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033

Early Warning, Emerging Issues and Futures

Water as a Circular Economy Resource

Background

The UN Environment Foresight Briefs are published by the UN Environment Programme to highlight a hotspot of environmental change, feature an emerging science topic, or discuss a contemporary environmental issue. The public is thus provided with the opportunity to find out what is happening to their changing environment and the consequences of everyday choices, and to think about future directions for policy. The 33rd edition of UNEP's Foresight Brief looks at how to apply circular principles to water management, and how circularity in water management is key to addressing both the triple planetary crisis and a global water crisis.

Abstract

Fresh water is crucial for most human activities as well as for the health of all ecosystems and biodiversity. However, easily accessible water in sufficient quantity and quality is limited and is decreasing rapidly (UN Water 2023) due to overdemand, mismanagement and the impacts of the triple crisis of climate change, biodiversity loss and pollution.

Humankind is now faced with the increasing risks of water scarcity, which requires a different approach to managing and reusing this precious resource. A circular economy approach – which is intended to ensure that resources are kept in use at the highest possible economic value for as long as possible – enables a more efficient use of natural resources, including water (UNEP 2019a).

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Introduction

According to global statistics (**Figure 1**), only around 3 percent of the Earth's water is freshwater and the remaining 97 percent is salt water stored in the oceans. Of the total freshwater, only 1 percent is found in lakes, rivers or wetlands, with the rest locked deep below ground (30 percent) or in the form of ice or permanent snow (69 percent). These statistics clearly show that although we live on the Blue Planet, the amount of freshwater we have at our disposal is in fact limited and its presence on the Earth's surface is unevenly distributed. Worryingly, our vital fresh water resources, have been in overdemand for the past few decades to the point that we have pushed the water cycle out of balance for the first time in human history (Global Commission on the Economics of Water 2023). How have we come to this point?

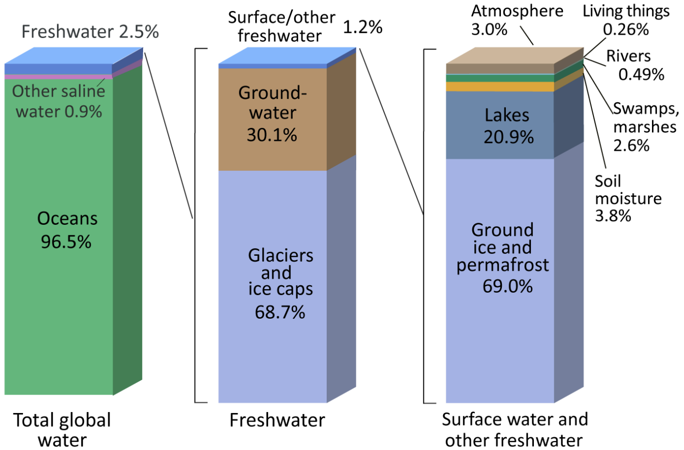

Figure 1: Distribution of water resources in the Earth's system (numbers rounded). Source: Shiklomanov (1993)

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There has been huge pressure on freshwater resources in recent decades. The main driver of this is "vampiric overconsumption" (Reuters 2023), worsened by the interlinked planetary crises of climate change, nature and biodiversity loss, pollution and waste. Water use is increasing due to a growing world population, agriculture, economic development, urbanization and industrialization water usage is increasing. In fact, agriculture and food production are already the largest source of water use per sector, and a major source of water pollution. As a consequence, according to the International Resource Panel (2019), the extraction, cultivation and processing of material resources in the form of biomass/food, minerals, metals, and fossil fuels are now responsible for almost 90 per cent of global water stress and land-use-related biodiversity loss. If we do not change our habits now, global demand for water could increase by 50 per cent by 2030, driven especially by agriculture, human consumption and climate change (FAO 2019). Human activities have put great pressure on natural cycles, changing the natural patterns of water flow (**Figure 2**).

These trends are already influencing humans' ability to use water across four important dimensions: places where water is available (or lacking), times when it can be accessed (or not), its amount, and finally water quality. How these dimensions are taken into account to ensure access to water is the result of complex governance processes involving multiple stakeholders at various levels and often reaching beyond strictly water-related aspects, encompassing social, political, economic, and environmental considerations.

To overcome these challenges and ensure equitable access to water of high quality, improved governance of every aspect of the water cycle – including transboundary water cooperation – is urgently needed to prevent, mitigate and manage increasing risks (UNEP 2019b). Water governance thus has the potential to help societies transition towards a circular and resource-efficient economy.

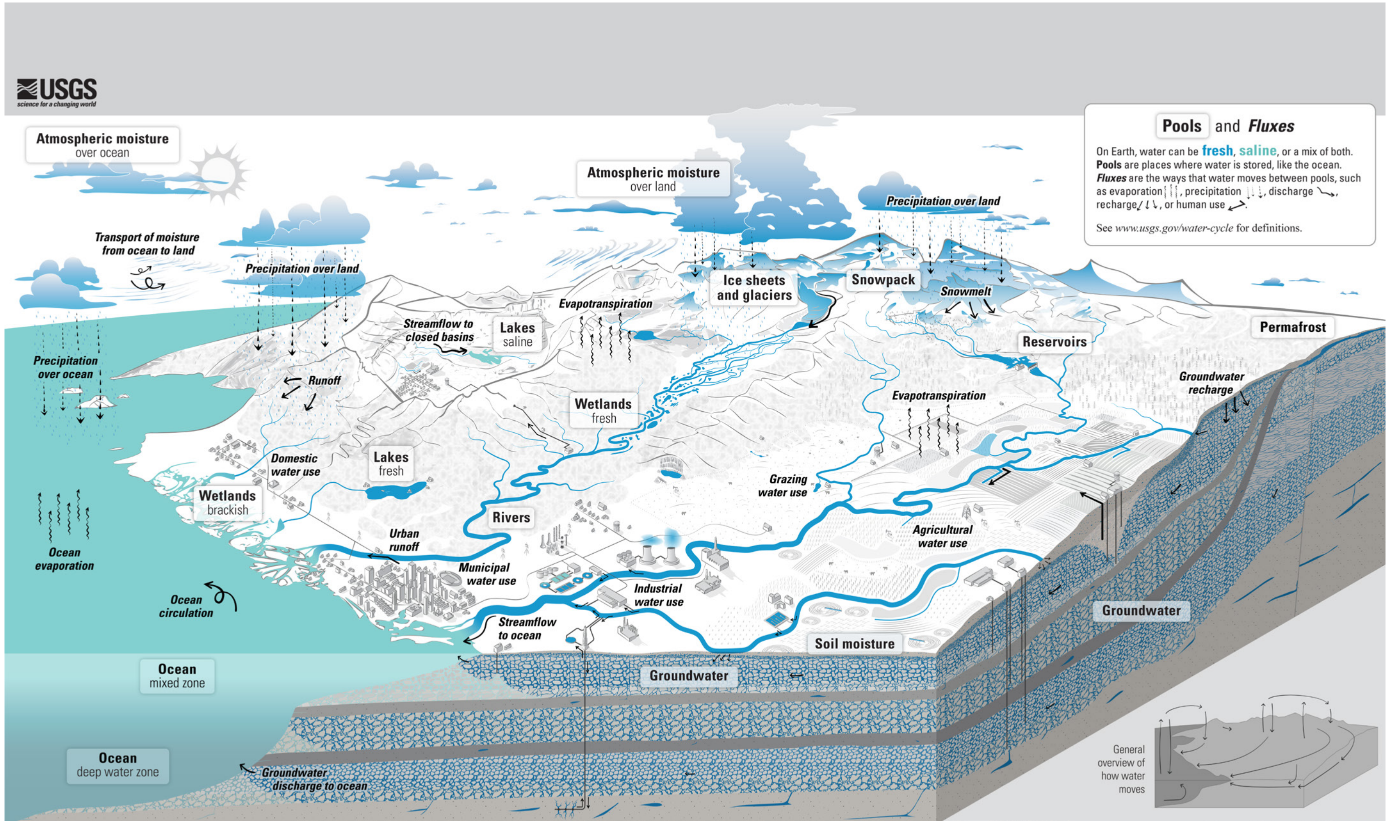

Figure 2: The global water cycle with human influences indicated. Source: USGS (2022)

Why this is important?

At the global level, climate change has a measurable impact on the water cycle. According to the IPCC Sixth Assessment Report (IPCC 2022) it increases the timing, frequency and intensity of water-related extremes such as floods or droughts, which also leads to water quality/pollution issues. The global population exposed to extreme-to-exceptional total water storage deficit is projected to increase from 3 percent to 8 percent in the course of this century. Between 3 and 4 billion people will face physical water scarcity, depending on the actual level of global warming (at 2°C and 4°C, respectively). This can disproportionately affect women and girls due to their traditional roles as primary caregivers, and household water-related tasks affecting their ability to engage in income generating activities or pursue education because of traveling long distances to find water sources which is physically demanding and time consuming. Since 1990, water-related catastrophes were linked to almost 90 per cent of the most devastating natural disasters. In some countries damage caused by those events amounted to 40 per cent of annual GDP (HLPW 2018). The conclusion is clear: climate change will impact water availability, with knock-on effects on food security, human health, urban and rural settlements, energy production, industrial development, economic development, and ecosystems, all of which are all water-dependent (UN Water 2020).

Climate change also affects the quality of water. Higher water temperatures reduce dissolved oxygen and thus the self-purifying capacity of freshwater bodies (UN Water 2020). In such conditions there is a higher risk of water pollution. Higher freshwater temperatures can also kill fish and reduce the health and resilience of these ecosystems. Extreme flooding can cause pathogenic contamination, while droughts can cause higher pollutant concentrations. Moreover, human activities still have a great impact on water quality. Globally, in 2022, only 58 per cent of all wastewater flows generated by households were safely treated before being released into the environment (UNEP 2023).

Water also has a direct impact on the climate crisis. Fresh water is behind all carbon storage in nature. Extreme water events are responsible for an immediate loss of carbon uptake. Thus, they contribute directly on the climate crisis. (Global Commission on the Economics of Water 2023).

According to the World Water Development report 2023, urban water demand is projected to increase by 80 per cent by 2050. As many as 700 million people could be displaced by 2030 due to intense water scarcity (HLPW 2018). Already one in three people do not have access to safe drinking water (WHO 2019). Moreover, the World Bank estimates global physical water losses due to leakages at 32 billion cubic metres per year (the equivalent to about 8.5 million Olympic swimming pools), half of which occurs in developing countries. If this process could be stopped in developing countries themselves, the saved water would be enough to supply around 90 million people (World Bank 2016).

At the same time, in water scarce areas, water that is of "too high" a quality for certain purposes – drinking and bathing but particularly agriculture – is squandered. There's no need, for example, to flush a toilet or water flowers with drinking-quality water. A system of re-use of water could be developed to protect water resources, limit water pollution and improve water quality. The same amount can be used for dishes, then the countertops, to the floor as it gets dirtier (UN Water 2015). Water is also structurally underpriced as our economic systems fail to account for the value of water. This leads to the unsustainable use of fresh water and, as a result, the lack of access for the poor and vulnerable in many places (Global Commission on the Economics of Water 2023).

Taking the above into account, we need to shift the philosophy of water resources usage from "where to extract clean water and where to get rid of wastewater" to "how to reduce water consumption; how to keep water used in the economy for as long as possible through value retention processes such as rethink, reduce, reuse; and how to regenerate existing water bodies". The most cost-effective solution is to invest in holistic water management plans that take into account the entire water cycle: from source to distribution, economic use, treatment, recycling, reuse and return to the environment (IRP 2015). As such, the circular economy offers an effective framework for sustainable water management (Kearney 2014, Tahir 2018, Sauvé *et al*. 2021), embedding existing strategies such as Integrated Water Resource Management (IWRM) into its wider scope. This seems logical, considering that it follows the pattern of such natural processes as the water or carbon cycle, in which the loop is closed by definition. According to this approach, water is treated as a precious resource, whereby its true costs of water use are recognized, helping to provide undisrupted water supply for different uses.

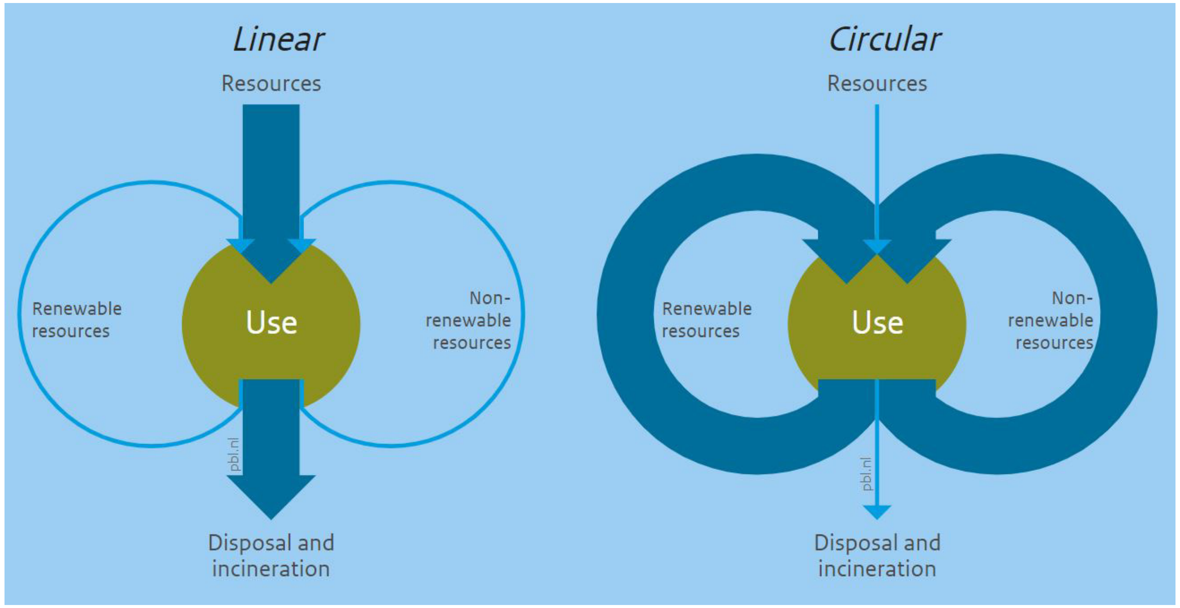

Figure 3: Approach to the resources use in linear vs circular economy. Source: Het Groene Brein (2023)

Introduction to circular economy principles in the water sector

In general, the circular economy aims at overcoming the traditional "take, make, consume, and waste" linear pattern of production and consumption (Merli *et al*. 2018, Delgado *et al*. 2021). In the circular system, resources are maintained for as long as possible and used for different purposes (**Figure 3**). A circular economy offers an alternative economic model, whereby natural resources, including water sources, are kept at their highest value for as long as possible (UNEP 2019a).

The circular economy offers a way to accelerate implementation of the UN 2030 Agenda for Sustainable Development and its goals, which "are integrated and indivisible and balance the three dimensions of sustainable development: the economic, social and environmental" (UN 2015). A circular economy can increase resource productivity and decrease the demand for virgin resources, as well as lower greenhouse gas emissions and improve energy security. Thus it is important that the link is made between resource efficiency and circularity. It is also worth mentioning that the circular economy can create benefits for our economies, well-being for all and the environment. As estimated by UNEP Finance Initiative (2020), the movement towards a circular economy could unleash $4.5 trillion of global economic growth by 2030.

Water-related ecosystems must be considered in any discussion about circularity. This is because: (a) several Sustainable Development Goals (SDGs) are linked to water and aquatic ecosystems, (b) water-related risks are among the most impactful global threats, (c) water is crucial for almost all human activities (Salminen *et al.* 2022).

Including water when addressing the benefits and risks of the circular economy makes this concept more comprehensive. Although circularity provides a holistic framework for more sustainable water management, the nexus between water and the circular economy has not been extensively explored and the water sector has not yet been systematically included in high-level discussions on circular economy strategies (Delgado *et al.* 2021).

In the current discourse, expressions such as "circular economy of water", "circular water economy" or "water circular economy" have been used to address the issue, yet none of them have solidified as a leading expression (Morseletto *et al*. 2022). However, they all describe a common approach (**Table 1**).

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Table 1. Water in circular economy: Descriptions

	Description	Source
1.	"Circular economy of water" (CEW): "an economic framework for reducing, preserving and optimising the use of water through waste avoidance, efficient utilization and quality retention while ensuring environmental protection and conservation"	Morseletto *et al.* 2022
2.	"A water-smart circular economy" (smart-water CE): "an economic concept through which water is abstracted from the environment to the technosphere within the ecological boundaries of surface and groundwater bodies. In a water-smart CE, abstracted water is used efficiently, thereby avoiding losses. Energy absorbed by and substances mixed or dissolved in water in use are recovered for reuse, thus allowing the recycling of water for various purposes within the technosphere. A water-smart CE implies that secondary materials are used and energy is produced in a manner that rules out significant risks to water-related ecosystems and human health".	Salminen *et al.* 2022
3.	The World Bank puts more attention to rethinking (urban) water also through resilience lenses. The Water in Circular Economy and Resilience (WICER) Framework addresses three main outcomes: 1) deliver resilient and inclusive services 2) design out waste and pollution, and 3) preserve and regenerate natural systems which should "ultimately improve livelihoods while valuing water resources and the environment".	Delgado *et al.* 2021

As pointed out by the World Bank, water "circulating" in the circular economy can play several different roles: "As a service (for example, it provides access to water supply and sanitation, as well as opportunities for reuse of unconventional water resources such as wastewater for afforestation and reforestation; it is used for cooling and heating purposes and it is needed to maintain and recover natural ecosystems), as an input to processes (in industry and agriculture, for example, through nutrient recovery from wastewater), as a source of energy (kinetic, thermal, biogas), and as a carrier of materials such as nutrients and chemicals" (Delgado *et al.* 2021). The circular economy helps preserve this natural capital: minimizing pollution or restoring watersheds and ecosystems.

Strategies for implementing circular economy principles in the water sector: main findings

Business as usual can lead, by 2030, to a 40 per cent shortfall between the forecasted demand for water and its available supply (UNEP 2015). Embedding circular principles into water management approaches, including through focusing on re-use, reduction (of consumption) and regeneration (of existing bodies), is an alternative to overcome this dire imbalance.

As outlined in the UNEP Circularity Platform, circularity builds on eight value retention processes: Refuse, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and one guiding principle of "Reduce by design". However, some of them, for example Repair, are directly linked to typical production and industrial business, making it less possible to use this strategy in the context of water management. Some others – for example: Recycle, Reduce – need to be re-defined for use in the water context (Morseletto *et al.* 2022). Morseletto *et al.* propose a set of nine strategies for "circular economy for water" (**Figure 4**). As a guiding principle, "Reduce by design" is proposed, thus it is all about re-conceptualizing the need for water, and how water is used to provide a more circular scheme. All other strategies were grouped in three categories with a focus on minimalization, optimization and retaining water use. The Decrease component of water use covers: Avoid (preventing unnecessary use of the resource), Reduce (minimalization of water use in comparison to business-as-usual scenarios) and Replace (substitution of water with another substance). Optimalization strategies focus on: Reuse and Recycle (both linked to the secondary use of water: without or with treatment), and Cascading (consecutive use of water derived from one process as an input to another). Retaining strategies are linked to: Store (keeping the used water in reservoirs) and Recover (cleaning water with retrieval of biochemical compounds and retention or energy generation).

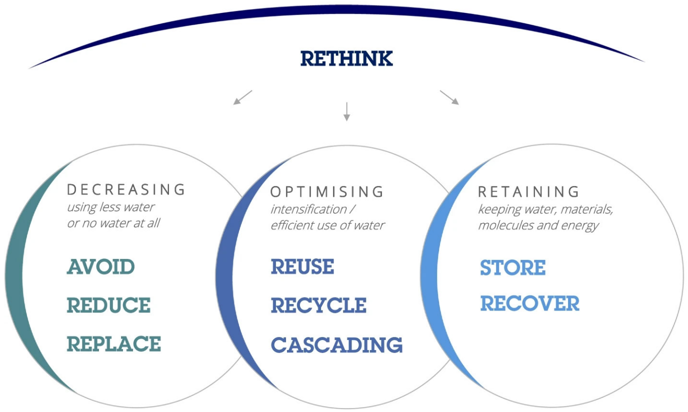

Figure 4: Strategies for implementing circular economy principles in water management. Source: Morseletto *et al.* (2022).

These strategies can be implemented separately or in combination with one another, creating a comprehensive framework in which various roles of water and water-related ecosystems in human activities and their links to other materials and energy are recognized. Such a general framework has been proposed by Salminen *et al* (2022) (**Figure 5**). This framework is based on five principles: 1) water resources are used sustainably, which means that the limits of the renewal rate of the water resource must be taken into account 2) losses,

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including leakages of the abstracted water, are avoided 3) in the technosphere, closed circulation and reuse must be applied to efficiently use the water abstracted 4) substances dissolved in processed waters are utilized at production facilities 5) substances harmful to the environment are removed from wastewater to minimize their environmental impact.

The World Bank is promoting the Water in Circular Economy and Resilience (WICER) framework, (**Figure 6**) which defines key elements in a circular and resilient urban water system, providing examples to guide practitioners in implementing the circular economy in urban water management (Delgado *et al*. 2021). The WICER Framework includes the following 3 components: (1) deliver resilient and inclusive services (through diversified supply sources, optimized use of existing infrastructure and planning and investing for climate and non-climate uncertainties) (2) design out waste and pollution (through energy efficiency and renewal energy, optimized operations and resources recovery) and (3) preserve and regenerate natural systems (through incorporating nature-based solutions, restoring degraded land and watersheds and recharging and managing aquifers) (Delgado *et al*. 2021).

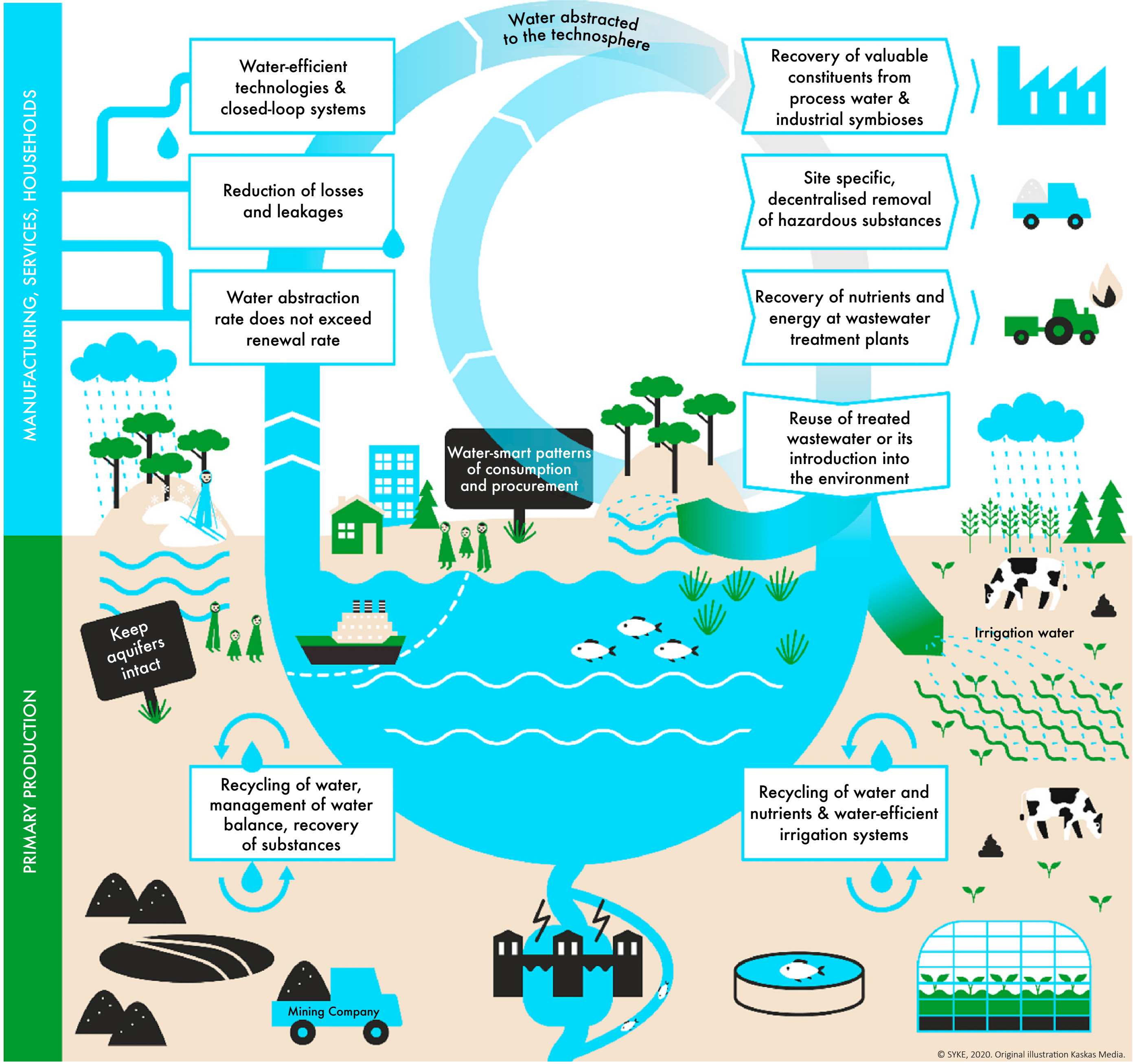

Figure 5: Elements of the smart-water circular economy. Source: Salminen *et al*. (2022).

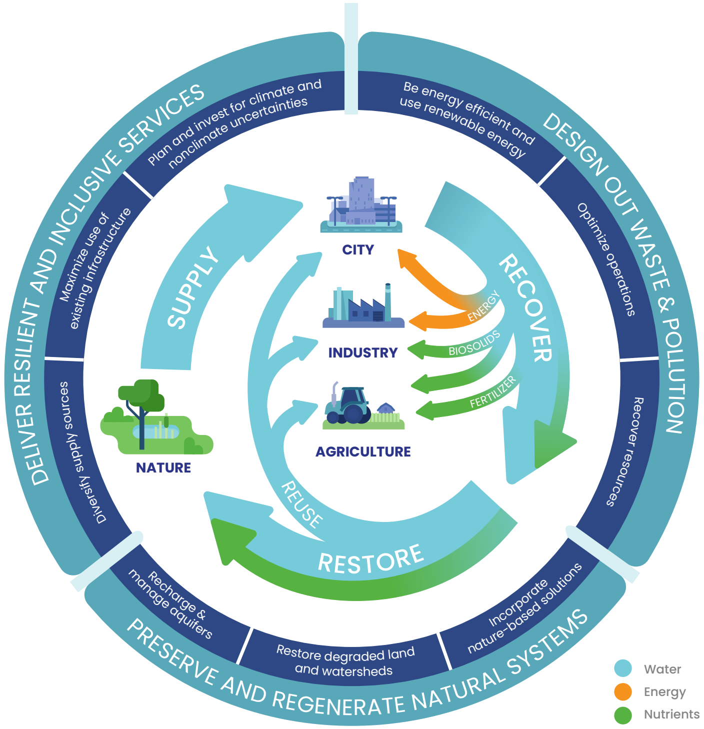

Figure 6: Water in Circular Economy and Resilience (WICER) Framework (focused on urban areas). Source: Delgado *et al*. (2021).

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Challenges and opportunities for the water-related circular economy: policy implications

Both frameworks presented above (concepts by Salminen *et al*., 2022 as well as Delgado *et al*., 2021) are complex, thus interconnectedness of their specific elements should be an essential part of the actions leading to their implementation. The World Bank report "Water in Circular Economy and Resilience" (Delgado *et al*. 2021), provides examples of the organizations and stakeholder groups which have included elements of these frameworks and concepts for better water management.

The Chennai Metropolitan Water Supply and Sewerage Board (CMWSBB) in Chennai, India, implemented several projects and investments in order to diversify water supply and become more resilient to droughts. Chennai was the first city in India to make rainwater harvesting obligatory. CMWSSB is also the only utility in India with two large-scale desalination plants and the first to reuse 10 per cent of collected wastewater, with plans to achieve a reuse rate of 75 per cent. CMWSSB sells treated wastewater to industrial users and, with the additional

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revenues, it can cover all operating and maintenance costs. The capital investment in the reuse project has been recovered in less than five years. CMWSSB also retrofitted seven of its wastewater treatment plants to recover energy from wastewater and to supply more than 50 percent of the energy needs of all the plants, saving on energy costs and helping sustain operations financially (WICER, 2021).

The desired transition to a fully circular economy for water itself would be long-lasting, with particular drivers, incentives, challenges, barriers and policy instruments which could accelerate or slow down the whole process. Research among organizations operating in Finland (one of the front-runners in the transition to a circular economy in the European Union) providing and/or using water-smart circular solutions revealed that financial and business-related benefits were among the key drivers for companies to implement the circular

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economy for water (Salminen *et al.* 2022). This included: reduced costs of wastewater discharge to sewage/ wastewater and limited water use, extended availability of public financing, and positive brand image. This last driver relates to organizational benefits: According to a survey carried out by the global technology and business services provider IBM, potential employees are increasingly likely to accept jobs from companies considered to be environmentally sustainable (IBV 2022). Moreover, increasing environmental awareness and the tightening of environmental regulations puts pressure on organizations to implement circular economy principles. As main barriers, the actors identified unclear and unpredictable regulations, negative attitudes towards the circular economy concept itself, lack of knowledge and expertise, and immaturity or poor market performance of water-smart circular solutions (Salminen *et al.* 2022).

A desktop review of some demonstrator cases has been performed. In the first large scale research on the circular economy (Kirchherr *et al.* 2018) the participants highlighted to the lack of consumer interest and awareness or the "hesitant company culture" to be the most pressing cultural barriers. On the other hand, technological barriers (lacking the ability to deliver high quality remanufactured products) is ranked lowest. Kirchherr *et al.* claim that if the cultural barriers are the ones being mostly cited by the participants, this suggests that the circular economy concept has not yet spread into the mainstream although it is well-known by – and remains in the lively interest of – mainly sustainable development professionals.

Participants of the research conducted by Qtaishat *et al.* (2022) confirm the above-mentioned findings. Stakeholders also ranked design and technology limitations as the least important barriers to implementing circular water solutions. On the other hand, issues related to initial costs, permits, authorization, or the absence of supportive financial and legislation tools, were ranked as the most important challenges.

In terms of opportunities, wastewater reuse and recovery of nutrients can help address other challenges including water scarcity, groundwater recharge and biogas production, while supporting the creation of green jobs.

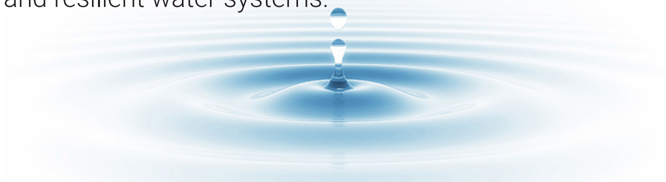
- For example, re-using treated wastewater can provide a reliable water source for industry, agriculture and – occasionally – drinking water, often with the requirement of lower investment costs and energy use than other sources (desalination or inter-basin water transfers).
- The International Finance Corporation (IFC) estimates that the cost of producing non-potable recycled water can be as low as $0.32 per cubic metre, and potable water $0.45, compared with more than $0.50 for desalination (World Bank 2021).
- Related to job creation, the International Labour Organization estimates that in India, wastewater could annually irrigate 1-1.5 million ha of farmland and generate 130 million person-days of employment (ILO 2017) and create new opportunities for women in income generation and entrepreneurship. Initiatives such as wastewater treatment, water conservation and resource recovery can lead to the development of small-scale enterprises.
- Additionally, education and training programmes targeting women's participation in a circular economy can build their skills and capacity in water management, conservation and sanitation.

Conclusion

As stressed by experts, water should be recognized as a catalyst for action and progress across all Sustainable Development Goals (SIWI 2023). Thus, sustainable water management contributes to a better, greener future. There have been increasing efforts at the global, international and national level to support this approach (e.g. the UN Water Conference 2023), complementing existing policies and strategies for sustainable water resources management, such as the European Water Framework Directive, Integrated Water Resources Management and WASH, amongst others.

However, full transition to a truly circular economy in the water sector requires further attention and collaboration among integrated groups of diverse gender identities; policy- and decision-makers, researchers from different disciplines, business people, and finally consumers, as it is all linked to three main challenges: normative (need for new legislation or the revision of existing legislation), governance-related (setting up clear roles and responsibilities for the design and implementation of circular economy strategies) and implementation-related (reducing barriers and enhancing opportunities). Addressing those challenges would help economies break away from a linear trajectory to a more circularity-orientated one.

Only cooperation between all stakeholders as under "integrated water resources management" can set us on a pathway to circular water management. Additionally, effective integration of gender perspectives for development and implementation of circular economy strategies is crucial for creating sustainable, inclusive, and resilient water systems.



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