THE CIRCULAR WATER ECONOMY

IDENTIFYING AND CAPITALISING ON THE COMMERCIAL OPPORTUNITIES FOR UK PLC

A Call to Action by the UK Water Partnership

THE UK WATER PARTNERSHIP

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PURPOSE

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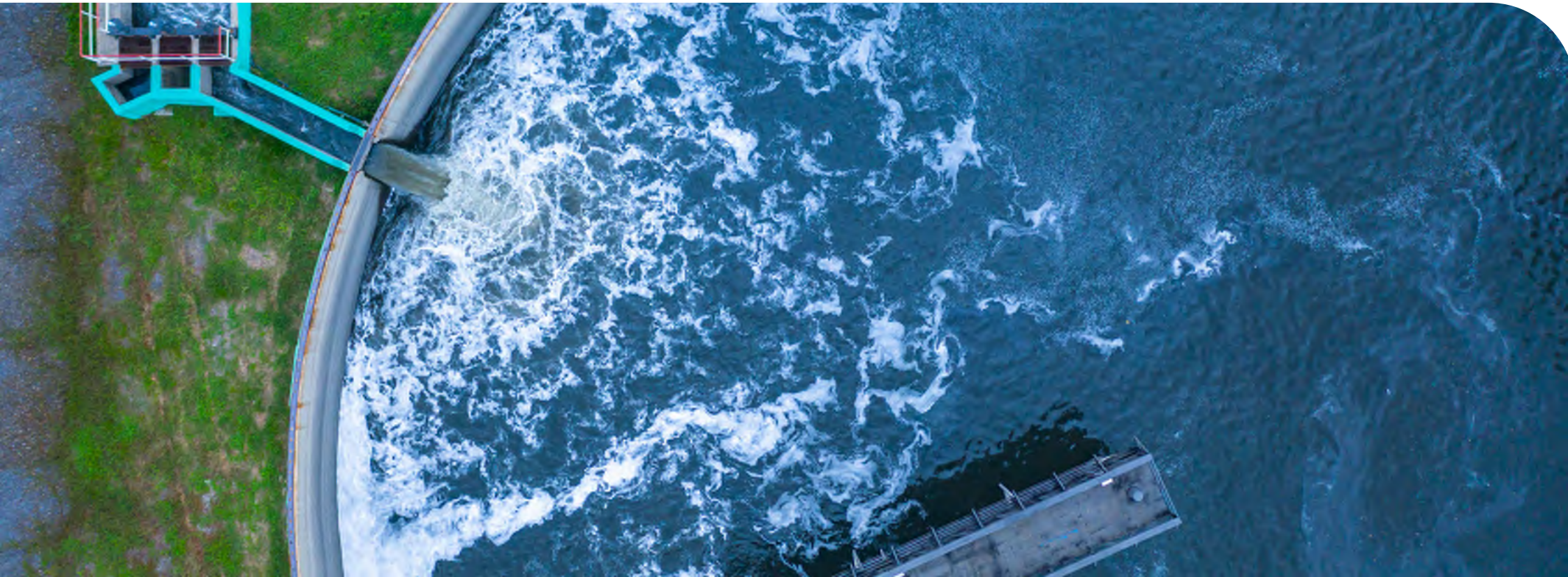
The Circular Economy (CE) covers three broad principles – eliminate, circulate and regenerate. The water industry is well placed to positively engage with all three principles – by minimising abstraction, implementing wastewater treatment solutions that return high quality effluent to the environment, by maintaining assets and recovering waste materials as useful resources, and by engaging with nature at catchment scales to improve biodiversity, water quality and water supply.

The scope and long-term approach to its activities provides the water sector with an unparalleled opportunity to take a leadership position in the transition to a circular economy, both as a consumer of raw materials and as a steward of natural resources. Many of the solutions that are central to a circular water economy, such as integrated water management and nature-based solutions, have the potential to deliver multiple benefits, including enhanced social amenity and gains in biodiversity and natural capital.

However, the potential system-wide value that circular approaches offer is at risk of being missed as the water sector – in common with most others – equates circularity with resource recovery. This paper explores the origins of the Circular Economy, the opportunities and barriers to resource recovery – and calls on experts, innovators and entrepreneurs to develop system-wide tools which can support the transition to genuine circularity in the water sector, allowing the UK to take a leadership position on this critically important topic.



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FOREWORD

There is no doubt that within the water sector, we live in the most exciting times. At no point in history have we been able or asked to deliver so much, for so many, and at such a pace.

The urban water cycle is inherently circular, but this circularity relies on hydrological processes to ensure that aquifers and surface water bodies continue to provide sources of supply. This continuity of supply has meant that the UK has come to rely on linear approaches through the subsequent use, treatment and discharge phases. However, climate change and population growth are putting unprecedented stress on the water system. Whilst water may be in abundance in one part of the cycle (eg surface water flooding owing to increasingly extreme rainfall) it is potentially in short supply in another (eg freshwater levels in water bodies and aquifers due to drought). Continuity of sustainable supply can no longer be assured.

Demand for new and advanced water infrastructure, services, products and technology remains unyielding, and is correlated directly with the expanding and diversifying expectations, needs and capabilities of our society. Yet at this time we are also faced with the unparalleled imperative to protect and nurture our global environment, the full breadth and depth of the communities we serve, and the economic systems from which we profit. In this, we also need to foster a future that is flexible and sustainable enough to respond to foreseeable changes, as well as those changes that have not yet even been conceived.

This creates a significant infrastructure investment challenge as we strive to maintain resilient water supplies, and it also places an ever-increasing pressure on natural resources, and in turn on the environment that we are striving to protect.

This paper introduces the important role that a circular water economy can play in protecting nature by minimising waste and resource consumption, whilst simultaneously regenerating natural systems. It highlights the need to think and drive change at a system level, and to do this collaboratively and innovatively, to optimise value through the solutions that are delivered. And importantly, it introduces a number of challenges to kick-start the process of shaping and delivering a Vision for a circular water economy.

EXECUTIVE SUMMARY

There is an ever-growing demand for the water sector to set clear and unbiased objectives and targets for truly sustainable outcomes. Ultimately, this means that in planning, designing, procuring, constructing and managing water assets, products and services, we are constantly challenged to consider and balance a wide range of (and sometimes competing) lifetime factors: how can we realistically continue to meet the long-term demands of different societies, whilst also achieving low carbon and net zero solutions, gains in biodiversity and natural capital, social and gender equality, and climate resilience? A significant part of solving this conundrum lies in realising a circular economy. In its simplest form, the circular economy asks us to look past our traditional 'take-make-use-dispose' linear approach, to create a less wasteful and damaging, regenerative system. It embraces three key principles, to:

- Minimise and eliminate waste and pollution;
- Keep resources in use, at their highest possible value; and
- Regenerate nature, and thereby preserve and enhance the earth's natural capital.

These principles can be applied at all points around the urban water cycle, from abstraction through use, treatment and discharge back to the environment. For example:

- Catchment management can improve surface water quality and reduce treatment costs for potable purposes whilst buffering water quantity and reducing surface flooding;
- Demand reduction, improved water use efficiency (WUE) and water re-use create cost-saving cascades throughout the urban water cycle; and
- Moderation of surface water flows through adoption of Nature-Based Solutions (NBS) improves biodiversity, increases system resilience and delivers high quality amenity value.

Another key aspect of the circular water economy is that water becomes a vector for other resources during use. Nutrients (including carbon in many forms), solid particulates and energy all find their way into the water matrix. Whilst these additions might previously have been considered 'pollution', requiring removal during wastewater treatment, there is an increasing tendency to see such inputs as recoverable resources with value – from heat to biopolymers.

Taken together, these aspects provide the water sector with multiple opportunities to transition to a circular economy, both as a consumer of raw materials and as a steward of valuable natural resources.

Opportunities are diverse, ranging from recycling or re-using water, seeking alternatives to traditional 'grey' infrastructure and the materials that enable them, opportunities for repair and re- manufacture of mechanical and electrical equipment, and the potential for resource recovery from wastewater and sewage sludge (**Figure 2-1**).

From a resource management perspective the water sector is primed to explore and embed circular economy opportunities but it cannot do it alone – it will be necessary to establish symbiotic relationships whereby organisations can directly source recovered resources from one another and create markets for recovered resources. Collaboration with partners from within and outside the sector will be essential to deliver the system-level change that is required as we transition to a circular water economy.

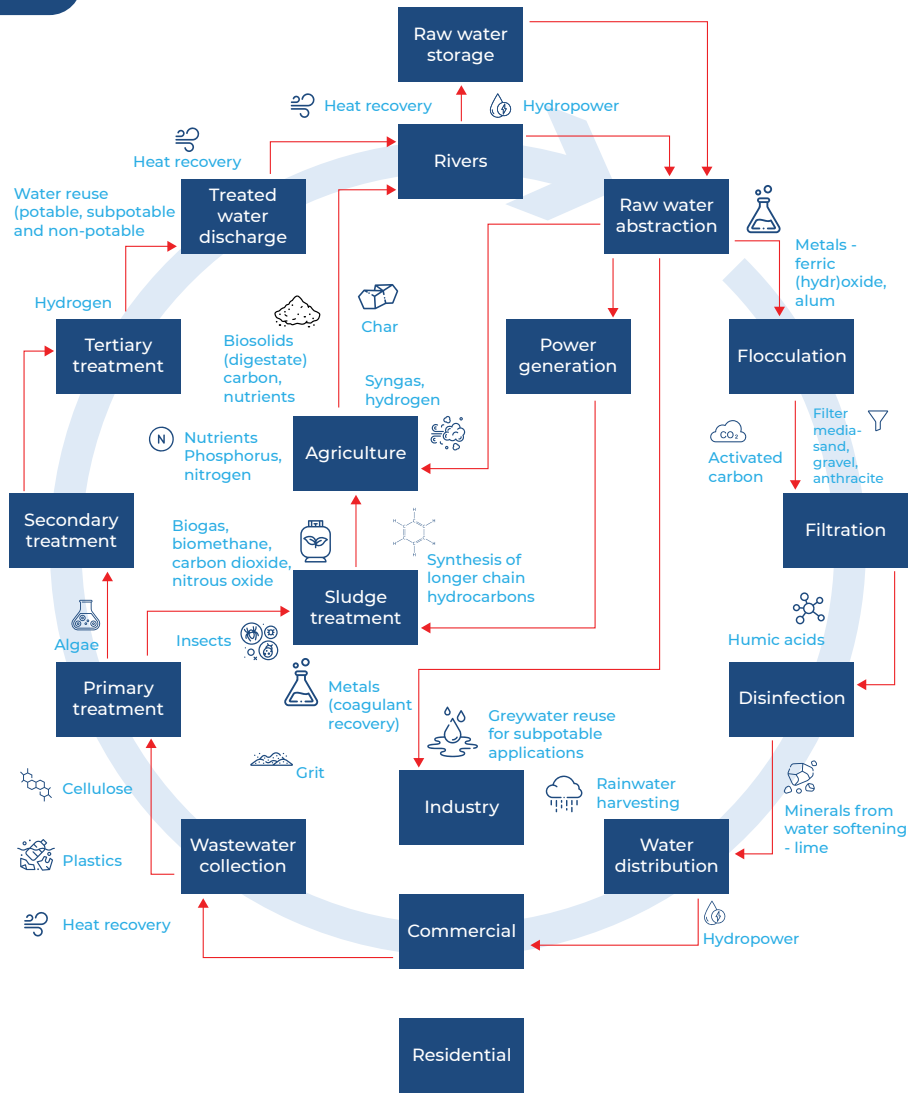


Figure 2-1 Resource-recovery opportunities in a circular water economy

The requisite policy framework to support this transition is not yet in place in the UK. In common with many European nations, the circular economy is most commonly viewed through a resource-recovery or recycling lens, rather than a lens that supports systemic change – facilitating delivery of net zero carbon, increasing system resilience and increasing sustainability across multiple metrics. Contrast this with The Netherlands, where the Dutch water sector aspires to be fully circular by 2050 (aligning with the same objective and deadline for their whole economy), or the Australian water sector, which has set out a clear transition plan for circularity. The meaning of 'fully circular' is expected to change over time as technological, environmental and wider societal contexts change – but requires metrics to be agreed and current performance to be baselined. The Dutch 'dot on the horizon' concept can be useful in this regard, since it acknowledges that the best we might achieve today through process integration and optimisation isn't necessarily reflective of what might be achieved in future. The dot may always remain slightly out of reach as our circular understanding and capabilities increase, but acknowledging this and developing metrics that can accommodate future developments will help to create a framework within which to begin the transition to circularity. This would allow aspirations to be tempered and progress to be made without having to wait for technologies to be invented or other contexts to change – letting perfect become the enemy of good. Regenerative aspects of the urban water cycle are undoubtedly being delivered in the UK, but a lack of alignment across different policy objectives and variances in policy language means that these are not yet considered circular water economy drivers or metrics.

The Water Sector is not unique in this respect. In the Waste Sector the circular economy has become synonymous with recycling ('resource recovery'), and indeed, metrics developed and implemented at a European level to monitor circularity in the wider economy focus largely on recycling activities and not on waste minimisation or nature regeneration.

This is instructive on several levels, as enabling Policy and Regulatory frameworks have been put in place to facilitate recycling and resource recovery in the Waste Sector. These frameworks provide transparency and market certainty, facilitating investment and driving transformation. Contrast this with the Water Sector, where no such frameworks exist.

While it might be argued that 100% of the basic resource (water) is recycled and that there is no need for change, robust public discourse around the security of water supply and quality of treated wastewater suggests otherwise. Viewing environmental destinations through a circularity lens would help to illuminate synergies and opportunities that are absent from linear models. Nonetheless, in common with the Waste Sector, the Water Sector would benefit from enabling frameworks to support recovery of resources including water.

Setting out a Circular Water Economy vision and transformation strategy are beyond the scope of this white paper. We focus instead on some of the resource recovery and re-use opportunities available to the sector, as a mechanism for stimulating value creation, carbon savings and dialogue around wider circular economy opportunities. We also highlight opportunities and challenges to bringing other aspects of the circular economy to life through the absence of enabling Policy, Regulatory and Commercial frameworks – and challenge stakeholders to collaborate on an appropriate Vision and Transformation Strategy to enable a circular water economy that supports the needs of all in society.

INTRODUCTION

There is an ever-growing demand for the water sector to set clear and unbiased objectives and targets for truly sustainable outcomes. Through well respected frameworks such as the United Nations Sustainable Development Goals (UN SDGs) (**Figure 3-1**), the Global Reporting Initiative (GRI) [1], and PAS2080 (Carbon Management in Buildings and Infrastructure) [2], our understanding of – and agreement on – how to plan, measure, quantify and comparably share our successes in environmental and social governance is growing rapidly.

Ultimately, this means that in planning, designing, procuring, constructing and managing water assets, products and services, we are constantly challenged to consider and balance a wide range of lifetime factors: how can we realistically continue to meet the long-term demands of different societies, whilst also achieving low carbon and net zero solutions, gains in biodiversity and natural capital, social and gender equality, and climate resilience? Realising a circular economy could help us to solve this conundrum.

Figure 3-1 The United Nations' Sustainable Development Goals [3]

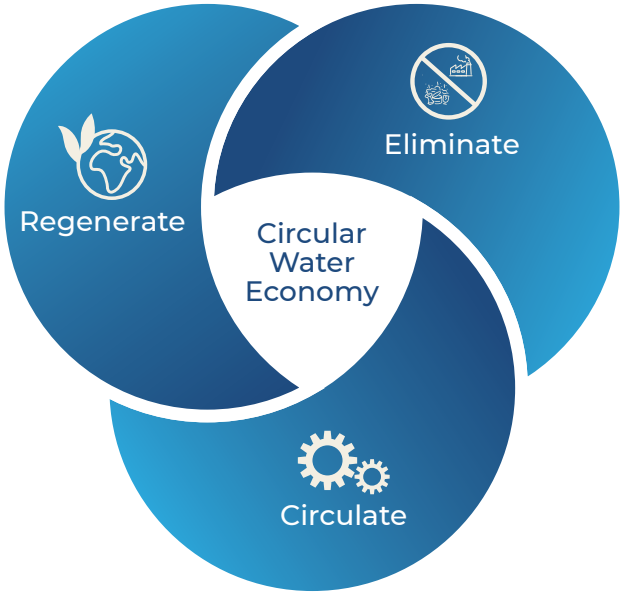
Whilst the concept of the circular economy cannot be traced back to a single origin, its principles have emerged over the last 50 years from a variety of sources: from biological, economic and energy theorists, to industrial and manufacturing models and policy instruments. In the last two decades, these theories and their underlying concerns have been brought to the fore by global events such as escalating raw material prices, resource dictatorships and economic crises.

In response, the values and codes that underpin the circular economy have needed to be brought together and articulated in a modern context, so that they can be applied to all sectors – including water. This has been achieved by organisations such as the Ellen MacArthur Foundation [4], and – through its Circular Economy Action Plans – the European Union [5]. Thanks to their efforts, and of many others in industry, the achievement of a circular economy is now widely recognised as an absolutely critical component of a sustainable and future-ready world.

WHAT IS A CIRCULAR ECONOMY?

In its simplest form, the circular economy asks us to look past our traditional 'take-make-use-dispose' linear approach to consumption, to find a less wasteful and damaging approach.

Perhaps the most widely accepted definition of a circular economy is set down by the Ellen MacArthur Foundation [4]. The definition is based on the need for us to take action across three pillars, which challenge and stimulate us to:



- Minimise and eliminate waste and pollution;
- Keep resources (whether water, materials, energy or waste) in use, at their highest possible value; and
- Regenerate nature, and thereby preserve and enhance the earth's natural capital.

These pillars build on the foundations of Lansink's R-Ladder, which articulated a simple waste hierarchy "Reduce, Reuse, Recycle" more than forty years ago [6]. This ladder has since been extended with additional rungs, to encompass principles that include Refuse, Remanufacture and Repurpose. The resulting combination of hierarchy and circulation may be most familiar as the Ellen MacArthur Foundation's butterfly diagram – with biological cycles on one side and technical cycles on the other.

However, the R-Ladder and Butterfly diagram can be overlaid, as illustrated by the Netherlands Environmental Assessment Agency (**Figure 4-1**). This highlights the importance of minimising resource take before it enters the use phase. Once in the use phase the resource should be kept there for as long as possible through Reuse, Repurpose and Recycle etc, as appropriate. Overall, a circular economy uses as few new resources as possible, minimising resource-related burdens on the environment. In the water sector this means taking as little water from the environment as possible – but it also means returning those other resources which find their way into water during use back into a productive economy, whether those resources are heat, grit, nutrients, polymers or other so-called 'contaminants'. Circular approaches also contribute to resource security, by allowing materials to cascade from one process to another both within and across sectors – and within national economies – reducing exposure to geopolitical shocks, and increasing system resilience.

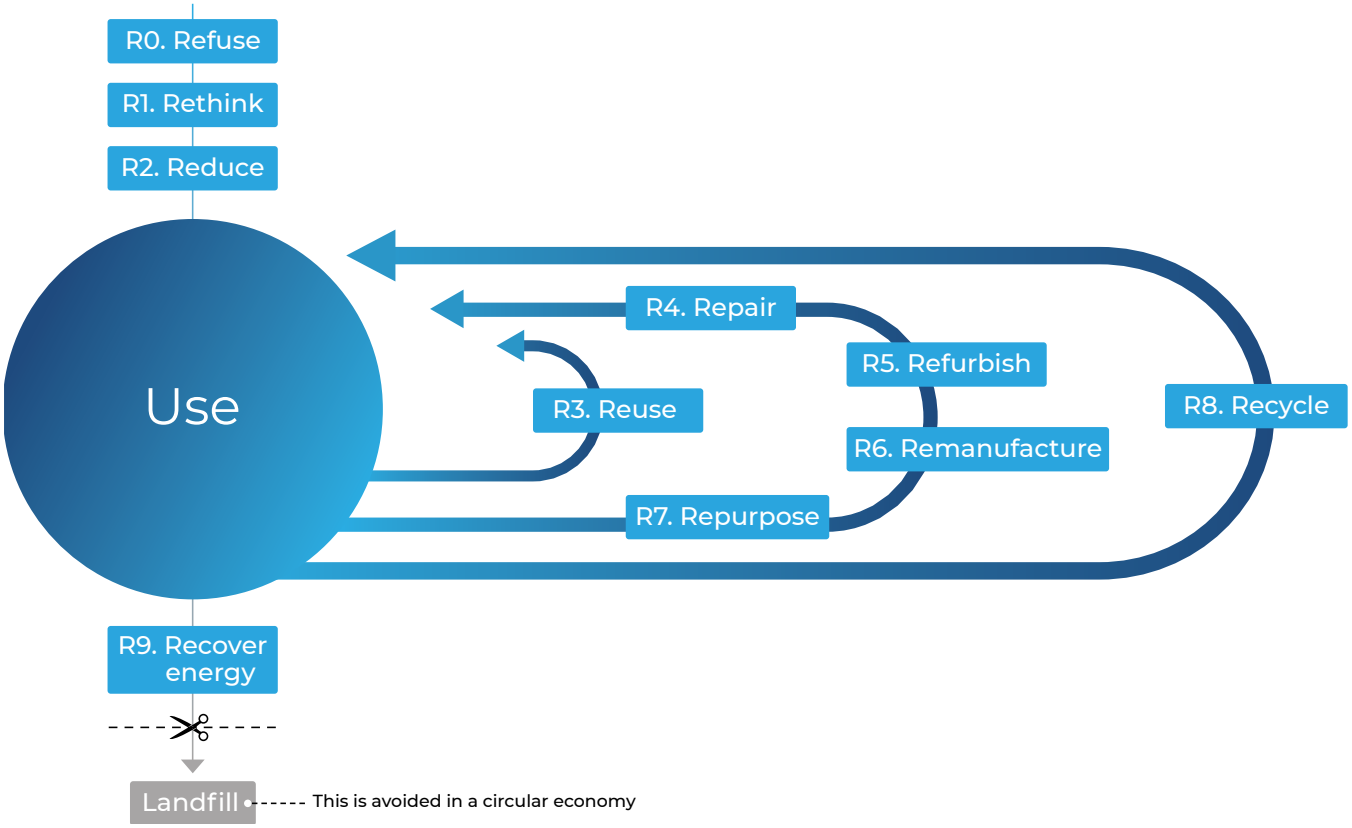


Figure 4-1 The Circular Economy: more than recycling [7]

The Circular Economy is sometimes described as a “System of Systems”, and there are multiple opportunities to apply its principles around the whole urban water cycle (**Figure 4-2**). Inputting and extracting resources from this cycle depends on a broad landscape of supply chains, many of which have close dependencies to other parts of the economy and some of which have little resilience.

As society strives to tackle climate change, limiting the increase in global temperature to well below 2°C above pre-industrial levels in line with the Paris Agreement, there has never been a greater focus on reducing greenhouse gas emissions. There has and continues to be a huge emphasis on our energy transition, with the UK’s energy supplies being on a course to be decarbonised by 2035. Now is the time to double-down our efforts on materials and waste, which contribute up to 45% of the UK’s carbon emissions. Transitioning to a circular economy is the means by which we can achieve this.

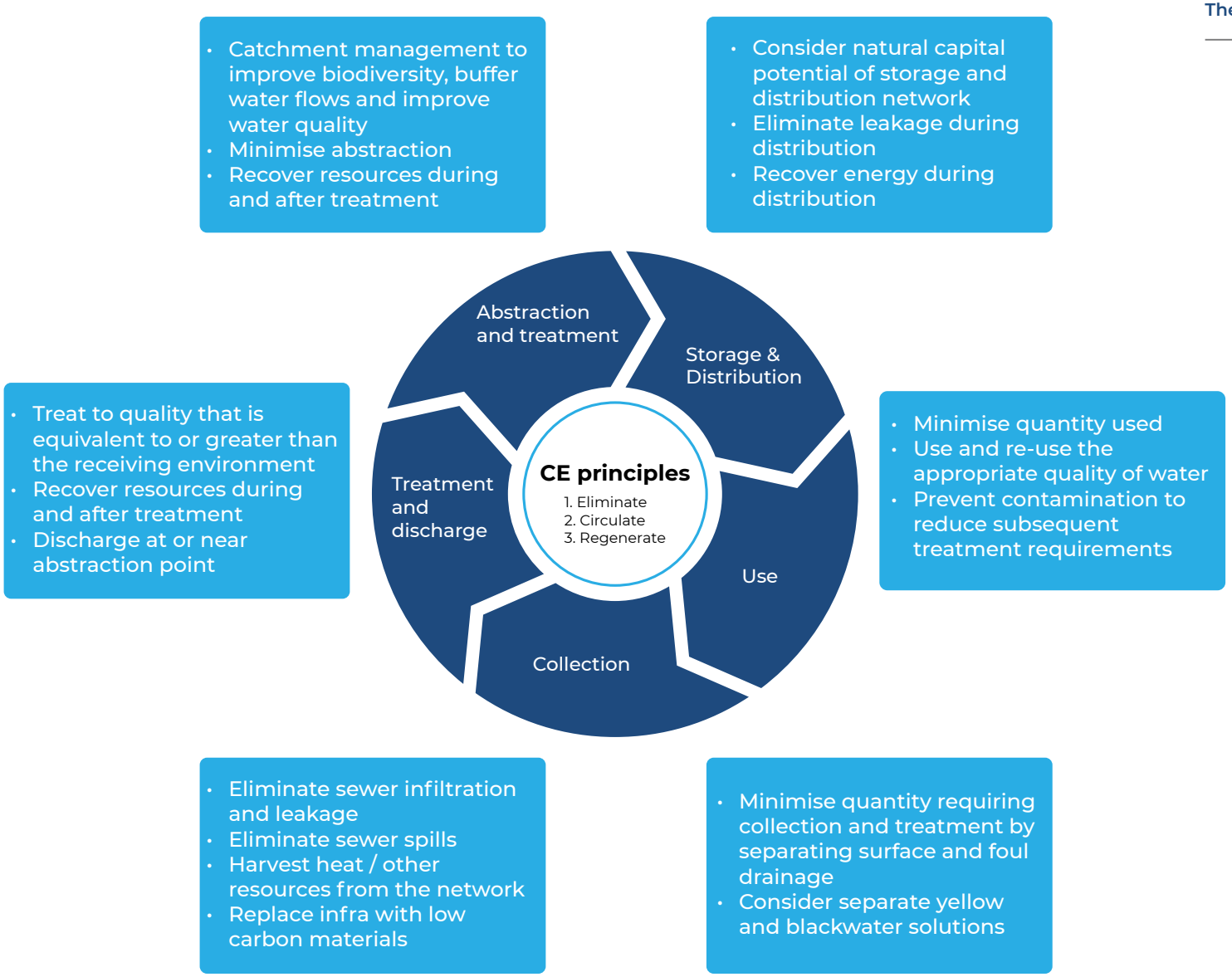


Figure 4-2 How Circular Economy (CE) principles might be applied around the urban water cycle

WHY IS A CIRCULAR WATER ECONOMY IMPORTANT?

The water sector has an unparalleled opportunity to take a leadership position in the transition to a circular economy, both as a consumer of raw materials and as a steward of valuable natural resources. As we seek to move away from a traditional take-make-use-dispose approach, we need to identify opportunities for circularity. There are numerous opportunities to recover and re-use products from the water cycle, some of which are illustrated in (**Figure 5-1**) and (**Figure 5-2**). However, it is imperative that we create a sustained demand for these products to make the transition sustainable.

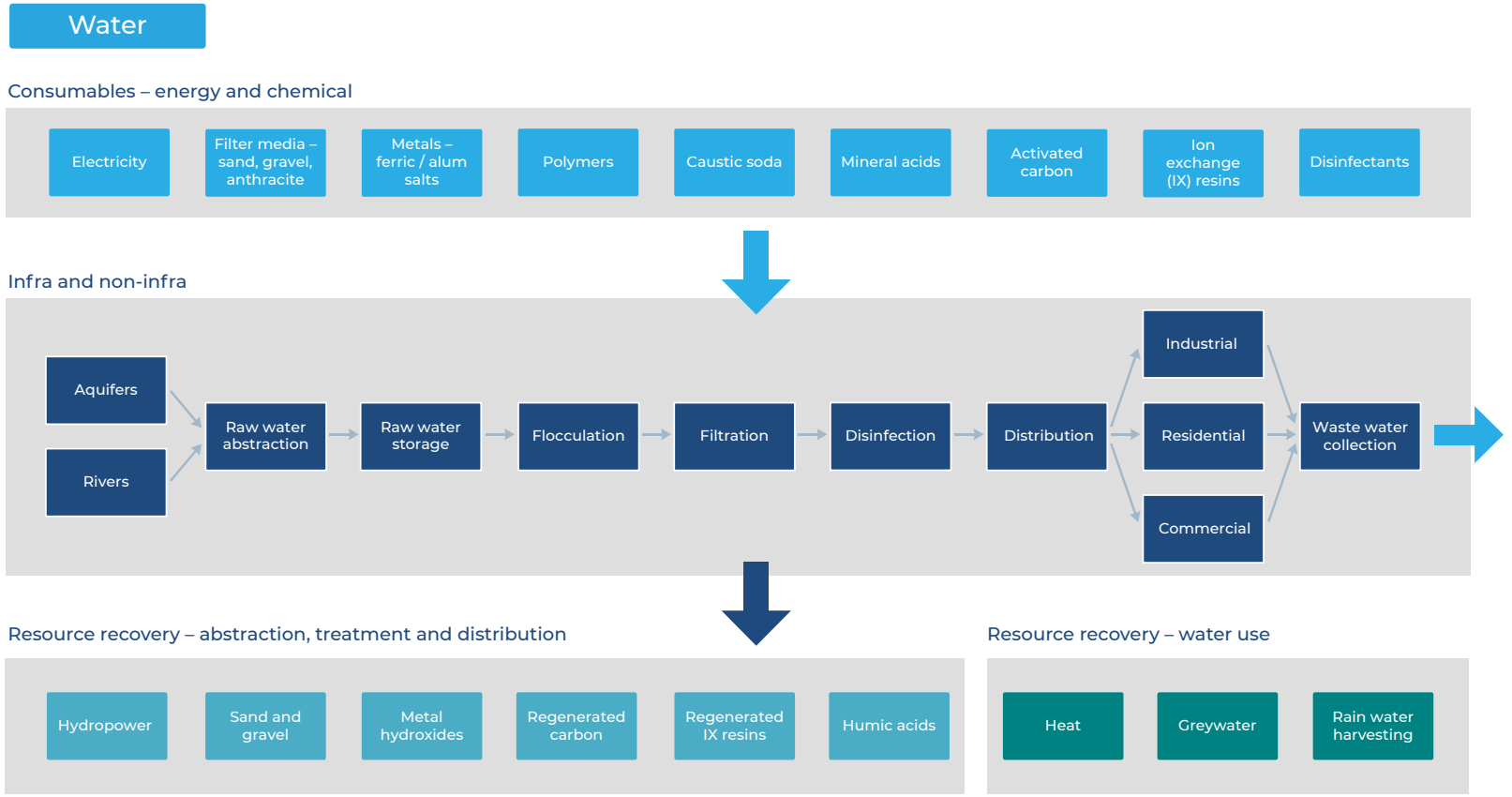


Figure 5-1 Resource flows in water system

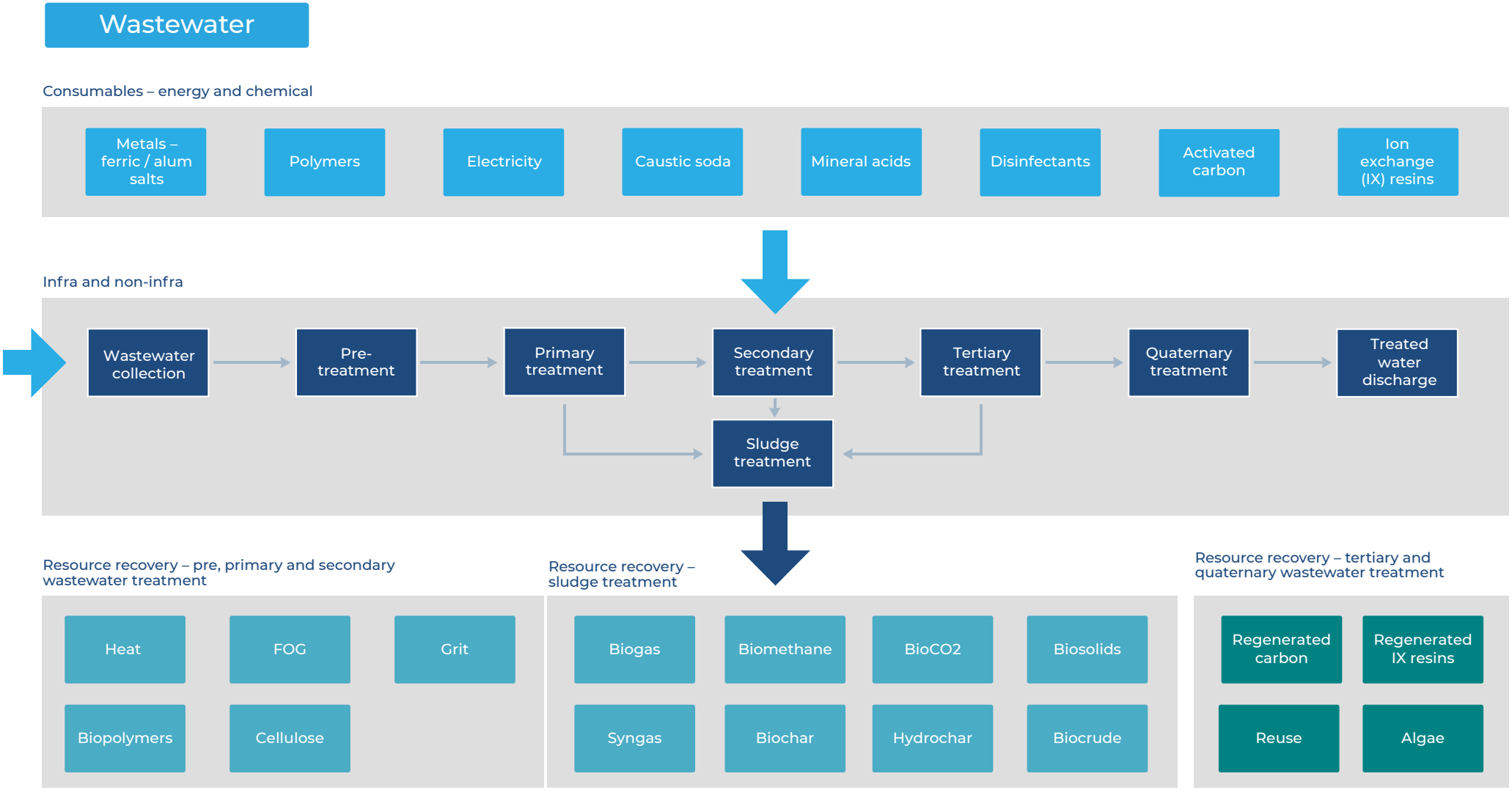


Figure 5-2 Resource flows in wastewater system

The water cycle is inherently circular. However, climate change and population growth are putting unprecedented stress on this cycle – and circularity is frequently broken at a local level as water moves between catchments as it cycles through abstraction, treatment, use, treatment and discharge. Furthermore, whilst water may be in abundance in one part of the cycle (such as surface water flooding resulting from more frequent, more extreme rainfall events) it is potentially in short supply in others (as droughts deplete our freshwater resources). This is driving huge increases in infrastructure investment as we strive to maintain resilient water supplies and to protect the environment.

Recycling or re-using water at a domestic, community or industrial scale presents an opportunity to reduce the demand on traditional infrastructure and deliver more resilient and sustainable supplies. An integrated water management approach can deliver wider benefits at a community or city level including improvements to biodiversity and enhanced social amenity. This ability to deliver multiple benefits for society and the environment demonstrates the value of a circular approach and highlights the first tenet that underpins a circular water economy – systems thinking. Making this a reality, however, requires the alignment of multiple actors, including water companies, local authorities and private developers.

This highlights the need for collaboration between stakeholders who have the ability to enact change and deliver solutions, with those that may be beneficiaries of the solutions.

The water sector is a significant consumer of energy and of carbon-intensive materials such as concrete and steel. Energy efficiency has been a focus for many years, driven in large part by cost, and the UK's water companies have embraced the opportunity to generate renewable power. More recently, the drive to reduce carbon emissions has given new momentum to reducing the consumption of raw materials. There has been a marked increase in alternatives to traditional 'grey' infrastructure, such as nature-based solutions, but there is much more still to be done to reduce dependence on virgin materials. This is not limited to construction – the sector consumes a vast array of products and equipment that have the potential to be re-used, repaired and re-manufactured – from chemicals to water meters. Where use of conventional construction materials is unavoidable, then lower-carbon alternatives must be specified, whether concrete [8], or steel [9]. Upcoming regulatory controls such as the UK Carbon Border Adjustment Mechanism (CBAM) [10], are expected to support domestic markets for low carbon construction products, encouraging such practices.

A unique attribute of the water sector is the potential for resource recovery, an opportunity that has been exploited for many years by extracting energy from sewage sludge and recycling the residue to farmland as a fertiliser. As we strive to keep materials at their highest value, water companies are exploring the extraction of other resources – such as heat, nutrients and biopolymers – so that they can be re-used in a more targeted way. This illustrates an attribute which is central to a circular economy – it is no-longer adequate to recycle – we must optimise value wherever possible. There are many other untapped opportunities for resource recovery in the water sector, some of which present technological, cultural or economic challenges. To overcome these we need to be prepared to push the boundaries – to adopt innovation.

There are currently no detailed estimates for the benefits of moving to a circular economy in the water sector, but these are likely to be significant: demand management and other resource efficiency measures offer the potential to reduce the use of energy and other consumables, whilst optimising network and non-infrastructure

operations (the reduced use of consumables will have direct beneficial impacts on cost and carbon). Nonetheless, the breadth of the circular economy clearly illustrates the value of circularity in areas where the water sector currently operates – such as in the production of biogas and other forms of renewable energy – or where it might operate in the future, such as in the production of low-carbon fertilisers and construction materials.

Investor awareness of environmental risks plays an ever-increasing role in investment decisions. A range of measures have previously been introduced in the UK, including funding for the development of the Taskforce on Nature-related Financial Disclosures (TNFD), while in October 2021 it became mandatory for large businesses to disclose climate-related risks and opportunities in line with recommendations from the Taskforce on Climate-related Financial Disclosures (TCFD). The integration of climate, biodiversity and other related metrics into a Sustainable Investment hierarchy is expected imminently. The Circular Economy approach provides a valuable consolidating function in such scenarios.

The UK economy as a whole is performing poorly when assessed against circularity metrics. If water is set to one side, more than 90% of the materials used in the UK economy derive from virgin sources – and 80% of these are sourced from beyond the UK. On a per capita basis, the UK consumes around double the quantity of resources that might be considered sustainable (15.3 tonnes of materials per person per year, as against a sustainable consumption of 8 tonnes).

It has been estimated that circular economy interventions could cut the UK's material footprint by 40%, with an accompanying reduction in carbon emissions of 43%. Circular business models also offer the potential to create thousands of jobs across multiple sectors, increase productivity, and improve the competitiveness and resilience of the UK economy. Further detail and the methodology behind these statistics can be found in the United Kingdom Circularity Gap report [11].

BARRIERS TO A CIRCULAR WATER ECONOMY

Despite its obvious advantages, the benefits of a Circular Economy approach have not yet been fully realised by the UK water sector. Where CE approaches have been adopted, they have tended to be restricted to resource efficiency and recycling rather than embracing system-wide transitions from linear to circular models. This misunderstanding of CE principles risks locking the economy into prevailing linear patterns and is by no means unique to the water sector.

While a circular economy is at the heart of the European Union's Green Deal – the metrics developed to monitor progress are all related to resource-efficiency and recycling (**Table 6-1**). The same is true in the UK, where the 25 Year Environment Plan set out an ambition to meet our existing recycling targets and to 'work towards' zero avoidable waste by 2050. The Resources and Waste Strategy for England likewise focusses on improving recycling rates, with limited reference to recyclate quality. This focus on "recycling as circular economy" is reflected in current UK water company ESG reports and strategies.

Material consumption
Material footprint
Resource productivity
Green public procurement
Waste generation
Total waste generation per capita
Generation of waste excluding major mineral wastes per GDP unit
Generation of municipal waste per capita
Recycling rates
Recycling rate of municipal waste
Recycling rate of all waste excluding major mineral waste
Secondary raw materials
Contribution of recycled materials to raw material demand
Trade in recyclable raw materials

Table 6-1 EU Circular Economy Monitoring Framework (selected metrics) [12].

More holistic (or truly circular) policies are beginning to emerge. Slovenia, Germany, Italy and France have set out transition plans to decouple production from consumption, albeit on an (initially) voluntary basis. By contrast, The Netherlands has set a hard circular economy target of 2050, which will be applied to both the national water sector and wider economy. The UK could also look to The Netherlands for examples of circular economy metrics applicable to the water sector. Based on the principles of Doughnut Economics [13], circularity is benchmarked and measured in three layers: The Systems level (which includes aspects such as financial and ecological value); Energy and Material Flows (which includes resource consumption and recovery); and Social Foundations (which include the quality of the living environment, customer satisfaction and public health) [14].

Many of these aspects are already captured by Ofwat Performance Commitments (PCs) in England and Wales, although categorised as environmental rather than circular outcomes (**Table 6-2**). If extended to embrace variants of the customer service and asset health commitments, we would find ourselves with something akin to the Dutch approach with minimal change in data capture – although benchmarking and target setting would require close attention to ensure that a genuine transition to circularity was delivered over time. Multiple Capital approaches are increasingly used within the UK water sector to capture and communicate values beyond the purely financial [15], and might also lend themselves to circular economy benchmarking and monitoring.

Water and Wastewater	Water only	Wastewater only
	• Leakage	• Total pollution incidents
• Biodiversity	• Per capita consumption (PCC)	• Bathing water quality
• Discharge permit compliance	• Business demand	• River water quality (phosphorus)
• Serious pollution incidents	• Operational greenhouse gas emissions - water	• Storm overflows
		• Operational greenhouse gas emissions - wastewater

Table 6-2 AMP8 Performance Commitments: Environmental Outcomes by Price Control

The current lack of appropriate CE metrics is accompanied by a lack of industry Vision for anything which might genuinely represent a Circular Water Economy. Addressing water supply constraints through inter-basin transfers is a typically antiquated linear economy approach to a problem. A circular approach would seek to minimise resource use and maximise reuse before considering alternatives. Likewise risks to agricultural use of treated sludges due to concerns around contamination could be addressed (in the longer term) through source controls and the application of principles such as Extended Producer Responsibility. Thermal solutions reflect linear thinking, although do offer the prospect of novel resource recovery and may be necessary in the medium-term pending implementation of source controls or other more fundamental system change.

Any vision will also need to clearly communicate the benefits that accrue from circular approaches – to the water sector itself, but also to its customers and many other stakeholders. Some of these are captured by the circular economy transition plans set out by our water sector peers outside the UK – such as Australia, where stated benefits include: Resilience to supply chain shocks; Opportunities for innovation and business diversification; Inspired, engaged and adaptable staff; High levels of trust from local communities; Delivery of reliable, resilient and affordable water; Improved ecosystem health and amenity value; Reduced greenhouse gas emissions; Optimised costs.

In the absence of a high-level Vision for a Circular Water Economy the focus must fall on the current state of the art: resource recovery. As highlighted in (**Figure 5-1**) and (**Figure 5-2**), there are opportunities for resource recovery throughout the urban water cycle, and projects to demonstrate the technical feasibility of these recovery routes are common at pilot scales. Commercial scale operations are less common, particularly for any approaches that might be considered 'advanced resource recovery', such as the transformation of sludge treatment centres into biofactories or biorefineries. Nonetheless, entities such as AquaMinerals [16] demonstrate what can be achieved with appropriate focus and funding, marketing a range of products derived from both the water and wastewater parts of the cycle.

Once the technical feasibility of a new resource recovery route has been demonstrated, the commercial case demands close attention. Since most residuals from water and wastewater treatment can be expected to fall under waste regulatory controls, an 'End of Waste' (EoW) position is normally considered desirable. However, achieving such a position is not necessarily straightforward and when achieved can attract regulatory controls that did not apply when the material was a waste. Products must be manufactured to a specification, marketed, sold and distributed. Whether this supply chain is owned and managed by the water company within which the waste materials arise, whether it is owned by manufacturers specialising in specific products and markets – or a combination of these two – is likely to be resource and market-specific. Where third parties are essential to new value chains, then questions of consistency become relevant to risk analysis: consistent supply, quality and cost will need to be ensured for a robust commercial case to be made. These aspects are visualised in (**Figure 6-1**).

Whether new resource-recovery operations are delivered in-house or in conjunction with third parties, full consideration must also be given to the location of the technology / technologies. The options will be familiar to those handling sewage sludges / bioresources, where efficiencies of scale have led to the development of logistical models built around hub and satellite concepts. These rely on sludges from smaller wastewater treatment works being hauled to larger works (hubs) for processing – normally through Advanced Anaerobic Digestion. Thickening and/or dewatering may occur at intermediate sites to reduce haulage costs. Depending on the resource in scope, an alternative 'milk round' approach may be more suitable, with the technology mobilised to the resource, rather than vice-versa (**Figure 6-2**).

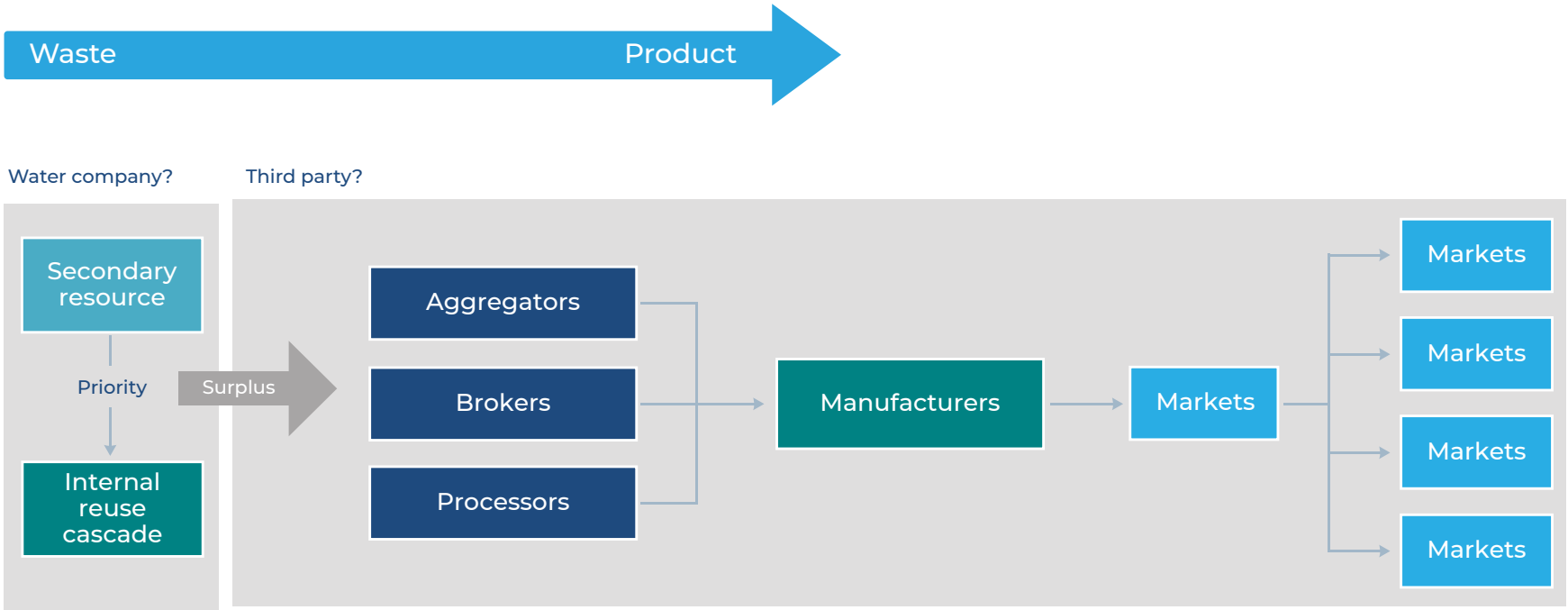


Figure 6-1 Conceptualising risk-reward boundaries for resource recovery

Linked to the requirement for technology and logistics is the option of "servitisation", whereby a price is paid for an outcome rather than for the means of achieving that outcome. In the water sector this could mean paying per volume of water or wastewater conveyed, rather than the network which enables the conveyance – or paying for treated effluent of a specific quality rather than the means of achieving this quality. Such business models are fundamentally misaligned with current water sector business structures, again challenging current norms around asset ownership, risk and reward as a preliminary to strategic transformation from linear to circular economies.

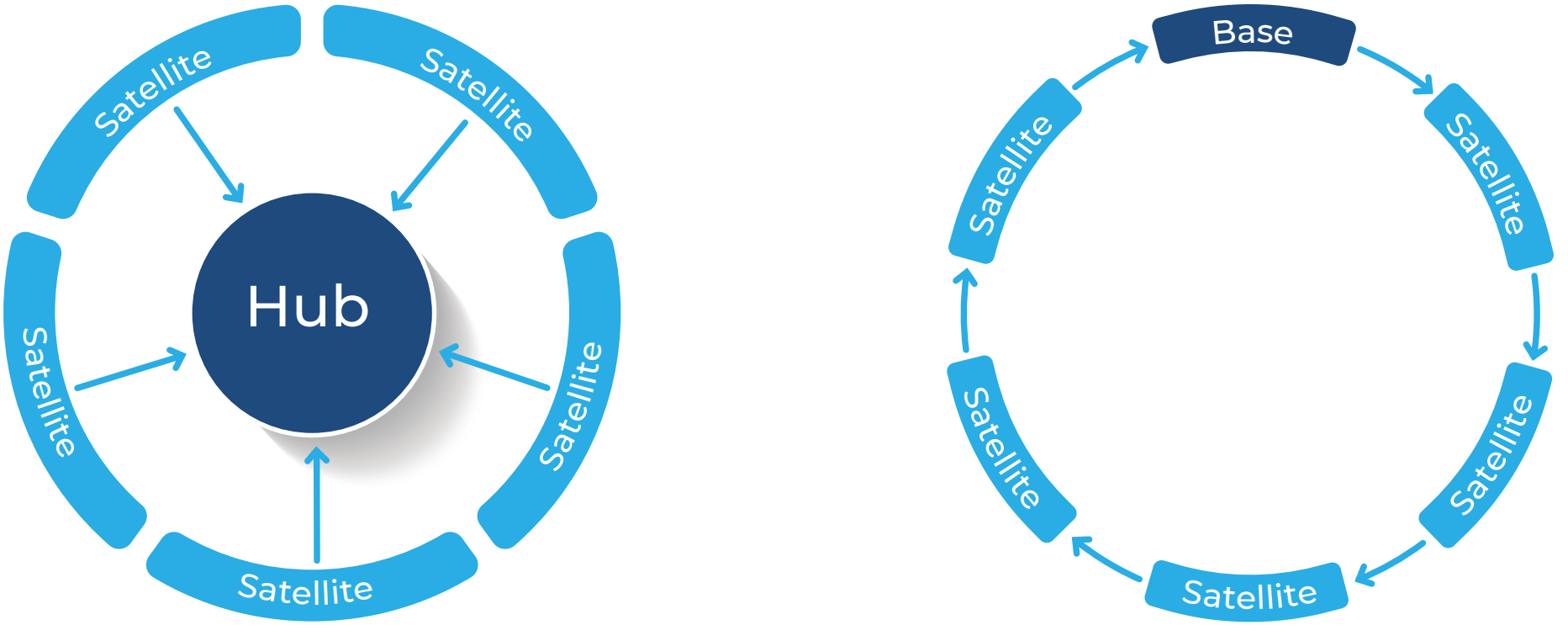


Figure 6-2 Conceptualising technical solutions to resource recovery: Hub and spoke (left) and Mobile treatment (right)

CREATING ENABLING FRAMEWORKS FOR A CIRCULAR WATER ECONOMY IN THE UK

Unlocking the system level change that is required as we transition to a circular water economy will require collaboration with stakeholders from within and outside the sector to develop synergistic policy, regulatory and commercial frameworks. An essential first step will be to agree a functional definition for the Circular Water Economy, reflecting the opportunity and ambition for the sector to impact across all three pillars: Eliminate, Circulate and Regenerate. The aspiration should be for circular thinking and circular design to become business as usual.

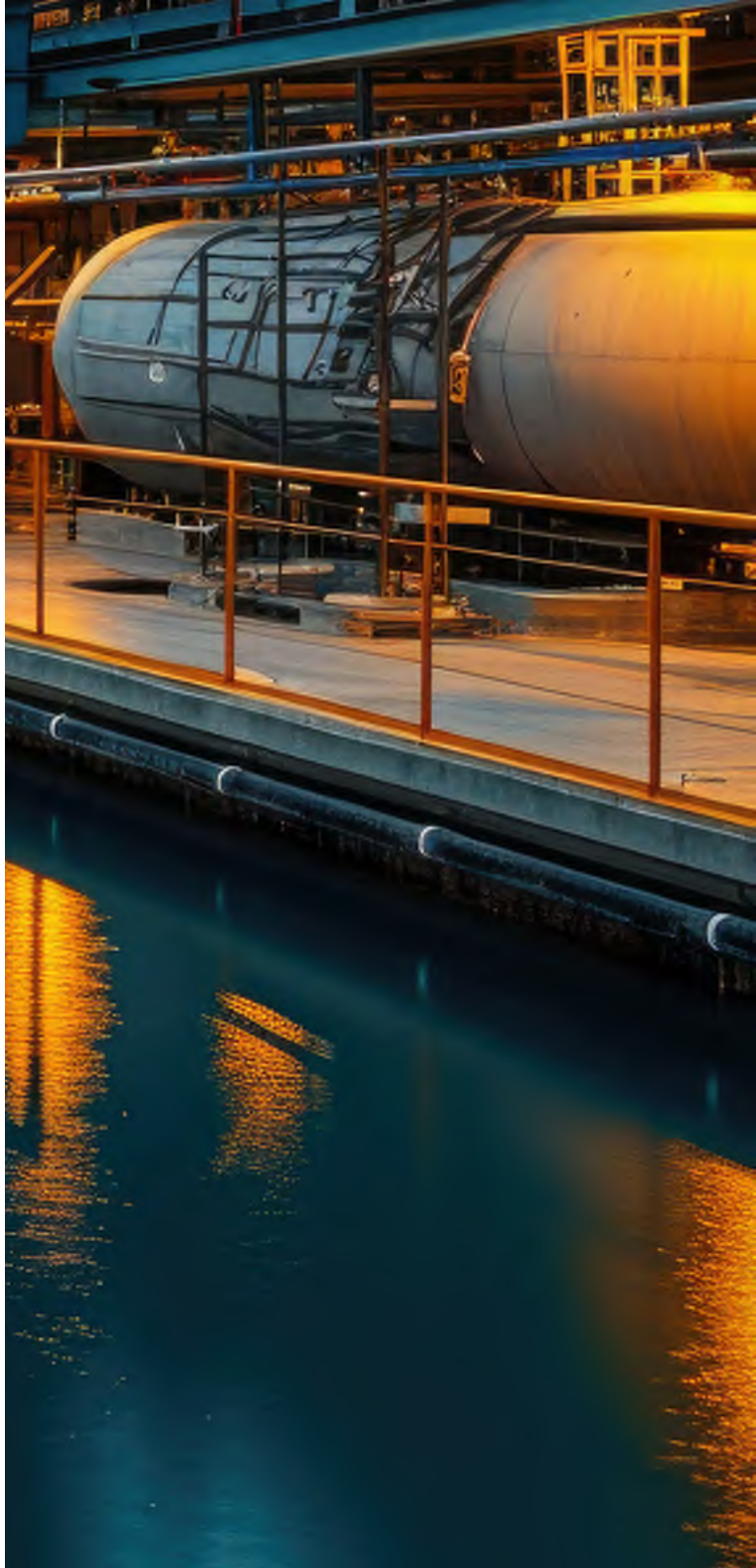
Metrics and targets for circularity can follow, perhaps adopting the approach of our water sector peers in The Netherlands, where the art of the possible is understood and the 'dot on the horizon' established on this basis. Targets should not become ossified but should change over time as innovations come to market and contexts change. However, rather than let future uncertainty act as a brake on transformation we must design future systems based on what we know is achievable now. As we come to know more, then targets and timetables can be modified accordingly. Ideally an initial target will be linked to desired Policy outcomes, since these act as conduits for supporting regulatory change and incentives. National recycling targets have been in place for decades in the waste sector and whilst these only reflect one aspect of the circular economy they have driven change in that sector.

Once a definition and target has been set (such as full circularity by 2040), then questions of detail can be addressed to facilitate delivery. Here again the water sector has much to learn from colleagues in the waste sector, where process regulation and end of waste legislation have operated for many years. Current frustrations with end of waste frameworks [17] and the retarding effect this is having in waste sector innovation signals opportunities for cross-sector collaboration that could benefit the entire economy.

Regulatory controls only become a constraint where the wider business case would otherwise support change, and alongside agreement on what the circular economy means for the water sector it is the understanding of the commercial landscape which requires most urgent attention. To date there have been numerous bench and pilot scale studies to explore the technical potential for resource recovery operations, but few if any of these then transition to full commercial scale implementation. That many available resources are dispersed across many thousands of small sites is a particular challenge, which calls for collaboration and transparency across water company boundaries – and beyond – to identify commercially interesting opportunities. Sharing the risks and rewards under such circumstances will be difficult, particularly within a sector that is economically regulated. Ofwat, WICS and their fellow regulators will need to accompany the sector on every step in its circular transformation – and this process of change needs to be just, in the sense that all consumers must retain access to water and wastewater services at a price they can afford.

Transformation is possible. Experience and success stories from other sectors and geographies are available to drive systems thinking to maximise the scale and impact of the change that it enables, recognising that the circular economy is not limited to recovering individual materials but about redesigning systems to eliminate waste and deliver multiple benefits. Examples include:

- AquaMinerals, an association of water companies in the Netherlands, which develops markets for materials originating in the water cycle. AquaMinerals now markets over 30 products with diverse applications including drinking water, agriculture and consumer products [16].
- The National Industrial Symbiosis Programme or NISP® which was run by International Synergies. Over five years the programme helped 12,500 companies divert over 7 million tonnes of waste from landfill, reduce carbon emissions by over 6 million tonnes, reduce costs by over £156 million and generate £176 million in additional sales [18].
- Water Europe Marketplace, a website created and then developed by several Horizon 2020 projects: NextGen, B-WaterSmart and ULTIMATE. It allows users to search for technologies, tools, products and services that facilitate the adoption of Circular Economy principles within the Water Sector. It is also designed to stimulate contact between stakeholders, to share ideas and collaborate [19].
- Scottish Water's interactive sewer map shows flow rates across parts of their network as a means of illustrating potential for heat recovery from the wastewater before treatment [20].
- Winnovatie ('winnovation') is an online community for collaboration on innovation in The Netherlands, hosting case studies across multiple aspects of the water cycle, including circular economy. Examples include direct potable reuse, use of dredged materials as a substitute for aggregates in concrete, and synthesis of formic acid from CO_2 captured during wastewater treatment [21].



NEXT STEPS

This paper aims to present a high-level state of the nation summary of circular economy opportunities and challenges, as currently evident to the UK water sector. In considering CE developments in other sectors there is a significant risk that the circular economy will become synonymous with recycling, and that other key CE principles such as designing out waste and pollution, and regenerating nature will be marginalised or left in separate siloes. The current policy landscape reflects the long-standing separation of the water and waste sectors, with their different regulatory and delivery structures. It is clear that both sectors have many common interests with respect to the Circular Economy, and the potential to support transitions to truly sustainable patterns of production and consumption. The absence of cross-sector CE policy means that there is currently no common platform around which interested parties can coalesce and no compelling stimulus for the water sector to nurture a vision for circularity.

In the absence of current sector-specific policy, we are looking to stimulate a bottom-up approach to establishing a circular water industry in the UK.

Our primary vehicle for this is to promote success by publicising examples of CE principles in practice. For example:

- Where have resource-recovery initiatives translated from pilot to commercial scale?
- Where have novel business cases been developed to balance risk and reward associated with circular business models?
- Where have regulatory frameworks been successfully negotiated to deliver positive circular business outcomes?
- Where have new metrics been deployed to capture data on circularity?

It has been particularly clear during the development of this paper that there is an appetite for visibility and collaboration – sharing information on secondary resources and driving change. This appetite is on display both within and beyond the water sector. Stakeholders in construction are desperate to know where and what alkaline substrates might be available to use as drop-in replacements for conventional cement constituents; Commercial developers are keen to know where they might be able to access the sewer network to capture heat; Manufacturers of Sustainable Aviation Fuel need good quality data on sludges and other biogenic feedstocks for their processes.

Anyone with a circular success story relevant to the water cycle is welcome to contact the UK Water Partnership to discuss options for sharing it with the widest possible audience.

THE BENEFITS OF BEING A MEMBER OF THE UK WATER PARTNERSHIP

The UK Water Partnership was established in 2015 to provide a strategic vision for the development and growth of the UK water industry. It brings together a wide cross section of UK water sector stakeholders in a single coherent alliance to support research excellence, promote collaborative innovation and secure the UK a greater share of the $500 billion global water market.

Joining the UK Water Partnership gives you the opportunity to increase your influence, visibility and access to cutting edge research and innovation in the UK water sector, which will help you to grow your organisation and reduce business risk.

Our members:

- Work directly with government departments, engaging with officials and Ministers, to shape the government's priorities for research, innovation and capability in the water economy and to promote increased commercialisation both here and overseas
- Access new insights and strategic networks – for businesses this means scientific and technical information and capability, while for the academic community, connections to a wide end-user community which will help accelerate the uptake and impact of research
- Help to shape the debate and the way forward, in partnership with other stakeholders, through involvement in activities and events, and collaborations with fellow members
- Raise their profile through participation on our website, facilities register, newsletter features, logo placement in UK Water Partnership literature, and invitations to events.

Members of the UK Water Partnership have the opportunity to participate in one or more of our strategic Delivery Groups, which are driving transformative change in the UK water industry. In addition to Water Resilience, the partnership has recently focused on:

- Digital Water –The UK Water Partnership launched an action plan to help UK plc win its share of the $30 billion digital revolution in water.
- Flood Resilience – promoting a high quality, UK-wide flood Resilience industry and providing a unique forum to help tackle one of today's biggest natural threats
- LITSoN (Linking innovation to societal needs) – creating a single source of data on innovation activity in the UK and using this to create solutions for societal needs
- Net Zero – UKWP is committed to set out a simple but compelling explanation of the importance for society of Net Zero being achieved.

- Circular Water Economy – Capturing circular water solutions, showcasing UK capability, and identifying opportunities to embed circular economy thinking at the heart of the water cycle.
- Capabilities Directory – The UK Water Partnership has worked in partnership with the Department for International Trade to develop a UK water Capabilities Directory. This will be used to help UK-based organisations improve their access to UK and international markets.
- Water Accelerator – connecting innovation activity in the UK to accelerate the development and implementation of new technology in the water sector.

Our focus

Our Delivery Groups strive to:

- Promote applied research excellence
- improve the ability to model and simulate urban water systems
- facilitate and accelerate the route to market for innovations in the water sector
- encourage research and testing capability in the UK
- drive engagement with Government, the Department for Energy Security and Net Zero and the Industrial Strategy Challenge Fund
- improve the alignment of UK innovation with the UK water industry
- identify how global needs link to UK expertise
- develop the UK offer on flood resilience

How we are financed

The UK Water Partnership is a public-private not-for-profit company limited by guarantee with its operations funded by financial contributions from its members.

Private sector contributions are used to carry out core operational activities such as administration, marketing and promotion, as well as planning and hosting events that help promote the UK water economy both at home and overseas.

The Partnership is indebted to its members, not just for their continued financial support, but also for their substantial gifts of time and for their willingness to co-design our emerging products and services.

Contact

For more details go to:
www.theukwaterpartnership.org/join-us

Or email us at:
info@theukwaterpartnership.org

ACKNOWLEDGEMENTS

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- Barry Greig, Scottish Government
- Carly Perry, Spring
- Chris Newsome, Anglian Water
- Deryck Irving, University of Stirling
- Donna Rawlinson, Northumbrian Water Ltd
- Fiona Millar, University of Stirling
- Gabriela Medero, Herriot-Watt University
- George Ponton, Scottish Water
- Hans Hensen, UKWP
- Jason Ash, aiimi
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- Laura Mitchell, University of Stirling
- Louise Elliott, WSP
- Marcia Banks, SEPA
- Martin Shouler, Arup
- Rebecca Pankhurst, University of Stirling
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- Tom Arnot, University of Bath
- Tom Millbrow, aiimi
- Tom O'Farrell, aiimi
- Will Brownlie, UKCEH

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Appendix A
CASE STUDIES

LOW CARBON FOOD PRODUCTION

ORGANISATION(S)

Anglian Water, Oasthouse Ventures

CLIENT(S)

Water companies, food producers

LOCATION

FOCUS AREA

- ○ Digital Water
- ○ Water Resilience
- ● Net Zero
- ● Circular Economy
- ○ Other

SERVICE OFFERING

- ● Research
- ○ Advisory
- ● Design
- ○ Build
- ○ Operate

UK CAPABILITY

- ● Now (existing capability)
- ○ New (emerging capability)
- ○ Next (future capability)

OVERVIEW

In a world first, Anglian Water has partnered with Oasthouse Ventures to use warm water, which is a natural by-product of the sewage treatment process, to heat two of the UK's largest greenhouses – one in Norfolk and one in Suffolk.

The project uses a readily available, but generally unused, low carbon energy source to provide low carbon heating to another organisation. By capturing this warmth, the tomatoes grown in the glasshouses have a carbon footprint that is 75% lower than normal.

Closed-loop heat pumps are used to capture and transfer waste heat from nearby sewage treatment works to the greenhouses to accelerate the growth of the tomato plants all year round. The heat pumps are powered by a new CHP plant, the carbon emissions of which are channelled back into the greenhouses to help the plants grow.

There are additional environmental benefits too, since the water that is recycled to the nearby chalk stream is cooled first, which is better for aquatic life and helps prevent algae growth in the river. Further, the approach also contributes to food security and economic growth.

COMPANY PROFILES

Anglian Water is the largest water and water recycling company in England and Wales by geographic area. We supply water and water recycling services to almost seven million people in the East of England and Hartlepool. We were the first major utility to enshrine our purpose in the fabric of our company constitution: our Articles of Association. Our purpose is to bring environmental and social prosperity to the region we serve through our commitment to Love Every Drop. This is a bold idea about the role we want to play in the world. It acts as a north star for our team and is a genuine promise to our customers, partners and shareholders. We're constantly challenging ourselves to be the best company we can be, and to make a real and meaningful impact for our customers, communities and the planet.

Oasthouse Ventures is born from the founders' desire to build businesses of integrity and honesty. From the very beginning, we've advanced ideas, people, and enterprises that not only interest us but also create positive change.

KEY WORDS

water resourcess	resilient infrastructure	ecosystem services
catchment management		planning and urban design
demand management	green infrastructure	urban retrofit
buildings and public realm		rivers and waterways
asset management	smart infrastructure	coasts
eliminating waste and pollution		resource recovery

For more information	
Company website	https://www.anglianwater.co.uk/
Partner websites	https://www.oasthouseventures.com/

DARK FIBRE LEAKAGE DETECTION

ORGANISATION(S)

Severn Trent Water, Costain Group plc, Dŵr Cymru Welsh Water, Focus Sensors, Northumbrian Water Limited, Hafren Dyfrdwy Cyfyngedig, South Staffs Water plc

CLIENT(S)

Water companies, Contractors, Consultants

LOCATION

FOCUS AREA

- [x] Digital Water
- [x] Water Resilience
- [ ] Net Zero
- [x] Circular Economy
- [ ] Other

SERVICE OFFERING

- [ ] Research
- [ ] Advisory
- [ ] Design
- [ ] Build
- [x] Operate

UK CAPABILITY

- [ ] Now (existing capability)
- [x] New (emerging capability)
- [ ] Next (future capability)

OVERVIEW

The water industry is facing a significant supply-demand deficit due to population growth, climate change and the need to balance customers' needs. In response to these challenges, the water industry is striving to reduce, and ultimately eliminate, leakage from the water supply network.

The use of fibre leak detection has been successfully demonstrated but uptake of this technique has been prevented by the cost and disruption of laying new fibre either above or within water mains. This project investigated the use of unused optical fibre strands ("dark fibre") within existing cable networks for leak detection and provided additional information about Severn Trent's network, including monitoring the creation of voids around leaks or damaged sewers.

The trial was delivered in two phases:

1. Controlled environment where fibre optic cable was fitted, and seven different leak types were simulated.
2. A live environment where the equipment was installed on a main road. Two types of leak detection using fibre were used:
    a. Direct detection for nearby leaks, by picking up resultant sounds in the fibre.
    b. Indirect detection by monitoring changes in the water saturation of ground near the fibre.

The trial successfully proved that leaks can be monitored using dark fibres using either approach. Directly detected leaks could be identified within around 0.5m of the dark fibre, while indirectly detected leaks could be identified within 5m of the fibre. Overall, the use of third-party fibre networks was shown to provide low cost, rapid and accurate leak detection.

COMPANY PROFILES

As one of Britain's largest water companies, Severn Trent Water impact on the lives of millions of people across the Midlands, from the outskirts of Sheffield, down to Bristol, and into north and mid-Wales. We provide over eight million people across our region with fresh, clean drinking water every day – about two billion litres. We take away the used water, clean and treat it before returning it safely to the environment.

We pride ourselves on doing the right thing for our customers, and for the communities in which we live and work. Our Community Fund provides grants to groups and organisations across the Midlands for the projects that are close to their hearts. We also help tens of thousands of our most vulnerable customers with support, whether through money off bills or by offering them advice and special devices so they can become more water efficient.

We've signed up to the triple carbon pledge – to be carbon zero, to use all renewable power and to have an all-electric fleet of vehicles by 2030. Our plans include ambitions to improve biodiversity throughout our region, including planting more than 1.3 million trees, establishing new wildflower meadows and restoring moorland, bog and peatland, all of which will help fight climate change and protect our water supplies. Our visitor sites enable everyone to take advantage of some of the most beautiful countryside in our region, with sites from Carsington Water in the Peak District to Lake Vyrnwy in Powys.

KEY WORDS

water resourcess	resilient infrastructure	ecosystem services
catchment management	planning and urban design	
demand management	green infrastructure	urban retrofit
buildings and public realm	rivers and waterways	
asset management	smart infrastructure	coasts
eliminating waste and pollution	resource recovery	

For more information
Company website
https://www.severntrent.com/
Partner websites
https //www.costain.com/
https://www.dwrcymru.com/en
https://www.focussensors.co.uk/
https://www.nwl.co.uk/
https://www.hdcymru.co.uk/
https://www.south-staffs-water.co.uk/

ANMBR – ANAEROBIC MEMBRANE BIO REACTOR

ORGANISATION(S)

Severn Trent Water, Cranfield University

CLIENT(S)

Water companies, Contractors, Consultants

LOCATION

FOCUS AREA

- ○ Digital Water
- ○ Water Resilience
- ● Net Zero
- ● Circular Economy
- ○ Other

SERVICE OFFERING

- ● Research
- ● Advisory
- ○ Design
- ○ Build
- ○ Operate

UK CAPABILITY

- ○ Now (existing capability)
- ● New (emerging capability)
- ○ Next (future capability)

OVERVIEW

Secondary biological treatment at a wastewater treatment works is key to ensuring the quality of the final effluent before it's discharged into a water course. However, this essential process has a very high energy demand and hinders the path to Net Zero wastewater treatment. In warmer climates such as Brazil, two-stage conventional wastewater treatment is frequently replaced with Anaerobic Membrane Bioreactors (AnMBRs), which combine anaerobic digestion with physical separation membranes, resulting in both biogas production and organic load removal. This technology is successfully used to provide low-carbon, energy positive wastewater treatment for millions of people in the tropics, but its applicability to temperate climate zones such as the UK is not yet proven.

Severn Trent has been working with partners Cranfield University to see how anaerobic treatment works in more variable climates and with funding by the EU Horizon 2020 nextGen programme have built "Europe's Largest AnMBR" at their Resource Recovery & Innovation Centre outside Redditch.

The AnMBR combines three different technologies:

- A UASB (Up-flow Anaerobic Sludge Blanket) reactor: a methane-producing digester, which uses an anaerobic process and forms a blanket of granular sludge.
- A submerged membrane ultrafiltration (UF) plant that ensures adherence to site permits.
- A membrane degassing unit to remove any dissolved methane.

Results show there is potential to recover biogas to a similar quality of conventional digestion and that pH and alkalinity are compliant with discharge requirements for recycled wastewater. Once proven, AnMBR has the potential to be the future standard for waste treatment, reducing the capital investment of future works by £20-30m.

COMPANY PROFILES

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The Water Science Institute at Cranfield University undertakes globally leading research and post graduate teaching in water and wastewater process science, engineering, governance and policy to:

- Propel sustainable solutions to combat the multiple threats and challenges being faced by our water resources, assets and services
- Deliver collaborative cutting-edge discovery science on the transformation, removal and recovery processes in water wastewater treatment systems
- Equip graduates with the technical and management skills to elicit change and transformation

We have been working in water for over 40 years. Our academic and research staff, including scientists, engineers, technologists, policy specialists and social scientists, are engaged in delivering postgraduate teaching, research, consultancy and training in an international arena.

COMPANY PROFILES

KEY WORDS

water resourcess	resilient infrastructure	ecosystem services
catchment management		planning and urban design
demand management	green infrastructure	urban retrofit
buildings and public realm		rivers and waterways
asset management	smart infrastructure	coasts
eliminating waste and pollution		resource recovery

For more information	
Company website	https://www.severntrent.com/Partner
Partner website	https://www.cranfield.ac.uk/centres/water-sciences-institute

CELLULOSE RECOVERY

ORGANISATION(S)

Severn Trent Water, CirTec, ReCell

CLIENT(S)

Water companies, Consultants

LOCATION

FOCUS AREA

- ○ Digital Water
- ○ Water Resilience
- ● Net Zero
- ● Circular Economy
- ○ Other

SERVICE OFFERING

- ○ Research
- ○ Advisory
- ● Design
- ● Build
- ● Operate

UK CAPABILITY

- ○ Now (existing capability)
- ● New (emerging capability)
- ○ Next (future capability)

OVERVIEW

Toilet paper is approximately 80% cellulose, meaning that sewage treatment works in the Severn Trent region receive around 100,000 tonnes of cellulose a year. This presents a significant opportunity for resource recovery.

CirTec, a Dutch company, have developed a process where the cellulose fibres can be recovered. This recovered cellulose can be used as a structural material to substitute virgin cellulose and has been used in asphalt, concrete and other building materials as well as biocomposite materials. It can also be used as a feedstock for chemicals such as acetic acid and biopolymers. Life cycle analysis has estimated that cellulose recovery can help to reduce operating costs – and the carbon footprint – of sewage treatment works by up to 15%.

Trials funded as part of the EU Horizon 2020 SMART-Plant project have been run at two wastewater treatment works, recovering between 4.5 and 6kg of cellulose a day. This was dried and sent to ReCell in the Netherlands for comparative testing against cellulose recovered during similar trials in the Netherlands & Italy. This analysis showed that the recovered cellulose was suitable for use in a number of products and as a chemical feedstock.

The cellulose recovery process has also been shown to remove 99% by mass of microplastics from the incoming wastewater, which are then concentrated in the sludge stream and not the cellulose product.

Cellulose recovery not only provides potential revenue from sales of a recovered raw material, it can also improve the treatment capacity of sewage treatment works and may provide an option for removal of microplastics from wastewater final effluent.

COMPANY PROFILES

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CirTec is an acronym for circular technology. Energy saving and re-use of materials become more and more important and are crucial for maintaining a good and healthy environment for future generations. CirTec meets today's needs without ignoring future challenges. Our company helps to promote eco-citizenship, by reducing the environmental impact of our own activities, develop technologies for the recovery of renewable materials and use of renewable energy. We provide the most appropriate solution for many environmental issues, by applying proven as well as innovative technology. The transition to a circular sustainable society is not a goal but an absolute must.

Recell specialises in extracting, reprocessing and developing applications for cellulose as a raw material. Our customers include both government bodies and industry. Every year, European companies put 20 million tonnes of cellulose into waste streams. Our mission is to recover all of it for use in green supply chains. As a brand and as a team we're inspiring everyone who is on the path with us to the new green and circular economy. Recell's R&D ranges from fundamental research and waste treatment technology to process technology and products.

COMPANY PROFILES

KEY WORDS

water resourcess	resilient infrastructure	ecosystem services
catchment management		planning and urban design
demand management	green infrastructure	urban retrofit
buildings and public realm		rivers and waterways
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For more information	
Company website	https://www.severntrent.com/
Partner website	https://www.cirtec.nl/
	https://recell.eu/