to implement the 5Rs. The first step is to identify one or several drivers for reducing water use, or for reusing or recycling water. Once a driver or drivers have been identified, the options for reducing water use, or reusing or recycling water can be evaluated using the evaluation decision tree (**Figure 14**).

The next step is to find an appropriate 5Rs solution, then to evaluate and tackle barriers (**Chapter 4**). The implementation checklists indicate the requirements for ensuring success.

It is important to take existing and future local water availability into account (amount, water use, outputs, value, political issues) in prioritizing risks. The process for constructing a water strategy depends on a company's management systems. **Section 9.2** describes factors to take into account when deciding the process to follow. The checklists provide guidance on overcoming barriers that may be encountered.

9.2 Evaluation checklists for reducing water use, and for reusing and recycling water

Checklists 1–5 distil keys to success demonstrated in case studies from project experiences and best practices developed by WBCSD members. Companies may use the checklists as an aid to getting started with circular water management and developing initial pilot projects.

9.2.1 Key success factors

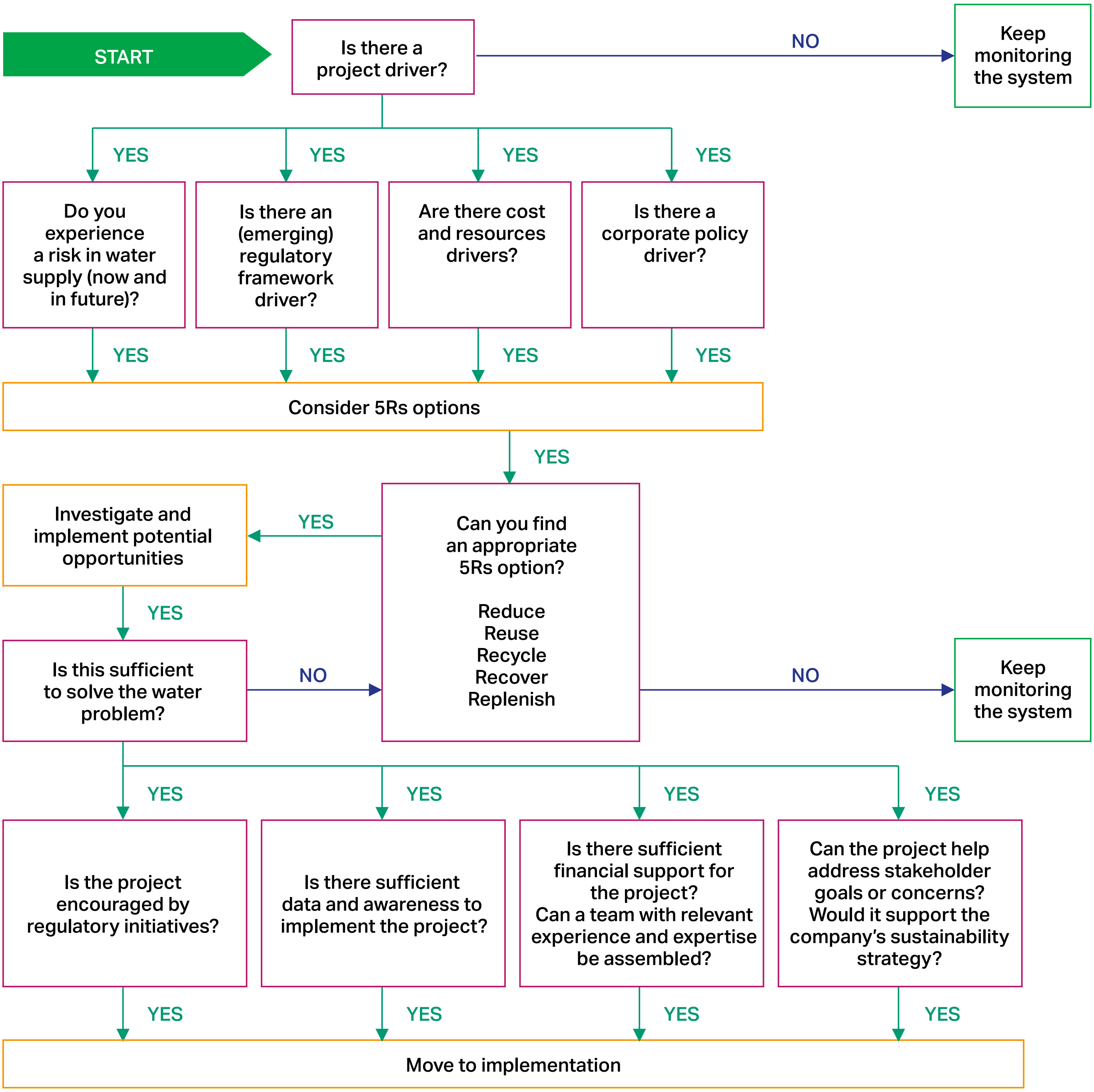
OBJECTIVE The key success factors checklist helps companies to identify whether or not conditions in-house for a project to reduce water use, or to reuse or recycle water are favorable.

Checklist 1. Key success factors checklist for reducing water use, reusing or recycling water

CHECKLIST: KEY SUCCESS FACTORS

- ☐ **Company culture and leadership.** Support of top management gained.
- ☐ **Integrated project approach.** Opportunities for reusing or recycling water and ensuring sustainability integrated in the early phases of the project assessed.
- ☐ **Changing mindset.** Concerns regarding cost, value and human resources replaced by acknowledgment of potential value, savings and revenues.
- ☐ **Tools and support.** Data, such as on water balances and risks, provided by appropriate tools.
- ☐ **Standards and benchmarks.** Operational improvements required for efficient water use in maintenance systems, monitoring equipment, control strategies, and for sharing and transferring knowledge among similar operations set out in standards and benchmarks.
- ☐ **Good basin governance.** Responsibilities of users for the regional water supply determined and guide interaction.

Figure 14. Decision tree to evaluate the applicability of the 5Rs



9.2.2 Implementing water reduction, reuse or recycling

OBJECTIVE The regulatory and quality checklist for implementing a water reduction, reuse or recycling project helps identify the regulations and systems in-house that favor the project.

Checklist 2. Regulatory and quality checklist for reducing water use, reusing or recycling water

CHECKLIST: REGULATORY AND QUALITY

- [ ] **Regulatory system.** Consider existing regulatory framework, fit-for-purpose quality requirements and regulatory risk for concentrated effluents due to water reuse or recycling projects determined. The process of developing the regulatory framework involves engagement with water users.
- [ ] **Enhanced branding.** The potential for promoting the company's capability and investment in protecting water supplies, re-branding the company, for example as a 'Pioneer in Water Reuse', and social and regulatory benefits highlighted.
- [ ] **Technology and alternatives.** Existing technologies and potential alternative uses of waste (e.g., efficient water utilization) and wastewater (e.g., zero discharge) considered.

Checklist 3. Resource checklist for reducing water use, reusing or recycling water

CHECKLIST: RESOURCES

- [ ] **Support of management.** Support of management in place.
- [ ] **Integrated project approach.** Opportunities for integrating water reuse or recycling and sustainability in the early phases of the project assessed.
- [ ] **Return on investment.** Business plan showing the true cost of water, non-financial benefits, water associated business risks, and recognizing and calculating potential funding and grants prepared.
- [ ] **Sustainability infrastructure.** Potential resources and company culture to initiate or strengthen corporate infrastructure to support water reuse or recycling evaluated.
- [ ] **Operational improvement system.** System for improving operations to realize efficient water use through maintenance, monitoring, controls, and sharing and transferring knowledge among similar operations in place.
- [ ] **Monitoring program.** Monitoring program collecting input and data, and assessing outcomes and progress on water reuse or recycling in place.

Checklist 4. Awareness checklist for reducing water use, reusing or recycling water

CHECKLIST: AWARENESS

- [ ] **Water database.** Data collection and monitoring system to facilitate reliable analysis of water issues created and implemented.
- [ ] **Tools.** Data on water issues developed with appropriate tools is a basis for communication and encouraging the sharing the dissemination of experiences.
- [ ] **Increase in awareness.** The entire process chain – key site personnel from leadership to operators – shares a common perception of the value of water and prioritizes water reuse and recycling.
- [ ] **Recognition of water stress.** Operational risks of water stress recognized and acted upon by assessing the impacts of water stress on company operations and participating in existing water platforms.

Checklist 5. Dialogue checklist for reducing water use, reusing or recycling water

CHECKLIST: AWARENESS

- [ ] **Participation in shared water users' platform.** Interactions with other water users in the water basin provide insights on the overall water balance, the impact of the company's water discharge and the company's position on the scale of water use in the basin.
- [ ] **Connections with local water authorities.** Dialogue with the water board, water companies and environmental authorities is helping facilitate water reuse or recycling and is encouraging interest in the resources and knowledge the company has on water treatment.

10 Conclusions

Based on current trends, water demand is projected to exceed sustainable supply by 40% in 2030. Population and economic growth, urbanization, climate change and many other factors are adding pressure to sustainable water supplies. This may lead to competition for water between different users, such as communities, industries, agriculture and tourism. This competition affects the day-to-day operations of companies, and increases both operational risks and costs. At the same time, public authorities are tightening regulations on water discharge and water extraction, making it more difficult for businesses to stay in compliance. More and more, forward-thinking companies are setting internal and external water-efficiency targets.

These trends make a very strong case for widespread adoption of water reduction, reuse and recycling practices, and for a circular approach to water management overall. This Business Guide outlines the why, what and how of circular water management in order to equip companies with tools to begin implementing water reduction, reuse and recycling practices.

An understanding of the **global water cycle** is important for appreciating the rationale for circular water management. The mass of available water on the planet does not change. While water always moves through the same cycle, climate change and the resulting increased temperatures influence the local or regional availability of water and opportunities for water storage.

To manage the impacts of climate change, population growth, urbanization and other trends on the availability of water, **risk-based water management** is critical. The latest evidence shows that water-related risks apply to all sectors of the economy as all sectors rely on water as an input for their working processes. Water-related risks can be mitigated by adopting water management strategies based on the **5Rs approach: water reduction, reuse, recycle, restore water reserves and resource recovery**. Even though there is rapid innovation in water management, there are still few examples of large-scale marketable technologies to apply the 5Rs or collaboration models. This Business Guide addresses some of the barriers in realizing more widespread industry take-up of circular water management.

10.1 Common barriers to a circular approach to water

Barriers to the adoption of water reduction, reuse and recycling practices include:

- **Regulatory and water-quality issues.** Lack of trust in water quality continues to prevail in many industries, in particular in the case of wastewater reuse.
- **Cost of water.** Many businesses rarely account for the true cost and value of water. An understanding of the true cost of water used in a factory and consideration of the value of water to water users outside the company makes projects to reduce, reuse and recycle water more likely to succeed.
- **Lack of awareness.** A lack of understanding of water issues in general, and of the opportunities that water reduction, reuse and recycling practices present at corporate and site level, hinders projects to reuse and recycle water.
- **Lack of supporting dialogue.** Dialogue among industries, governments and other water users at watershed level is still not common practice.

Barriers can, however, be overcome. **Chapter 4** describes potential barriers that companies could encounter in implementing circular water management practices and **Chapter 5** provides suggestions as to how these could be addressed.

10.2 Drivers, key success factors and enablers

Research has shown that there are several key drivers for implementing water reduction, reuse, recycling, restoration and resource recovery practices in a company. The drivers include **emerging regulatory frameworks**, both at legislative level and at company level through a company's sustainability or efficiency targets. In addition, **current and projected risks in water supply** may affect a company's license to operate and may pose risks to operational continuity. **Significant cost savings**, and corporate policies on watershed collaboration and reducing water withdrawals, are further drivers for water reduction, reuse, recycling, restoration and resource recovery projects.

High-level buy-in to the potential of circular water management is important. Getting buy-in means convincing internal and external stakeholders, including changing the mindsets of decision-makers on **the value of wastewater. An integrated project approach** that takes account of sustainability and circular water management alike is important and needs to be considered in the early stages of a project. This means doing water-efficiency **due diligence**, and selecting a **technology that is fit-for-purpose** and suited to the context. Finally, companies need to consider implementing **good basin governance principles**, which include collaboration and dialogue with other water users, particularly water boards and water companies.

10.3 Tools

Many tools are available to help companies overcome barriers to circular water management. **Chapter 6** provides an overview of tools for specific contexts. Three of the most frequently used tools are the WBCSD Global Water Tool, World Resources Institute (WRI) Aqueduct, and the World Wildlife Fund (WWF) and Deutsche Investitions- und Entwicklungsgesellschaft (DEG) Water Risk Filter. Companies often also develop in-house tools to measure water consumption and opportunities for saving water.

10.4 Technologies

The technologies companies choose will depend on their overall circular water management strategies, sources of wastewater, and the end use for reclaimed water. The **technologies most commonly used** include biological treatment, membrane filtration, separation processes and chemical oxidation processes.

The choice of technology depends on the **type of wastewater and the quality required for the end use**: **low-grade industrial water** can be used for irrigation, flushing or cleaning; **intermediate-grade industrial water** can be used in cooling towers, as process water and for cleaning; and **high-grade industrial water** can be used as boiler feed, demineralized water and condenser make-up water. The applications of different grades of water vary widely by industry. Legislation and public opinion affect applications in the food and beverage sector, for example, more often than in other sectors. **Appendix B** gives an overview of the technologies available.

10.5 Economics

The return on investment (ROI) on circular water management is often undervalued because water is cheap. It is important for decision-makers to **consider the full costs of water.** This requires the following:

- **Include the full costs of water inside the fence**, particularly where water has previously been available at a very low price
- **Take account of risks associated with water use**, using some of the tools described in this Business Guide, for example, the Veolia True Cost of Water methodology
- **Consider the value of water**, which entails including externalities of water use.

The decision tree (**Figure 14**) and evaluation checklists (**Section 9.2**) bring together the issues addressed in this Business Guide in a simple framework. They show companies considering circular water management practices when and how to implement water reuse.

Circular water management practices present immense opportunities for business. Not only do they allow for significant efficiency gains and cost savings, they are also key to reaching corporate water targets. In addition, circular water management presents a portfolio of solutions for a water-constrained world in which climate change and other trends will make the availability of water ever more unpredictable and scarce.

Businesses need to make a significant paradigm shift to realize circular water management across industry globally. Companies need to consider the true costs of water, and to take the true costs into account in designing projects and making decisions. Existing tools need to be refined so that companies can establish baselines, determine benefits and identify opportunities. This Business Guide is a starting point for companies aiming for a world where circular water management practices are no longer the exception but the norm, and where the potential of circular water management is fully realized.

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13 Links to tools

Aqueduct, World Resources Institute

GEMI Local Water Tool™, Global Environmental Management Initiative

Growing Blue Water Impact Index

ISO 14046: Water Footprint – principles, requirements, and guidelines, International Organization for Standardization

OECD Principles on Water Governance, Organisation for Economic Co-operation and Development

True Cost of Water, Veolia

True Cost of Water Toolkit, Beverage Industry Environmental Roundtable.

Water Footprint Assessment Tool, Water Footprint Network

Water Impact Index, Veolia

Water Risk Filter, World Wildlife Fund for Nature (WWF) Deutsche Investitions- und Entwicklungsgesellschaft (DEG)

Water Risk Monetizer, Ecolab

WBCSD Global Water Tool©, World Business Council for Sustainable Development

Appendix A. Case studies

Within the framework of sustainable water management, water reuse projects have a central place. More and more industries are starting to reuse water because of growing economic pressure, regulatory developments and supportive funding at governmental level. The benefits are:

- Less waste and wastewater
- Less withdrawal from freshwater supplies
- Lower abstraction, disposal and discharge fees.

Even though, in theory, there is a clear case for reusing and recycling water, in practice it can be challenging. The main barriers that prevent water being reused and recycled are:

- Regulatory and quality
- Resources (costs, value and human resources)
- Lack of awareness (perception and culture)
- Lack of supporting dialogue.

Figure A.1 maps case studies according to the barriers tackled, the risks experienced and the level of engagement that was required. **Table A.1** lists case studies 1–23 collected by WBCSD for this Business Guide and **Table A.2** lists case studies 24–32 featured in the report *Framework for the Successful Implementation of On-site Industrial Water Reuse*. The case studies represent different regions, types of risk, industries, motivations, tools and revenues.

Tables A.1 and **A.2** provide summaries of the case studies to provide businesses with guidance in answering the following questions:

- Which case study can your organization use as a model?
- How can revenue streams be created?
- What kinds of financial/insurance models are available?
- What types of tools can be used?

Figure A.1. Case studies collected by WBCSD for this Business Guide (1–23) mapped according to the barriers tackled, the risks experienced and the level of engagement required

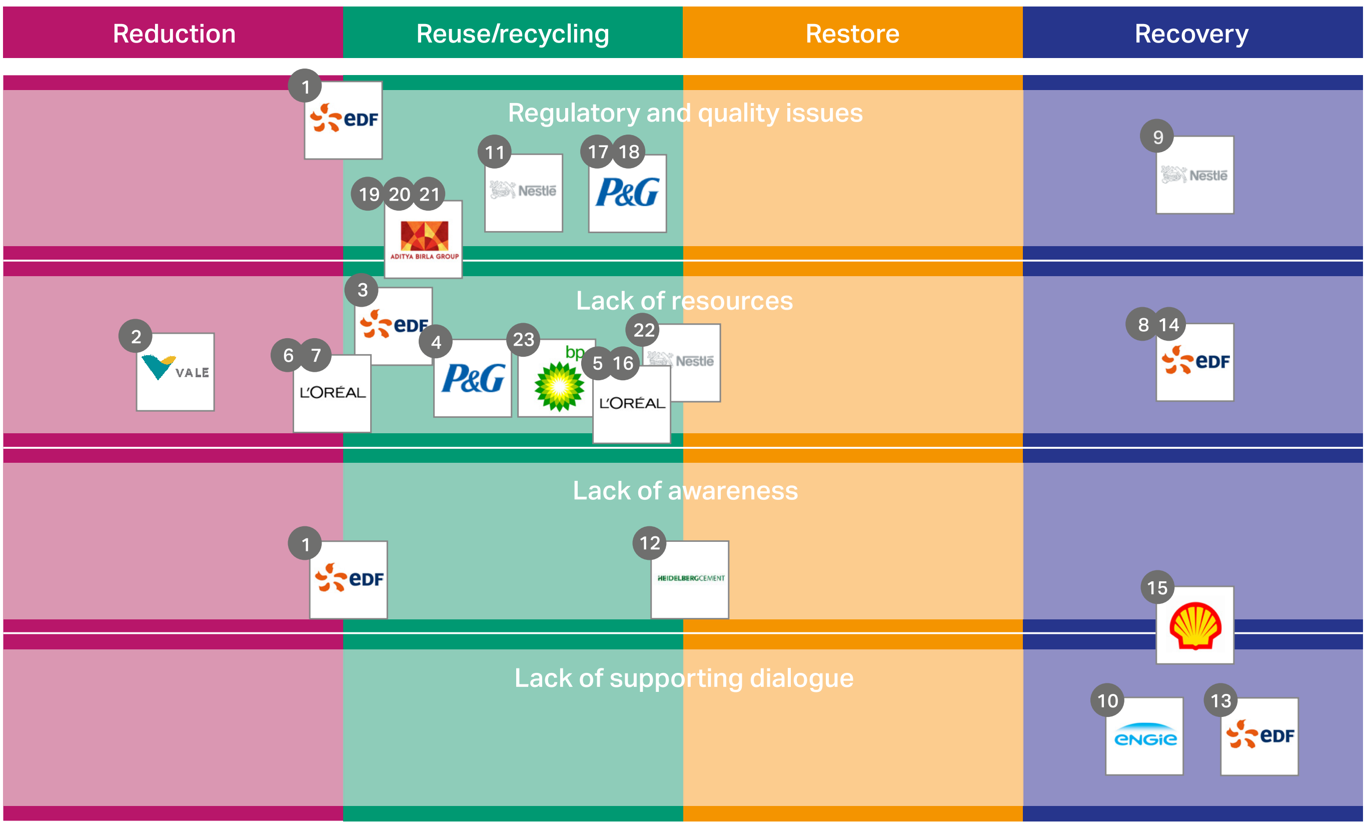

Table A.1. Summary of case studies gathered by WBCSD for this Business Guide

Case #	Company	Country	Description	Solution	Drivers	5R
1	**Electricité de France (EDF) Group**	Brazil	Usina Termeléctrica Norte Fluminense (UTE Norte Fluminense) (90% owned by the EDF Group) has put in place a full program to reduce the use of water in its Macaé combined cycle gas turbine (CCGT) power station, in Rio State.	The project started three years ago, with the identification and reduction of all leaks and the reduction of purges. This first stage also involved ensuring employees were aware and involved. The results were impressive: a 30% reduction in water use. In 2011, the station management went further and launched the construction of a rainwater capture system, which allowed them to reduce by a further 5% the water extracted from the River Macaé (100–150,000 m^3 of rainwater is collected per year). Raising the bar further, 2012 saw the launch of a program to collect all process water in order to reinject it into the plant's water circuits. This aims to reduce water consumption by a further 15%. These heavy investments (EUR 3.8 million), with a payback over 18 years, would not have seen the light of day without the support of the Board of Directors.	Regulatory and quality Lack of awareness	**Reduction** **Reuse**
2	**Vale**	Carajás, Brazil	The project consists of the installation of a robotic system that automatically washes mining equipment (including trucks). The system comprises two industrial robots, one on each side of the washer, moving linearly on rails in order to reach all parts of the truck. The conventional process was completely manual. The project reduces the risk of accidents resulting mainly from the height of the trucks and contact with chemical products.	In terms of water savings, there is a water consumption reduction of 36,793 m^3/year and it would be possible to replicate this process at other mines as well.	Resources	**Reduction**
3	**Electricité de France (EDF) Group**	Seven nuclear power plants in France	During a shutdown of a nuclear reactor every 12–18 months all technical components are serviced. This includes the secondary water circuits too. These produce the steam needed for electricity generation while also cooling the reactor circuit.	The water is purified and reconditioned by injecting reactive chemicals which prevent erosion of the circuit. It is at this moment that a rather special machine steps in – called by the EDF Group's nuclear engineering division the mobile purification station. Without it there is only one way to purify the water – discharge it into the river. In this case, you empty the secondary circuit of its 'used' water and refill it with pure water. This is repeated until the impurities have disappeared. The mobile purification station acts like an artificial kidney, it continually filters the water in the secondary circuit. Furthermore, it does this twice as fast as the traditional technique. Ultimately, the mobile station allows water savings of between 400 and 2500 m^3 for each shutdown (equivalent to an Olympic-sized swimming pool). It was first used in 1996. Today seven stations are equipped and its roll out to a further 11 is planned.	Resources	**Reduction** **Recycle**
4	**Procter & Gamble (P&G)**	Egypt, Czech Republic, Turkey	The dry laundry system was continuously consuming freshwater while soapy water was being treated off-site at an added cost to the site.	Using standardized water mapping, several Dry Laundry facilities identified the opportunity to implement innovative water reuse practices to reduce the amount of fresh water needed in the production process. The new reuse practices allowed the sites to reuse soapy water in the dry powder making process instead of using freshwater. This approach resulted in a nearly 40% reduction of fresh water intake at the Egypt site and eliminated the need for off-site treatment of the soapy water.	Resources	**Reuse**

Table A.1. Summary of case studies gathered by WBCSD for this Business Guide

Case #	Company	Country	Description	Solution	Drivers	5R
5	**L'Oréal**	Global	Water use in the cosmetic factory is mainly linked to the cleaning of production equipment and might represent about 20–70% of total water consumption. Mainly potable urban water is used for production. The group set up the ambitious target – to reduce total water consumption in the factories and distribution center per finished cosmetic product by 60% by 2020 compared with a 2005 baseline.	Having conducted a large program to reduce water needs by optimizing production processes, L'Oréal is developing a number of wastewater recycling projects. By the end of 2015, 10 facilities were in place – at sites in Karlsruhe (Germany), Rambouillet and Aulnay (France), Libramont (Belgium), Burgos (Spain), Settimo (Italy), Istanbul (Turkey), Pune (India), Suzhou (China) and Montreal (Canada). The approach involves re-treating the wastewater discharged from the wastewater treatment facilities of the plants to bring it up to the group's quality standards. Primarily, membrane technologies are installed. The water is then reused by the plants to wash manufacturing tools and to cool processes. Depending on the site needs, up to 60% of all freshwater for such uses might be replaced by recycled water. Plans are now in place to implement similar measures at a number of other sites and to include them in the group's industrial standards.	Opportunity for growth Cost and resources Corporate policy	**Recycle**
6	**L'Oréal**	Settimo, Italy	With nearly 50% of the total water consumption allocated for cleaning production equipment this use represents the main water consuming process in the factory. The project was developed not only to achieve the environmental targets of the group to reduce water consumption, but also to reduce the production of transportable waste. The implementation of this multiple-target project allows optimization of the water-waste-energy equation.	Since 2014, the plant in Settimo, Italy, has been treating its wastewater by concentrating it by evaporation. This technology involves heating the effluents so as to recover the treated water, which can then be recycled, and to likewise recover the concentrates. The factory, therefore, installed the necessary amenities to reuse a heat source already available on-site – the compressors. As a result, concentration by evaporation does not consume any additional energy. But another technical aspect inherent to concentration by evaporation technology had to be addressed – waste generation. Concentration by evaporation produces concentrates to be eliminated, like the sludge from the wastewater treatment plant. So that the overall equation is positive, a portion of the liquid waste to be destroyed (manufacturing losses, non-compliant waste fluids, etc.) is also treated with the evapo-concentrator to recover the water, thereby reducing the factory's overall waste generation. By decreasing the effluent load to be treated, the system also helps improve the efficiency of the site's water purification plant. Thus, the teams that developed this project have focused on optimizing the entire process so that both the environmental equation – dependent upon the water-treatment efficiency, liquid wastes, availability of the energy needed, etc. – and the economic equation – based on costs of energy, water, waste treatment, etc. – are positive. The evapo-concentrator can potentially treat 10,000 m^3/year. When this system is combined with all the washwater optimization projects underway, the site should reduce water consumption by more than 40%.	Cost and resources Corporate policy	**Reduction** **Recycle**

Table A.1. Summary of case studies gathered by WBCSD for this Business Guide

Case #	Company	Country	Description	Solution	Drivers	5R
7	**L'Oréal**	Sao Paulo, Brazil	The bulk of different cosmetic products are produced in batches. Between different batches the equipment has to be cleaned. The cleaning process consists of multiple cleaning and sanitization stages. The cleaning of production equipment represents about 50% of the water consumption of the plant.	The last rinsing water of the cleansing cycle has a very good quality. The project idea was to capture this last rinsing water of the cleaning process and to reuse it for the first flush of the next cleaning cycle. Without any major modifications and investment, and using the existing clean, in-place equipment of the production skid, the plant could reduce significantly the amount of water. This could be achieved while maintaining high quality standards.	Cost and resources Corporate policy	**Reduction Recycle**
8	**Electricité de France (EDF) Group**	St. Barts, Antilles	In St. Barts in the Caribbean, TIRU (Traitement Industriel des Résidus Urbains), a subsidiary of the EDF Group, will modernize the treatment of its energy plant waste and build a sorting plant and a composting platform to convert all waste from the island. The treatment of this waste will supply heat to the facility for the desalination of sea water, thereby reducing fossil fuel consumption and CO_2 emissions.	This is a doubly virtuous solution. All of the island's waste is recovered and TIRU will help to produce three-quarters of the drinking water needed on the island thanks to green energy. To preserve the landscape, these facilities will be aggregated and the plant will not generate any smoke plume or liquid waste. Twenty new jobs will be created. TIRU CEO, Hervé Druart, sees this as the market "…of new development opportunities in the Caribbean."	Resources	**Recovery**
9	**Nestlé**	Fawdon, UK	The overall objective was to contribute to the 'low carbon and renewable energy' strategy adopted by the Fawdon factory. Initially, the effluent had to be sent to the municipal treatment plant.	With an investment of more than GBP 3.2 million, a state-of-the-art effluent plant has been implemented in the confectionery factory in Fawdon. This plant has delivered a ground-breaking solution. The novel process is the first of its kind, taking both solid and liquid waste then using natural biological digestion processes to produce clean water and methane gas. The immediate benefits are reduced effluent volumes, reduced solid waste, reduced CO_2 emissions and reduced cost. Instead of landfilling, 4 tonne/day food waste is digested anaerobically to produce green energy and fertilizer. It took several months of careful commissioning to stabilize the process and deliver the planned effluent reductions and gas production.	Resources Lack of awareness	**Recovery**
10	**ENGIE**	Australia	A combined heat and power (CHP) plant at an industrial site has started to use water recovered from neighboring industries instead of freshwater.	This was achieved following an integrated approach looking beyond the borders of the CHP plant site. This led to an 85% reduction in freshwater use. Additionally, surplus energy (in the form of heat) is also being shared with surrounding industries.	Lack of supporting dialogue	**Recovery Recycle (off-site)**
11	**Nestlé**	Mexico	The Lagos de Moreno factory is located in an area of water scarcity and it is projected that the water scarcity will worsen over time. The factory's annual water consumption in 2010 was 786,097 m^3, making it one of the top 55 water consumers that contribute to 50% of the group's water consumption. The objective of Zer'Eau (zero water) was to create a dairy factory with a positive water impact. This has been achieved by recycling the water which is present in fresh milk (so-called milk water).	The factory uses recovered water from milk (in a milk powder production facility) for daily operational water needs. Additionally, water use in the facility was reduced. Water is recycled within the plant for lower grade uses (cooling, irrigation, etc.) so that the plant can run solely on water recovered from the milk.	Regulatory and quality Resources Lack of awareness	**Reduction Reuse Recycle (on-site)**

Table A.1. Summary of case studies gathered by WBCSD for this Business Guide

Case #	Company	Country	Description	Solution	Drivers	5R
12	**Heidelberg Cement**	Belgium	At a limestone quarry in Antoing, Belgium, which is considered a water-scarce area, stakeholders were concerned about over-exploitation of the region's water table level. Indeed, this would have placed water restrictions on consumer and would have meant severe geological consequences. Solution: Heidelberg Cement was able to augment the drinking water supply of the local community with quarry water and thereby cater to directly to their needs. Namely, about 95% of dewatering from the quarry is used for drinking water. Consequently, the piezometric level of the water table which had reduced by around 1m/year started to stabilize and has slowly increased since.	Heidelberg Cement was able to augment the drinking water supply of the local community with quarry water and thereby cater to directly to their needs. Namely, about 95% of dewatering from the quarry is used for drinking water. Consequently, the piezometric level of the water table which had reduced by around 1m/year started to stabilize and has slowly increased since.	Lack of awareness	**Restore Recycle (off-site)**
13	**Electricité de France (EDF) Group**	Edison and Ciccolella, Italy	Heat from a thermal power plant is used for a greenhouse for tropical plants. On one side of the road is Edison's Candela combined cycle gas turbine power station. On the other side of the road are 90 ha of greenhouses owned by Ciccolella, the world's largest grower of the tropical flower Anthurium. In the middle, a win-win partnership designed to preserve water, a resource that is scarce in the Italian region of Puglia.	The agreement between Edison and Ciccolella is simple: the hot water produced by the power station is used to heat the greenhouses in this mountainous region that experiences bitter winters. The flower producer receives the 20,000 m^3 of water heated to 37°C that it needs every hour to run the heating system. Edison, in return, receives water cooled to 30°C to reinject into its steam production system. A win-win for a sensible reuse of water, all without emitting CO_2. The total investment for Ciccolella, EUR 200 million. The grower buys hot water from Edison at a preferential rate which helped minimize the risk of its investments.	Lack of supporting dialogue	**Recycle Resource recovery**
14	**Electricité de France (EDF) Group**	Durance, France	Water-saving convention between the EDF Group and irrigators in Durance Valley, France. The objective was to optimize water allocation between energy generation and irrigation and to develop appropriate incentives for water savings to restore financial margins and to answer future demands. Located in the valley are a major dam and reservoir with 32 hydropower plants that produce over 6 billion KWh of energy, and that supply drinking water and water for industry, and irrigate 150.000 ha of farmland.	The EDF Group carried out an assessment of the monetary value of water savings from reduced abstraction for agriculture. The main business argument for the study was to demonstrate the benefits of optimizing water uses for each party. The parties entered into a win-win agreement whereby the EDF Group was to optimize hydro-generation and benefit from further flexibility to generate electricity during daily peak periods when energy prices are higher. Irrigators were to benefit from remuneration from the EDF Group based on the water savings they were able to create and having more water stored in the reservoirs during dry periods. This led to a reduction in agricultural water use from 325 to 235 million m^3.	Regulatory and quality Resources	**Recovery**
15	**Shell**	Ground-birch, British Columbia	This natural gas venture is the largest consumer of the water supply in the city of Dawson Creek.	To minimize the use of the water supply, Shell and the city of Dawson Creek jointly commissioned a 4000 m^3/day water recycling plant and a 48 km pipeline to transport water from the treatment plant to the Groundbirch area.	Lack of awareness Supporting dialogue	**Recycle**

Table A.1. Summary of case studies gathered by WBCSD for this Business Guide

Case #	Company	Country	Description	Solution	Drivers	5R
16	**L'Oréal**	Burgos, Spain		An integrated water management solution, incorporating recycling, and including a sludge drying and biomass power plant.	Resources	**Recycle Recovery**
17	**Procter & Gamble (P&G)**	China, Brazil	The more a site becomes water-efficient, the more concentrated the wastewater becomes and the more difficult and expensive it is to treat.	This case study concerns the recycling of the water and chemicals within washwater. The washwater streams are a mixture of water and product. Three innovation pathways were initially investigated and partly combined to arrive at a solution that uses membrane technology to extract the raw materials (mainly surfactants) from the washwater and split the washwater into water and concentrate fractions. The concentrate is a mixture of surfactants and other raw materials. which can be recycled into a variety of applications (e.g., lower grade surfactants for industrial use). The water stream is treated in order to meet the legal discharge requirements or, in the ideal case, to reuse in the process after an additional polishing step.	Regulatory and quality Resources	**Recycle Recovery**
18	**Procter & Gamble (P&G)**	China	The site is located in a water-stressed area with detailed permit requirements, while the short-cycle production at the site requires more and more frequent cleaning of the manufacturing and packing equipment.	Traditionally, wastewater from cleaning and sanitization (C&S) activities is the main contributor to the chemical oxygen demand of discharge at a typical Beauty Care site. In order to address this issue, C&S water was optimized during shampoo production and 60% of the treated water coming from the cooling towers was reused. Quality and safety requirements were maintained throughout. Today, the site is the company's benchmark and recycles most of the C&S water – allowing for a very effective and flexible operation.	Regulatory and quality Resources	**Reduction Reuse Recovery**
19	**Grasim Industries Limited**	n.a.	Water for the process is sourced from a nearby reservoir and the effluent flow is treated in the existing water-treatment plant. The softened and demineralized water is required and used in various processes.	The plant has adopted a sustainability road map targeting reduction of specific freshwater consumption by 10% over the reference year (2013/14) and meeting global standards by 2017. This motivated the plant to work on initiatives to achieve the target. Under the scope of these initiatives several water reuse projects have been implemented: • A sodium hypochlorite absorption system has been installed for the scrubbing of residual chlorine • Water from this system is collected and reused in the vacuum pump for vapor cooling • Condensate water produced in a caustic plant is recycled to be used as vacuum pump sealing water after being cooled by a heat exchanger • A system has been developed to collect and reuse mechanical seal cooling water. This water is used for the brine circuit make-up water • Demineralized water, used for pump gland cooling in a membrane and CSF plant, is collected and recycled to be used partly in brine preparation and partly in cooling towers • Wastewater from pump gland cooling and steam condensate is collected and recycled to be used in the preparation of milk of lime in a hypochlorite plant.	Regulatory and quality Lack of awareness	**Reduction Reuse Recycle**

Table A.1. Summary of case studies gathered by WBCSD for this Business Guide

Case #	Company	Country	Description	Solution	Drivers	5R
20	**Birla Cellulosic, Kharach**	India, Pulp and Fiber	The viscose manufacturing process is highly water intensive. Given the water scarcity in the region, the production capacity was limited. It was the ambition of the plant to reduce the freshwater uptake and sustain the continuity of production even in summer during water shortages.	The main purpose was to pre-treat the acidic multistage flash evaporator (MSFE) condensate. This was later passed through a suitable reverse osmosis membrane to get a permeate of low hardness, which can be used in viscose manufacturing. A large quantity vapor condensate from MSFE was going to an effluent treatment system, which increases the effluent load as well. After implementation of the improvement project, the permeate (reclaimed water) produced by the reverse osmosis unit was recycled to the process as a soft water input.	Resources Lack of awareness	**Recycle**
21	**Birla Cellulosic, Karach**	India, Pulp and Fiber	This was a study to find options for using the surplus condensate available from the main plant. With operations in scattered places, the challenge was to find, collect and pump the condensate to user points at minimum cost.	This project helped to conserve heat and water. In the sodium sulfate extraction process steam and vapor condensate is produced from triple effect evaporators (TEE). This had very little use in the department where it was generated. In the sulfuric acid plant demineralized water from the main plant was heated and de-aerated before being used as boiler feed water. The steam condensate from the TEE that was already at 75–80°C could readily replace the demineralized water as boiler feed water.	Resources	**Reuse** **Recycle**
22	**Nestlé**	Global study	Corporate engineering has developed a methodology which allows evaluation of water-saving projects taking into account their environmental and social benefits and not just their financial benefits.	This involves applying a 'shadow' or 'notional' cost of water which increases in proportion to water scarcity in the location of the factory where the project is proposed. This allows the company to identify the projects with the most overall benefit and to prioritize investment in those.	Resources	**Reuse**
23	**BP**	Australia	With water supply constraints and cost pressures as potential risks, it was essential that BP implement approaches that lowered the use of water at the refinery. In 1997, the refinery started the Water Minimisation Programme, with three key objectives: • Minimize water use and increase reuse • Use lower quality water instead of potable water wherever possible • Achieve zero discharge of process wastewater to environmentally sensitive Cockburn Sound.	A five-step program was implemented to minimize potable water use. This program included formation of a cross-functional team, completion of a detailed cost analysis, development of a detailed water balance, setting and promoting targets for water use, and detailed examination of each refining process. Over a 10-year period, before the water reclamation project, the refinery water demand was reduced by around 48%. Besides this achievement in water reduction, BP worked with other stakeholders (e.g., the local regulator and a number of industries) to develop an alternative source of water for industrial use. The Kwinana Water Reclamation Project was implemented. This promotes the use of treated municipal wastewater for industrial purposes, reducing potable water demands from six industrial partners.	Regulatory and quality Resources Lack of awareness Lack of supporting dialogue	**Reduction** **Reuse** **Recycle**

Table A.2. Summary of case studies featured in *Framework for the Successful Implementation of On-site Industrial Water Reuse*

Case #	Company	Country	Description	Solution	Drivers	5R
24	**PPG Industries**	Huntsville, USA	This specialized glass factory was using significant amounts of water for glass washing.	A relatively simple improvement in the rinsing cycle resulted in a 45% reduction in rinsing water use. This led to cost savings.	Resources	**Reduction**
25	**General Motors (GM)**	Kansas City, US	The GM facility noticed unusually high water use in the factory paint shop. After closer investigation, it was found that one of the reverse osmosis skids was not configured correctly and was wasting huge amounts of water for flushing.	A simple adjustment of the set points and some small optimizations led to a 220 m^3/day water reduction. This example demonstrates the importance of measuring, tracking and monitoring water data in the different departments of factories.	Lack of awareness	**Reduction**
26	**General Motors (GM)**	Wentzville, US	Internal GM benchmarking showed that the Wentzville facility used significantly more water than other GM facilities.	An audit helped identify 26 water conservation opportunities, 23 of which had a return on investment (ROI) of less than two years. The 23 together could reduce the water demand by 610,000 m^3/year, which led to an annual cost reduction of approximately USD 1 million.	Lack of awareness	**Reduction**
27	**General Motors (GM)**	Joinville, Brazil	This new GM facility was designed with water efficiency in mind from the beginning. One of the features is that domestic wastewater and rainwater are collected and treated using several units – septic tank, constructed wetland, chemicals, multimedia filtration, carbon filtration and reverse osmosis.	This treated water is used as process water for machining coolants, cleaners and for cooling towers. Even though costs were a constraint, management carried out their commitment to operate a water-efficient plant and ensured that the treatment systems were built. This system recycled approximately 5,400 m^3 in 2015.	Lack of awareness	**Reuse Recycle**
28	**Ford Motor Company**	Chennai, India	The site had already implemented several water-saving schemes, such as a wastewater recycling system. Nonetheless, an audit revealed several additional opportunities. One of them was to reduce the contribution of handwashing to freshwater use.	Low-flow fixtures and misting fans were installed to cool employees (so they would not use taps for cooling themselves). It was estimated that these measures could reduce the site's freshwater consumption by 38% with an ROI of less than three years.	Lack of awareness	**Reduction**
29	**Ford Motor Company**	Global Strategy	In 2000, Ford implemented their Global Water Management Strategy, focusing on reducing the company's water impacts. In 2011, Ford published their manufacturing water strategy, which ensures alignment of water reduction actions and encourages continued reduction of water use at Ford manufacturing plants.	Because of these strategies, water-related progress is evaluated at all levels of the company. This has helped the company to achieve its goal of a water-use-per-vehicle reduction of 30% by 2015 (compared to 2009) two years ahead of schedule (2013).	Lack of awareness	**Reduction**
30	**PPG Industries**	Wichita Falls, US	In 2013, Wichita Falls was experiencing extreme drought while the glass production site was using approximately 405,000 m^3 of water per year. Though no restrictions were placed on industrial water users, site managers looked for ways to reduce demand while maintaining operations and product quality.	The investigation revealed that half of the water demand came from the site's cooling towers. To meet this demand, a new pipeline was built to transport effluent from the municipal wastewater treatment plant to the site and a reservoir was constructed to contain the water. The city paid for the pipeline through a tax fund and PPG paid for the construction of the reservoir.	Lack of awareness	**Recycle**

Table A.2. Summary of case studies featured in *Framework for the Successful Implementation of On-site Industrial Water Reuse*

Case #	Company	Country	Description	Solution	Drivers	5R
31	**Coca-Cola Company**	Puerto Rico	The Coca-Cola facility initially had an agreement with a neighboring facility to treat its wastewater. When this facility was no longer available, the wastewater had to be trucked to the municipal wastewater treatment plant for disposal at a cost of more than USD 1 million per year. The site was highly inefficient, producing 568 m^3 of wastewater/day and was approaching the permitted withdrawal capacity from their wells.	In order to stay operational and expand production, the facility had to resort to water reuse and resolve its wastewater disposal issues. Various reduction, reuse and recycling options were identified and implemented, and an on-site wastewater treatment plant was built to resolve the wastewater disposal issue. The effluent is used for various applications on-site, so that no water is discharged from site at all.	Regulatory and quality Resources	**Reduction** **Reuse** **Recycle** **Recovery**
32	**Bavaria Beer Brewery**	Nether-lands	The Bavaria Beer Brewery was abstracting a large volume of groundwater and discharging treated wastewater to local surface waters, which rapidly transport it out of the region. At the same time, neighboring farmers were investing in sprinkler irrigation systems to maintain their crop production during drought periods. In this region, increasing pressure is put on regional groundwater and surface water availability. Reusing treated wastewater from the Bavaria Brewery for the regional freshwater supply decreases the pressure for abstractions from groundwater systems. By bringing treated wastewater back to the groundwater system, Bavaria lowers its water footprint and contributes to sufficient freshwater in the area.	Bavaria developed infrastructure to transport (part of) its treated wastewater directly to i) a sub-irrigation field and ii) a channel from which water can be extracted by farmers. The channel acts as a transport infrastructure. In this way, treated wastewater is reused for agricultural water supply. Within the sub-irrigation pilot study, a sub-irrigation system has been installed, using subsurface drains. These are interconnected through a collector drain, and connected to an inlet control basin for the treated wastewater to enter the drainage system. The equipment installed allows remote and continuous management of the drainage by controlling the water infiltrated to the groundwater system. All units are coupled with a telemetry system for control, visualization of information and data management. The automated control system provides opportunities for continuous and online control of field soil-moisture conditions.	Regulatory and quality Resources	**Restore**

Appendix B. Technologies

A wide range of water and wastewater treatment technologies used in water reclamation are commercially available. To identify and describe all the available technologies is beyond the scope of this report. Some of the more commonly used technologies (**Figure 11**) are briefly introduced below.

B.1. Phase separators (oil/water separator)

Phase separators (OWS) work according to the principles of gravity to separate oil and water mixtures into their separate components. Depending on the design of the separator, larger solid particles may also be removed. Separation occurs because of the density differences between water and oil as well as between the water and solids. Phase separators are efficient in removing free oil as well as larger droplets (greater than 60 μm for plate interceptors) of emulsified oil. American Petroleum Institute type separators and gravity plate separators are the most common types of phase separators. Oil accumulates at the top of the units and has to be periodically removed. The oil can be recovered or recycled back into the process, depending on the level of contamination. Settled solids are discharged from the bottom of the separator unit. Chemicals (for example emulsion breakers) may be dosed to enhance the separation of the oil and increase removal efficiency.

Benefits:	Simple operation, few moving parts Reduced oil load on downstream processes
Challenges:	No dissolved oil or fine colloidal suspensions removed Large space requirements (e.g., for American Petroleum Institute type separators)

B 2. Coagulation, neutralization and precipitation

Suspended solids in wastewater could be present in the form of a colloidal suspension that will settle very slowly or not at all because the colloidal particles carry surface electrical charges that mutually repel each other. In order to remove these particles from the water, a coagulation chemical is added to the water to 'destabilize' the colloidal suspension. With the use of flocculant chemicals, the destabilized particles will cluster together to form large particles, which can be separated from the water by gravity in a conventional clarifier.

Chemical precipitation is used to convert soluble ions to insoluble salts based on changes in pH, temperature and chemical reagent concentration. An example of chemical precipitation is the removal of calcium ions by forming calcium carbonate at high pH using lime or soda-ash. Solid particles that form during the precipitation process can also be removed by gravity in a clarifier. Heavy particles sink to the bottom where they are removed from the wastewater and the clear supernatant overflows at the top of the clarifier.

In some cases, it may be required to neutralize or adjust the pH of the water by adding acid or caustic chemicals to reach the optimum pH required for coagulation and/or chemical precipitation reactions.

Benefits:	Improved clarity of water compared to the system where no chemicals are used
Challenges:	Potentially high chemical consumption, depending on water chemistry Handling of excess sludge resulting from chemical reactions

B.3. Dissolved air flotation

Dissolved air flotation (DAF) is a water-treatment process that clarifies water by removing suspended matter, such as oil or solids. The removal is achieved by dissolving air in the water or wastewater under pressure and then releasing the air at atmospheric pressure in a flotation tank. The released air forms tiny bubbles which adhere to the suspended matter causing it to float to the surface where it can be removed by a skimming device. The feed water to the DAF is typically dosed with a coagulant (for example ferric chloride or aluminum sulfate) to coagulate the colloidal particles and/or a flocculant to conglomerate the particles into bigger clusters and improve removal.

Dissolved air flotation is very widely used in treating industrial wastewater effluents from oil refineries, petrochemical and chemical plants, natural gas processing plants, paper mills, general water treatment and similar industrial facilities.

Benefits:	Removes residual oil and fine suspended solids in a single unit operation
Challenges:	Requires good control of the air saturated water system for optimal operation

B.4. Constructed wetlands

A constructed wetland is an artificial (man-made) wetland created for the purpose of treating wastewater or storm water runoff. Constructed wetlands are engineered systems that use the natural functions of vegetation, soil and organisms to treat and remove different contaminants. Depending on the type of wetland as well as the wastewater that has to be treated, an additional pre- or post-treatment system might be necessary.

Constructed wetlands can be designed to emulate the features of natural wetlands by acting as bio-filters or removing sediments and pollutants, such as heavy metals, from the water. The two main types of constructed wetlands are subsurface flow and surface flow wetlands.

Benefits: Sustainable green infrastructure, small environmental footprint, no chemicals
Challenges: Large physical space requirements

B.5. Aerobic and anaerobic biological treatment

Aerobic biological treatment is used to remove the organic fraction from (waste) water. The process is based on the biological assimilation of organic matter by the biomass. Aerobic systems, such as the activated sludge process, are typically used when the chemical oxygen demand (COD) concentration of the wastewater is below 2000–3000 mg/L. Actual limits will depend on the biodegradability of the effluent and economics of aeration. In addition to the removal of organic substances, the system can be adapted to enable the removal of nitrogen and phosphorus.

Anaerobic treatment is primarily used for treating concentrated organic wastewater. The anaerobic sludge (mixed culture) converts organic material to biogas via hydrolysis and acidification. A final polishing step such as aerobic biological post-treatment may be required after anaerobic treatment for the removal of residual fractions of COD and nitrogen and phosphorus.

Benefits: Low-cost removal of COD compared to other physical/chemical removal processes
Production of biogas as a useful by-product (anaerobic systems)
Challenges: Need for effluent polishing

B.6. Sand filtration

Sand filtration is a process that removes suspended particles from water. Removal takes place by a number of mechanisms that include straining, flocculation, sedimentation and surface capture. The wastewater passes through a bed of sand and/or gravel. Sand filters need to be backwashed regularly to remove accumulated solids from the filter bed (depending on the solids load and pressure loss though the filter). There are two main types of sand filter used in industrial water treatment; continuous filters (mostly upward-flowing) and batch filters (mostly downward-flowing). In continuous filters the polluted sand is removed, rinsed and reused continuously without interrupting the filtration process. Discontinuous (batch) filters are taken out of operation to perform a backwash, which takes place in the opposite direction to filtration. Backwash is done by a water only or combination of water and air. The main sand-filter applications are cooling water production, drinking-water preparation, and pre-filtration prior to active carbon treatments and membranes.

Benefits: Simple operation, cheap
Challenges: Concentrated backwash water discharge/disposal

B.7. Membrane filtration and separation processes

Membrane-based processes are increasingly being used in (waste) water treatment to obtain a high quality final effluent for various end-users. Microfiltration (MF) and/or ultrafiltration (UF) are typically used as pre-treatment for nanofiltration and reverse osmosis. The latter processes are followed by a polishing step (e.g., ion exchange).

B.7.1. Ultrafiltration (UF)

Ultrafiltration (UF) is based on forcing a liquid through a semipermeable membrane by pressure. UF is mainly used for the removal of suspended solids from water and wastewater. In UF membranes, suspended solids and solutes of high molecular weight are retained, while water and low molecular weight solutes pass through the membrane. Depending on the type of UF membrane used, UF is ideal for the removal of colloids, proteins, bacteria, pyrogens, proteins and macromolecules from water.

UF can be used as a pre-treatment for reverse osmosis systems or as a final filtration stage for deionized water, in the elimination of micro-organisms in drinking water, pre-treatment of demineralized water and purified water, and boiler water. UF membranes will produce a reject stream, which is generally 3–10% of the inlet flow and will have high total suspended solids (TSS) concentration. There are several types of membranes with individual application ranges available commercially. Hollow fiber membranes are typically recommended for wastewater with a high TSS and low concentrations of solvents, oils and grease. Ceramic membranes can be used for streams containing high levels of solvents and oil/grease.

Benefits: High and constant quality of the treated water in terms of particle and microbial removal

Challenges: Fouling imposes a major challenge for efficient application of membrane technology
Treatment of backwash and chemical cleaning waste
Cost of membrane replacement
High capital expenditure (CAPEX)

B.7.2. Nanofiltration (NF)

NF is a pressure-driven membrane process which, with respect to separation level, lies between ultrafiltration and reverse osmosis (RO). NF membranes have a larger pore size and higher salt permeability than RO membranes. NF membranes have a higher rejection of larger divalent and trivalent ions compared to monovalent ions and can be customized for selective ion removal (e.g., sulfate removal membranes). NF can, for example, be used for softening, removal of heavy metals, removal of pesticides and reduction of total dissolved solids. NF membranes are available in tubular, spiral wound or flat sheet configuration. Spiral wound elements are typically used in water-treatment applications. The required feed pressure of a NF system is generally lower compared to RO systems.

Benefits: Lower operating pressure and lower associated power requirement as compared to RO
No addition of sodium ions (as compared to base ion exchangers) when used for water softening

Challenges: Membranes are sensitive to chemical oxidizers, such as free chlorine
Extensive pre-treatment required
High capital expenditure (CAPEX)

B.7.3. Reverse osmosis (RO)

Reverse osmosis (RO) refers to a water-treatment technology using a semipermeable membrane for the purification of water. Elevated pressures are required to push water through the membrane to overcome osmotic pressure. The pressure required to push water through the membrane depends on the membrane type (i.e., the degree of permeability), temperature (lower pressure for higher temperatures) and the concentrations of the dissolved solids in the water being treated. Feed pressures range from 10 bar to more than 60 bar depending on the feed total dissolved solids (TDS).

RO membranes are capable of achieving more than 99% removal of dissolved salts from solution. During the operation of RO membranes, water will pass through the membrane to produce a purified stream (permeate). Dissolved ions and organics will be carried away in the membrane reject (or concentrate) stream.

The water-production efficiency with which membranes produce permeate is an important factor in membrane operation (i.e., what percent of the RO feed exits the membrane system as permeate). The efficiency of the membrane will largely depend on the operating pressure limits of the RO unit as well as the TDS, hardness and silica levels in the RO feed. For the purification of well water or city water, RO efficiencies of 75–90% are typical. For recycle projects, the wastewater being fed to a RO unit will often be more challenging to treat than city or well water and, thus, production efficiencies may be lower.

Benefits: High removal efficiency of dissolved salts
Minimum chemicals used in treatment process

Challenges: Membrane fouling
Disposal of high TDS concentrate
High capital expenditure (CAPEX)

B.7.4. Ion exchange

Ion exchange is the reversible interchange of ions between a solid (ion exchange resin) and a liquid, involving counter ion displacement from the resin phase and electrostatic interaction between ionic functional groups. Ion exchange resins are made from insoluble polymers and are typically bead-shaped. Various process configurations are available, for example, packed bed or floating beds, and operation can be co-current or counter-current.

Ion exchange can be used to soften water by capturing multivalent cations, such as calcium and magnesium, for specific ion removal such as boron, or for full demineralization where all dissolved inorganic solids are removed from the water. For the latter process, two distinct types of resins are used to remove cations and anions respectively.

Ion exchange media that is saturated (i.e., all exchange capacity used) has to be regenerated. Regeneration is achieved using a concentrated solution of salt, acid or base chemicals. Choice of regeneration chemicals depends on the type of resin used and type of ions to be removed from the ion exchange resin.

Benefits: High water recovery for wastewater with low total dissolved solids concentration
Production of high quality demineralized water or ultra-pure water

Challenges: Concentrated regenerated waste disposal and discharge
Storage and handling of regenerated chemicals (salt, acid, base)

B.7.5. Continuous electro-deionization (CEDI)

Continuous electro-deionization (CEDI) is a technology bringing together ion exchange resins and ion-selective membranes with direct current to remove ionized species from water. It reduces the limitations of ion exchange resin beds, especially the release of ions as the beds exhaust and the associated need to change or regenerate the resins increases. Reverse osmosis is typically used prior to CEDI to ensure that the CEDI stack is not overloaded with high concentrations of salts. CEDI systems typically consist of a number of cells operating in parallel. Ion-selective membranes allow the positive ions to separate from the water towards the negative electrode and the negative ions towards the positive electrode. CEDI systems produce high purity deionized water.

Benefits: Chemical-free operation. No regeneration downtime

Challenges: Sensitivity to organics and high salt concentration. Requires upstream reverse osmosis treatment

B.7.6. Organic scavenging

Removal of residual organics downstream of a biological treatment system may be required to minimize organic fouling in downstream unit processes or end-user equipment. In addition, some reuse applications have low total organic carbon limits and the residual organics, therefore, have to be removed from the wastewater. Two main polishing mechanisms are available for the removal of organic matter. These are ion exchange and adsorption. In addition, several niche technologies are available to remove dissolved organic contaminants, such as benzene, toluene and polycyclic aromatic hydrocarbons from the water (e.g., extraction, steam stripping, magnetic ion exchange, etc.). A brief overview of ion exchange and activated carbon adsorption is provided elsewhere in this document.

Benefits: Resins can be reused through regeneration
Minimized fouling on downstream processes

Challenges: High cost of media replacement and/or regeneration in case of high organic loads
Disposal of waste from regeneration or saturated media

B.8. Activated carbon adsorption

Adsorption is a well-established process for the removal of organics from wastewater given carbon's strong affinity to hydrophobic organic compounds even at low concentrations. Organics are adsorbed onto the carbon, which is either in granular (granular activated carbon – GAC) or powdered (powdered activated carbon – PAC) form. This process has been widely used alone as well as in combination with other treatment processes (e.g., coagulation/flocculation and membrane filtration).

The performance of the activated carbon treatment system in removing organic compounds depends on the properties of the adsorbent (e.g., specific surface area, porosity, surface polarity, physical shape of the material, etc.), the characteristics of the adsorbate (e.g., molecular structure, charge, hydrophobicity, etc.), and the aqueous matrix characteristics (e.g., pH, temperature, the presence of other species in the solution, etc.).

GAC is mainly suitable for the removal of dissolved organics. However, it can also be efficient at removing low levels of oils. GAC is used in fixed-bed filter systems (pressure or gravity filters) and PAC is typically dosed as a slurry into the main wastewater flow. GAC will, over time, become saturated and has to be regenerated periodically – this is achieved by either *in situ* regeneration or regeneration off-site by a third party.

Benefits: High removal efficiency of low molecular weight hydrophobic organic compounds

Challenges: Replacement of activated carbon

B.8.1. Advanced chemical oxidation processes

Advanced chemical oxidation processes (AOPs) are used extensively in the water and wastewater treatment field. AOPs refer to chemical oxidation procedures designed to remove organic and/or inorganic materials in the wastewater by oxidation through reactions with hydroxyl radicals (OH). The term usually refers to systems that use ozone (O_3), hydrogen peroxide (H_2O_2), ultra-violet light or a combination of these processes.

B.8.1.1. Ultra-violet based applications (UV, UV/H_2O_2)

Ultra-violet (UV) technology is an effective chemical-free technology for water disinfection. It is widely used for a number of applications to produce ultra-pure water, ranging from pharmaceuticals to cosmetics, electronics and general industries. The main means of removing organic materials is irradiation with an artificial light source (usually performed with low- or medium-pressure mercury vapor lamps). Photolysis occurs through the direct absorption of the emitted light. UV-driven processes combined with H_2O_2 (which yields additional H from its dissociation), significantly enhances the efficiency of the oxidation process by further reducing organic compounds.

During UV-driven photolysis, the reactivity with OH is directly related to the structural characteristics of organic compounds (i.e., aromaticity, carbon bonding and functional groups). The inorganic chemical species present in the aqueous matrix and UV intensity are also important factors. The presence of high concentrations of inorganic substances, such as carbonates/bicarbonates and chlorides can cause inefficient and slower removal of organic matter.

Benefits:	Minimal chemical addition (in combination with peroxide)
Challenges:	Fouling of lamps, requiring cleaning Loss of lamp efficiency (UV intensity) requiring lamp replacement

B.8.1.2. Ozone-based applications (O_3, O_3/UV, O_3/H_2O_2, O_3/H_2O_2/UV)

Ozone (O_3) is a powerful oxidant. With the ability to destroy resistant pathogens, ozone-based applications are used extensively in water and wastewater treatment for disinfection purposes. O_3 may react with organic matter through two distinct mechanisms: (i) O_3 decomposes in water to form HO, thus inducing indirect oxidation, and (ii) O_3 can react selectively with certain functional groups, particularly the double bonds and aromatic rings of organic molecules, through an electrophilic mechanism (ozonolysis). The simultaneous addition of H_2O_2 or UV irradiation to the ozone system leads to an increase in process efficiency by accelerating the O_3 decomposition and promoting HO formation, and results in a shorter reaction time than the individual processes.

Several operational conditions can affect ozone-based treatment processes with respect to their removal efficiency, including the O_3 dose, contact time, pH, H_2O_2 concentration and UV dose.

Benefits:	Disinfection function (including bacteria and viruses). Capable of degrading a wide range of organic pollutants
Challenges:	Safety issues given the aggressive nature of the chemicals

B.8.1.3. Chlorine dioxide

Chlorine dioxide is used in many industrial water-treatment applications – including cooling towers, process water and food processing – as a biocide. Chlorine dioxide is less corrosive than chlorine gas, is not negatively affected by pH and does not lose efficacy over time. Chlorine dioxide can be produced on-site by chemical reactions, including sodium chlorite, hypochlorite and hydrochloric acid.

Benefits:	On-site production of chemicals, less corrosive than chlorine
Challenges:	Use and handling of aggressive chemicals on-site

B.9. Evaporation and crystallization

Evaporation and crystallization are equilibrium-based, thermal separation processes used to concentrate wastewater and recover clean distillate. The concentrate could be treated off-site (e.g., incineration) or further concentrated and dewatered on-site to yield a solid by-product (crystallization). Depending on the process chemistry and operating parameters, the solid by-product can consist of pure salts, which can be recovered and reused. Evaporation and crystallization processes are often paired with other pre-treatment processes that are more energy efficient at removing lower total dissolved solid concentrations in water. Energy for the process can be supplied in the form of steam, electricity or warm water. Falling film and forced circulation units are the two most common types of evaporators and crystallizer used for wastewater treatment.

Crystallization is commonly used in zero liquid discharge systems to recover water for recycling while generating no aqueous waste.

Benefits:	Zero liquid discharge objectives can be achieved High purity distillate suitable for reuse Potential recovery of valuable salts
Challenges:	High capital and operating costs (high energy demand) Volatile compounds in the distillate may require separate (post) treatment Disposal of concentrate or solid waste

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