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Closing the Loop on Resource Generation and Use in the Water Industry

A Circular Economy Research Framework

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Collaborate Innovate Impact

Background

The linear delivery model currently utilised in our economy, which consists of **take-make-use-dispose**, is no longer tenable given its impact on our already stressed environment. As a result, finite resources such as freshwater, nutrients and fossil fuels are depleting, affecting the environment, the economy and communities[1]. There is, therefore, an urgent need to *close the loop on resource generation and use*; we need to transition to a circular economy. The Ellen MacArthur Foundation[2] bases the circular economy on three principles:

(i) elimination of waste and pollution

(ii) circulation of products and materials

(iii) regeneration of nature

In addition, achieving net zero and beyond, along with mitigating the threat posed by biodiversity loss, are not possible without transitioning to a circular economy.

For the water sector, this transition corresponds to **maximising the value of water** by considering it not only as a resource but also as a nutrient and energy carrier[3]. It also represents an opportunity for the water sector to position itself as an aspirational steward to society and the economy.

This paper serves as a basis for Water Research Australia's circular economy research roadmap in the water industry by identifying research drivers, gaps, and needs. It outlines a circular economy framework to capture all aspects of the circular economy in the water industry (referring to the three circular economy principles), promote innovation within the sector, and explore collaboration opportunities within and beyond the water sector. This also includes comments on topics for future research projects based on evaluating research gaps and priorities identified by water utilities in the circular economy space.

Drivers

Water utilities are early adopters of practices that support the circular economy as stringent environmental regulations, such as restrictions on waste, hinder the linear approach. Communities expect water utilities to provide clean and available water in a safe, reliable, affordable and sustainable way. However, current water infrastructure does not guarantee such services long-term as it is inadequate for future demand and a changing climate[4]. Additionally, the depletion of finite resources is building economic barriers as the cost of virgin materials and energy is increasing. Therefore, the transition to a circular economy is not only driven by **regulatory requirements** but also by a need to respond to **community expectations** and improve **resilience**.

Embracing the circular economy and closing the loop brings numerous opportunities that can benefit water utilities, the environment, the economy and communities. Firstly, water utilities can succeed long-term by meeting and exceeding current and future regulations and achieving revenue diversity and energy security. The water sector can have a net-positive impact on the environment and communities by shifting its approach from process-driven to outcome-driven. Finally, water utilities can become economy and community stewards by collaborating to shape future regulations, working with other sectors as they transition, and supporting communities through liveability outcomes.

The drivers behind the transition to a circular economy come from pressures that impede current practices and opportunities that bring numerous benefits. The drivers fall into seven overarching pressures and opportunities categories (see Table 1), including five that together are considered development factors. It is important to note the overlapping and interplaying nature of these categories when examining Table 1. For example, "limited landfill space" could very well be a driver for logistics and resource recovery. The key aspects, pressures and opportunities are further discussed in the next section.

[1] Kakwani, N.S. and P.P. Kalbar, Review of Circular Economy in urban water sector: Challenges and opportunities in India. Journal of Environmental Management, 2020. 271: p. 111010.

[2] Ellen MacArthur Foundation. What is a circular economy? [cited 2022]; Available from: https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview.

[3] Jazbec M., Mukheibir P, and Turner A., Transitioning The Water Industry With The Circular Economy. 2020, University of Technology Sydney.

[4] Melbourne Water, Melbourne Water System Strategy. 2017: Melbourne, Victoria.

Table 1 - Classified water utilities drivers to transition to a circular economy

Category		Pressures	Opportunities
Logistics		• Limited landfill space • Inadequate infrastructure/network • Supply chain instability	• Resource independence • Water and energy security • Shorter supply chains
Resource Recovery		• Depleting resources • Improve resilience	• Turn waste into beneficial resources • Reduced greenhouse gas emissions
Development Factros	Economics	• Increased cost of virgin materials and energy • High cost of waste disposal	• Cost reduction • Stimulate the local economy • New revenue streams
	Environment	• Climate change • Impact on the environment from waste disposal • Greenhouse gas emissions	• Preserve waterways and freshwater sources • Reduce pollution and emissions • Soil remediation • Carbon sequestration
	Regulations & Policies	• Stringent environmental regulations (emissions, resource efficiency, and waste disposal)	• Shape future regulations
	Social	• Community expectations	• Liveability outcomes
	Strategy & Technology	• Urgent need for a plan of action	• Resource stewardship • Collaboration across sectors • Rethink and redesign

Research Gaps

The main challenge is the need for more knowledge and guidance to close the loop. In collaboration with water utilities, Water Research Australia has identified **critical gaps** in the research as part of developing a circular economy framework based on three crucial aspects: resource recovery, logistics and development factors. Figure 1 below shows a summary of the framework.

Resource Recovery

Resource recovery is at the core of a circular water industry due to the value embedded in the resources managed by water utilities and the benefits they provide once circulated. Water utilities can recover three resources: water, energy and materials.

Framework to guide water industry circular economy research efforts

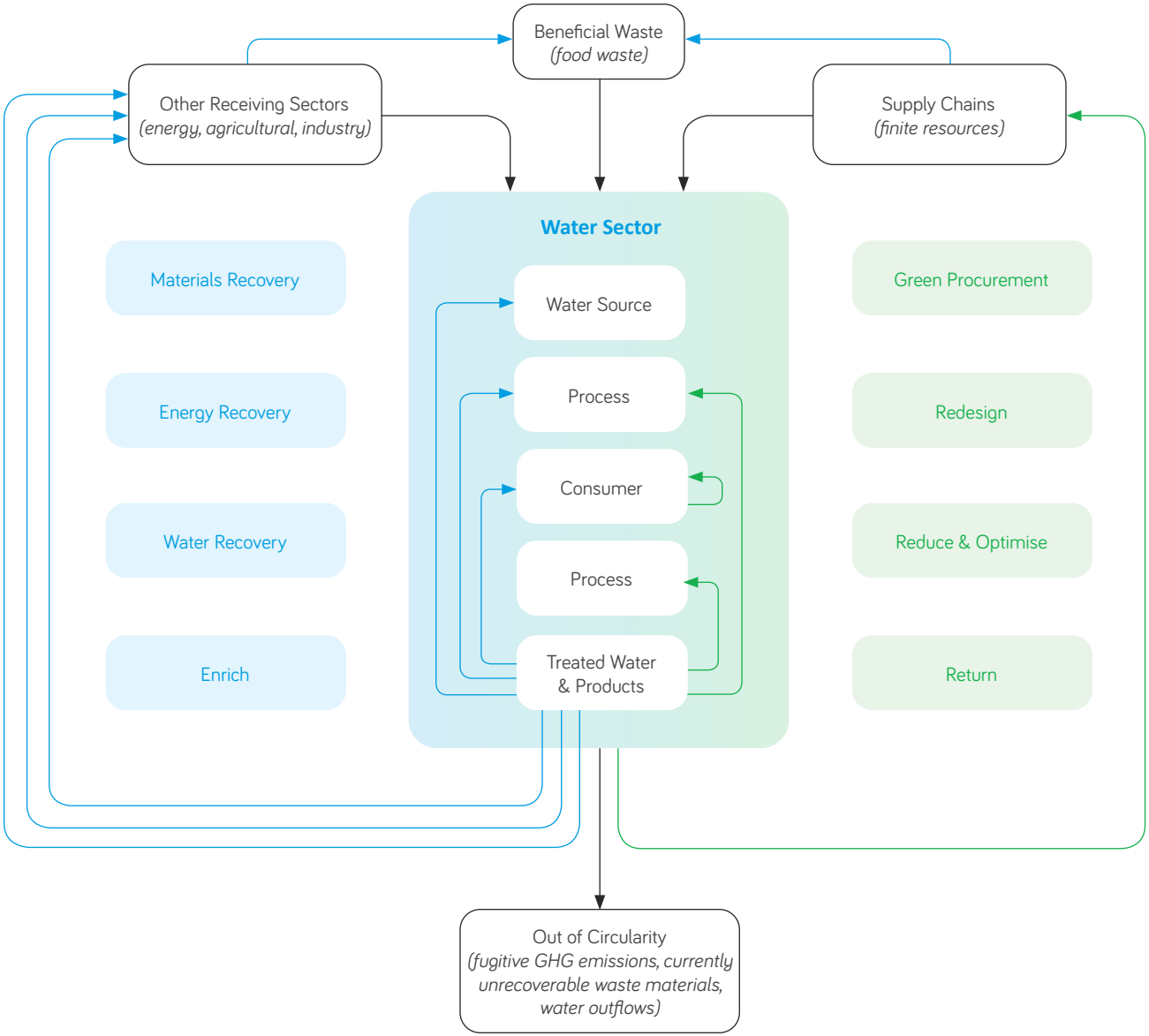
Water Research AUSTRALIA

Objectives

1. Capture all aspects of the circular economy based on its 3 principles
2. Promote innovation
3. Explore collaboration opportunities

Overarching Risks & Opportunities Categories

Environment	Regulations & Policies	Materials Recovery
Social	Strategy & Technology	Water Recovery
Economics	Logistics	Energy Recovery



Water recovery plays a significant role in the circular economy by preserving water resources and circulating water at its highest value. Therefore, maximising system efficiency, sustainably making the most of all water source options, and optimising reuse are vital. However, knowledge of the various water options needs to be improved as their relative risks, costs and benefits are only partially defined. Additionally, the impact of contaminants of emerging concern (CECs) on the application of recycled water needs further investigation to unlock the full potential of water recovery.

Recovering the **energy** embedded in water and wastewater and minimising the energy losses within the water cycle are other critical aspects of resource recovery. Water facilities can become energy producers, which requires a comprehensive understanding of how to harvest and maximise the energy content in water and wastewater sources, including the role of water in developing a hydrogen economy[5,6]. The success of energy recovery relies on identifying the risks it brings and ensuring that water services continue to be delivered at the required level.

Materials recovery is the key to achieving revenue diversity, cross-sectoral circularity, and a regenerative economy[7]. However, its success relies upon developing products that can compete in existing markets[8] and/or be used within a water utility. Further research is required to determine scalability, provide sufficient evidence for regulators to enable their use, and ensure that communities are comfortable with water utilities diversifying. The recovery of materials is interlinked with logistics as a crucial aspect.

Logistics

Considering logistics in the framework is essential to **improving resilience** and reaching **net-zero emissions**. The goal is to mitigate the risks associated with the supply chains while maximising the opportunities it presents. A mapping exercise showcasing the current state of the supply chain can help understand how to offset it and how to build resilience through circular practices.

Such outcomes require a strategy for **green procurement** that includes a list of alternative products and materials (e.g. green concrete) and their characteristics, and an understanding of practices that promote the circulation of finite materials (e.g. iplex Pipeback program). In addition, this strategy should help respond to current and future regulations and policies like the National Waste Policy and NGER Scheme.

Development Factors

Six development factors shape the circularity in the water sector: Economics, Environment, Regulations & Policies, Social, Strategy, and Technology.

Currently, new approaches are supported if shown to be financially profitable. Therefore, it is crucial to identify **revenue streams** that support the circular economy. The research goals include understanding the benefits and value of carbon offsets, developing a methodology to obtain carbon credits and strategies to unlock funds from the investment community (e.g. ethical super). Additionally, regulations shape the future of industries by placing barriers to inadequate practices, but some **regulations** also hinder circular practices, such as transforming biosolids to biochar. Therefore, research and innovation are required to reduce these **barriers** and enable a closed-loop system.

Environmental and **social** aspects are becoming increasingly important in decision-making. Current and future environmental regulations, as well as government targets, are dictating the priorities of water utilities. Despite significant efforts in that space, monitoring and mitigating GHG emissions of complex systems like reservoirs and lakes still need improvement. Additionally, overcoming social barriers represents a considerable challenge, as it prevents adopting new practices (e.g. direct recycled potable water). Therefore, understanding strategies enabling changes in consumer behaviour and perception is required.

The success of the shift to circular practices relies upon a comprehensive **strategy**. Therefore, there is a need to develop tools for effective implementation and share case studies on how water utilities have partnered with other sectors and communities and contributed to embedding circular economy principles in their activities.

Technology plays a significant role in reaching circularity. Technology can maximise resource use while minimising resource needs. Additionally, rethinking and redesigning assets, from pumps and piping to tankers and treatment plants, with end-of-life in mind, enables repair, reuse and recycling, thereby addressing various other aspects of the circular economy.

Research Priorities

Research and innovation are vital to building the necessary knowledge to close the loop on resource generation and use. Additionally, **stakeholder engagement and communication** are crucial to create a circular economy[9]. Internal and cross-sectoral collaboration is required to develop research priorities, determine the most efficient research roadmap, and explore funding opportunities.

With the collaboration of water utilities, research priorities and completed and ongoing projects in the circular economy space have been identified. Currently, most of the efforts from water utilities are on **materials recovery** driven by restrictions on waste disposal and the potential for solid wastes to be used beneficially. The research priorities identified by water utilities are **Energy Recovery**, **Environment**, and **Strategy**, including achieving net zero. Therefore, future research needs to help water utilities reach their net zero emission targets by enabling monitoring and mitigation of greenhouse gas emissions, changing the way energy is produced and consumed, and defining a clear plan of action for an effective transition to circular practices.

Australian water utilities were asked about their research priorities and completed and ongoing research projects in the circular economy space. These are shown on radar charts in Figure 2.

[5] Victorian Government, Victorian Renewable Hydrogen Industry Development Plan, E.a.C.C. Energy, Editor. 2021.

[6] Water Services Association of Australia, Water Fuelling The Path To A Hydrogen Future The Role of Urban Water Industry In Australia And New Zealand's Renewable Energy Future. 2021.

[7] Water Research Australia and Water Services Association of Australia, Unlocking our future potential Australian Urban Water Industry Research Priorities Agenda.

[8] International Water Association, Water Utility Pathways in a Circular Economy. 2016: London.
Water Services Association of Australia, Circular Economy Action Plan. 2022.

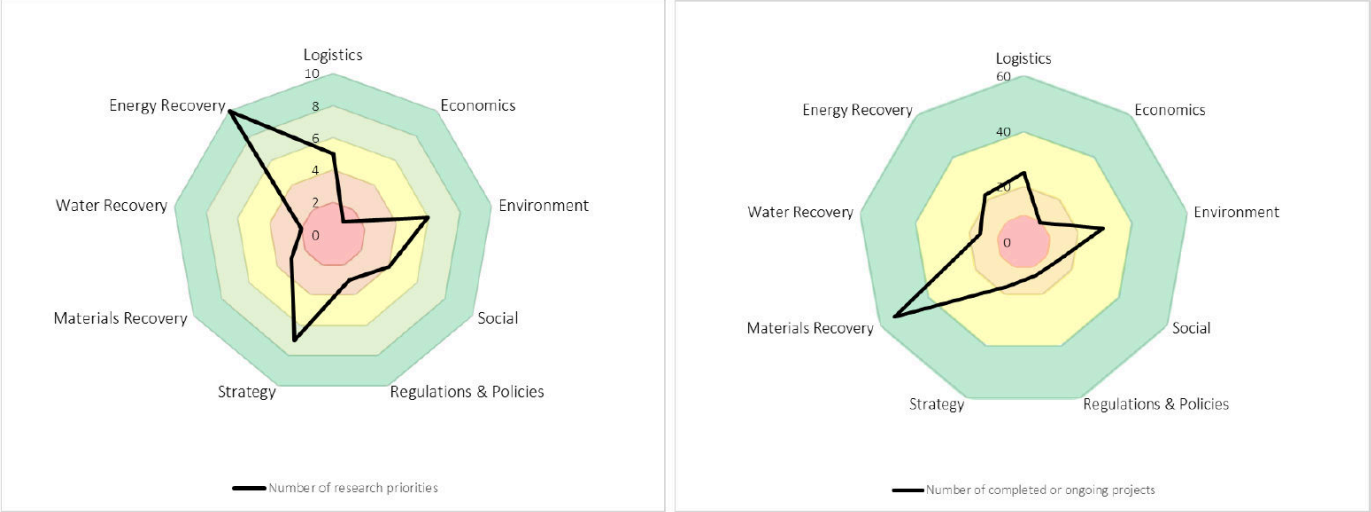


Figure 2 - Radar chart of research priorities (left) and completed and ongoing research projects (right) per category

The similarity of research priorities identified by water utilities led to the development of a list of potential research projects, shown in Table 2. These projects could serve as a basis for the circular economy research roadmap as it responds to the needs of water utilities and clears some of the research gaps identified.

Table 2 - List of potential circular economy projects

CATEGORY	PROJECT TOPIC	INTERESTED UTILITIES
Strategy & Technology	List all circular opportunities for the water sector, determine how to embed circular economy principles in all activities, and define circular economy KPIs	• Water Corporation • Sydney Water • Icon Water • Wannon Water • TasWater • YVW • Hunter Water
Energy Recovery	Understanding the risks and opportunities for the water sector around the hydrogen economy and determining the value and benefits of green oxygen	• Water Corporation • WSAA • Hunter Water • Icon Water • YVW
Environment	Measurement and mitigation strategies for Scope 1 emissions from lakes and reservoirs, wastewater treatment, and wastewater network.	• SA Water • Water NSW • Seqwater • Melbourne Water • Hunter Water
Logistics	Understanding green alternative options for finite materials, including materials flows, suppliers of materials with recycled content and technical standards	• Wannon Water • SA Water • Water NSW • YVW
Regulations & Policies	Regulatory framework around the circular economy: understanding regulatory barriers and developing strategies to prevent them	• Water Corporation • GWW • SA Water
Materials Recovery	Biosolids and biochar: their various applications and quantifying their highest value	• GWW • Sydney Water • YVW

Conclusion

Water Research Australia has developed a **circular economy framework** for the Australian water industry, describing drivers, research gaps and ideas, providing insights on completed and ongoing works, and identifying the priorities of water utilities. This framework shows where the water sector stands, as a whole, in its efforts to transition to a circular economy, and provides a tool to ensure complementary projects and efficient progress. Additionally, it gives perspective on the circular economy, and the summary diagram supports water utilities to capture all its aspects, generate ideas, and explore collaboration opportunities. Finally, a list of six potential research projects was developed based on the research needs of water utilities and research gaps identified in the circular economy space, which serves as a basis for Water Research Australia's circular economy research roadmap.

Company	Name
Barwon Water	Michael Thomas
Coliban Water	Megan Kreutzer
Greater Western Water	Jason Cotton; Mark Langley
Hunter Water	Abigail Morrow; Lauren Randall
Icon Water	Benjamin Bryant; Joel Edwards; Clare Idriss; Caitlin Launt
Melbourne Water	Nicholas Crosbie
Monash University	Arash Zamyadi
NSW Health	Katherine Gajo
NT Health	Tracy Ward
SA Water	Ilda Clos; David Daminato; Nick Swain; Paul Monis
Seqwater	Michael Bartkow; Nayim Kabir; Solvej Patschke; Joseph Tam
South East Water	David Bergmann; Li Gao; Kevin Munidasa; Joel Segal
Sydney Water	Philip Wood; Glenda Stowell; Elliot Cichero; Jean Davis; Michael Young
TasWater	Luc Richard
Wannon Water	Joanne McBain; Murray Dancey
Water Corporation	Anthony Bodycoat; Paul Nolan
WaterNSW	Lisa Hamilton; Quinn Oliver
WaterRA	Vincent Bianchini; Karen Rouse
WSAA	Jason Mingo; Elliot Stuart
Yarra Valley Water	Lisa Ehrenfried; Jamie Lynch; Simon Prunster

Disclaimer

Water Research Australia Limited (WaterRA) is a profit-for-purpose company funded by the Australian water industry.

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This research report does not purport to be a comprehensive statement and analysis of its subject matter, and if further expert advice is required; the services of a competent professional should be sought.

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