TREND OBSERVATORY ON WATER

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TREND SHEET

Capitalising on circular economy principles to tackle challenges in the water sector and beyond

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Globally, around 80% of wastewater flows back into the environment without being treated or reused. This not only represents a major threat to ecosystems, but also a lost opportunity in reusing valuable resources (water, materials and energy) contained in these effluents.

The Circular Economy approach provides ample opportunities for the water and sanitation sector to contribute to water, energy and food security while creating environmental and economic benefits.

Read this Trend Sheet to learn more about current trends and examples of innovative cross-sectoral and multi-stakeholder approaches.

Content

Why this Trend Sheet?

What trend do we observe?

The concept of Circular Economy experienced a worldwide boost over the last two decades. However, its implementation in the water and sanitation sector is not yet wide spread and remains confined to recycling rather than circularity.

Why is this trend important for water practitioners in development cooperation?

Embracing a circular economy perspective in water and sanitation management may help address several development challenges in combination, including: reducing water insecurity and -stress, increasing water use efficiency and effectiveness, preventing pollution of water sources, providing access to safe sanitation, generating renewable energy and fertilisers - while contributing to the financial sustainability of water and sanitation services and creating business opportunities.

What is new?

Digitalisation, nature-based solutions, and innovations in technology and process design provide new opportunities for circular approaches in water and sanitation management.

Summary

The Circular Economy (CE) approach, with its principles of reducing consumption, reusing resources and recovering materials in production processes, experiences a boost worldwide. It also provides ample opportunities in the water and sanitation sector, where its application has only yet started to take ground.

Circular Economy in the water and sanitation sector may involve, among other, water reuse for various purposes, recovery and reuse of nutrients contained in sewage, or generating energy from sewage sludge. Related resource loops can be closed within systems of different sizes, from household to cities' and basin level. Closing resource loops in water and sanitation management may therefore not only contribute to increasing water security, but also to energy and food security. Moreover, it can help protecting ecosystems through reducing discharge of nutrients and organic matter into the environment and through recharging natural water storage systems such as aquifers and wetlands.

While reuse of water and resources is not new to the water sector, the circular economy approach may add value through its integrated systems perspective. Moreover, digitalisation and innovation provide increasing opportunities for implementing circular approaches in the water sector. A circular economy approach should therefore be considered in designing water projects and systems in the future.

This Trend Sheet outlines opportunities for closing water and sanitation resource loops in and across systems at different levels and points out to common challenges for implementation. It introduces current trends in the global transition towards a circular economy and provides examples of innovative cross-sectoral and multi-stakeholder circular economy approaches and technologies.

Introduction

How the Circular Economy concept can be translated to the water and sanitation sector

Circular Economy definition and principles:

In general terms, a Circular Economy is one in which the use of resources is minimised as waste from one process becomes an input into other processes and products are reused, repaired, or recycled, rather than thrown away. While the concept has emerged in the 1960, it has experienced a boost over the past two decades, as can be seen in the numerous initiatives and strategies that emerged recently (e.g. the EU circular economy action plan, World Circular Economy Forum, Global Alliance on Circular Economy and Resource Efficiency).


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Today, the concept of a circular economy is understood as a systematic and fundamental **shift away from a linear take-make-waste extractive industrial model**, towards a system that follows the **three core principles of Circular Economy** (Ellen MacArthur Foundation):

- designing out waste and pollution,
- keeping products and materials in use, and
- regenerating natural systems.

Applied to the water and sanitation sector, the Circular Economy concept could be translated as: a shift away from the commonly adopted linear take-use-discharge approach, towards closing **three interconnected resource cycles: the water, materials and energy cycle (see Figure 1 below).**

- **Water cycle:** includes water in the environment, water supplied for consumptive- and non-consumptive uses (e.g. irrigation, production processes, cooling, water-borne sanitation), and storm-water runoff.
- **Materials cycle:** includes organic matter, nutrients, fats, minerals and chemicals included in domestic and industrial wastewater, faecal and sewage sludge, that can be further processed, e.g. into inputs for agriculture (fertiliser, soil conditioner) and other production processes.
- **Energy cycle:** includes kinetic, thermal and chemical energy included in water and wastewater streams as well as faecal and sewage sludge, which can be recovered to supply energy to the water and sanitation system or as a source of renewable energy for other uses.

Core principles of Circular Economy in the water sector

- **Designing out waste and pollution (Avoid & Reduce):**
  Reducing the amount of water used by designing water-less technologies, through water conservation and efficiency measures, and reducing the use of chemicals and energy for water and sanitation services
- **Keeping products and materials in use (Reuse & Recycle & Recover):**
  Reusing water effluents, for example for irrigation, industrial purposes. Recycling human waste and faecal sludge in order to create new products, such as briquettes and compost. Recover valuable components (e.g. nutrients, metals, energy) from wastewater and faecal sludge, directly or through further (bio) processing.
- **Regenerating natural systems:**
  Preventing pollution and other negative effects on the environment and recharging natural water bodies and water-related ecosystems with reclaimed water, e.g. through managed aquifer recharge (MAR), or by returning valuable nutrients from sewage and faecal sludge to the soil to support regeneration.

Opportunities for circular economy in water and sanitation

Applying Circular Economy principles to water and sanitation can contribute to multiple goals. Globally, around 80% of wastewater flows back into the environment without being treated or reused (UN Water). This not only represents a major threat to ecosystems, but also a lost opportunity in reusing valuable resources (water, materials and energy) contained in these effluents. Closing resource loops can help address global challenges, such as water scarcity, missing sanitation facilities, nutrient-poor soils, and degrading ecosystems - while at the same time generating financial income to support water and sanitation service provision and creating business opportunities for various actors along the water and sanitation value chains.

A systems perspective on water, materials and energy cycles related to water and sanitation. Applying a circular economy lens may help going beyond common approaches, such as water reuse or using sewage sludge as fertilizer, by introducing a systems perspective. Systems thinking helps to understand the complex interrelationships of multiple resource flows within a given system and thus to identify more circular solutions for more efficient and effective resource use. Adopting a systems perspective to water and sanitation implies considering the three resource cycles (water, materials, and energy) and their entire value chains, as well as the context of the environmental and societal systems they are embedded in. Opportunities for closing resource loops arise at different interfaces (see Figure 1) – for example in communities including industry and agriculture, or at wastewater treatment plants, which can function as resource factories in a circular economy.

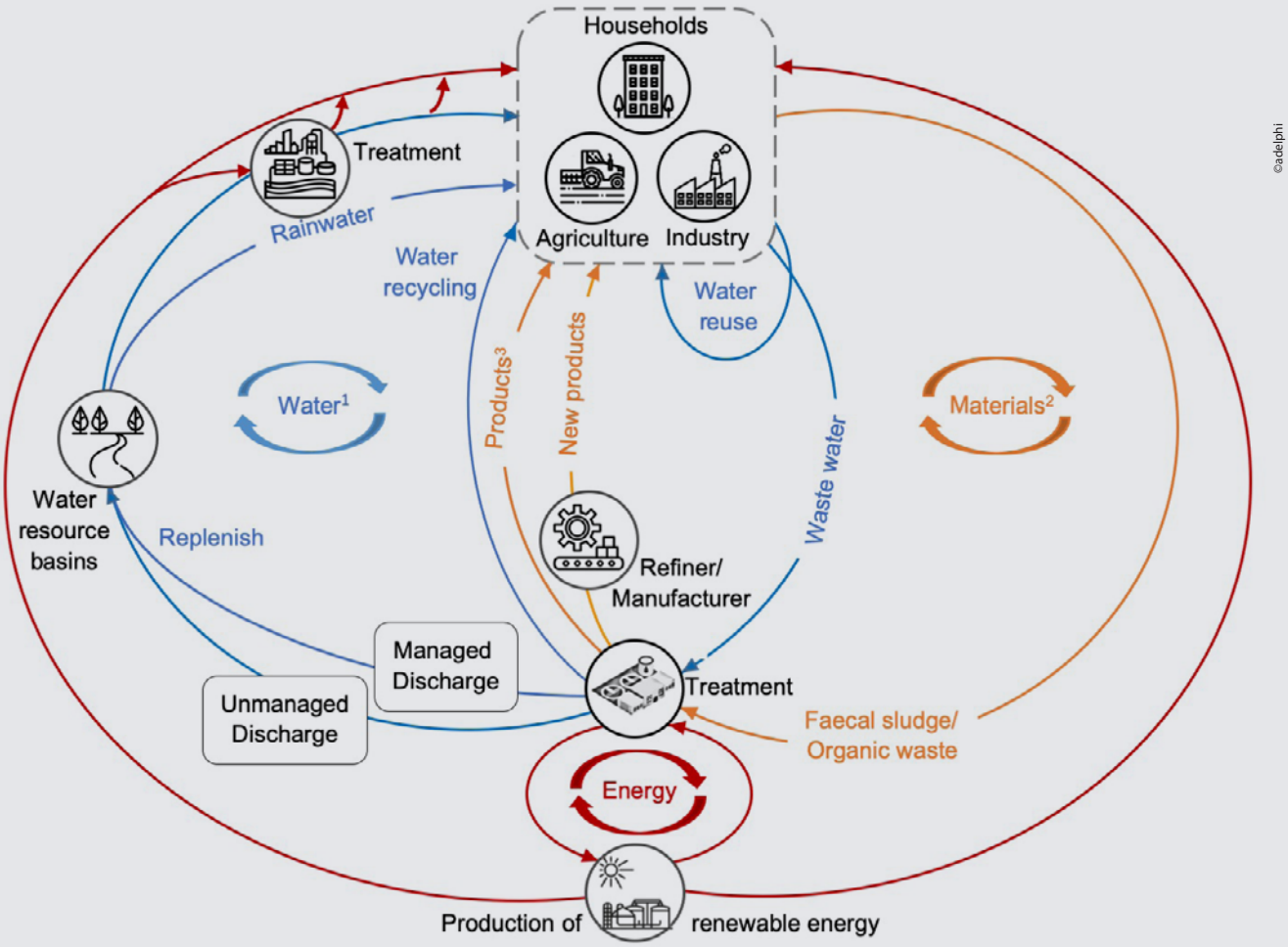


Figure 1: The Circular Water and Sanitation Economy System (adelphi, 2020)

Closing loops within systems at different levels

Water, material and energy cycles can be closed within interdependent systems of various sizes, from households to cities and catchments. The potential to close water, material and energy cycles within a given system will depend on the correspondence between resource supply and demand. The smaller the system, the closer are supply and demand side, reducing transportation and transaction cost between the various actors involved. However, smaller systems also provide fewer opportunities to balance supply and demand side, e.g. if reclaimed water produced within a city does not meet the demand for it, or if nutrient produced cannot be used within the system.

The different system levels include:

- **Households and communities/utilities**
  A household represents one of the smallest systems within which the three water and sanitation resource cycles can be closed. A common application of Circular Economy at household level are dry toilets combined with reuse of greywater for gardening, use of urine as fertiliser, and small-scale biogas generation for cooking. Within communities, water and wastewater utilities can play an important role in supporting communities with reclaimed water, nutrients, energy, heat, etc. In Lobitos, Perú, for example, a pilot project by the small NGO Ecoswell installed a dry (waterless) composting toilet unit, saving more than 15,000 litres of water and producing close to 2,000 litres of high-grade compost per year that can be used for agricultural purposes.

- **Companies and industrial compounds**
  Within one company or in an industrial compound, Circular Economy approaches are implemented mainly to reduce costs and water risks by increasing water and energy use efficiency in production processes, and reducing effluents, waste and emissions. In addition to reusing water, industries can often use energy and heat recovered from cooling water, and other resources recovered from process water. When different industries supplying and demanding water, materials and energy are located in close vicinity in a compound, this provides additional potential to close resource cycles through industrial symbiosis. In industrial compounds, for example, reusing water in cascading water quality is a notable option, as different industries can make use of water of different quality. Kujala waste symbiosis and Kalundborg Symbiosis are good examples of industrial symbioses towards implementing a circular economy.

- **Farms and agricultural associations**
  Similar to households, potential to close resource cycles within the small system of a farm exists, for example, in reusing water from various sources for irrigation, in reusing nutrients from sanitation and manure as fertilisers, and in generating energy from organic waste, manure, and faecal sludge. Again, opportunities for balancing supply and demand increase if several farms, e.g in an agricultural association jointly consider Circular Economy opportunities. The sustainable farm "Songhai" in Benin has set an example that has been adopted in many countries of the region. With zero waste farming, where waste is used as animal fodder and manure to produce biogas and the water from the fish ponds (aquaculture) is then used to irrigate the fields (Links: Success story in Benin: Meet Benin's zero waste farmer inspiring an agricultural movement.)

- **City level**
  In cities, a variety of actors are located in close vicinity to each other. This opens up opportunities for closing resource cycles and establishing partnerships. Water reuse, for example, has a wide spectrum of usage in urban areas. It can be used for cooling buildings, irrigating landscapes, recharging ground water, or flushing toilets. Nutrients can be reused within the city for urban agriculture, and energy produced by wastewater utilities can be fed into the electricity network. In Cape Town, South Africa, water reuse is being implemented on a large-scale. Innovative approaches now lead the way to avoid a repeat of getting so close to a Day Zero situation as in the year 2018. Treated wastewater is being redirected and purified so that it can be used again for multiple purposes, wise water principles are applied to share benefits and manage risks related to regional water sources. Innovative examples of city-wide approaches for resilient and circular water management have been developed within the Water as a Leverage (WaL) initiative, which supported multidisciplinary (research and) design processes aimed to develop innovative urban projects.

- **Catchment level**
  While larger systems provide more opportunities for closing resource cycles, activities on a catchment level are a lot less common in practice. Realising the Circular Economy on catchment level seems to be challenged by geographic factors, making water transportation indispensable. Activities at this level can relate, for example, to infiltration and discharge of water for reuse at catchment level, and closing loops across upstream and downstream users, or urban and agricultural areas. In the Baltic Sea catchment, the NGO Metabolic analysed opportunities for a circular agri-food system in the Baltic region, including nutrient recovery and preventing eutrophication, towards closing the cycle of water and nutrients.

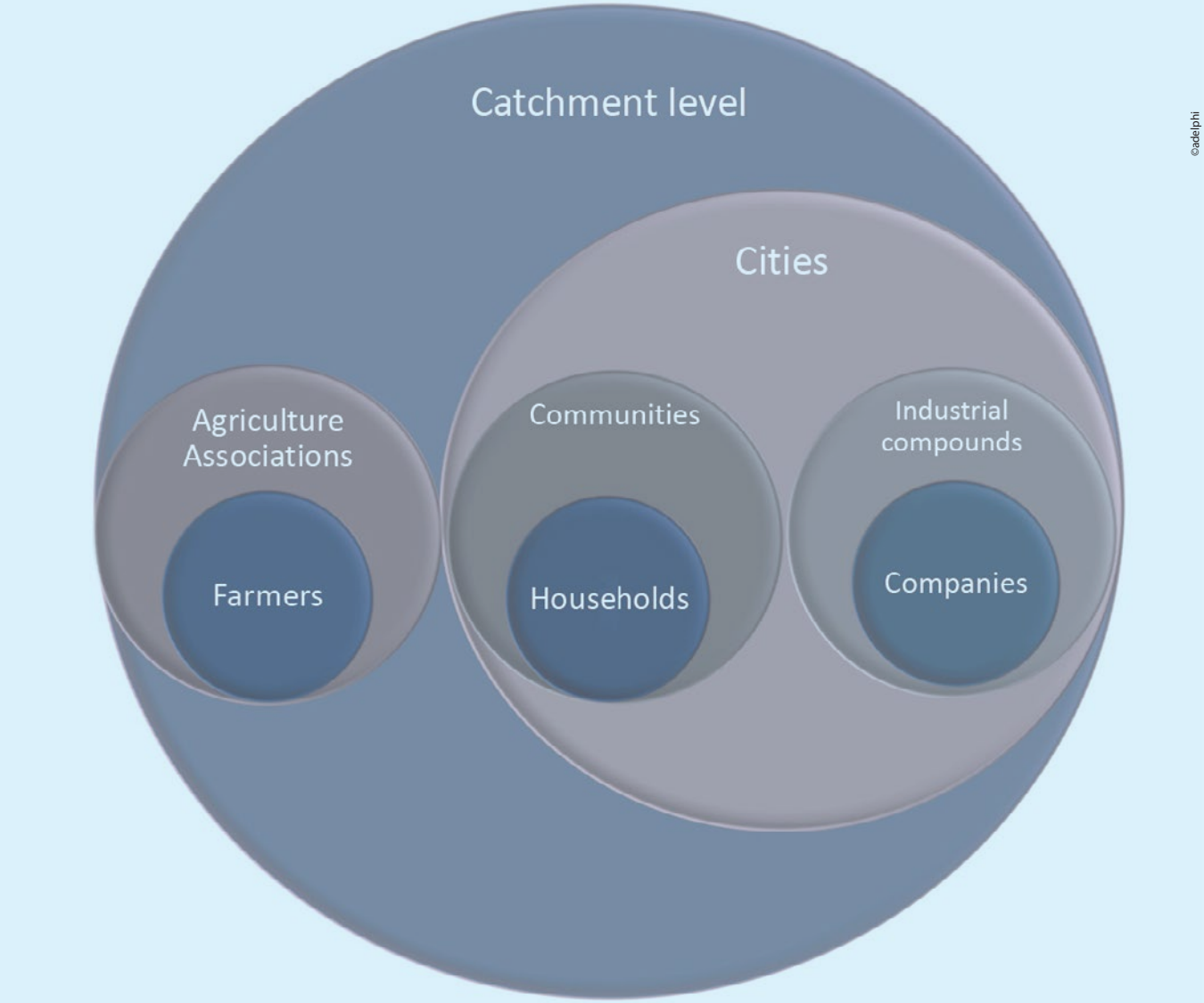


Figure 2: System levels for circular economy in the water sector (adelphi, 2021)

Business models

Applying circular economy approaches in the water sector has the potential to create additional economic benefits through

- costs savings from increases resource efficiency, reduced disposal/discharge fees etc. and
- revenues from additional business opportunities along the water and sanitation value chain.

Prospects for the creation of new business opportunities arise in the construction of facilities for circular water and sanitation management, in services related to operation and maintenance, transport and treatment of resource flows. Recovery resources from sanitation streams add many more potential direct and indirect business opportunities in distribution, processing and marketing of (recovered) resources and products, such as biosolids as soil conditioners, nutrients for use of fertilisers, proteins, bioplastics etc. A compendium prepared by the International Water Management Institute provides an overview of tested business models for low- and middle-income countries. A recent EU funded project assessed wider business opportunities for raw materials from wastewater, such as bioplastic, biodiesel, bio-oil, biochar, and acetic acid.

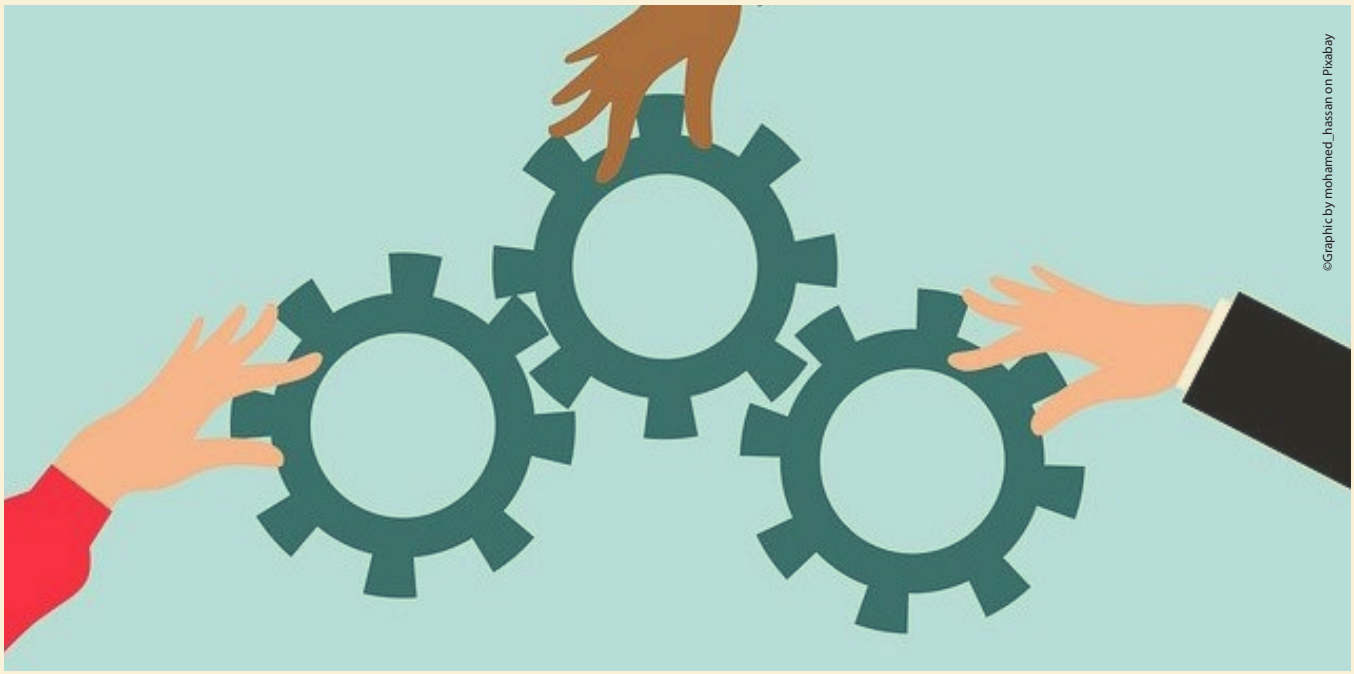
Many of these economic benefits and opportunities are long-term, indirect and require significant investment. Often additional incentives are needed to drive the change. For example, economic incentives, such as feed in tariffs for energy generated from sludge, subsidies for recovered material or public procurement of related products and services can foster adoption of CE approaches. However, experts believe that the profits to be made from applying circular economy in the water and sanitation sector are not as high from e.g. electronic or plastic wastes.

Nevertheless, with ongoing research and innovation in technologies, processes and business models (see e.g. a batch of recently started EU-funded Innovation projects), as well as rising political and legal drivers for increased resource efficiency, the business case for circular economy in water and sanitation may well increase in the future. Some even imagine wastewater volumes and recovered materials to be traded as commodity options (see www.wastewaterexchange.com).

Actors involved

Circular Economy in water and sanitation requires a multi-stakeholder approach, it implies involving actors that manage, supply and demand water, energy and nutrients, as well as actors along the value chain of water and sanitation. This will allow proper assessments of the relevant resources flows, identifying cross-sectoral opportunity for closing resources loops, and understanding business opportunities and challenges along the relevant value chains. Relevant actors include:

- **Water and wastewater utilities** can supply a range of products and services in the water and sanitation circular economy, including treatment, recovery, and supply of water, energy, nutrients, organic compounds and other materials contained in wastewater streams.
- **Governments and public authorities** design the enabling environment for a Circular Economy, including adequate regulations and standards, incentives and procurement rules, they also support awareness raising and capacity development programs; (urban) planning units play an important role in providing for a systemic Circular Economy perspective already in the planning stage of urban and infrastructure development or when revisiting the city / neighbourhood / household setting with a view to integrating Circular Economy approaches.
- **Businesses and entrepreneurs** (public and private) provide water and sanitation services, technologies and other products for a Circular Economy approach. Moreover, they are potential investors and drivers of innovation based on their economic interests.
- Customers and consumers demand water and sanitation-related products and services and thus indirectly influence the market and political prioritisation. They can also act as advocates for more sustainable approaches.
- **Agricultural actors** are a key player in Circular Economy for water and sanitation, as they supply (e.g. biowaste) and demand related products. Farmers are potential large buyers of sanitation products, such as compost. Furthermore, as agriculture is one of the largest water users, water efficiency and reuse approaches in the agricultural sector are likely to have big impacts on scarce resources.
- **Financial entities (public or private)** can support both, the demand and supply sides of services and products in a circular water and sanitation economy.
- **Research and development** can foster technological and social innovation.
- **The private sector,** in general, can take various roles in a Circular Economy system, be it as customers or consumers, as the business that produce and supply products and services, or in financing entities. Involving the private sector in Circular Economy systems therefore provides many opportunities and can be a promising pathway to foster Circular Economy in water and sanitation. Nevertheless, as water and sanitation are basic services with impact on common goods such as the environment and public health, involving public sector actors remains critical.



Challenges for successful implementation of Circular Economy in water and sanitation

While applying Circular Economy principles provides many opportunities for water and sanitation putting the concept into practice is often hampered by the existing governance framework and residual technical challenges, including:

Legal and institutional barriers

- In several cases, laws and regulations directly hinder reuse of water and resources from sanitation. This is further complicated by the fact that sectoral legal frameworks for water and sanitation, agriculture, energy are not always coherent.

Knowledge, acceptance, and awareness

- **Lack of data and information on material flows for planning.** This impedes the identification of the potential for reuse, supply and demand for products and services related to Circular Economy.
- **Lack of human capacity:** Circular Economy in water and sanitation involves complex processes, not only from a technological but also from management and governance perspectives.
- **Gaps in acceptance and awareness:** The perception of reused water as being "dirty" and products based on faecal sludge (such as co-compost) as being not safe is widespread.

Market and Financing

- **Need to create markets for Circular Economy products and services:** Sanitation services are often not yet sufficiently valued in developing countries, limiting the market for sanitation service providers.
- **Lack of financing:** In many cases, market conditions will not allow to recover all costs related to a given Circular Economy approach in water and sanitation, requiring additional financing from public or private sources.
- **Need for innovative financing models**. Existing financing schemes are often not appropriate for financing Circular Economy in the water and sanitation sector.

Technical challenges

- **Quality of effluents and waste flows:** care must be taken with regulating and monitoring levels of contaminants in the recycled water according to its use.
- **Transportation costs:** One major challenge of water recycling and reuse for different purposes is transportation of water. High costs arise through transportation of water – this leads to a trend closing the water cycle in vicinity to the location where effluents are generated.

Trends and innovations

Some of the persisting challenges and barriers for closing resource loops of the water and sanitation sector may be overcome through current trends and developments in approaches to support Circular Economy.

Digital solutions can play a vital role in effectively closing water, energy and material cycles. Examples are:

- **Augmented Reality (AR)** to support the adoption of Circular Water Economy – The water industry is exploring AR to accelerate circular solutions implementation. In the H2020 Nextgen project, the demo site in Athens investigates AR as a tool to help increase public engagement on water reuse. This case explores three aspects of the circular economy: optimisation of water resources uses, nutrient mining, and energy generation. (Source: kwrwater.nl)
- **The Internet of Things (IoT)** can be used to improve water-treatment, e.g. of highly polluted winery wastewater. South Australian Company Factor UTB uses 3G networks to access water tank controls. The tanks are fitted with probes and sensors to detect changes in alkalinity or oxygen levels and automatically adjust settings to optimise water treatment. With the support of IoT the treated effluent gains a quality suitable to be returned to the environment and for irrigation purposes. (Source: beveragedaily.com)

Nature-based Solutions (NBS)

Nature-based Solutions (NBS) provide great potential for circular economy in water and sanitation as they provide sustainable solutions for water treatment and storage, reuse of nutrients for food and biomass production, while restoring and maintaining the natural water cycle and related biodiversity. Natural and constructed wetlands, for example, can be applied for (waste)water treatment while growing biomass for energy generation. NBS also include green areas for effective rainwater management and recharge of groundwater, and as such play an incremental role in the concept of Sponge Cities (see Case Study below), where they further contribute to flood risk management and improving the urban climate. NBS can also be adopted in the form of compact technologies, such as in the Metabolic Network Reactor (MNR), applied as a water treatment technology that maximizes the efficiency of microorganisms to harness clean water, energy, nutrients, and minerals from wastewater and organic waste in a brewery in Belgium. (Source: www.ellenmacarthurfoundation.org). For a comprehensive review of NBS for urban water management and resource recovery in cities see Oral et al. 2020 and Kisser et al. 2020.

Water less technologies

Within the field of water-related technologies, a clear trend towards water-less and non-water-based technologies can be observed, rather than a trend towards more water recycling. Examples include waterless toilets, waterless cooling technologies, or waterless dyeing in the textile industry.

Innovations in product development and resource recovery processes

Business opportunities based on products made from by-products of water and sanitation systems, such as compost, fertilisers, and briquettes are still limited. However, innovation in product development, incl. bioplastics, lime pellets, proteins, cosmetic and medical products, produced based on organic matter, minerals and chemicals captured from wastewater and sludge are expected to increase business opportunities in the future. Another potential product is health data and information: Sampling and monitoring human waste can produce valuable basic health data. An example of innovative product development is the production of proteins through Black Soldier Flies described in the case study below.

Examples of innovative circular approaches

Aquaponics in the Gaza Strip

Aquaponics is a nutrient-resource sharing system of combined culture of fish and plants in closed recirculating systems. It combines hydroponics, i.e. soil-less agriculture, and aquaculture including three biological components: fish, plants, and bacteria. The fish water is used as fertilizer for the plants, and the plants clean the water for the fish. The result is value-added, local production of both fish and vegetables together, using the same water.

Especially in areas like Gaza, where access to fertile agricultural land is limited and water resources are scarce, aquaponics serve as an applicable food production option mainly due to: 1) efficient water utilization, and 2) easy installation of each production unit (fish and plant) on any flat, urban platform using local low-tech materials. PETRICHOR is the first company to pursue aquaponics in Palestine. While their installations are small scale there are also large scale examples, e.g. in the US.

Development of sanitation-based products with the Black Soldier Fly

In the project FORWARD (From ORganic WAste to Recycling for Development), the larvae of the Black Soldier Fly (BSF) is being used for upcycling of urban organic solid waste – including faecal sludge. In small-scale organic waste recycling facilities in Indonesia, larvae are successfully grown on waste and later harvested and processed into animal feed (for fish and poultry) while the remaining residue is used as compost.

According to eawag, the larvae are able to reduce the waste material by 50-80% and convert up to 20% of the waste material into larval biomass within ±14 days. The grown larvae make an excellent protein source and their sale can contribute to lower waste treatment cost and potential income opportunities from organic waste. The multi-stakeholder project FORWARD is funded by the Swiss State Secretariat for Economic Affairs (SECO) under a framework agreement with the Indonesian Ministry of Public Works & Housing and carried out in cooperation with national and local authorities, researchers and private sector entities. (Source: Eawag)

Sponge cities

In sponge cities, multiple spaces are created to absorb large quantities of water and passively disperse it back into the environment. Porous surfaces and green spaces capable of keeping water just like sponges are key. This might include permeable roads and sidewalks, green roofs, wetlands and natural vegetation, which absorb, infiltrate, store, purify, drain and manage rainwater. Recycling runoff mimics nature's own circular way of dealing with rainwater, offering a cleaner and more holistic approach for growing cities.

China's "sponge city" initiative supports cities to absorb rainwater, reduce flooding, ease pressures on municipal treatment systems and increase their water supply. Wuhan is one of the pilot sponge cities that demonstrated how appropriate infrastructure can be employed both quickly and cost-effectively to increase the resilience of urban areas to a changing climate.

The "**Trend Observatory on Water**" of the Swiss Agency for Development and Cooperation (SDC) aims at informing the RésEAU, SDC's Water Network, and interested parties about relevant emerging trends and innovative approaches for development cooperation in the water sector. Initiated by SDC's Global Programme Water and run by adelphi, it analyses how major global trends can affect water resources and management practices in the future. Through various communication formats and its website https://hazu.swiss/deza/trend-observatory-on-water it aims to raise awareness of opportunities that arise for more sustainable solutions, but also of the risks and challenges that might come along with them.

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