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8Rs for circular water and sanitation systems: Leveraging circular economy thinking for safe, resilient and inclusive services

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ABSTRACT

To achieve their normative health, environmental and social objectives, water and sanitation services must be safely managed, inclusive and climate resilient. Meeting these imperatives presents a need and opportunity for innovative thinking about water and sanitation service systems. Circular economy concepts are being applied across a multitude of product and service sectors with the aim to facilitate regenerative flows of resources. Given the dependence on water resources, associated climate risks, and the generation of reusable waste products in water and sanitation service delivery, circular economy concepts can be usefully leveraged to drive sustainability outcomes. This article contributes a heuristic in the form of a conceptual framework for applying circular economy concepts in the design and delivery of water and sanitation services in diverse Global South contexts. The framework seeks to drive multiple outcomes relevant to water and sanitation initiatives: safely managed services, social inclusion, and climate resilience. Co-developed by an international research team applying a theoretical multiplicity approach and collaborative sensemaking, the heuristic takes the form of a suite of eight adapted circular economy 'R strategies' for water and sanitation. The R strategies were selected and articulated to reflect theory-based principles of circular economy, climate resilience and inclusion. They are intended to prompt thinking and action in pursuit of safely managed, climate resilient, inclusive water and sanitation services that align with the broader sustainability directions that circular economy narratives aspire to. The heuristic offers a conceptually rigorous, practical tool that can support collaborative, deliberative processes to realise the potential benefits of circularity in water and sanitation service systems.

1. Introduction

Addressing the interconnected challenges of ensuring safely-managed water and sanitation services for all, driving social inclusion and equality, and building resilience in the context of climate change, demands re-imagining resource and service systems. Historic approaches focused on access to water and sanitation facilities failed to achieve requisite gains in public health and environmental

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protection (Tilley et al., 2014). Current systems-oriented efforts are better able to grapple with critical governance dimensions of water and sanitation service delivery (Huston and Moriarty, 2018; Pugel et al., 2022), yet require more thinking about how to achieve universal, safely managed services in times of increasing environmental uncertainty. Equally, the intrinsic connections between water, sanitation and natural resources demands a focus on strengthening, and not undermining, the natural systems on which services depend – in other words, thinking beyond an instrumental view of 'resource management for people' towards striving for environmental sustainability and regeneration (Carrard, 2024; Tàbara, 2023). In this complex context with multiple imperatives there is a need for new thinking about how to integrate promising sustainability pathways with ongoing efforts to progress climate resilient, inclusive water and sanitation services.

Circular economy is a popular and potentially powerful concept to address a range of sustainability challenges. Now considered a research field in its own right (Kirchherr et al., 2023a), circular economy has evolved from origins in product and material recycling to represent a means of achieving sustainable development (Geissdoerfer et al., 2017). Circular economy ideas are increasingly applied to water, where imaginaries of circularity resonate with the cyclical nature of water systems (Nika et al., 2020). While applying circular economy ideas to services (such as water and sanitation) presents conceptual challenges when compared with application to materials and product manufacturing (Morseletto et al., 2022), a growing body of work explores how both service providers and users can adopt circular practices and seeks to quantify the potential benefits (Castellet-Viciano et al., 2022; Das et al., 2024; Furness et al., 2024; McKenna et al., 2023; Sauvé et al., 2021). For water services, circular economy thinking is relevant for the production, supply and use of water, all of which offer opportunity for reducing use of water and energy resources through efficiency, optimisation or demand management (Morseletto et al., 2022). For sanitation services, circular economy thinking demands a focus on how water, energy and nutrients can be recovered and reused rather than discharged into the environment (Mallory et al., 2020a; UN-Habitat, 2023), often with inadequate treatment to protect waterways and ecosystems (WHO/UNICEF, 2023).

As thinking about the relevance of circular economy ideas to water and sanitation systems develops, there is a need for particular focus on services in Global South contexts. In using the term 'Global South' and noting the importance of explicit definition (Haug et al., 2021), we refer to places that have been historically marginalised in a world shaped by colonialism with consequent lower incomes and levels of access to safe water and sanitation compared with Global North contexts. Critiques of circular economy scholarship note the nascent focus on human development (Schröder et al., 2020) and climate resilience (Kennedy and Linnenluecke, 2022), both of which are critical in contexts where access to services is not yet universal or safe. Similarly, while there is a long history of work applying ideas of reuse and nutrient-capture to sanitation systems in low- and middle-income countries, initiatives have been at niche scales and not connected to the ideas of systems change that circular economy ideas demand (Carrard and Willetts, 2017; Ddiba et al., 2020; Desing et al., 2020). There is opportunity to progress thinking about how circular economy concepts might be useful for a range of water and sanitation contexts and systems, including bringing in critical dimensions of climate resilience and inclusion.

This article contributes a heuristic, in the form of a conceptual framework, for applying circular economy ideas in the design and delivery of water and sanitation services in diverse Global South contexts. The framework - termed the '8Rs framework for circular water and sanitation systems' - was developed by a transdisciplinary team of Global South and North researchers and is based on insights from a review of circular economy, water and sanitation, social inclusion and climate resilience scholarship. In this article we first describe the research process, which applied a theoretical multiplicity approach and collaborative sensemaking. We then synthesise key aspects of the four included theoretical perspectives and their intersections, presenting principles that informed (and underpin) the resulting framework. In the results and discussion section, we present the 8Rs framework, elaborating its scope and intended use before reflecting on tensions and limitations that should inform its application.

2. Materials and methods

The study, situated within a wider transdisciplinary research project, adopted transdisciplinary tenets of a problem-driven framing, plural epistemological perspective and intent to integrate theoretical insights to generate constructive engagement with complex challenges (Hadorn et al., 2006; Mitchell et al., 2015; Pohl, 2010). A heuristic approach defined both the process of research and its output, in line with the view that wicked problems are epistemological challenges that cannot be addressed by focusing on specific management or governance responses that seek to reconcile different views of a problem (Huutoniemi, 2014). Instead, a heuristic approach suggests that "a more helpful strategy might be to search for 'cognitive shortcuts' to framing and dealing with the situation" (Huutoniemi, 2014: 2). As such, our process was scoped and designed to encompass a breadth of relevant theories, leverage the diverse perspectives of the research team, and work towards development of a conceptual frame that facilitates constructive thinking through complex, contextually specific situations.

The process of research involved three qualitative methodological steps undertaken iteratively: (i) a structured review of literature across four bodies of scholarship pertinent to the problem situation, (ii) collaborative sensemaking by the author team, and (iii) development of the 8Rs framework as a heuristic for progressing circular economy-informed water and sanitation service systems. The structured literature review adopted a theoretical multiplicity approach. Emerging from transition studies (Dewulf et al., 2009; Termeer and Dewulf, 2012), applied by Karpouzoglou et al. (2016) to social-ecological system governance and by Fallon et al. (2022) to resilience and water governance, theoretical multiplicity aligns with ideals of transdisciplinary research in its recognition that using a variety of theories leads to more nuanced understanding of complex sustainability issues. Driven by our problem-framing, we engaged with scholarship across four fields: water and sanitation, circular economy, social inclusion and climate resilience. The approach sought to constructively examine the different perspectives of each field, identifying areas of overlap as well as points of distinct value offered by each field (as described by Karpouzoglou et al. (2016). An expert-informed snowballing approach identified articles to include in the review, seeking both foundational studies and work at the intersections of the four fields. Our analysis of each

theoretical perspective is elaborated in section 3.

The second and third steps involved a series of sensemaking meetings, in which the team collaboratively reflected on theoretical insights and worked towards development of the conceptual framework. Sensemaking leveraged the diverse expertise of team members, spanning circular economy, water engineering and economics, geography, history and environmental management. Beyond the author team, we sought input from colleagues with expertise in circular economy water in the Australian context, complementing the Global South focus of authors and testing ideas with reference to established frameworks (Jazbec et al., 2020). Discussions spanned 'horizontal reflection' across concepts, and 'vertical reflection' about the relevance and potential applications of ideas in practice. The resulting conceptual framework – presented in section 4 as our heuristic for progressing circular economy or thinking in water and sanitation – was adjusted through several iterations as we discussed both included concepts and their structure.

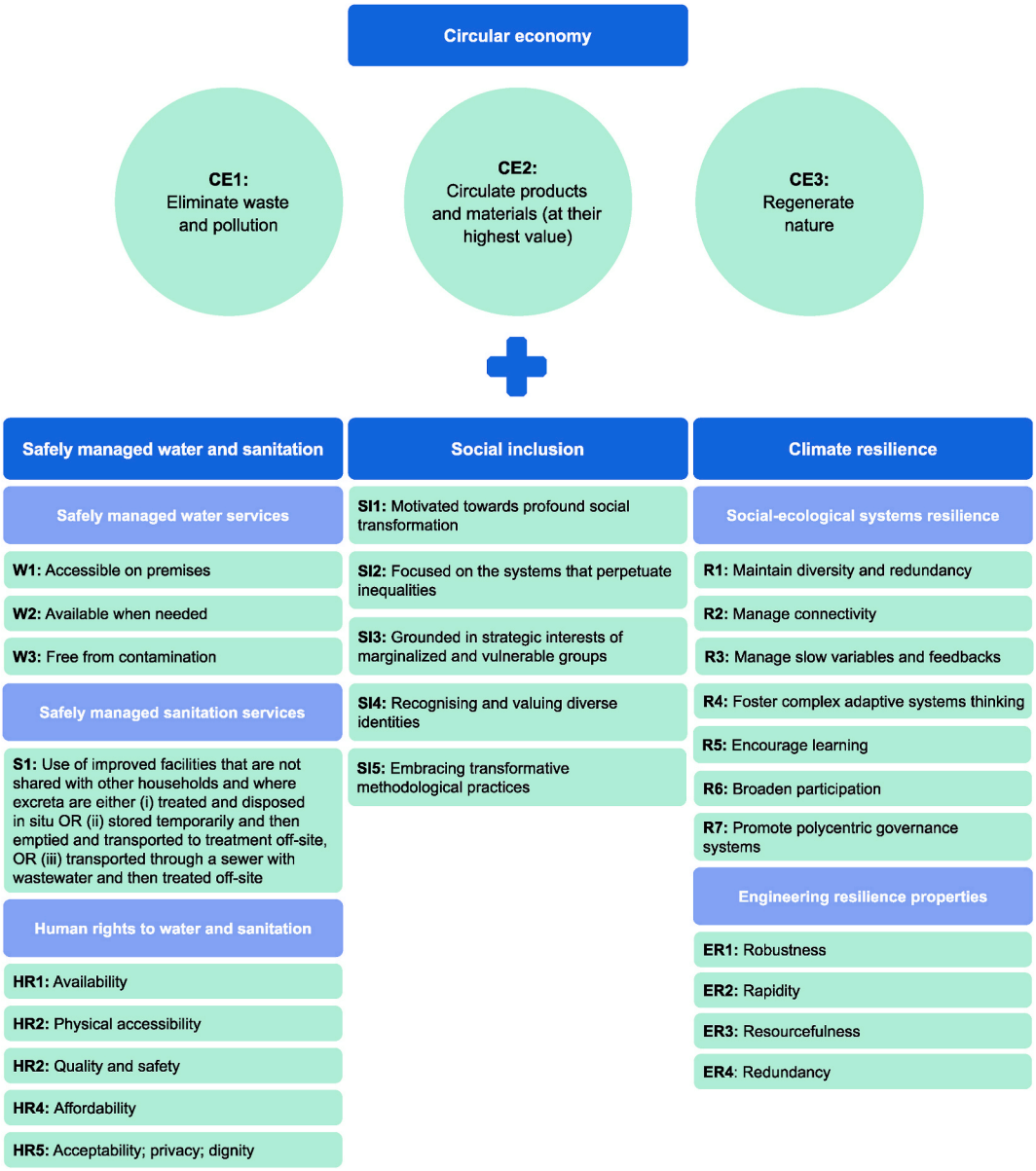

Fig. 1. Principles underpinning the 8Rs framework. Applying circular economy principles alongside those of safe management, inclusion and climate resilience enables us to navigate potential tensions and achieve multiple interconnected sustainable development objectives. Sources: circular economy principles drawn from the work of Ellen MacArthur Foundation (Ellen MacArthur Foundation, 2012, 2015, 2021), safely managed water and safely managed sanitation defined by WHO/UNICEF Joint Monitoring Programme (JMP), human rights to water and sanitation criteria from United Nations Office of the High Commissioner for Human Rights (OHCHR), social inclusion principles adapted from MacArthur et al. (2022), social-ecological systems resilience from Biggs et al. (2015) and engineering resilience properties from Bruneau et al. (2003).

3. Theoretical foundations and intersections

In this section, we synthesise key aspects of the four bodies of scholarship underpinning the 8Rs framework, namely: (i) water and sanitation, (ii) circular economy, (iii) social inclusion, and (iv) resilience. For each, we present and justify principles used as theoretical scaffolding for the 8Rs framework and consider their intersections. The complete set of principles are summarised in Fig. 1. Codes allocated to each principle in Fig. 1 are used throughout sections 3 (theory) and 4 (results) to facilitate tracing of the study's engagement with principles from theory to application.

3.1. Water and sanitation

Principles guiding conceptualisation of water and sanitation services in this study align with human rights standards and WHO/UNICEF global Joint Monitoring Programme (JMP) definitions of safely managed services. Access to safe drinking water and sanitation services are basic human rights (United Nations, 2010, 2015), with duty bearers (often local governments) compelled to progressively realise services using the maximum available resources. To meet human rights standards, services must be available when needed (HR1), physically accessible (HR2), of appropriate quality and safety (HR3), affordable (HR4) and acceptable (HR5) – including ensuring privacy and dignity in the case of sanitation (United Nations, 2015). These human rights standards are complemented by practice-oriented definitions of 'safely managed services' provided by the WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply, Sanitation and Hygiene. Under the JMP criteria, to be considered safely managed for the purposes of global monitoring, water services must be accessible on premises (W1), available when needed (W2) and free from contamination (W3). For sanitation, excreta must be either treated and disposed in situ, stored temporarily and then emptied and transported to treatment off-site, or transported through a sewer with wastewater and then treated off-site (S1).

While drawing on human rights and JMP definitions for water and sanitation service standards, we also conceive access to water and sanitation as dependent on strong governance systems. While water and sanitation initiatives historically focused on technologies and facilities, current conceptions emphasise that service delivery requires well functioning social, economic, environmental and governance systems (Huston and Moriarty, 2018). A range of actors are implicated including government agencies (with a central role as duty bearer), businesses, and diverse service users. Similarly, water and sanitation value chains can be complicated, connecting with multiple related sectors (for example manufacturing, solid waste, agriculture). We adopt a systems approach as it acknowledges the multi-faceted complexity of how water, sanitation and hygiene systems operate in contexts with limited resources, with often unclear mandates of where the responsibility of service provision lies. Taking a systems perspective can enable identification of diverse entry points for circular approaches to contribute to inclusive and climate resilient water and sanitation services, in ways that guide thinking beyond production and consumption systems (where much circular economy thinking has developed) towards recognition of the particularities of water and sanitation value chains and ultimately systems change.

Water and sanitation literature has explored intersections with circular economy, social inclusion and climate resilience. The concept of 'circular economy water' has been proposed, defined as "an economic framework for reducing, preserving and optimising the use of water through waste avoidance, efficient utilisation and quality retention while ensuring environmental protection and conservation" (Morseletto et al., 2022). Conceptual and practice-based literature has developed strategies for advancing circular water and sanitation systems, primarily focused on Global North countries and utility managed service systems (IWA, 2016; Jazbec et al., 2020; Marques et al., 2023; Nika et al., 2020). Focusing on Global South contexts, circular economy sanitation research has explored aspects of technology (Mijthab et al., 2021), finance (Carrard et al., 2021; Mallory et al., 2020b), business models (Otoo et al., 2018) and social acceptability (Madzaramba and Zanamwe, 2023; Sutherland, 2023). Integrating social inclusion and resilience into the water-circular economy intersection, the World Bank's Global Water Practice developed the Water in Circular Economy and Resilience (WICER) framework for applying circular economy approaches in urban areas with a utility service orientation (Delgado et al., 2021). WICER offers an assessment tool and practice-based case examples to draw on, while articulating inclusion and resilience as normative outcomes for any circular initiative.

More generally, the connections between water, sanitation and inclusion have been widely discussed in literature. Strengthened service delivery is acknowledged to be foundational for social inclusion (Macura et al., 2023), and persistent inequalities hinder more rapid and sustained progress towards achieving Sustainable Development Goal (SDG) targets (WHO/UNICEF, 2023). Reflecting widespread agreement on the central importance of inclusion, there is increasing focus on gender equality, disability and social inclusion (GEDSI) in water and sanitation programming (MacArthur et al., 2023; Macura et al., 2023). Water and sanitation initiatives are also opportunities to advance wider equality, with inclusion-oriented activities contributing to women's empowerment (Caruso et al., 2022; Dickin et al., 2021), gender equality (MacArthur et al., 2024) and disability inclusion (Mactaggart et al., 2021; Wilbur et al., 2022). Increasingly, water and sanitation initiatives are seeking to contribute to transformative societal change, challenging inequitable structures and norms both within and beyond service delivery activities (MacArthur et al., 2023).

Climate resilience is a newer, though rapidly increasing, focus of water and sanitation literature. A tendency to focus on risks and hazards to infrastructure (as characterised by Kohlitz et al., 2017) has evolved to stronger engagement with resilience (e.g. Charles et al., 2022; Howard et al., 2021; Mills et al., 2020; Willetts et al., 2022), social and governance dynamics of climate-service delivery connections (e.g. Abrams et al., 2021; Dickin et al., 2020; Donkor, 2020; Grasham et al., 2021) and mitigation opportunities (particularly for onsite sanitation) (e.g. Johnson et al., 2022; Kulak et al., 2017; McNicol et al., 2020; Somlai et al., 2019; Van Eekert et al., 2019). A narrative that progress in water and sanitation strengthens broader climate resilience is also emerging – particularly in support of a sector claim to climate finance – with ongoing work seeking to explore and validate the links (e.g. Mason et al., 2020; Mikhael et al., 2021; UNICEF, 2021).

3.2. Circular economy

Three principles guide the study's engagement with circular economy: (1) eliminate waste and pollution (CE1), (2) circulate products and materials (at their highest value) (CE2), and (3) regenerate nature (CE3). These principles were articulated in foundational circular economy work by the Ellen MacArthur Foundation (Ellen MacArthur Foundation, 2012, 2015, 2021), drawing on several decades of work in ecological economics and industrial ecology fields (Antikainen et al., 2018). The principles have since been applied in academic and practice realms (IWA, 2016; Jazbec et al., 2020; Marques et al., 2023; Nika et al., 2020). The principles provide normative, though not prescriptive, directions for implementing circular economy thinking. They transcend specific circular economy strategies such as "recycle" (see section 4.1 for an elaboration of terminology around principles and strategies) and encourage connection with the sustainability goals embedded in circular economy thinking that can be lost in a narrower focus on 'closing loops'. The principles have also already been used to progress thinking about circular economy-informed water systems, for example as a foundation for Nika et al.'s (2020) circularity assessment framework for complex water systems.

The three principles of eliminating waste, circulating products and regenerating nature align with conceptions of circular economy as both a sustainability narrative, and as a suite of strategies guiding economic activities towards greater alignment with natural systems. As a sustainability narrative, circular economy is aspirational and inspirational (Pascucci et al., 2023). It transcends techno-industrial conceptions and becomes a worldview, in which circularity is seen as essential if we are to successfully transform economies in ways that address societal and environmental challenges (Geissdoerfer et al., 2017; Pascucci et al., 2023; Schöggl et al., 2020; Webster, 2021). Such transformations demand increasing alignment of industrial and ecosystem processes, which requires us to "change frames and perspectives on how we organise production, consumption and exchange of resources, goods and services" (Pascucci et al., 2023: 2). The inclusion of services in this appeal (in contrast to traditionally materials-oriented circular economy literature) supports application of circular economy to water and sanitation as both resource and service systems.

As a guide for shifting the intrinsic nature of economic activities, circular economy articulates strategies for reducing, reusing, recycling and recovering materials across extraction, production and consumption phases of supply chains. Such strategies are variously defined using an evolving and expanding list of 'R' activities (Kirchherr et al., 2017; Valencia et al., 2023) or as "narrowing, slowing and closing" activities (Geissdoerfer et al., 2017, 2018). Activities are articulated as relevant and requisite across micro, meso and macro scales (Su et al., 2013), indicating how different actors (businesses, governments, civil society) can play roles supporting circular economy activities. In this study, the practical opportunities elaborated across circular economy literature are central and complementary to a sustainability narrative conceptualisation. We employ circular economy to both inspire and to shape practical action, seeking to move beyond dichotomous presentations characteristic in scholarly and practice-based CE literature towards constructive integration.

Circular economy literature has been critiqued as slow to engage with the social dimensions of system change (Mies and Gold, 2021; Schröder et al., 2020), with a tendency towards technocratic and apolitical framings (Genovese and Pansera, 2021). However, an emerging body of work is exploring how circular economy thinking can better consider imperatives of inclusion and equality. Valencia et al. (2023) explore the social contribution of circular economy approaches and propose a set of socio-economic R strategies founded on the capabilities approach. Clube and Tennant (2023) propose a human-centred approach to circular economy activities in which meeting human needs is both an objective and means in circular economy initiatives.

Similarly, thinking about how circular economy ideas can support resilience is nascent (Kennedy and Linnenluecke, 2022). Emerging work asserts the potential of circular economy to build community resilience to climate shocks by promoting local, resource efficient supply chains, and scaling-up the sharing economy to facilitate access to essential goods and services when needed (Wang et al., 2022). Yet empirical evidence is lacking, and literature has focused more on potential circular economy contributions to climate change mitigation (Khanna et al., 2022) compared with adaptation or resilience. Assertions that circular economy can support social-ecological resilience are often implicit rather than the focus of analyses (Kennedy and Linnenluecke, 2022). Furthermore, the potential for circular approaches to result in unintended perverse outcomes from a resilience perspective has not been well studied (Kennedy and Linnenluecke, 2022), despite the risk that circular economy activities can undermine ecological integrity if not pursued with a core focus on environmental gains (Bosschaert, 2022; Desing et al., 2020).

3.3. Social inclusion

Principles for social inclusion used in this study are adapted from research on gender-transformative approaches in international development by MacArthur et al. (2022). With foundations in feminist development, the capabilities approach and Aristotelian ideas of human flourishing, the five principles draw from thirty years of research on inclusion-oriented social transformation (MacArthur et al., 2022). While focused specifically on gender equality, the principles are equally relevant for inclusion more generally, emerging from ideas of social empowerment and transformations (MacArthur et al., 2022). As such, we extend application of the principles beyond gender to cover other diverse aspects of marginalisation such as income, age, physical ability, race, nationality, religion, sexuality, marital status, class and caste – each of which are variously relevant in different socio-cultural, economic and political contexts.

The principles span both goals and processes of social inclusion, with an agenda to transform norms and structures that impede equality. Goal-oriented principles demand that social inclusion initiatives must be motivated towards profound social transformation (SI1), focused on the systems that perpetuate inequalities (SI2), and grounded in the strategic interests of marginalised and vulnerable groups (SI3). Process-oriented principles assert the importance of recognising and valuing diverse identities (SI4) and embracing transformative methodological practices (SI5), with a necessary strong focus on meaningful participation and citizen voice. Without repeating full elaboration of the principles as described in MacArthur et al. (2022), we note here two considerations relevant for

pursuing inclusion in and through circular economy-informed water and sanitation initiatives. First, a commitment to do no harm is implicit in the principles, which requires balancing transformative agendas with the need to prioritise safety, while avoiding unintentional harm and addressing backlash/resistance (Water for Women Fund, 2019). Second, social inclusion principles should be locally interpreted and driven by actors embedded within the relevant social and structural context. Implicit in the social inclusion principles is an intention towards decolonising development, demanding a reflexive and power-aware approach to their application in diverse contexts (MacArthur et al., 2022; Worsham et al., 2021).

3.4. Climate resilience

Climate resilience in this study is understood as the "capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure […] a positive attribute when it maintains capacity for adaptation, learning and/or transformation" (IPCC, 2023). Beyond this climate-change specific definition, we articulate resilience as a multidimensional concept that can be variously viewed as trait (system characteristics), process (system actions and interactions) and emergent or desired outcome (normative direction) (after Moser et al., 2019). The multidimensional nature of resilience makes practical application of resilience principles in complex and uncertain situations challenging – a situation likely to intensify given we are now in uncharted territory in the climate crisis (Ripple et al., 2023).

Reflecting the complexity of resilience and with a view to practical relevance, we adopt principles drawn from resilience scholarship across social-ecological systems (SES) and engineering fields. SES resilience includes structural, complexity and governance-oriented dimensions (as characterised by Berbés-Blázquez et al., 2017). SES resilience is defined by seven principles, as presented in the foundational work of Biggs et al. (2015): maintain diversity and redundancy (R1), manage connectivity (R2), manage slow variables and feedbacks (R3), foster complex adaptive systems thinking (R4), encourage learning (R5), broaden participation (R6), and promote polycentric governance systems (R7).

As presented in section 3.1, climate resilience is an increasing focus of water and sanitation discourse. Applying SES resilience principles to water and sanitation means considering how to ensure the continuous provision of essential water and sanitation services by adapting or reconfiguring system components such as social actors, organisations, infrastructure, and environmental resources to accommodate climate-related hazards (Kohlitz et al., 2019a). By building SES resilience, a water and sanitation system becomes capable of accommodating various types of disturbances, including climate hazards, while accommodating their inherent uncertainties. This approach complements a risk-hazard perspective, in which a water and sanitation system is designed to adapt to change through a specific risk assessment and management strategy. Examining the climate resilience of water and sanitation through the lens of SES resilience offers several benefits, including consideration of the dynamic and unpredictable nature of social-environmental interactions, the exploration of adaptation solutions beyond infrastructure strengthening and management of predictable risk, and the simultaneous strengthening of social and environmental systems.

The breadth of SES resilience principles is both a strength and limitation for their practical application. In spanning multiple dimensions of the dynamic interactions between biophysical and social systems, SES resilience principles facilitate grappling with the inherent unpredictability, uncertainty and complexity induced by climate change upon both society and nature. Yet for application to service-oriented sectors in which infrastructure is a necessary (albeit insufficient) area of focus, the abstract nature of principles can sideline critical questions about the technical functionality of extraction, treatment and transport aspects of accessing water and sanitation. As such, we include complementary engineering resilience principles, adapted from Bruneau et al.'s (2003) work on seismic resilience. Engineering resilience properties address outcome attributes of robustness (ER1) and rapidity (ER2) as well as process-oriented measures of resourcefulness (ER3) and redundancy (ER4).

Both SES and engineering resilience principles have positivist epistemological origins, and SES resilience – which seeks to incorporate social and governance dimensions – has been critiqued as lacking engagement with politics and power (Fallon et al., 2022; Matin et al., 2018). In this study, we assert the value of engaging with social inclusion principles alongside climate resilience principles, and in line with water and sanitation work on contextual vulnerability (Kohlitz et al., 2017), to drive interpretations of SES resilience that are more nuanced in their engagement with politics and power.

4. Results and discussion: 8Rs for circular water and sanitation

In this section we present our conceptual framework for progressing circular economy approaches (or thinking) in water and sanitation. The heuristic is designed for use by skilled facilitators in an ideation process involving stakeholders representing diverse context and content expertise. The heuristic takes the form of a suite of eight adapted circular economy 'R strategies' for water and sanitation. The R strategies embody theory-based principles of circular economy, climate resilience and social inclusion. They are designed to prompt thinking and action in pursuit of safely managed, inclusive, climate resilient water and sanitation that aligns with the broader sustainability directions that circular economy narratives aspire to. In this section we first clarify terminology (purpose, principles, strategies) to guide interpretation of the heuristic's scope and potential application. We then present and justify the 8Rs with reference to theory-based principles, before discussing the intended use of the heuristic as a tool for collaborative ideation of circular economy opportunities.

4.1. Scope of the heuristic

In pursuit of a heuristic that honours its intention to offer a 'mental shortcut' while maintaining integrity of included concepts, we

situate it within a hierarchy of purpose to action. The heuristic sits at the level of *strategy*, informed by *purpose* and *principles* and intended as a tool for constructive dialogue about potential *contextualised opportunities*. Fig. 2 illustrates the scope of the heuristic, with each level elaborated below.

Purpose in this hierarchy is the normative direction, namely the realisation of climate resilient, inclusive, safely managed water and sanitation services. We intentionally use the language of purpose rather than goal or objective, in line with transdisciplinary conceptions of purpose as values-based and goal-transcendent (Jantsch, 1970). Framing the heuristic as purposeful (rather than goal-oriented) creates space for non-linear conceptions of knowledge-action pathways and can complement goal-driven water and sanitation sector discourse (Carrard et al., 2022). Our purpose communicates the aspirational impact of the heuristic. It defines the scope of focus as spanning (in addition to circular economy) climate resilience, inclusion and safely managed water and sanitation. The purpose also aligns with broader sustainability agendas implied in circular economy and climate resilience narratives and reflected in the Sustainable Development Goals (Garcia-Saravia Ortiz-de-Montellano et al., 2023).

Principles distil relevant fields of scholarship into 'scaffolding' that informed development of the heuristic, and should guide its application. As described in section 3, our theory review identified principles for each of circular economy, water and sanitation, social inclusion and climate resilience. The ways in which principles are reflected in the 8Rs framework is elaborated in section 4.2. Interpreting the 8Rs strategies with reference to principles is an ideal, though complex, feature of intended application of the 8Rs. We reflect on the complexity of navigating ideal and practical application in section 4.3.

Strategies are the 8Rs included in the heuristic, which are presented and justified in section 4.2. The strategies are an adapted set of Rs for progressing water and sanitation in low- and middle-income contexts. We took the common and memorable idea of circular economy being enacted through 'R strategies' (Kirchherr et al., 2017; Valencia et al., 2023), interpreting them for water and sanitation by identifying three 'practical' strategies mapped to circular economy principles and five strategies related to purpose and process. We note that in circular economy literature, Rs that we term 'strategies' are often referred to as principles (Kirchherr et al., 2023b). We

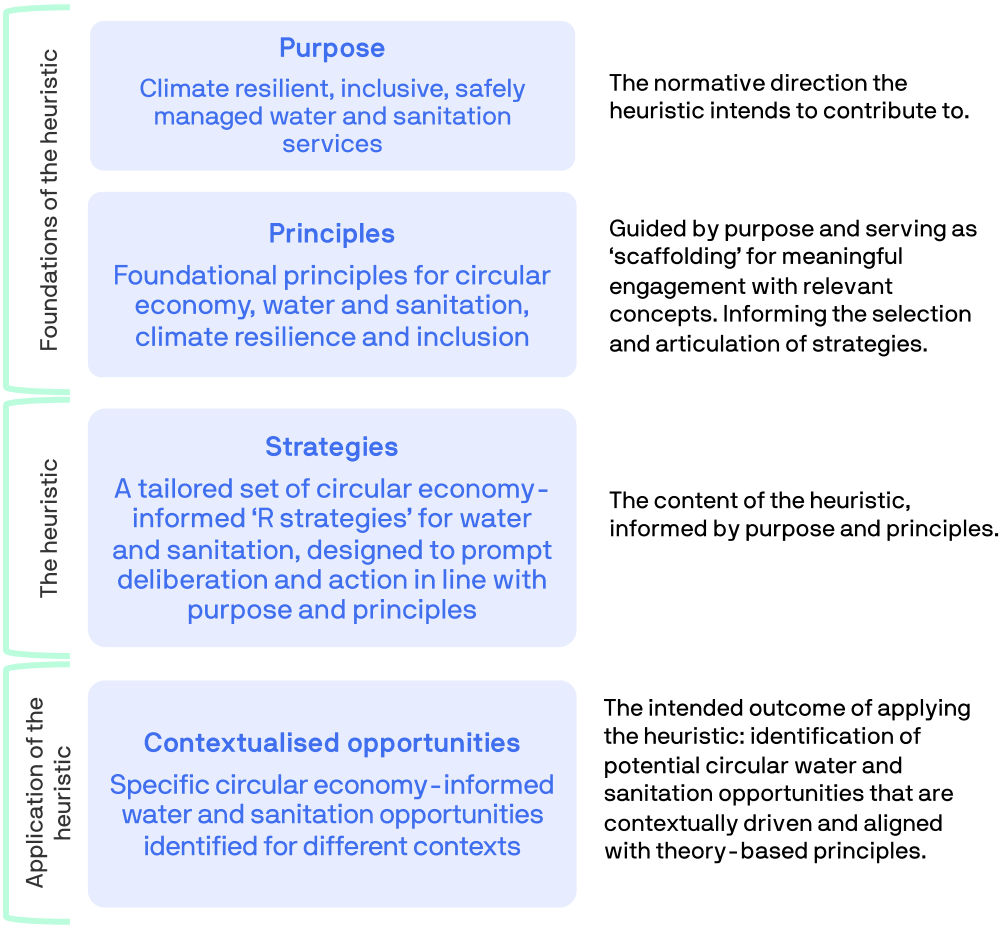

Fig. 2. Heuristic scope: informed by purpose and principles, articulating strategies that can be used to explore contextualised circular water and sanitation opportunities.

intentionally use the word strategies to differentiate the level of action and process (our strategies) from higher level principles and purpose.

Finally, the heuristic is designed to support ideation of contextualised circular water and sanitation *opportunities*. We define opportunities as case specific ideas for bringing circularity into water and sanitation service systems. While strategies are generalised ways of thinking about circular economy-informed water and sanitation systems, opportunities must be embedded in context and cannot be prescribed. As such, opportunities are beyond the scope of the heuristic itself, and refer to its intended impact. We also note that the heuristic is designed to support an ideation process, with resulting potential opportunities requiring further assessment for suitability of implementation. Ideally such assessments are informed by relevant principles and based on locally determined values and prioritisation processes.

4.2. 8R strategies for circular water and sanitation service systems

Fig. 3 presents the heuristic: 8Rs for circular water and sanitation. The heuristic comprises 8 'R strategies', of which three are practical Rs for applying circular economy ideas in the design of water and sanitation service systems. The other five Rs relate to critical dimensions of purpose, process and inclusion. They are intended to ensure that practical thinking is situated within (and guided by) these considerations. In this section we present each R, noting its definition within the framework, its basis in relevant theories (as articulated in section 3), our rationale for including it and an example of how each R might inspire contextualised opportunities. While the presentation here is necessarily linear and articulates the Rs as discrete, in practice we see them as interlinking, overlapping and operating together, sometimes in synergy but also with potential trade-offs. Any circular opportunity will be aligned with at least one practical R strategy, and will benefit from the perspectives prompted by working through others.

4.2.1. Reduce or refuse

Reduce or refuse is about optimising the way we use natural resources, focusing on efficiency and questioning norms of use. It is the first of three practical R strategies, intended to prompt consideration of opportunities that minimise the use of water, energy and materials in water and sanitation service delivery. Reducing and refusing are core to the circular economy principle of eliminating waste and pollution (CE1). In product-oriented circular economy hierarchies they are separated (Kirchherr et al., 2023b), with refuse taking a higher place than reduce in its potential to achieve desired waste-elimination objectives. For public services like water and sanitation the distinction is not so helpful (refusing water use is not possible or desirable), so we group them with a view to prompting consideration of both efficiency and potential resource-use avoidance. We note that reducing and refusing must be pursued in ways that align with, and do not undermine, principles asserting that water and sanitation must be available in sufficient quantities to meet human rights (W2, HR1). Reducing and refusing may also be in tension with resilience principles of maintaining diversity and redundancy (R3, ER2) (Kennedy and Linnenluecke, 2022), which should be navigated when assessing and implementing circular opportunities.

For water and sanitation systems, reducing and refusing aligns with Morseletto et al.'s (2022) circular economy water 'decreasing' strategies of avoid, reduce and replace. Refusing refers to situations where business-as-usual water use is completely avoided, for example waterless toilets such as composting or container-based systems (Russel et al., 2019). Refuse can also be applied to material

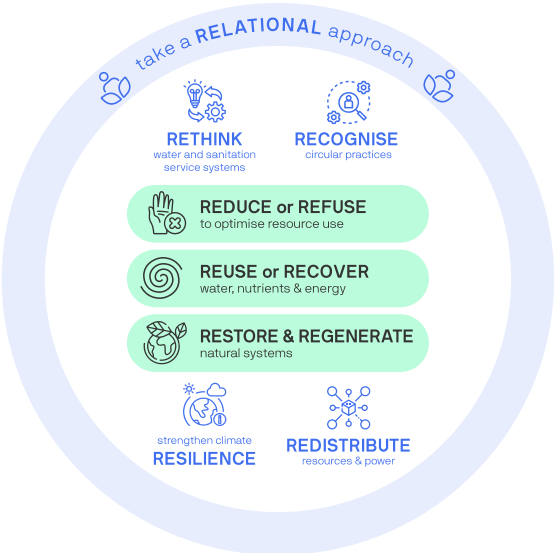

Fig. 3. 8Rs for circular water and sanitation, comprising three practical R strategies (reduce, reuse, restore) and five strategies related to dimensions of purpose and process (rethink, recognise, resilience, redistribute, relational).

and chemical aspects of services, for example through use of local materials to treat wastewater in drains (Jamwal et al., 2019). Refuse can also be applied to menstrual health and hygiene, for example the use of menstrual cups instead of disposable sanitary products (Mehrotra and Jaladi, 2022). Reduce encompasses a range of efficiency measures, including non-revenue water reduction, installation of efficient appliances, or tariff structures that disincentivise high volumes of use and resultant wastewater. Reduce can also be applied to the design of water and sanitation systems with lower GHG emissions (ADB, 2023).

4.2.2. Reuse or recover

Reusing and recovering, the second 'practical' R strategy, is about closing loops. This strategy reflects the circular economy principle of circulating products and materials at their highest value (CE2). The terms reusing and recovering evoke the popular 'recycling' idea of circular economy that dominates circular economy water and sanitation literature (Kirchherr et al., 2023b). In the 8Rs framework, the scope of reusing and recovering encompasses recycling, with the distinction between the terms meaningful in light of planned end-uses of the circulated resource. Reuse and recover have different definitions when applied to industrial or manufacturing processes and therefore occupy different places in the dominant circular economy hierarchy (Kirchherr et al., 2017). In the 8Rs framework, we group them to convey their comparable intention, but distinct practical meanings for water (where reuse is more relevant) and for sanitation (where recover is more apt and applies to both water and nutrients). As with reduce and refuse, we note that this practical strategy must be pursued in alignment with principles of safely managed water and sanitation, social inclusion and resilience. Particular attention is warranted for quality and safety (W3, HR3) given the health and environmental risks associated with inappropriate reuse of water or human excreta.

Opportunities for reusing (water) and recovering (nutrients, energy) include storage and reuse of water for lower value purposes, wastewater treatment and reuse at various scales, faecal sludge reuse to improve soil condition, nutrient capture and use to benefit food production, or use of sludge in biogas systems. These examples align with Morseletto et al.'s (2022) circular economy water 'recover' strategy in which recover is "the retrieval of valuable materials (i.e. organic matters, chemical elements, biochemical compounds) and the retention or generation of energy". Technological opportunities for reusing water (treated or for lower quality purposes) and recovering nutrients are a focus of water and sanitation systems analysis (Orner and Mihelcic, 2017; Werkneh and Gebru, 2023; Xu et al., 2023), as are strategies for generating energy from human waste (Almansa et al., 2023). The widely used sanitation service chain concept commonly has safe disposal or reuse/end-use as the final step (e.g. WHO, 2022), illustrating the extent to which this thinking has already influenced sector norms.

4.2.3. Restore and regenerate

Restore and regenerate, the third 'practical' R strategy, reflects the circular economy principle of regenerating nature (CE3). Beyond minimising waste and resource use, efforts to restore and regenerate seek to proactively strengthen the integrity of natural systems. A focus on restoration aligns with an increasing emphasis on improving environmental quality in circular economy definitions (Kirchherr et al., 2023b). Similarly, there are opportunities for water and sanitation systems to move away from minimisation of negative externalities ('do less harm') towards 'do more good' approaches (Carrard and Willetts, 2017). Including restore and regenerate in our heuristic reflects an ambition that water and sanitation systems are both resilient *and* contribute to wider sustainability and climate resilience imperatives, with ecological restoration strongly implicated in adaptation and resilience efforts (Bustamante et al., 2019). Climate resilience principles are therefore core to interpretation of restore and regenerate strategies, particularly those focused on connected social-ecological systems (R1-R7).

For water and sanitation systems, restore and regenerate drives thinking in two directions. First, progressing safely managed sanitation services is inherently restorative when pollution reduction is achieved. Inaction in sanitation contributes to degradation of natural systems, for example contamination of groundwater and surface water from inadequate or inappropriately sited pits, tanks and disposal methods. Conversely, sanitation improvements have potential to enhance a range of ecosystem services from water purification to food provisioning and recreation, comprehensively outlined by Trimmer et al. (2019). As such, a restore and regenerate perspective can facilitate greater focus on often-lagging sanitation investment (Wenger et al., 2023).

Second, there are opportunities to proactively regenerate nature in tandem with progressing both water and sanitation service delivery. Nature-based solutions (NBS) exemplify such opportunities, and are an increasingly mainstream (WWAP/UN-Water, 2018) as a complement to essential technological treatment processes. Examples relevant for water services include source water protection (Cooper, 2020; Everard, 2019) and aquifer recharge (Qadir et al., 2015; Ribeiro, 2021). For sanitation services, restoring and constructing wetlands provides wastewater treatment functions while enhancing environmental amenity and reducing greenhouse gas emissions (Masoud et al., 2022; Nguyen et al., 2021). Beyond improving environmental quality, nature-based solutions can achieve a range of co-benefits including climate regulation and wider health and wellbeing outcomes (Kolokotsa et al., 2020; WWAP/UN-Water, 2018). The 2018 World Water Assessment Report (WWAP/UN-Water, 2018) also asserts alignment between NBS approaches and diverse religious, cultural or totemic conceptualisations of nature, suggesting additional socio-cultural benefits that may complement technology-oriented approaches.

4.2.4. Rethink

Rethink has two connected intentions. The first is about critically questioning how we frame problems and define solutions for progressing water and sanitation service delivery. Rethinking also means noticing, then appreciatively and critically questioning social norms and institutional structures that may enable or constrain circularity, opening space to consider what could be different. Rethinking is a commonly-identified strategy in circular economy literature focused on systems change (Kirchherr et al., 2023b; Valencia et al., 2023), including for circular economy water specifically (Morseletto et al., 2022). Re-thinking is also foundational for

considering incremental and transformative adaptation to climate change, with strong links to transformational adaptation characteristics of restructuring and path-shifting (Fedele et al., 2019). While not explicit in the three circular economy principles of eliminating waste, circulating materials and regenerating nature, rethinking is implied as a prerequisite for achieving the system changes required to progress circularity. Similarly, rethinking is implicit in social inclusion principles, which demand transformation in social structures (SI1) and ways of working (SI5). Similarly, the resilience principle of fostering complex adaptive systems thinking (R4) demands rethinking how we conceive and respond to situations with a focus on connectivity and dynamism. Rethinking from a systems perspective also resonates with circular economy literature advocating systems thinking approaches (Iacovidou et al., 2021) and engagement across nested micro, meso and macro scales (Su et al., 2013).

For water and sanitation service systems, rethinking prompts a stepping back from business-as-usual approaches, questioning assumptions about service provision and considering 'how else could inclusive, climate resilient, safely managed services be realised?'. Circularity represents a fundamental rethinking of traditional linear models, offering opportunities to critically examine established approaches across various scales and aspects of water and sanitation service systems. For instance, applying circular economy principles to achieve citywide inclusive sanitation in areas lacking municipal-managed centralized systems raises important questions: What types of systems will best meet future needs in the context of climate change? Is incremental improvement of onsite systems sufficient, or are transformative shifts necessary, requiring large-scale service reconfigurations and investments? If transformative changes are needed, how can they be facilitated?

This rethinking approach can challenge conventional views on roles and responsibilities, as exemplified by ongoing efforts to reframe urban sanitation as a public service rather than a private concern (Schrecongost et al., 2020). It can also influence discourse and terminology. For example, shifting from 'waste-water' to 'resource-water' could potentially reshape perceptions and responses. While often unconsciously used, terminology can reinforce or challenge norms, as has been discussed with reference to sanitation (Rosenqvist et al., 2016; Strande et al., 2023) and circular economy (Rödl et al., 2022). By critically examining existing paradigms and terminology, we can potentially uncover innovative approaches to addressing sanitation challenges in a more sustainable and inclusive manner.

4.2.5. *Recognise*

Recognise is a prompt to notice circular practices already happening in the delivery and use of water and sanitation services. Circularity may be extant, based on traditional practices and wisdom (e.g. conserving and/or reusing water in dry seasons, using faecal sludge for soil conditioning) (Cassin and Ochoa-Tocachi, 2021). Circular approaches may also be coping mechanisms (termed 'necessity driven circular economy' by Korsunova et al. (2022) driven by climatic events and socio-economic conditions, such as the reuse of household greywater to augment water supply (Madzaramba and Zanamwe, 2023). Dialogue arising from a 'recognise' prompt will likely identify practices across one or more of the three practical R strategies (reduce, reuse, restore), and may be connected to (or discussed with reference to) resilience and redistribute. The intention is that recognised practices can be leveraged or adapted. There may be opportunity to formalise, regulate and support informal circular practices to ensure safety and to align with principles of inclusion and resilience. Similarly, nascent circular systems may have potential to be scaled up and optimised.

Articulating recognise as a strategy within the 8Rs framework serves two aims. The first is worldview-oriented, reflecting the author teams' ideals of locally-led development that recognises and builds from strengths (as articulated in Baguios et al., 2021; Roche et al., 2020; Winterford et al., 2023). This aim transcends our principles, though resonates with ideals of social inclusion, particularly embracing transformative methodological practices (SI5) that recognise and value diverse identities and knowledge types (SI4). Deliberately recognising existing practices aligned with the normative direction of circularity challenges the dominant technocratic framing of circular economy (Genovese and Pansera, 2021), opening space for conceptions of circular economy as novel terminology for established practices and wisdom. The second aim is pragmatic. Working from a basis of existing practices is likely to align with social norms, coping strategies, policy drivers and available technologies. Water and sanitation systems historically have high rates of failure, attributed to a focus on technologies and infrastructure as well as local governance challenges and the institution of inappropriate management arrangements (Adams et al., 2020; Herrera, 2019; Howard et al., 2021; Tilley et al., 2014). Building from current practices before, and as enablers of, implementing new circular opportunities is a strategy for more situated, sustainable solutions.

4.2.6. *Resilience*

Strengthening climate *resilience* features in the 8Rs heuristic to emphasise the study's normative imperative. Climate change is the operating context in which water and sanitation services are delivered, and will be the greatest threat to natural and human systems in coming years (Hoegh-Guldberg et al., 2019). As such, strengthening resilience to climate hazards must be core to the identification and development of any circular economy water and sanitation opportunities. Meaningful engagement with resilience when using the 8Rs framework requires familiarity with underpinning principles from engineering scholarship (ER1-4) and social-ecological systems theory (R1-7). Engineering principles will be most helpful for assessing and strengthening infrastructure components of water and sanitation service systems, while social-ecological systems resilience principles demand a broader perspective across natural, social and governance dimensions. Any consideration of *how* to strengthen resilience will require grappling with the inevitable tensions that arise when pursuing multiple aims in complex systems and making judgements about relative priorities.

The heuristic seeks to drive resilience *in* and *through* circular water and sanitation systems. Resilient water and sanitation systems ensure continuity of services during climatic changes and shocks. A range of water and sanitation system resilience frameworks have been developed that can support consideration of service resilience (GWP and UNICEF, 2022; Howard et al., 2021; WHO, 2017; Willetts et al., 2022). Empirical evidence of resilience in water and sanitation systems is still emerging, but examples can be seen in the

form of rural households diversifying their water sources to manage seasonal risks to water security (Elliott et al., 2017), improved design and construction of latrine superstructures that better withstand the windforce of cyclones (Gordon and Hueso, 2021), and water storage at the household to maintain functionality of toilets when water supplies are cut off (UTS-ISF, UI, UNICEF, 2021). Overall, water and sanitation system resilience may be built through a blend of approaches that aim to reduce specific risks of climate hazards (e.g. the use of Climate Resilient Water Safety or Sanitation Safety Plans), ensure provision of alternative services during times of disruption, address structural deficits in human development and institutions to empower people to handle environmental disturbances in general (e.g. addressing land tenure issues that inhibit people and organisations from investing in climate resilient infrastructure in informal settlements), and develop governance systems that are able to adapt or reconfigure themselves to accommodate changes in the environment (e.g. supporting sanitation service providers to adapt their service delivery models or operations based on the season) (Kohlitz et al., 2019b; UTS-ISF and SNV, 2019; Willetts et al., 2022). These latter pathways have potential to strengthen broader climate resilience beyond the boundary of the service itself.

4.2.7. Redistribute

The R strategy *redistribute* embodies the heuristic's aim to drive focus on inclusion and equality when progressing circular water and sanitation opportunities. Redistribute is a cross-cutting theme requiring attention to *how* a circular water and sanitation ideation process is run (diversity of perspectives, inclusive approaches) as well as *what* and *how* potential opportunities are assessed and pursued. The choice of the term 'redistribute' evokes Raworth's (Raworth, 2017) 'regenerative and **distributive** by design' principle of doughnut economics (emphasis added) and the reality that inequitable distribution of resources and power constrain achievement of global goals and their foundational value of leaving no one behind (Gupta and Vegelin, 2023). Social inclusion principles (SI1-5) underpin redistribution ideals, with the intent that circular economy water and sanitation opportunities are pursued in ways that transform, and do not entrench, structural inequalities. Placing redistribute within the heuristic intends to elevate this aim and progress circular economy scholarship's nascent engagement with social dynamics (Clube and Tennant, 2023; Mies and Gold, 2021; Schröder et al., 2020; Valencia et al., 2023). Similarly, giving resilience and redistribute equal place seeks to drive more power-aware deliberations about resilience strategies, recognising that "[r]esilience-thinking embraces complexity in water–society relations but misses power" (Fallon et al., 2022).

The substantial body of academic and practice-based work at the intersection of water, sanitation and social inclusion (as described in section 3.1) offers illustrative examples and guidance on how to enact 'redistribute' strategies when identifying and implementing circular water and sanitation opportunities. Increasingly, such examples are framed within social transformation discourse (MacArthur et al., 2023), emphasising how water and sanitation – when inclusion is an intentional and central concern – can drive meaningful shifts towards equality (MacArthur et al., 2023; Macura et al., 2023; Willetts et al., 2023).

4.2.8. Relational

Finally, our framework recommends taking a *relational* approach when identifying and planning circular opportunities in water and sanitation. Articulating a relational approach is an intentional response to a tendency of circular economy literature and examples to prioritise technical (and mechanistic) approaches (Webster, 2021). It reflects our conviction that focusing on the complex web of relations between actors in water and sanitation systems, and between people and their environment, is critical to realise desired service delivery, circularity, resilience and social inclusion outcomes. Our conceptualisation of 'relational' echoes those of West et al. (2020) and Tàbara (2023) who advocate for a relational reimagining of sustainability science and sustainability transformations. A relational perspective means shifting focus away from interactions between entities towards continuously unfolding processes and relations (West et al., 2020), and recognising that any individual's expression of agency is "always done in relation to others and their broader biophysical and institutional contexts" (Tàbara, 2023). These definitions encompass both human-human and human-nature relationships, with the latter identified as a potentially powerful lever for shifting current unsustainable patterns (Riechers et al., 2021). Cognisant of the diverse cultural, ontological and epistemological settings in which the 8Rs heuristic may be used, we expect (and welcome) that the interpretation of 'relational' in practice will vary depending on the context, participants and facilitation.

With reference to our principles, taking a relational approach facilitates deeper alignment with social-ecological resilience principles of connectivity (R2), systems thinking (R4), learning (R5) and participation (R6). Relationality also embodies epistemological alignment with social inclusion principles (SI1-5), particularly the intent to embrace transformative methodological practices (SI5). While relationality is not explicitly evoked in circular economy principles, it has strong resonance with 'reduce' strategies enacted through the sharing economy and with collaboration-oriented 'rethink' concepts. Recent literature directly advocates for a stronger focus on collaboration when progressing circular economy (Danvers et al., 2023), including for example a relational approach to contracting and agreement-making in which goals are qualitative and trust-building facilitates persistence through uncertainty (Danvers et al., 2023; Fischer and Pascucci, 2017).

Taking a relational approach when progressing circular water and sanitation opportunities demands emphasis on process in the ideation phase (how opportunities are canvassed) and their development (assessment through to implementation). It requires a central focus on how people inter-relate with each other and with nature, and making space for the emergence of situated, relationally driven opportunities. West et al. (2021) suggest the usefulness of a research pathway of 'working backwards from concepts' in which participants re-negotiate collective understandings of concepts (such as those underpinning the 8Rs framework) as relevant for their own context and purpose. Such an approach reflects the intent of the heuristic as an offering of useful concepts that can inspire and inform contextually specific directions towards circular, inclusive and resilient services.

4.2.9. Synthesis of the 8Rs

Table 1 synthesises the 8Rs, summarising their connections to relevant theory-based principles and offering examples of practical application to water and sanitation service systems.

4.3. Application of the framework and critical considerations for its use

While the focus of this article is on theoretical development of the framework, in this section we briefly identify its intended applications and related considerations. Ongoing related work is piloting application of the framework for collaborative ideation and investigation of circular water and sanitation opportunities in Vietnam and Kiribati. A learning brief developed with UNICEF East Asia

Table 1
Synthesis of the 8Rs

R strategy	Prompts	Connections to principles	Example
REDUCE OR REFUSE to optimise resource use	How can we optimise use of resources in water and sanitation systems? Are there alternatives to water and energy use (refuse)? How can we improve efficiency (reduce)?	Core to the circular economy principle 'eliminate waste and pollution' (CE1). Must be pursued in alignment with water and sanitation availability principles (W2, HR1). Potentially in tension with resilience principles of maintaining diversity and redundancy (R1, ER2).	Reducing water losses and water demand. Designing low-energy wastewater treatment systems. Waterless toilets. Reusable menstrual health products.
REUSE & RECOVER water, nutrients & energy	How can we close loops in water and sanitation systems? Are there opportunities to reuse water (treated or for lower quality purposes)? Can nutrients or energy be recovered from waste?	Reflects the circular economy principle 'circulate products and materials (at their highest value)' (CE2). Must be pursued in alignment with water and sanitation quality and safety principles (W3, HR3).	Household storage and reuse of water for different uses. Faecal sludge reuse to improve soil condition, nutrient capture and use to benefit food production, wastewater reuse at various scales, use of sludge in biogas systems. Natural reuse systems e.g. irrigation system recharges groundwater where it is naturally treated before reuse.
RESTORE & REGENERATE natural systems	How can water and sanitation systems connect to natural systems? How can they contribute to the regeneration of nature?	Reflects the circular economy principle 'regenerate nature' (CE3). Should be applied in ways that seek alignment with social-ecological systems resilience (R1-R7).	Nature based solutions e.g. source water protection, aquifer recharge, wetland restoration or construction as a component of wastewater treatment.
RETHINK service systems	How could water and sanitation systems be different? What ideas come to mind if we think about changing typical approaches and questioning the assumptions that underlie current systems and models?	Implied as a pre-requisite for progressing circular economy (CE1, CE2, CE3) and social inclusion (particularly SI1, SI5). Fostering complex adaptive systems thinking (R4) demands rethinking how we conceive and respond to situations with a focus on connectivity and dynamism.	Changing thinking from 'wastewater' to 'resource-water'. Sanitation as a public service with shared government, service provider and household responsibilities.
RECOGNISE circular practices	What is already circular? This could include traditional practices and coping or adaptation strategies. How can we value existing circular practices and ensure they are safe?	Transends specific principles, aligned with ideals of social inclusion regarding transformative methodological practices (SI5) and valuing diverse identities and knowledge types (SI4).	Saving and reusing water in a household, e.g. bathing water for garden. Use of dried faecal sludge as soil conditioner. Use of human urine as fertilizer.
strengthen climate **RESILIENCE**	What climate change impacts do we need to consider when planning circular water and sanitation systems? How can circular options strengthen resilience? Resilience includes social, institutional, technical and natural dimensions.	Defined by engineering resilience principles (ER1-ER4) and social-ecological resilience principles (R1-R7).	Capturing, treating and reusing water supports resilience during times of drought. Soil conditioners from faecal waste can increase water storage capacity of soil.
REDISTRIBUTE resources and power	How can we ensure everyone has equal access to water and sanitation services? How can we include diverse voices when planning circular approaches? How can the benefits of circular approaches be fairly shared?	Defined by social inclusion principles (SI1-5).	Sustainable cost recovery approaches that balance what user pays with public investment to ensure affordability. Representation from diverse social groups when planning and implementing circular opportunities.
take a **RELATIONAL** approach	A relational approach emphasises collaboration and trust building. It focuses on connections between people and the world around them. Taking a relational approach means focusing on the *process* of moving towards circularity and on interdependence between people and nature.	Facilitates deeper alignment with social-ecological resilience principles of connectivity (R2), systems thinking (R4), learning (R5) and participation (R6). An expression of social inclusion principles (SI1-5), particularly the intent to embrace transformative methodological practices (SI5).	Bringing diverse perspectives together for conversations about circular economy water and sanitation systems. Creating space for connections to emerge and to shape actions. Building new connections and trust to enable new pathways. Re-imagining human–nature connectedness to shift unsustainable patterns.

and Pacific Region elaborates four areas of application: ideation, investigation, implementation and evaluation (Carrard et al., 2024). Future directions include exploring potential complementary use of the 8Rs framework with established tools and approaches such as Water Safety Planning, Sanitation Safety Planning and Citywide Inclusive Sanitation. There is also scope to explore how the framework can be useful in sub-national and national cross-sector planning processes, in collaboration with actors from connected fields including solid waste management, water resource management and agriculture.

In exploring the range of potential applications, it is important to note that the framework is intended to be used by skilled facilitators to both: (1) leverage the value of collaborative ideation when exploring innovative service delivery pathways, and (2) ensure engagement with strategies maintains connection with foundational principles. Our assertion of the value of a collaborative approach draws on transdisciplinary methods of knowledge co-production (Chambers et al., 2021; Norström et al., 2020). As such, the framework offers a structured set of strategies around which participants can "collaboratively and iteratively produce knowledge, action and societal change" (Chambers et al., 2021: 1). Participants involved should reflect an appropriate mix of expertise across relevant fields and roles, including those involved in water and sanitation service delivery as well as those with knowledge of climate risks, social dynamics and wider environmental considerations. The process should also strive for diversity, valuing knowledge beyond traditional disciplinary boundaries (e.g. practice-based knowledge or lived experience) and representation from voices of those who will implicated in further development of circular opportunities identified as worthy of consideration. This includes actors from government, private sector and user groups as well as those representing voices of potentially vulnerable or marginalised citizens.

Facilitated use of the framework also seeks to ensure that discussions about the 8R strategies are situated in their underpinning principles. The nature (and intention) of a heuristic is to simplify in order to enable grappling with complexity and uncertainty in the pursuit of 'good enough' decisions. As such, heuristics like the 8Rs framework risk losing conceptual integrity if their scholarly basis is absent from deliberative processes. One role of a facilitator in an 8Rs ideation process is therefore to bridge purpose and principles with strategies, ensuring integrity of interpretation and application. The role also ensures engagement across the practical and process oriented Rs, to give focus to aspects of social inclusion and climate resilience that have been under-valued in circular economy frames to date.

Finally, there are inherent tensions that must be negotiated when pursuing the multiple aims of circularity, safely managed services, social inclusion and climate resilience. Deliberative processes using the 8Rs framework will likely unearth several tensions and potential trade-offs, particularly if those involved are appropriately diverse. Circular opportunities that are identified, and resulting decisions about what to pursue, will be values-based and likely reflect the status quo in terms of structures and norms in any context. While it is impossible to resolve tensions, surfacing values when working through R strategies may lead to more open, richer conversations based on participants' ideals. From a foundation of appreciating diverse values, plans to realise benefits and mitigate risks can be developed with underpinning principles in mind. As such, the framework can be used as a tool for thinking about both incremental and transformative change, navigating questions about what is possible, desirable and necessary to strengthen resilience to the impacts of climate change as we pursue inclusive, safely managed water and sanitation service delivery.

4.4. Limitations and unresolved questions

The heuristic, by definition and intention, is reductionist. We defend this based on a view that simplified frameworks play an important role bridging theory and practice. However, we acknowledge that use can be mis-aligned with intention, with resulting pathways co-opted to serve dominant unsustainable patterns. While the research team cannot (and would not want to) control potential applications of the 8Rs framework, we intend that users engage with its underpinning purpose and principles and ensure appropriate facilitation of deliberative processes. These are two strategies to ensure that the intention of the framework maintains integrity in its use, and further application of the framework in a range of case study locations will provide valuable insights on their success and whether alternative approaches are required.

An unresolved question relates to the language and cultural transferability of the 8Rs framework. As noted above, ongoing research in two very different Southeast Asian and Pacific Island locations (Vietnam and Kiribati) is exploring how the 8Rs framework can inform circular water and sanitation service systems, moving from ideation about opportunities to analysis of key dimensions of practical applicability. Translating the R strategies into local languages, as has been done for Vietnam and Kiribati (see supplementary material), requires detailed discussion about the literal and implied meanings of different words. The principles and strategies all originate from English-language scholarship founded in Western scientific epistemologies. Whether the ideas resonate across diverse cultural and epistemic contexts remains to be seen, though initial use of translated versions has been successful in driving rich discussions.

5. Conclusion

This article has presented and justified a novel heuristic, 'the 8Rs framework', for leveraging circular economy concepts to progress safely managed, inclusive, climate resilient water and sanitation services. The contribution intends to bridge conceptual rigour with practical usability, being both grounded in theory and presented in simplified form with ongoing work testing its practical application. Principles underpinning the framework draw from scholarship across circular economy, water and sanitation, social inclusion and climate resilience fields. Strategies span levels of practice, process and purpose, with three practical strategies for enacting circular economy ideas (reduce, reuse, restore) complemented by prompts to rethink service systems, recognise extant circular practices, strengthen resilience, redistribute resources and power, and adopt a relational approach. The framework facilitates thinking across concepts in integrative ways, guiding users to work through multiple perspectives (the R strategies) to consider how circular economy

principles can drive safe, climate resilient, and inclusive water and sanitation services.

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CRediT authorship contribution statement

Naomi Carrard: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Avni Kumar:** Writing – review & editing, Writing – original draft, Visualization, Project administration, Funding acquisition, Formal analysis, Conceptualization. **Đinh Văn Đạo:** Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Jeremy Kohlitz:** Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Monique Retamal:** Writing – review & editing, Visualization, Formal analysis, Conceptualization. **Avinandan Taron:** Writing – review & editing, Conceptualization. **Ngaouea Neemia:** Writing – review & editing, Conceptualization. **Juliet Willetts:** Writing – review & editing, Visualization, Supervision, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Naomi Carrard reports financial support was provided byAustralian Government Department of Foreign Affairs and Trade. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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Data availability

No data was used for the research described in the article.

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