Water and Circular Economy

White Paper (Draft 2-b)

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### Authors

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<tr>
<th>Arup</th>
<th>Siraj Tahir, Dr Kristian Steele, Martin Shouler</th>
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</thead>
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<tr>
<td>Antea Group</td>
<td>Tristan Steichen, Peter Penning, Nick Martin</td>
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Water and Circular Economy
Intersection of Initiatives

This white paper explores the common characteristics, ideas and approaches between Circular Economy Initiatives being implemented by organisations and Water System Management in its most holistic sense.

It establishes a common language that will allow Circular Economy and Water practitioners to better understand each other.

The paper sets out an initial context and identifies synergies between the two topics before exploring areas of common opportunity and how by applying circular economy ideas greater value can be generated. It concludes with a Prospectus of ideas for Ellen MacArthur Foundation (EMF) Co.Project(s).

Our focus is on:

• **Circular economy principles**: and how they relate to Sustainable Water Management including key intersection topics

• **Alignment of opportunity**: by identifying projects, approaches and goals that are aligned to both Sustainable Water Management and Circular Economy, the potential is to accelerate their deployment and application

• **Enterprise, value and impact**: and the interface points between the natural water system and managed systems (e.g. energy, municipal use, materials manufacturing, agriculture, etc.), and how Circular Economy can be used to:
  - consider the potential of new business models
  - improve functional performance and impact
  - generate greater value and commercial opportunity
## Water and Circular Economy

### Relationship between Circular Economy Principles and Water Systems Management

|----------------------------------------------------------|---------------------------|
| **Principle 1:** Design out waste externalities | • Optimise the amount of energy, minerals, and chemicals use in operation of water systems in concert with other systems.  
• Optimise consumptive use of water within sub-basin in relation adjacent sub-basins (e.g. use in agriculture or evaporative cooling)  
• Use measures or solutions which deliver the same outcome without using water |
| **Principle 2:** Keep Resources in Use | • Optimise resource yields (water use & reuse, energy, minerals, and chemicals) within water systems.  
• Optimise energy or resource extraction from the water system and maximise their reuse.  
• Optimise value generated in the interfaces of water system with other systems. |
| **Principle 3:** Regenerate Natural Capital | • Maximise environmental flows by reducing consumptive and non-consumptive uses of water.  
• Preserve and enhance the natural capital (e.g. river restoration, pollution prevention, quality of effluent, etc.)  
• Ensure minimum disruption to natural water systems from human interactions and use. |
Water and Circular Economy
Establishing a common understanding – principles to practice

Systems thinking and environmental stewardship are core concepts to circular economy and for the management and supply of water. The interplay and relationship between these aspects is therefore important to considering any circular economy related initiatives. In an effort to help those focused on transitioning to a circular economy to develop solutions with water systems experts, a common understanding of key concepts must be understood. To set the basis for this, this White Paper presents a Circular Economy diagram for the management and supply of water based on the principle of ‘restorative by design’.

Much like materials, water is most traditionally looked at in a linear fashion. And the Take-Make-Dispose strategy that is synonymous with materials consumption is mirrored by the Take-Use-Discharge strategy that is commonly adopted in the water sector.

Water is sourced, or ‘withdrawn’, from streams, rivers, lakes, reservoirs, oceans, and groundwater aquifers as well as harvested directly as rainwater.

Water is ‘used’ by these four traditional categories: Agriculture, Municipality, Industries, Environment within in the water cycle. This includes consumptive and non-consumptive uses.

Non consumptive used water is ‘returned’ to the basin directly or via a municipal treatment facility. Depending on location within the basin this returned water can then be further used downstream or lost to the basin in similar way as the consumptive uses.

This linear approach of human-managed water use, which is prevalent in a majority of basins today, is short-sighted and inherently unsustainable. This Take-Use-Discharge approach also goes against all three Circular Economy Principles.

To manage water systems for long-term sustainability, addressing the projected global and local demands for water, a circular approach is relevant, timely, and achievable and offers opportunity for commercial advantage.
Water and Circular Economy
Establishing a Common Understanding – Water Specific Circular Economy Systems Diagram

The Circular Economy Systems Diagram published by Ellen MacArthur Foundation is not reflective of the water systems, e.g. manufacture / remanufacture, landfill, etc. An adapted version of Circular Economy Systems Diagram specific to Water System is presented below.

Nature Managed

Human Managed

Principles 1 and 3

Principle 2

Principles 1 and 3
Water and Circular Economy
Establishing a Common Understanding – Water Specific Circular Economy Systems Diagram (Continued)

Although visually similar to the materials Systems Diagram with “biological” on the left side and a “technical” on the right, the water butterfly is instead divided into the “nature managed” and the “human managed” halves.

Water is a complex system, so to simplify the applicability of this model, it currently represents a single basin. On the left side, water is depicted in its natural state where no human induced uses are occurring. There is continuous movement of water on, above and below the surface of the Earth.

Precipitation is naturally collected within the boundaries of a basin or basin flowing from higher to lower elevations and from source to sink, usually an ocean. Water is captured and held by soil, vegetation, and surface water bodies until ultimately percolating into the ground and aquifers.

Water also leaves a basin through evaporation and transpiration, engineered water flows, discharges to oceans, embedded in products or otherwise shipped out of the basin. The total volume of water available at a given time in a basin is called the watershed balance.

Nature Managed System

Within a given basin, the natural water cycle acts to re-optimise, reuse, and replenish water:

Re-optimise – nature needs a specific supply of water to maintain the ecosystem and biodiversity. This is naturally variable and based upon the complexity of the ecosystem, climate, and general ability to adapt by plants and animals to a changing environment.

Reuse – as water cycles it is naturally treated as it moves from higher to lower elevations and interacts with flora and fauna.

Replenish – the natural cycle concludes with a return of water to the environment through evapotranspiration, infiltration or surface water flows.
Human Managed System

On the Human Managed side, Water’s circularity is impacted by human action when we alter the natural water cycle, such as by:

- Abstracting freshwater above its rate of replenishment.
- Accelerating water loss through inefficient irrigation and distribution methods.
- Polluting water and limiting its utility for other users.

Such outcomes have adverse impact on the natural water cycle, and can result in economic and environmental losses or additional costs to meet the human needs.

The Opportunity

The opportunity with Circular Economy for Water is to better align the human water cycle with the natural water cycle through following measures:

Avoid Use – through rethinking products and services and eliminating ineffective actions.

Reduce Use – driving continuous improvements through water use efficiency and better resource allocation and management.

Reuse – pursuing any and all opportunities to reuse water within an operation (closed loop) and for external applications within the surrounding vicinity or community.

Recycle – within internal operations and / or for external applications.

Replenish – efficiently and effectively returning water to the basin.

The function of water use in these loops can have multiple dimensions. Understanding these is fundamental to realizing the opportunity and enterprise potential of water and Circular Economy.
Water and Circular Economy

Dimensions of Water Use

Water is fundamental to meeting basic needs of all living things. This service to life (including human consumption) cannot be satisfied by substituting water with other measures or materials.

However, beyond this water is used and offers value in a number of different ways. These dimensions of water use can be clustered into the three themes of Service, Energy and Carrier as illustrated.

They exist throughout the water cycle and are intrinsic in the Water Specific Circular Economy Systems Diagram.

The dimensions of water also map against the Food – Water – Energy Nexus, e.g. Nutrients (Service), reducing consumptive uses (service), and generating energy (hydropower / biomass).

Whether these can be harnessed and value generated and optimized, and appropriately balanced between nature and human needs will vary from basin to basin, societal development level, and the use category (Agricultural, Municipal, Industrial, and Environmental)

Water as a service:

Water provides services such as: sanitation in our homes and businesses, for cooling and heating our buildings, and as part of production processes in our factories. Water is often not fundamental to the service and the delivery of these outcomes can, at least in principle, be achieved by other means.

For example, water is ubiquitously used in evaporative cooling, but air forced cooling can achieve the same service outcomes but at lower energy efficiencies.

Water as a source of energy

Water, through its physical properties and how it can be utilized can act as a source of energy.

- The mass and momentum in the flow of water can be harnessed to generate hydro-electric energy.
- The thermal properties enable it to absorb thermal energy from the environment or human activity that can be extracted (e.g. water source heat pumps and energy harvesting from sewers).
- Bio-thermal energy such as anaerobic digestion from municipal sewage.
Water and Circular Economy
Dimensions of Water Use (continued)

Water as a carrier
As a liquid natural resource, water is a commonly available and universal carrier in the natural and built environment. In both contexts water is acting as a carrier of chemicals, particles and droplets (dissolved and suspended state) which represent potential resource or pollutant.

• In agricultural settings, there is high potential of nitrogen and phosphorus from fertilizers to be present.
• Within municipal and industrial settings, it could include trace chemicals in treated water and wastewater.

Removal of these chemical and nutrients may be driven by economic reasons, but in many situations it is driven (by regulatory requirements), for pollution prevention and environmental protection, e.g. recent limits on nitrate and phosphate being implemented in the European Union.

Extracting this nitrogen and phosphorus from final effluents at wastewater treatment plants before discharge provides these benefits:

• Improves the quality of outflows to increase opportunity for water reuse and reduce cost of treatment for downstream users (e.g. for potable water treatment).
• Reduces environmental impacts and enhances natural capital;
• affords the opportunity of their use as fertilisers and enhance the Urban Bioloop potential.
Water and Circular Economy

A Systems Approach

System of System

When viewed from a systems approach, the water system is a sub-system of a ‘System of Systems’, which includes the environmental systems, agricultural systems, industrial systems and municipal systems.

Application of systems thinking is critical for identification of the circular economy opportunities that exist within the system as well as other associated systems.

Systems approach will also enable impact assessment and maximising the value created as result of application if circular economy principles.

Municipal Water System and example circular economy initiatives

The figure to the right presents a simplified abstraction of a municipal water system, which are significantly more complex with greater level of links and interfaces with other systems.

A few potential circular economy initiatives have been identified that have the potential to enhance operational optimisation of the municipal water system, as well as potential circular economy initiatives that rely on other systems – agriculture and industry in this instance.

Mapping these systems in more detail will help further areas of opportunity and value creation.
Water and Circular Economy

Basin archetype and impact on potential suites of solutions

The type of basin has a significant bearing on the type of systems that are likely to be present, and the nature of the opportunities that would be present for generating additional value by application of Circular economy principles.

Basin archetype characteristics include

• Climatic conditions
• City scale and development level,
• Use type: Environmental, Municipal, Industrial, Agriculture
• Topography and geography of basin, and
• Level of development in the city.

Relevance

The suite of solutions that have a high viability in one city archetype would have lower viability in another, e.g. municipal water reuse is more suited in lower basin while hydroelectricity more suited in upper basins.

The suite of solutions that can be utilized therefore would likely to differ for each archetype basin, and it is assumed that the value proposition of each of the solutions would also be different in the different contexts. This perspective is illustrated in the adjacent graphics.

To address this current a knowledge gap on the solutions and value propositions, they would need to be researched as part of any future project.

Arid lower plains
- Ecosystem services potentially high value
- Water reuse would be key measure
- Solutions that displace water with other measures would be suitable.

Lush green middle plains
- Water as service is key water use dimension.
- Low benefit for water reuse
- High value of water treatment to maximise utility for downstream users.

Potential to extract nutrients

Upper Highlands
- Energy extraction a key water use dimension
- Water treatment of high value to maximise utility for downstream users.

Illustrations by Creative Republic / GIZ
Water and Circular Economy
Example and opportunities

**Cellulose extraction from waste water**

**Process:** The extraction of cellulose from waste water streams in a process involving separation, purification, hygienisation, and drying.

**Dimension:** Water as a carrier

**CE Opportunity:** (1) optimisation for water reuse and energy use, (2) extract other nutrients

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**Livestock effluents**

**Process:** capture and treat livestock farm effluent to ensure water quality.

**Dimension:** Water as a carrier

**CE Opportunity:** (1) capture nutrients and (2) extraction of bio-matter to generate of energy through anaerobic digestion.

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**Fertilizer and pesticide application**

**Process:** Application of fertilizers and pesticides for in agriculture.

**Dimension:** Water as a service

**CE Opportunity:** (1) Capture of chemicals and nutrients from runoff or waste biomass;

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**Greywater reuse**

**Process:** Capture and reuse of slightly used ‘greywater’ for non-potable purposes within the urban fabric.

**Dimension:** Water as a service

**CE Opportunity:** (1) extracting value from byproducts from greywater processing, (2) extraction of thermal energy.

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**Continuous Thermal Hydrolysis**

**Process:** Continuous process treatment of sludge to form biogas. Compared to other methods, it offers a significantly smaller carbon footprint.

**Dimension:** Water as source of energy

**CE Opportunity:** (1) Utilisation of byproducts (2) reuse of treated effluent

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**Wastewater Treatment & Industrial Symbiosis**

**Process:** Continuous process treatment of sludge to form biogas. Compared to other methods, it offers a significantly smaller carbon footprint.

**Dimension:** Water as source of energy

**CE Opportunity:** (1) Utilisation of byproducts (2) reuse of treated effluent
Water and Circular Economy
Realizing the potential

The dimensions of water as a Carrier, Energy source and Service provider are not exclusive and confluences exist across them. For example, in cities wastewater conveys human/organic wastes whilst at the same time can be harnessed as a source of thermal Energy. This confluence is central to the opportunity that Circular Economy offers the water sector.

Humans have learned to harness the natural environment and develop their own man-made environments to realize value from the dimensions of water. These activities are not always undertaken in the most resource efficient and regenerative way.

Utilisation of a systems approach and taking into account the local environmental conditions will better enable the identification of opportunities and required outcomes as well as in evaluating impacts and any multiple benefits.

This White Paper proposes that the Circular Economy lens can bring a new viewpoint to our man-made managed water systems, and to the way that they are designed and operated.

The Circular Economy lens has the potential to change the value proposition of the system under consideration whilst ensuring that its purpose and function is still delivered.

It creates a shift that seeks value from the wider system rather than just from the fixed point at which consumption applies. Functional requirement will still be met; whilst at the same time as creating value from resource efficiency and water use dimensions of service energy and carrier. Digital technology and innovative business practice can be used to realize this.

In this way application of circular economy principles can help us meet the step changes to practice that will be necessary for it to meet future water demands, whilst facing key challenges access to resource, increased demand, and more stringent quality and pollution and environmental controls.
Water and Circular Economy
Assessment Tools and Frameworks

Within the water and Circular Economy communities, there are broad range of assessment tools, initiatives, project approaches and other methods that may be effective starting points to establishing a framework that links Water and circular economy. The ReSOLVE framework provides an overarching approach that exemplifies the concepts of circular economy. Some of other existing frameworks are listed in the highlighted table.

To enable assessment of an organisation for potential value extraction or generation, there is a need to either develop a new framework or adapt current frameworks.

The framework should include method and tools to enable the assessments. This will require further investigation.

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<td>Related to service and medium dimensions of water</td>
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<td>International Water Association (IWA)</td>
<td>Perspective of CE from water utility perspective</td>
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<tr>
<td>7s Model – Circular Economy &amp; Buildings</td>
<td>Arup</td>
<td>Provides holistic approach to CE assessments</td>
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<td>Alliance for Water Stewardship</td>
<td>Water resources, water quality</td>
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<td>Performance in Watershed Context:</td>
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<td>Disclosure Initiatives for Cities and Water:</td>
<td>Carbon Disclosure Project (CDP)</td>
<td>Water footprint, sustainable water use</td>
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<td>Water Risk and Action Framework (WRAF)</td>
<td>International Water Stewardship Programme (IWaSP)</td>
<td>Sharing of resources in participatory manner</td>
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<td>InVEST &amp; RIOS Ecosystem Health Assessment:</td>
<td>Natural Capital (NatCap) Project</td>
<td>Ecosystem services, carbon and economics of solutions</td>
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Water and Circular Economy
Next Steps - Three Co.Project Ideas

Framework Development

There is a need for development of an assessment framework that will enable all users of water to establish the value propositions that can be derived from improving the operation of the water system individually and holistically.

This Co.Project will explore development of a framework that takes into consideration:

- the three dimensions of the water cycle;
- the nature of the system and the scale of the opportunity;
- other environmental considerations (e.g. climate, topography).

Maturity Assessment

A maturity assessment will identify the knowledge and awareness of Water & CE within an organisation.

Water is ubiquitous and water systems directly and indirectly interact with most of the other systems.

Due to this ubiquity, even where an organisation does not have direct interaction with water, it may be able to affect a positive change on the Water & CE system and derive additional value.

Urban Bio-loop + Energy Positive Wastewater Treatment

A city’s built environment includes the hard infrastructure for its function, such as a wastewater treatment plant.

The city also relies upon the urban green spaces that provide a multitude of benefits to its residents.

Both systems are interlinked by multiple circular economy streams of water, nutrients, food, and materials.

This Co.Project would explore the interaction between the two, identify where further value can be created and how to find balance between the two objectives.
# Water and Circular Economy

## Steering Group

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<th>Name</th>
<th>workshop</th>
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<tr>
<td>1</td>
<td>Antea Group</td>
<td>Tristan Steichen, Peter Penning, Nick Martin</td>
<td>Reykjavik, Chicago, London,</td>
</tr>
<tr>
<td>2</td>
<td>AquaEnviro</td>
<td>Paul Lavender</td>
<td>London</td>
</tr>
<tr>
<td>3</td>
<td>Arup</td>
<td>Kristian Steele, Siraj Tahir, Martin Shouler</td>
<td>Reykjavik, London</td>
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<tr>
<td>4</td>
<td>Avespa</td>
<td>Philippe Bois</td>
<td>Chicago</td>
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<tr>
<td>5</td>
<td>Cranfield University</td>
<td>Fiona Charnley</td>
<td>Reykjavik</td>
</tr>
<tr>
<td>6</td>
<td>Danone</td>
<td>Khaoula Essoussi, Ewelina Szopinska</td>
<td>Reykjavik</td>
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<tr>
<td>7</td>
<td>Davines</td>
<td>Paolo Goi</td>
<td>Reykjavik</td>
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<td>8</td>
<td>Dell</td>
<td>Jonathan Perry, John Pflueger</td>
<td>London</td>
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<td>9</td>
<td>Government of Catalonia</td>
<td>Maite Ardevol</td>
<td>Reykjavik</td>
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<td>10</td>
<td>Grundfos</td>
<td>Louise Schjoett Nielsan</td>
<td>Reykjavik</td>
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<td>11</td>
<td>Hera Group</td>
<td>Filippo Bocchi, Enrico Piranccini</td>
<td>Reykjavik</td>
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<td>12</td>
<td>Low and Behold / WRC</td>
<td>Philippa Roberts</td>
<td>London</td>
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<td>13</td>
<td>Loyola University, Chicago</td>
<td>Nancy Landrum</td>
<td>Chicago</td>
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<td>14</td>
<td>McDonald’s Corporation</td>
<td>Townsend Bailey</td>
<td>Chicago</td>
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<td>15</td>
<td>Metropolitan Water Reclamation District of Greater Chicago</td>
<td>Barbara Scarpardine</td>
<td>Chicago</td>
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<td>16</td>
<td>Microsoft</td>
<td>Jim Hanna</td>
<td>Chicago</td>
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<td>17</td>
<td>Suez</td>
<td>Frederic Grivel, Ywann Penru</td>
<td>Reykjavik / London</td>
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<td>18</td>
<td>The Plant Chicago</td>
<td>Jonathan Periera</td>
<td>Chicago</td>
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<td>19</td>
<td>University of Bradford</td>
<td>Amir Sharif</td>
<td>Reykjavik</td>
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<td>20</td>
<td>University of Chicago</td>
<td>Carolyn Amadon</td>
<td>Chicago</td>
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<tr>
<td>21</td>
<td>Veolia</td>
<td>Gary Crawford</td>
<td>Reykjavik</td>
</tr>
</tbody>
</table>
Contacts

Arup
Siraj.Tahir@arup.com

Antea Group
Tristan.Steichen@anteagroup.com

Ellen MacArthur Foundation
Nick.Jeffries@ellenmacarthurfoundation.org