CIRCULAR INFRASTRUCTURE

HOW INFRASTRUCTURE OPERATORS CAN IMPLEMENT
CIRCULAR ECONOMY STRATEGIES

Altermind

VAUBAN
INFRASTRUCTURE PARTNERS

FOREWORD

Since its creation, Vauban Infrastructure Partners has sought to invest in essential public infrastructures that provide long-term sustainable solutions to local communities: clean water, efficient waste management, district energy systems, safe and low-carbon transportation, fiber to the home, and a broad range of social infrastructure around education, health, justice and leisure. We believe that it is our duty to act in the best interest of investors and society, to help build and maintain vital infrastructure systems so that communities can thrive in a sustainable environment.

In the fight against climate change, governments and companies' strategies have mainly focused on renewable energy and energy efficiency, while the massive "mitigation" potential of circularity has long been overlooked. Yet, an estimate from the 2021 Circularity Gap Report states that the adoption of circular practices could reduce global carbon emissions by 39% and cut virgin resource use by 28%.

For the infrastructure sector, the challenge is huge considering its massive impact on carbon emissions and materials consumption, and we have a collective responsibility to step up with much more ambitious targets and commitments in terms of circularity. All instrastructure stakeholders must urgently embrace the new circular paradigm.

In this context, at Vauban Infrastructures, we want to embed more circularity in our investment approach and corporate culture and engage with our assets portfolio to help them transition toward more "circular infrastructure".

This is why we conducted alongside Altermind this research work that has allowed us to gather high-level insights from top international experts through a series of "events": a masterclass on circular infrastructure, a breakfast panel exploring the regulatory stakes, three podcasts on new circular business models and challenges and an Innovation Morning highlighting the most innovative start-ups.

With this study, we hope to improve our climate and circular economy strategy, strengthen our commitment to a long-term investment approach, be transparent about our practices, and advance knowledge on circular economy to help the whole infrastructure sector embrace the circular revolution.

Gwenola Chambon,
CEO, Founding Partner

Mounir Corm,
Deputy CEO, Founding Partner

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Altermind is a consulting firm enhanced by the insight of the international academic world. Its teams, based in Brussels, London, Munich and Paris, offer executives a 360-degree intervention capacity on the most complex issues.

VAUBAN INFRASTRUCTURE PARTNERS

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Vauban Infrastructure Partners (Vauban IP) is a leading infrastructure asset manager focused on the core infrastructure market. Headquartered in Paris, Vauban IP employs 75 professionals, the majority of whom have been working together for over a decade. Vauban Infrastructure Partners targets predominantly European brownfield mid-market assets, and pursues a long-term, yield-driven strategy matching the underlying nature of the assets and long-term commitment to all stakeholders' interests through a strong focus on creating sustainable value and a unique ESG approach. To date, Vauban IP has raised over €8bn across 7 funds in core infrastructure, and has invested in the mobility, energy transition, social infrastructure, and digital infrastructure sectors spanning 12 different geographies.

EXECUTIVE SUMMARY

While humanity has prospered immensely in recent decades, it has come at a devastating cost in terms of carbon emissions, biodiversity loss and resource consumption. As of today, it would require 1.6 Earths to maintain the world's current living standards[1] and, without action, resource extraction will likely double by 2060[2].

Although governments and companies have stepped up to achieve Net-Zero commitments and avoid environmental depletion, the linear economic model that has prevailed since the industrial revolution – based on a "take-make-dispose" pattern – is a major impediment to achieving these objectives. Continuing down the current path – where demands on nature far exceed its capacity to supply – presents extreme risks and uncertainties for global economies.

The world needs a new paradigm, and it needs it now.

In a circular economic model, the extraction of primary resources is minimized by extending the useful life of existing resources and materials, thus contributing to wisely manage natural resources, build more resilient production systems and include waste as a source of value to adapt swiftly to ecological challenges. By creating "material loops", circular principles can help maintain the value of products, materials and resources for as long as possible by returning them into the product cycle. According to the Ellen MacArthur Foundation, a rapid shift to more circular practices in five key areas of manufacturing (cement, aluminum, steel, plastics, and food) could eliminate more than 40% of carbon emissions[3].

Considering its massive impact on the environment, the infrastructure sector – responsible of 79% of global CO_2 emissions and 63% of materials consumption – is at the forefront of the circular revolution. The world clearly needs more "circular infrastructure", i.e. a system of infrastructures that either contribute directly to the circular economy activity (Infrastructure for Circularity) or minimize and manage the amount of material used across the infrastructure lifecycle (Circularity of Infrastructure).

On the one hand, waste management and water treatment systems are two essential infrastructures for circularity that will be key facing the coming waste upsurge and the need to secure access to clean water in developing countries, although recycling activities cannot achieve sustainability goals without reductions in production and consumption.
On the other hand, infrastructure operators (in transport, telecommunication, energy, housing, etc.) must activate a series of key levers to fully embrace the circular transition: design infrastructure in a modular way, source renewable materials, create "integrated" supply chains (with reverse logistics for instance), leverage on engineered industrial solutions mobilize and educate key stakeholders, etc.

The task will not be easy. While it must happen swiftly, the circular transition of the infrastructure sector yet faces massive challenges due to large-scale and external trends (urbanization, rising demand for infrastructure, etc.) and the nature of infrastructure itself (a long lifespan, a high carbon footprint of the built environment, long planning processes, etc.). But the case is strong: for the built environment only, if Europe increased its circularity rate for aggregates from the current 7% to 20%, it would reduce virgin raw material costs of up to EUR 6bn each year by reusing 546m tons of aggregates[4].

For infrastructure operators, the transition toward more circularity makes sense. First, more circularity within infrastructure operating models can create sustainable value by helping companies meet their climate change commitments and challenges (carbon neutrality, material sourcing, zero waste, etc.), get ahead of government regulations – for instance to protect biodiversity – and reduce exposure to an unstable environment (geopolitical tensions, changes in consumer preferences, etc.).
Second, from a bottom-line point of view, circular investments, processes and practices can increase asset performance and cost-efficiency and open new avenues of revenues.

To maximize those business opportunities, infrastructure asset operators must design their business and operating models with a circular economy mindset. Five very innovative business models are emerging and are particularly relevant for circular infrastructure: infrastructure as a service, sharing economy, track & trace digitally, infrastructure retrofit and industrial symbiosis.

To go even faster, operators should be able to rely on powerful accelerators including innovative and digital technologies, value-chain collaborations, comprehensive and consistent regulations (notably on eco-design and reuse, upcycling and incorporation of recycled material requirements), new procurement schemes, and new contractual arrangements promoting circular practices. In this context, the investment community will also have a major role to play as the transition toward circular infrastructure requires massive investments. According to the European Commission, to achieve the goals set out at the European level by 2030, the overall environmental sustainable investment gap can be estimated at between €100bn and €150bn per year (while social investments needs amount to €142bn per year)[5].
As far as the circular economy is concerned, investment in new industrial facilities, waste and water management facilities or engineered industrial solutions will be critical.

Considering that 80% of the global population will live in cities by 2050, the transformation of the way to design, build, operate and govern infrastructure in urban areas will be a key trigger of success or failure of the circular transition. As epicenters of innovation, infrastructure, investment and culture, urban hubs are where circularity can get scaled up, cities are both circular cradles in which circular solutions are developed, and circular facilitators since city authorities can effectively drive the transition.
Looking forward, "circular cities" of the future will therefore be multifunctional and embed the principles of a circular economy across all functions, establishing an urban system based on low-carbon, restorative (even regenerative) and inclusive infrastructures. Building those "cities of tomorrow" requires a systemic approach engaging all stakeholders – policymakers, elected officials, industrials, end-users – and can rely on digital technologies, smart urban planning and circular public procurement.

[1] Sir Partha Dasgupta, The Economics of Biodiversity: The Dasgupta Review, 2021.
[2] OECD, Raw materials use to double by 2060 with severe environmental consequences, 2018.
[3] Ellen MacArthur Foundation, Completing the picture: how the circular economy tackles climate change, September 2019.
[4] Sweco, Circular materials in infrastructure, 2023.
[5] European Commission, Sustainable Europe Investment Plan European Green Deal Investment Plan, 2020.

METHODOLOGY

A study combining academic expertise and business insights

This study aims at providing Vauban IP with a forward-looking approach on circular infrastructure. It has been conducted conjointly with Altermind, a consulting firm enhanced by the insight of the international academic world, and focuses on how the adoption of circular best practices can help the infrastructure sector tackle the challenges of our times, including climate change, resource depletion and biodiversity loss.

Reflecting Altermind and Vauban IP's DNAs, this study combines academic expertise with business insights, relying on the review of the existing literature and the outcomes of a series of thematic events. Those events have mobilized a wide range of expertise with a multistakeholder approach to fully apprehend the impact of circularity: beyond academics to industrials, thought leaders, start-ups, policymakers and entrepreneurs have participated.

— **A masterclass on circular economy by Dr Janez Potočnik** (former European Commissioner for Environment and co-chair of the International Resource Panel) followed by an academic "deep dive" on the concept of circular infrastructure by Dr Phil Purnell (Professor of Materials and Structures in the School of Civil Engineering, University of Leeds), presented to Vauban IP's investors and asset managers

Watch the masterclass

— **A breakfast panel at Vauban IP's office exploring** the regulatory stakes of the circular transition for infrastructure, co-organized with ESSEC Global Circular Economy Chair, with the insights of Florian Flachenecker (Policy Officer at the DG Environment of the EU Commission), Gabrielle Gauthey (CEO High Representative by the EU institutions, Senior Vice President for European Public Affairs at TotalEnergies), Sébastien Petithuguenin (CEO of the waste management company Paprec), Dr Oriana Romano (Head of Unit, Water Governance and Circular Economy at OECD) and Dr Wilfried Sand-Zantman (Professor of Economics and Academic Director of the Global Circular Economy Chair of ESSEC Business School)

Watch the event

— **An Innovation Morning hosted during Vauban IP's CEO day,** highlighting four highly innovative start ups of the circular eco-system (Concular, Fairmat, Néolithe and Resourcify), followed by an open discussion with a selection of Vauban IP's Portfolio CEOs on how to industrialize such innovations

Watch the InnovMorning

— **A series of three podcasts** discussing the levers to activate for infrastructure operators to create "circular value" in three fields:

• **Road transport** with Martijn Lopes Cardozo (CEO of Circle Economy), Marta Gil de la Hoz (Chief Strategy, Innovation and Sustainability Officer at Sacyr), and Christophe Hug (Deputy General Manager at Vinci Autoroutes)

Listen to the podcast

• **Telecommunications** with Dr Paul Ekins (Economist, UCL Institute for Sustainable Resources), Sergio Oslé (CEO of Telefónica in Spain), and Benoît Torloting (CEO of Bouygues Telecom)

Listen to the podcast

• **"Cities of tomorrow"** with Olivier Brousse (CEO of idverde), Catherine de Wolf (Assistant Professor of Circular Engineering for Architecture at the Swiss Federal Institute of Technology Zurich (ETH Zurich)), Sébastien Fraisse (Chairman of Indigo), and Jérôme Stubler (CEO of Equans)

Listen to the podcast

SUMMARY

CIRCULAR ECONOMY IN THE INFRASTRUCTURE SECTOR: THE (ONLY) PATH TOWARD SUSTAINABILITY

Key takeaways

→ Without a massive change in the way goods and materials are produced, the transition toward more sustainability will not be possible.

→ Considering its impact on carbon emissions and on the environment, the infrastructure sector is in the front lines of the green transition: the adoption of circular practices by infrastructure operators can lessen climate change, reduce resource scarcity risks and decouple economic growth from material consumption.

→ The challenges to take-up are related to both external and large-scale trends (urbanization, demographic change, increasing demand for infrastructure) and the nature of infrastructure itself (high carbon footprint of the built environment, long lifespans, long planning processes, etc.)

→ While policymakers have started to move forward to enhance more circular practices, the pace of public policies must accelerate and embrace a "whole system" approach beyond recycling regulations.

Circular infrastructure, nexus of the transition(s)

No sustainability without circularity

LEAVING THE LINEAR MODEL BEHIND

In the fight against climate change, without a **massive change in the way goods and materials are produced,** the "green" transition will not happen. The massive raise of GDP and rapid population growth throughout the 20th century, combined with the rise of mass consumption and the prevalence of inexpensive and disposable goods, have put too much pressure on the environment and its capacity to renew in the long term. While humanity has prospered immensely in recent decades, it has come at a devastating cost:

— Between 1950 and 2020, global energy-related **CO_2 emissions have increased from 6bn tons to 36bn tons,** especially due to industrial and manufacturing production and management of land[6]; overall, 70% of global greenhouse gas (GHG) emissions are tied to material handling and use;

— **Resource extraction has tripled** between 1970 and 2017, growing from 27bn tons to 92bn tons (a yearly growth of 2.6%[8]) and material productivity – i.e. the reduction of environmental impacts per unit of economic output[9] – started to decline around 2000 and has stagnated in recent years (Figure 1). As of today, **it would require 1.6 Earths to maintain the world's current living standards**[10] and, without action, resource extraction will likely double by 2060[11]. The increase in production in the linear economic model has also caused excessive use of biological natural resources (water, biomass, gas, and other natural resources).

— The extraction and processing of new resources are causing **90% of biodiversity loss and water stress impacts**[12]. To date, 75% of the terrestrial environment and 66% of the marine environment have been "severely altered" by human activities; more than 80% of fish stocks has been overfished, rising to 93% within EU waters, and total fish populations have fallen by more than a third over the past half-century[13]. Plastic consumption has also quadrupled over the past 30 years and there is now an estimated 30Mt of plastic waste in seas and oceans, and a further 109Mt has accumulated in rivers[14].In fulfilling economic and social needs **the world has therefore crossed five of nine planetary boundaries:** climate change, biodiversity loss, land system change, chemical pollution, and cycles of nitrogen and phosphorus. Overall, estimates show that between 1992 and 2014, produced capital per person doubled and human capital per person increased by about 13% globally, but the stock of natural capital per person declined by nearly 40%[15].

Although governments and companies have stepped up **to achieve Net-Zero commitments** in line with the Paris Agreement and taken measures to limit the rise of carbon emissions and avoid environmental depletion, **the linear economic model that has prevailed since the industrial revolution** – based on a "take-make-dispose" pattern – is a major impediment to achieving these objectives (Figure 2).

Continuing down the current path – where demands on nature far exceed its capacity to supply – presents **extreme risks and uncertainties for global economies.** In the near future, according to the European Central Bank, climate change and hazards will not only severely damage the planet, but it will also cause income divergence across individuals, sectors, and regions, adjustment in energy markets, increased inflation variability, financial markets stress, increased migration, and rising public debts[16].

CIRCULAR ECONOMY: A GAME CHANGER

The world needs a new paradigm, and it needs it now. In search of this new model, **circularity gives strong credentials** to achieve sustainability on Earth. In a circular economic model, the extraction of primary resources is minimized by extending the useful life of existing resources and materials, thus contributing to wisely manage natural resources, build more resilient production systems and include waste as a source of value to adapt swiftly to ecological challenges.

In other words, a circular economy aims at **retaining value along the whole supply chain and lifecycle of a product or a service** and designing out waste and emissions from the start. By creating "material loops", circular principles can help maintain the value of products, materials and resources for as long as possible by returning them into the product cycle.

[6] Sources: International Energy Agency; Amundi Research Center, *Investing in the circular economy: closing the loop, Amundi*, October 2021.
[7] Circle Economy, *Circularity Gap Report*, 2021.
[8] United Nations Industrial Development Organization, *Circular economy: a question of design*, February 2021.
[9] In "Factor Four", authored by von Weizsäcker and Lovins, the idea of resource productivity (defined as "reduction of environmental impacts per unit of economic output") was introduced as a way to decouple the link between resource use and environmental degradation.
[10] Sir Partha Dasgupta, The Economics of Biodiversity: The Dasgupta Review, 2021.
[11] OECD, Raw materials use to double by 2060 with severe environmental consequences, 2018.
[12] World Bank, Squaring the circle, *Policies from Europe's Circular Economic Transition*, 2022.
[13] WWF Mediterranean Marine Initiative; Our world in data.
[14] OECD, Plastic pollution is growing relentlessly as waste management and recycling fall short, 2022.
[15] United Kingdom Government, *The Economics of Biodiversity: The Dasgupta Review*, February 2021.
[16] J. Breckenfelder et al., *The climate and the economy*, European Central Bank, March 2023.

FIGURE 1:

Global material use, demand per capita and material productivity in the years 1970-2017

Sources: IRP

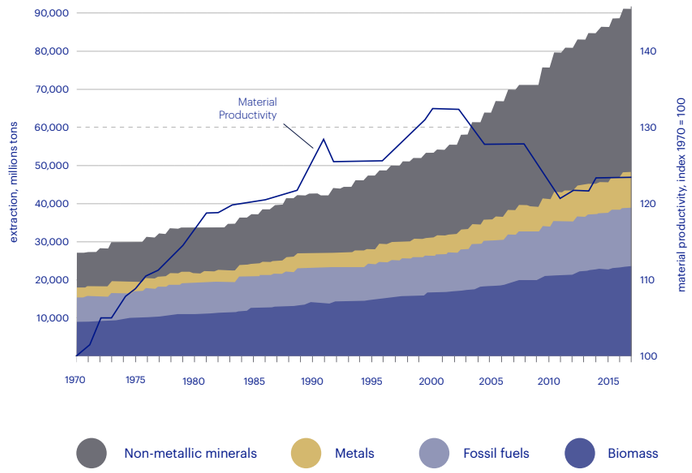
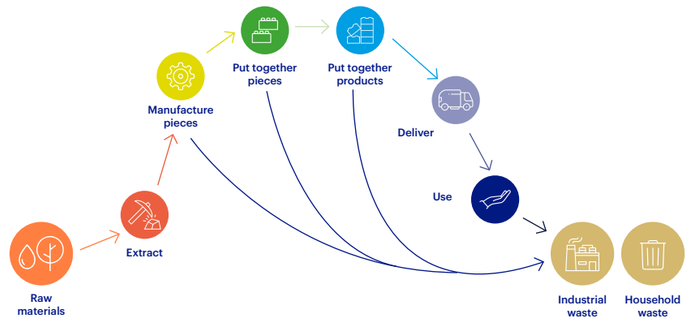


FIGURE 2:

The linear economic model

Sources: ESSEC Global Chair of Circular Economy, Circulab



When it comes to those material loops, circular strategies rely on **"R-ladder strategies"** to achieve four main goals (Figure 3):

— **"Narrowing" the loops** (refuse, rethink, reduce) by (i) adopting sober behaviors therefore preventing consumption of material objects, digital technologies and energy product use when possible or (ii) intensifying and reducing use of materials through more efficient design and manufacturing processes;

— **"Slowing down" the loops** (reuse, repair) leveraging on the high-value use of materials and products: the design of long-life goods and product life extension (i.e. service loops to extend a product's life, for instance through maintenance and repair) extends the utilization period of products, resulting in a slowdown of the flow of resources;

— **"Closing" the loops** (process and recycle) through recycling materials, recovering energy, and ultimately focusing on eliminating "leakages" from the system when all the previous options are no longer possible;

— **Substituting** product with biobased, renewable materials instead of primary abiotic materials[17].

Clearly, **transitioning toward a more circular economy is not just about waste management**; it requires sober consumer and producer behaviors and embraces the **"functional economy",** which aims at optimizing the use (or function) of goods and services to create the highest possible use value for the longest possible time while consuming as few material resources and energy as possible[18].

EXPERT POSITION 1

Circular economy: narrowing, slowing, closing the loops

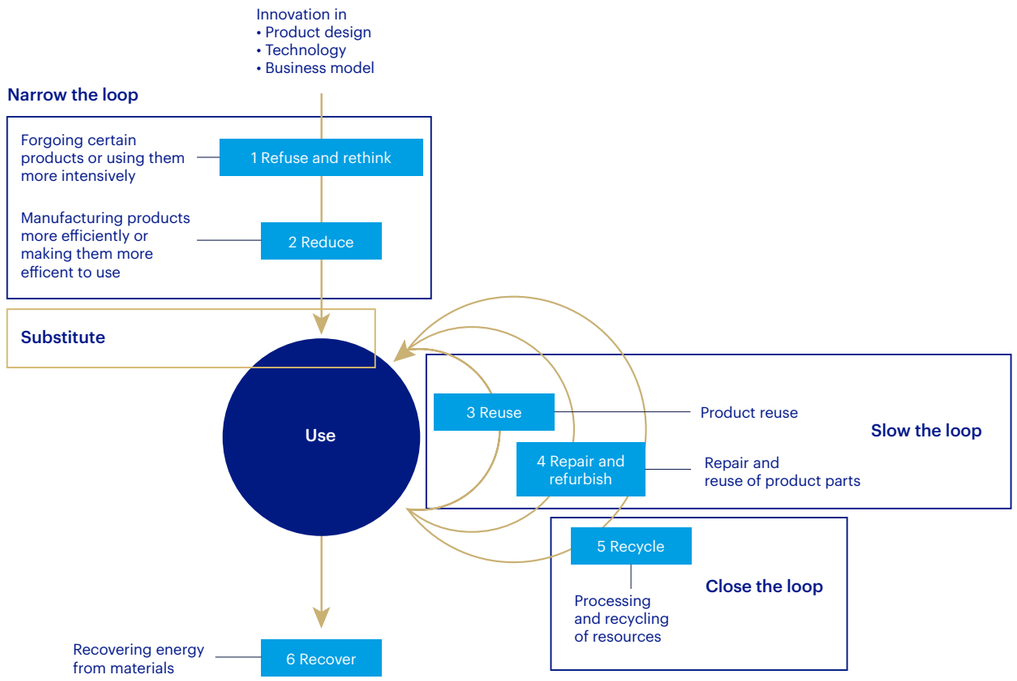
"In addition to substitution strategies, the characteristics of the circular economy are (i) narrowing the loop by reducing emissions in production and design processes, (ii) slowing the loop by consuming less through increasing the lifespan of products and repairing products, (iii) closing the loop by fostering recycling and reuse of resources and (iv) regenerating the loop by improving society and biodiversity."

Dr. Catherine de Wolf,
Assistant Professor of Circular Engineering for Architecture at the Swiss Federal Institute of Technology Zurich (ETH Zurich)

FIGURE 3:

R-ladder of circularity strategies

Sources: J. Potting, A. Hanemaaijer, 2018



Looking at the figures, **the circular transition could be a game changer.** A rapid shift to a more circular economy, could dramatically cut carbon emissions and increase resource efficiency, as well as support economic growth away from consuming the planet's finite resources while minimizing the impact on the environment. A study by the Ellen MacArthur Foundation disclosed in 2019 shows that **applying circular economy principles in five key areas of manufacturing** (cement, aluminum, steel, plastics, and food) could eliminate **more than 40% of carbon emissions**[19] through materials recirculation (-18%), product reuse (-12%) and waste elimination (-9.6%) (Figure 4). An estimate from the 2021 Circularity Gap Report also states that the adoption of national circular strategies could reduce global carbon emissions by 39% and cut virgin resources use by 28%[20].

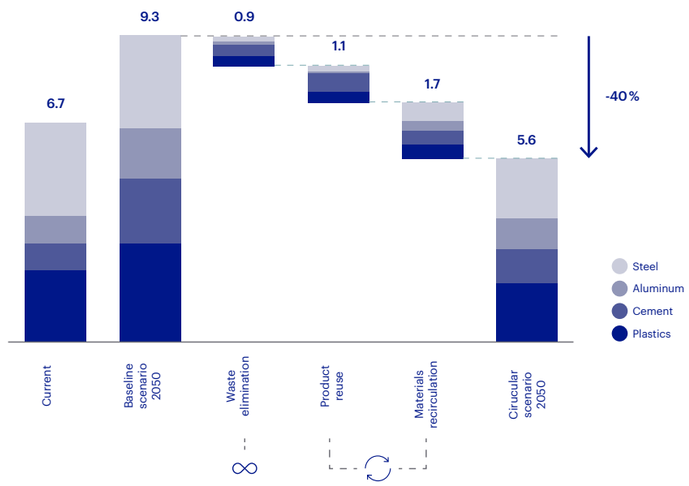
For the global economy, putting in place a circular economy for buildings, transport, and food, enabled by the technology revolution, would also present strong positive economic outcomes. It would allow Europe to grow resource productivity by up to 3% annually generating a primary resource benefit of as much as USD 600bn per year by 2030 and €1.2tr in non-resource and external benefits[21]. In China, circular economy practices at scale in five key sectors could save businesses and households USD 10tr or 16% of China's projected GDP in 2040[22].

By requiring less raw material input and establishing a more local supply of secondary materials, a circular economy can also **strengthen supply chain security and reduce the risk of short-term supply shortages.** Considering the current raw material price variability and risk exposures of certain regions – the EU has tripled its import of raw materials since 2002[23] – the adoption of circular strategies can reduce import dependency and ease geopolitical risks over scarce raw resources.

FIGURE 4:

Circular economy, a powerful mitigation lever (bn tons of CO_2 per year)

Source: Ellen MacArthur Foundation



[17] J. Potting, and A. Hanemaaijer, 2018. *Circular economy: what we want to know and can measure.* PBL Netherlands Environment Assessment Agency, 2021.
[18] W. R. Stahel, "The Functional Economy: Cultural and Organizational Change", *The Industrial Green Game: Implications for Environmental Design and Management,* The National Academies Press, Washington, DC.
[19] Ellen MacArthur Foundation, *Completing the picture: how the circular economy tackles climate change,* September 2019.
[20] Circle Economy, *Circularity gap report,* 2021.
[21] Ellen MacArthur Foundation, *Growth Within: A Circular Economy Vision for a Competitive Europe,* 2015.
[22] Ellen MacArthur Foundation, *The Circular Economy Opportunity for Urban and Industrial Innovation in China,* 2018.
[23] European Parliament, *Circular economy: definition, importance and benefits,* May 2023.

EXPERT POSITION 2

Circularity: a "must have" facing the challenges of our times

"The strong connection between circular economy, climate change, and infrastructure lies in the fact that a significant portion of the world's annual 60Gt GHG emissions are directly tied to production and extraction of natural resources. This lesser-known fact is crucial to understanding that circular economy plays a vital role in the battle to limit global warming to below 1.5°C.
In linear processes, approximately 80% of environmental impacts are linked to the design phase of a product.
By enhancing the efficiency of resource extraction and reducing reliance on new natural resources, we can both improve our way of life and combat emissions."

Pierre-Emmanuel Saint-Esprit,
Founder and Executive Director
of the ESSEC Global Circular
Economy Chair

FOCUS 1

Circular economy, an old nature-based economic model

The circular economy is an old and multifaceted concept. It was first approached in 1966 by Kenneth Boulding[24], when he stated human activities need to develop according to natural cycles and became popular with Pearce and Turner's "natural capitalism"[25] (1990) and Michael Braungart and William McDonough's "From cradle to cradle" theory[26] (2002) based on the principle "everything is a resource for something else"[27].

A recent meta-definition which screened over 114 scholar definitions of the term, defines it as "an economic system based on business models which replace the "end-of-life" concept with reducing, alternatively reusing, recycling materials in production/ distribution and consumption processes, with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations"[28].

With the rise of raw material prices and the need to tackle climate change, circular economy gained non-governmental support. The creation of the Ellen MacArthur Foundation in 2010 contributed to raise awareness on this issue supporting research and publications to develop circular economy solutions.

EXPERT POSITION 3

"For an intergenerational pact"

"Circularity is the oldest concept on Earth: nature is a "bioeconomy" based on the principles of circularity. Changing our relationship with nature is ultimately an economic, security and resilience imperative… central also to fairness and equity. We must set the order right and develop an economy in order to human needs (and not the opposite). We should stop stimulating extraction with the only goal of economic success and reward responsible, innovative, creative ways of meeting human needs. We must improve our collective resilience with a well-designed intergenerational pact."

Janez Potočnik,
Former European Commissioner
in charge of the first European package
for the circular economy, and Co-Chair
of the International Resource Panel
at the United Nations

THE WORLD IS STILL HEADING THE WRONG WAY

At this stage, although a circular economy has gained in visibility over the past decade, most **climate strategies have focused on renewable energy and energy efficiency,** overlooking the critical need to cope with material extraction and management. Circular strategies implementation still appears to be in the very early stages and the state of play is getting worse: material extraction is increasing every year, with **circularity declining from 9.1% in 2018, to 8.6% 2020, and now 7.2% in 2023**[29].

As a result, **the circularity gap is widening on an everyday basis:** the globe almost exclusively relies on virgin materials and more than 90% of materials are either wasted, lost or remain unavailable for reuse for years as they are locked into long-lasting stock such as buildings and machinery[30]. As of 2018, it is estimated that globally about 37% of waste is disposed of in some type of landfill, 33% is openly dumped, 19% undergoes materials recovery through recycling and composting and 11% is treated through modern incineration[31].

[24] K. Boulding, *The Economics of the Coming Spaceship Earth*, 1966.
[25] D.W. Pearce, and R.K. Turner, *Economics Of Natural Resources And The Environment*, John Hopkins University Press, Baltimore 1990.
[26] M. Braungart, W. McDonough, *Cradle to Cradle: Remaking the Way We Make Things*, North Point Press, 2002.
[27] William McDonough, "Cradle to Cradle", 2023.
[28] J. Kirchherr et al. *"Barriers to the circular economy: evidence from the European Union"*, Ecological Economics, 2018.
[29] Circle Economy, *Circularity gap report*, 2021.
[30] United Nations Development Program, *What is circular economy and why does it matter?*, April 2023.
[31] C. Le Meaux, *The time of Circular Economy has come*, Amundi, 2021.

Time to make infrastructure more circular

MITIGATING CLIMATE CHANGE

The availability of a quality infrastructure system – networks of roads, railways, bridges and waterways – is a prerequisite for all economic activity to flourish and is paramount for people's health, well-being and safety. Still, infrastructure's adverse impact on the climate is undeniable. Responsible for more than 79% of global GHG emissions, the infrastructure sector is on the front lines of the green transition as most existing infrastructure (energy, transport, etc.) were designed for a world of cheap and abundant fossil fuels[32].

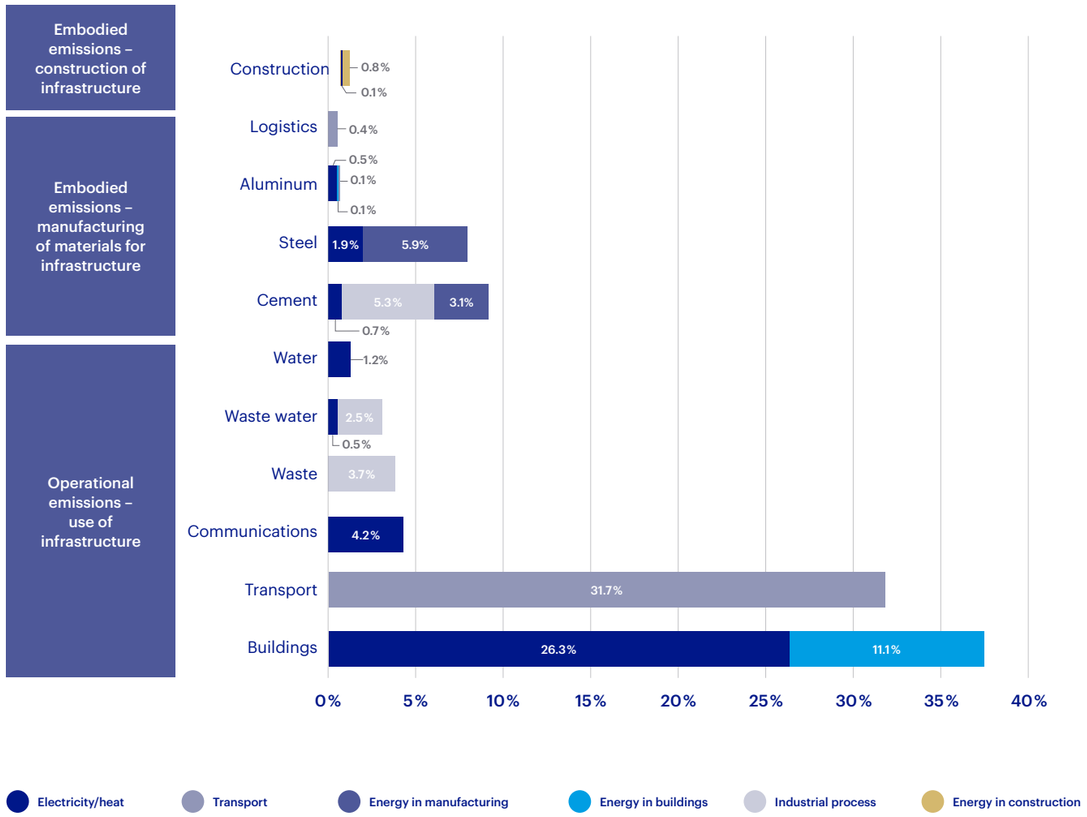
To decarbonize infrastructure assets and reach the Net-Zero target, the main lever lies in renewable energies: overall, according to the Global Infrastructure Hub, a move to renewable generation can potentially address up to 32% of electricity / heat emissions from the operations of infrastructure and the transition to electric vehicles can address another 32% emissions from the transport sector[33].

The remainder of emissions can be addressed through the adoption of circular economy principles across the infrastructure value chain to reduce embodied and operational emissions. Overall, **circular practices can potentially address up to 19% of total infrastructure emissions**[34] and waste elimination can help reduce around 10% of emissions through material efficient designs for buildings, industrialized construction processes and lightweight designs for vehicles reducing the amount of material input in products and assets.

FIGURE 5:

Operational and embodied emissions of infrastructure (% of infrastructure emissions)

Source: GI Hub, 2021



[32] Vauban IP – Altermind, Infrastructure for Climate, 2021.
[33] Global Infrastructure Hub, *Advancing the circular economy through infrastructure*, 2021.
[34] Ibid.

REDUCING THE RISK OF RESOURCE SCARCITY

As **infrastructure consumes around 63% of the world's materials**[35], resource scarcity ("below ground factors") also represents a critical concern, especially considering the increasing demand for energy and transport, and the long-lasting impact of geopolitical tensions (both "above ground factors"), like the Russian invasion of Ukraine shall have on energy and raw materials markets:

— Although the availability of materials on Earth are not per se a matter of concern, as reserves tend to be reevaluated upwards[36], **the IEA anticipates that global demand for critical materials might soar by 400% by 2040;**

— Issues linked to the global supply and transit of materials are already the source of geopolitical tensions, but critical materials may also cause blockages in some countries' supply chains. As global value chains become ever tighter, the fragility of one link threatens the entire structure.

For the built environment only, if Europe increased its circularity rate for aggregates from the current 7% to 20%, it would reduce virgin raw material costs of up to EUR 6bn each year by reusing 546m tons of aggregates[37].

New green solutions will also trigger bottlenecks for the very infrastructure and resources upon which they depend. While the supply of these sustainability related resources will expand due to investment and innovation, in many categories, rapid growth in demand will likely outstrip supply, heightening competition and pushing up prices. Technological and ecological progress adds uncertainty as substitutes can be found[38] making it difficult to predict which material will be crucial and missing in the future.

Water scarcity also presents a strong challenge for infrastructure, especially in third-world countries and megacities: the World Economic Forum (WEF) has consistently highlighted water as a global crisis, ranking it the fourth greatest risk by impact and the ninth greatest risk by likelihood in 2019[39]. Poor infrastructure and management of water resources can result in economic water scarcity and affect the economic infrastructure of other sectors e.g., education, health, energy, utilities (by far the most water intensive industries). With climate hazards' intensity and frequency increasing, by 2025, it is projected that **two-thirds of the globe's population will face water shortages**[40], which will inevitably impact the whole system of infrastructure.

PROTECTING BIODIVERSITY

Infrastructure has a variety of effects on biodiversity, including direct habitat loss within the footprint of existing infrastructure, changes in ecosystem characteristics, and fragmentation and deterioration of biological resources [41].

Currently, infrastructure and buildings are designed, developed and organized in a mostly linear way leading to a significantly environmental impact. Various assessments on the state of biodiversity over the past ten years have pointed to **infrastructure development as one of the main enablers of biodiversity loss.** Urban sprawl stands out as one of the most noticeable, swift, and irreversible forms of land cover and land-use transformation. Infrastructure like roads and railways can significantly disrupt ecological settings by cutting through natural habitats, leading to a consequent decline in the populations of numerous wildlife species[42].

A circular economy can massively help reduce those impacts keeping in mind that a thriving nature is the basis of a growing economy as 55% of global GDP depends on intact biodiversity and ecosystem services[43]. For example, it is projected that by 2050, the typical lifespan of buildings could be prolonged from 64 years to 91 years through the implementation of circular models: this would mean around a 30% lower long-term demand for new constructions, in turn saving construction material and avoiding soil sealing and land-use change[44].

[35] Ibid.
[36] A. Maneberger, "Critical Raw Material Supply Matters and the Potential of the Circular Economy to Contribute to Security", *Intereconomics*, 2023.
[37] Sweco, *Circular materials in infrastructure*, 2023.
[38] Ibid.
[39] World Economic Forum, *The Global Risks Report 2019*, 2019.
[40] Global Infrastructure Hub, "5 ways water scarcity will drive infrastructure development", 2020.
[41] G. Sharma, A. Kharbanda, "The role of green infrastructure in biodiversity conservation", *T20 Policy Brief*, June 2023.
[42] European Environment Agency, Circular Economy and Biodiversity, ETC CE Report 2023/7.
[43] Swiss Re, "Why managing biodiversity risk is critical for the global economy", 2020.
[44] J. Günther et al., *Circular Economy and Biodiversity*, ETC CE Report 2023/7, June 2023.

Major challenges for the infrastructure sector

A sinuous path ahead for infrastructure

EXTERNAL AND LARGE-SCALE TRENDS

While it must happen swiftly, the circular transition of the infrastructure sector faces massive challenges. Major issues are currently rising due to **large-scale and external trends** that shall affect the infrastructure sector in the long term and complexify the scaling up of the circular economy:

— With 80% of the world's population living in urban areas by 2050, **urbanization is a serious variable in the circular equation:** following the current trend, material consumption should more than double, raising from 41bn tons in 2010 to 88.8bn tons in 2050[45];

— **Demand for infrastructure is rising,** notably as the global population is expected to rise from 8bn people to 9.7bn in 2050[46]: a wave of infrastructure project renovations, replacements and new constructions for infrastructure shall happen over the next 15 years as 75% of the infrastructure expected to exist by 2050 is yet to be built. According to the Global Infrastructure Hub Outlook, the investment needed in infrastructure in 56 studied countries worldwide will double by 2040 compared to investments in 2015, from 2.3 to USD 4.6tr[47];

— To recover from recent external shocks (Covid-19, Russian crisis, etc.), **various actors across the globe have already launched ambitious infrastructure plans** over the next decades: the EU agreed on an infrastructure plan similar to China's new Silk Road, the US started the Biden plan and the G7 launched the Build Back Better World initiative[48];

— **The fast pace of technological development** leads to the relatively rapid obsolescence of equipment and generates complex waste streams thus presenting technical and logistical challenges for waste management operators and at the end-of-life stage.

CHALLENGES LINKED TO THE NATURE OF INFRASTRUCTURE

Those difficulties are compounded by **the "nature" of infrastructure itself:**

— **The built environment** is the building block of all physical infrastructure [49] and **has a particularly high carbon and environmental footprint.** It relies on very "hard to abate" industries such as the cement, steel and aluminum materials: global cement production, the main ingredient of concrete, is currently responsible for around 7% of global and 4% of EU CO_2 emissions[50]. Overall, the built environment is responsible of 35% of the continent's waste and 50% of materials extracted in Europe are directly linked to the built environment [51];

— **Much of the infrastructure already installed will have a relatively long service life,** and as such provisions are required to plan for the environmental and financial impacts of dealing with their waste in the long term;

— **Infrastructure is known for its very long planning processes,** which makes it less innovative compared to other sectors and lagging in terms of developments [52] ;

— Standards and regulations must be reinforced to ensure traceability throughout the whole asset lifecycle, with the hard task of **identifying the eco-responsibility of participants all along the chain** (manufacturer, operator, end user).

[45] B. Venditti, "The material impact of globalization", April 2022.
[46] Data from United Nations Population Fund.
[47] Global Infrastructure Hub. 2021a. Global Infrastructure Outlook - A G20 initiative.
[48] Rijkswaterstaat, *Circular infrastructure: the road toward a sustainable future*, 2022.
[49] Within the world of infrastructure, the built environment encompasses all aspects of human lives, including buildings (housing, industrial, commercial, hospitals, schools, etc.), distribution systems that provide water and electricity, and roads, bridges, transportation systems.
[50] A. Marmier, *Technical report by the (JRC), Decarbonisation options for the cement industry*, Joint Research Centre, European Commission, 2023.
[51] F. van Eijk, *Circular Buildings and Infrastructure. State of play report*, European circular economy stakeholder platform, 2021.
[52] V. Gruis, *Circular Infrastructure: the road toward a sustainable future*, Rijkswaterstaat, January 2022.

AN INVESTMENT GAP TO BRIDGE

The transition toward circular infrastructure requires massive investment. According to the European Commission, to achieve the goals set out at the European level by 2030, the overall **environment sustainable investment gap can be estimated at between €100bn and €150bn per year** (while social investment needs amount to €142bn per year)[53]. Experts have estimated that reaching net-zero emissions by 2050 in the EU27 would require total capital expenditure of around €1 trillion per year in the period 2021-2050[54]. As far as the circular economy is concerned, as described in section 2 of this report, investment in new industrial facilities, waste and water management facilities or engineered industrial solutions will be key.

FOCUS 2

The rising obsolescence of telco equipment: a critical challenge for the circular economy

Within the digital industry, continuous innovation coupled with strong competition have fostered massive investment and the rapid emergence of new technologies and new generations of equipment. In the telco sector, those technological changes and accompanying customer behaviors are shortening consumer devices and networks life cycles, resulting in greater production and increasing electronic waste: according to the WEF, 57.4 million tons of "e-waste" were generated in 2021, with only 20% recycled.

As the demand for telco products and services is expected to rise by up to 60% by 2040, tackling the generation of e-waste is crucial if telco operators want to succeed in achieving their sustainability goals. As electronic devices become outdated quicker, waste management facilities will struggle to keep up with the diverse and complex streams of e-waste, necessitating continuous upgrades to handle the growing challenge effectively.

"The circular economy transition must accelerate beyond mere words. However, even with the implementation of strong circular economy approaches, the low-carbon energy transition will involve extensive resource extraction, with some important materials facing scarcity due to geological or political factors, especially in the power and telecoms sectors with metals like copper. The waste issue arises when we dispose of products without proper planning, leading to mountains of waste, often mismanaged, causing pollution and health problems, particularly in developing countries."

Dr. Paul Ekins, UCL Institute for Sustainable Resources

[53] European Commission, *Sustainable Europe Investment Plan European Green Deal Investment Plan*, 2020.
[54] P. d'Aprile et al., *How the European Union could achieve net-zero emissions at Net-Zero cost*, McKinsey & Company, 2020.

Policymakers reacting

REGULATIONS MOVING FORWARD

While the support toward the circular economy is now widespread, public intervention and regulations will be critical to achieve the transformative change needed.

The primary focus of regulations around the globe usually lies on waste management, respecting a **"waste hierarchy"** (Figure 6) that lays down a priority order of what constitutes the best overall environmental option in waste legislation and policy: waste prevention and reuse are the most preferred options, followed by recycling (including composting) and other recovery (such as energy recovery), while waste disposal through landfills is considered as the very last resort[55].

Beyond this waste "lens", **sustainable product management is now central** to minimize the impacts of products on the environment at different stages (raw materials extraction, manufacturing, marketing, use and end of life) as 80% of products' environmental impacts are determined at the design phase. This focus on sustainable project management reinforces the obligations imposed on producers with "extended producer responsibility" (EPR) schemes[56].

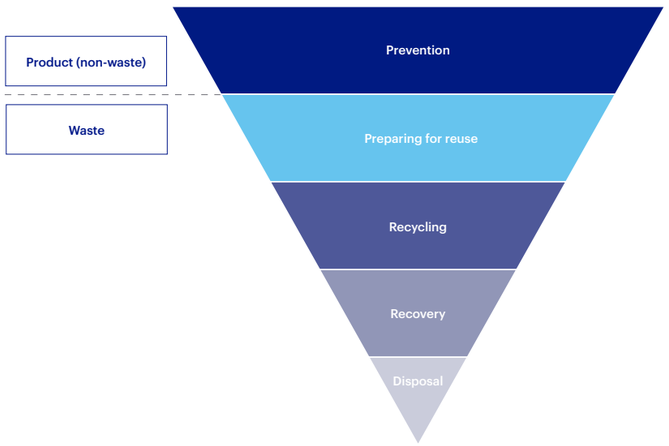
In this respect, the **EU has recently accelerated its "circular agenda":** the EU law now gives long-term objectives for the Union's waste management, clear directions to operators and Member States for the investments needed to achieve those objectives and has adopted a product lifecycle approach. In line with the EU's 2050 climate neutrality goal under the Green Deal, the European Commission proposed in March 2022 a new Circular Economy Action Plan – following the first circular package of 2015. The proposed revision of the EU legislation on Packaging and Packaging Waste sets a target to reduce packaging waste by 15% by 2040 per Member State per capita, compared to 2018. This would lead to an overall waste reduction in the EU of some 37% compared to a scenario without changing the legislation: Member States shall take the necessary measures to attain recycling targets of 65% by the end of 2025 and 70% by the end of 2030 of all packaging waste generated.

Regarding infrastructure, **a particular focus has been made on the built environment** with a new comprehensive Strategy for a Sustainable Built Environment. This strategy will promote circularity principles throughout the lifecycle of buildings through various levers (construction product regulation, building design, life-cycle assessment in public procurement, reduction of soil sealing, etc.).

FIGURE 6:

Waste hierarchy

Source: EU Waste Hierarchy (EU Commission, 2019)



[55] Article 4 of Directive 2008/98/EC (Waste Framework Directive).
[56] As defined by OECD, EPR is "an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle. An EPR policy is characterized by: 1/ the shifting of responsibility (physically and/or economically; fully or partially) upstream toward the producer and away from municipalities; and 2/ the provision of incentives to producers to take into account environmental considerations when designing their products.
[57] USEPA, National Recycling Strategy, 2021.
[58] Closed Loop Partner, How the Inflation Reduction Act Will Accelerate the Case for Investing in the Circular Economy in the United States, August 2022.
[59] The White House, Advancing a Circular Economy to Meet Our Climate, Energy, and Economic Goals, July 2023.

Some countries lie ahead in terms of circular commitments and regulations. The Netherlands is the front runner, notably in the construction sector: the Dutch government adopted the Raw Materials Agreement making the country's economy completely circular by 2050.

In the US, the successive circular economy plans released by the Environmental Protection Agency (EPA) have mainly focused on recycling activities. The National Recycling Strategy released in 2021 – which built on the National Framework for Advancing the U.S. Recycling System of 2019 – aimed at "enhancing and advancing the national municipal solid waste (MSW) recycling system and identifies strategic objectives and stakeholder-led actions to create a stronger, more resilient, and cost-effective domestic MSW recycling system"[57].

More recently, **the needle has moved toward energy savings.** The Inflation Reduction Act (IRA) ought to incentivize investment in solar and wind energy generation assets, as well as promote energy efficiency upgrades in both commercial and residential buildings. The introduction of these new installations will further intensify the demand for solutions addressing end-of-life considerations regarding energy infrastructure replacements or system re-powering. For instance, in the solar sector, it is anticipated that annual capacity additions will surge from 10GW in 2020 to nearly 50GW annually by 2025-2026[58]. In 2023, the Biden-Harris Administration has also made the circular industrial sector one of its five priorities for the Net-Zero Game Changers Initiative, which drives innovation in clean-energy technologies[59].

EXPERT POSITION 4

The role of regulations in the circular transition

"Regulation has a key role to play to overcome environmental externalities, short-termism of firms, consumers and politicians and coordination failures at the industrial level."

Wilfried Sand-Zantman,
Academic Director of the ESSEC Global Chair of Circular Economy founded in 2021, the ESSEC Global Circular Economy Chair aims to train young generations so they can contribute to the circular transition of the industry.

EXPERT POSITION 5

The EU reacting: three phases for circular policies

"Over the past decade, the EU has taken the lead in pursuing and enhancing more circular practices within its economy with a series of "circular packages" following three main phases:

— A "niche phase", pre-2009, when circular economy was mainly related to the sustainable development agenda and regulation was predominantly dedicated to waste management;

— An "awakening phase" during which the end of the lifecycle perspective has been switched to a resource-efficiency approach until the 2015 first circular economy action plan, which provided clarity and certainty for public and private infrastructure stakeholders to develop their respective models, especially for the sustainable built environment;

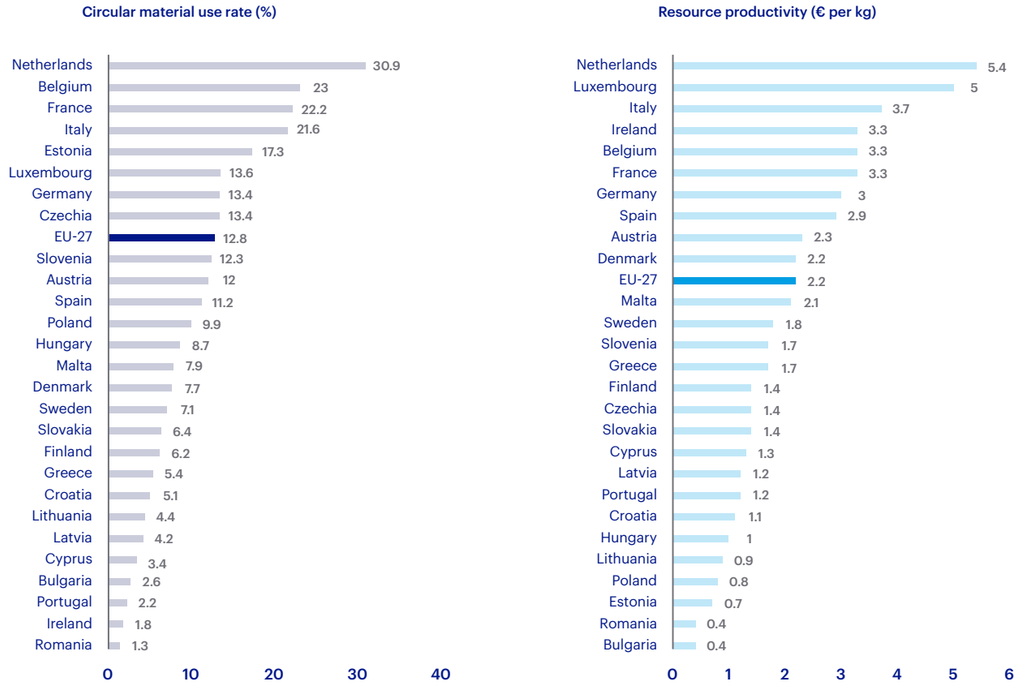
— A "mainstreaming and acceleration phase" with circular economy taking the center stage of the European Green Deal, being mainstreamed across many policy areas with a life-cycle perspective from eco-design to waste management, and being accelerated through numerous legislative and non-legislative initiatives ranging from revising the Waste Framework Directive to establishing circular economy criteria in the EU Environmental Taxonomy."

Florian Flachenecker,
Policy Officer at the DG Environment of the European Commission

FIGURE 7:

Progress accomplished by EU State Members on the pathway to a circular economy from 2015 to 2021

Source: ECA, based on Eurostat circular material use rate and generation of waste, 2022



A MORE COMPREHENSIVE AND CONSISTENT REGULATORY APPROACH NEEDED

Although many advances have been made, a margin of progress does exist for public policymakers and the pace of public policies must be accelerated. At this stage, **most national-level circular economy plans are based on recycling and/or substitution,** while a systems level approach is necessary to embrace the full scope of circularity:

— **Regulations have put a strong focus on waste management** due to growing pressure to regulate waste and its visible pollution, but this approach leaves the entire upstream part of the value chain outside the scope of legislation. It is notably the case in the US (see above) and in China, which framed its thinking on economic circularity back in 2008 in the Circular Economy Promotion Law[60] to build a "recycled-oriented society".

— **Policy attention is mainly given to the supply side of the economy** and to the cleaning of the existing economic system – lacking the attention to the demand side which is leaving out key solutions potential and questions of responsibility and equity.

— Resource management is not given enough importance within policy making.

Overall, regulations must combine **a constrictive-based approach** (the "stick") **and an incentive-based approach** (the "carrot"), i.e. forcing or promoting circular practices. Based on this mix, regulation should be more comprehensive and consistent in order to give the right signals and cannot only focus on waste management but grasp the circular economy as an economic system and rely on a product lifecycle approach.

In this perspective, it is critical to anticipate the end of life of products at the various stages of the product life: design, manufacturing, use of products and waste management. This means that regulation should **set out general objectives and give the right incentives** to industrials and consumers to fulfill them, with a comprehensive view. In practical terms, beyond recycling, a consistent regulatory approach should focus more on:

— Eco-design requirements, which refers to the integration of environmental aspects into the product development;

— Reuse, upcycling and incorporation of recycled materials requirements.

Such requirements will lead stakeholders to reorganize their value chain, from design and manufacturing to collection and recycling. The European level, the new Circular Economy Action Plan intends to promote this approach more, but much remains to be done (see section 1).

Plastic is a good illustration of the stakes and challenges ahead. According to an OECD study[61], global plastics production doubled in the last 20 years to reach 460m tons. It accounts for 3.4% of global GHGs emissions. During the same period, global plastic tons generation more than doubled to 353 million tons. Nearly two-thirds of plastic waste comes from plastics with lifetimes of under five years, with 40% coming from packaging, 12% from consumer goods and 11% from clothing and textiles. Only 9% of plastic waste is recycled (15% is collected for recycling but 40% of that is disposed of as residues). Another 19% is incinerated, 50% ends up in landfill and 22% evades waste management systems.

Going circular is therefore not an option and **regulations shoud combine various aspects**: bans and taxes on single-use plastics (which exist in more than 120 countries), landfill and incineration taxes that incentivize recycling, deposit-refund and pay-as-you-throw systems, setting recycled content targets, extended producer responsibility schemes, etc.

To be efficient, **regulations must also be science-based** (in a lifecycle perspective, some plastic uses may prove beneficiary), comprehensive and consistent. For instance, eco-design is a key enabler of having a separate collection and proper recycling system. Also, **consumers should be better informed and more incentivized** (for instance when they reuse their plastic packaging), through relevant price signals.

EXPERT POSITION 6

Expectations from industrials

"Regulation has to be consistent and stable. We do not need regulations which touch every aspect of business but a few & strategic key targets and incentives. In my wish list, regulation should take two elements into account: (i) the level of incorporation of raw materials from recycling which has to be linked with the waste collection and (ii) proper eco-design rules and incentives. Incorporation is key to develop circular loops from waste. That is why the chain of transformation that is going to make the proper raw materials for your next product is very often your own waste."

Sébastien Petithuguenin, CEO of PAPREC

[60] United Nations Environment Progamme, *Circular Economy Promotion Law of the People's Republic of China*, 2008.
[61] OECD Global Plastics Outlook Database.

CIRCULAR STRATEGIES FOR INFRASTRUCTURE OPERATORS: TOWARD MORE "CIRCULAR INFRASTRUCTURE"

Key takeaways

→ Circular infrastructure refers to a system of infrastructures that either contribute directly to the circular economy activity (Infrastructure for Circularity) or minimize and manage the amount of material used across the infrastructure lifecycle (Circularity of Infrastructure).

→ Waste management and water treatment systems are the two essential "infrastructures for circularity" and will be key in the circular transition facing the coming waste upsurge and the need to secure access to clean water in developing countries. Still, recycling activities cannot achieve sustainability goals on their own without reductions in production and consumption.

→ For infrastructure operators – such as transport, telecom, energy, housing – a lifecycle approach is needed to fully embrace the transition toward circularity and usually focuses on design & sourcing and the creation of integrated supply chains.

→ A two-speed strategy can be adopted: (i) the deployment of "quick wins" will help move the dial in terms of energy efficiencies and sobriety and (ii) longer-term strategies will maximize the amount of materials recovered and subsequently reused, repaired, refurbished and recycled.

→ By adopting circular-economy principles and integrating new technologies within their business models, companies can foster "growth within" by reducing costs during planning and operations and explore new streams of revenues following an "Infrastructure Lifecycle Model."

Infrastructure for circularity, essential by design

Waste management, the cornerstone of the transition

THE INEVITABLE UPSURGE OF WASTE GENERATION

With the expansion of the population, changing consumption patterns, and urbanization, **solid waste generation rates around the world will skyrocket** over the next 30 years. More than 2.24bn tons of solid waste were generated globally in 2020, with a per capita waste footprint of 0.79kg per person per day, and annual waste generation is expected to increase by 73% from 2020 levels to 3.88bn tons in 2050, under a business-as-usual scenario[62].

Considering that waste generation is expected to rise with economic development and population growth, low- and middle-income countries are likely to experience the greatest growth in waste production. It is especially the case in Sub-Saharan Africa and South Asia, where total waste generation is expected to triple then double by 2050, respectively, making up 35% of the world's waste; the Middle East and North Africa region is also expected to double waste generation by 2050[63] (Figure 8).

MORE INVESTMENT NEEDED IN WASTE MANAGEMENT FACILITIES

To collect, dispose or treat the rising amount of generated solid waste to come, **more investments and strategic planning in "infrastructure for circularity"** – i.e. assets supporting the circular economy within their core businesses – are needed. This puts waste management facilities operators at the core of the circular transition of the global economy. Indeed, these essential infrastructures enable the efficient collection and processing of waste, transforming them into valuable resources through three levers:

— **Resource Recovery:** through advanced sorting technologies and processes, facilities extract recyclable materials such as plastics, metals, paper, and glass, channeling them back into the production cycle;

— **Waste Diversion:** by diverting waste from landfills, recycling facilities help reduce environmental pollution and conserve valuable landfill space;

— **Closed-Loop Systems:** recycling plants support the concept of a closed-loop system, where materials are continuously recycled and reintegrated into the manufacturing process.

Operating this service requires integrated systems that are efficient, sustainable, and socially supported. High-quality recycling both prevents waste ending up in the environment, causing pollution or eutrophication – which is a key driver of biodiversity loss in marine environments – while at the same time saving virgin resource extraction as recycled materials can be used in new production, reducing extraction-related environmental and biodiversity impacts[64].

At this stage, compared to those in developed nations, residents in lower and middle-income countries, especially the urban poor, are more severely impacted by unsustainably managed waste. In low-income countries, **over 90% of waste is often disposed in unregulated dumps or openly burned,** which contributes to an increase in pollution, disease spread and changing weather patterns[65].

New types of waste are also expected to emerge and will have to be handled correctly. For instance, according to the European Environment Agency, waste arising from the development and use of renewable energy infrastructure is resource-rich and includes rare earth elements as well as other valuable materials such as steel, copper and glass[66]. Figure 9 highlights that substantial amounts of new types of waste will be generated over the coming years by the infrastructure required for the transition to clean energy. Currently, there is a lack of recycling technologies and the availability of large-scale recycling facilities, with only pilot plants, such as those found in Europe, attempting to cope with the impending surge in waste streams from lithium-ion batteries in the coming years[67].

EXPERT POSITION 7

Infrastructure for circularity, circularity of infrastructure

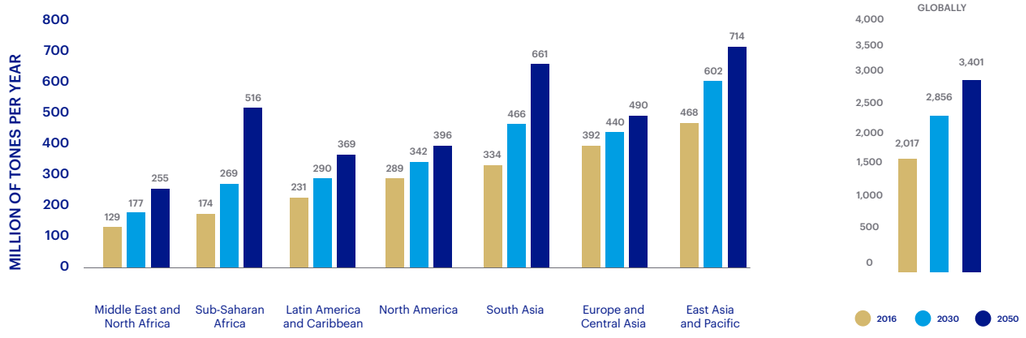
"Infrastructure is at the forefront of the circular revolution, either as a challenge for the circular economy (especially for construction and end life of an asset) or as a catalyst (with waste management facilities for instance) with wide-ranging implications for governments and business leaders. In other words, infrastructure must become more circular, and more infrastructure will be required to develop the circular economy."

Dr. Phil Purnell,
Professor of Materials and Structures in the School of Civil Engineering, University of Leeds

FIGURE 8:

Waste generation projections by 2050

Source: The World Bank, 2018



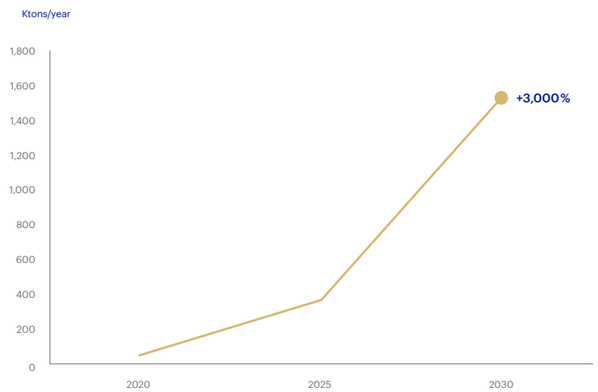
PROJECTED WASTE GENERATION BY REGION

[62] S. Kaza, L. Yao, P. Bhada-Tata, F. Van Woerden, *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050, Urban Development*, World Bank Group, Washington, DC, 2018.
[63] The World Bank, What a Waste: An Updated Look into the Future of Solid Waste Management, September 2018.
[64] J. Günther et al., Circular Economy and Biodiversity, ETC CE Report 2023/7, June 2023.
[65] The World Bank, What a Waste: An Updated Look into the Future of Solid Waste Management, September 2018.
[66] European Environment Agency, Emerging waste streams: Opportunities and challenges of the clean-energy transition from a circular economy perspective, August 2021.
[67] Oeko-Institut e.V., et al. *Emerging waste streams – Challenges and opportunities*, February 2020.

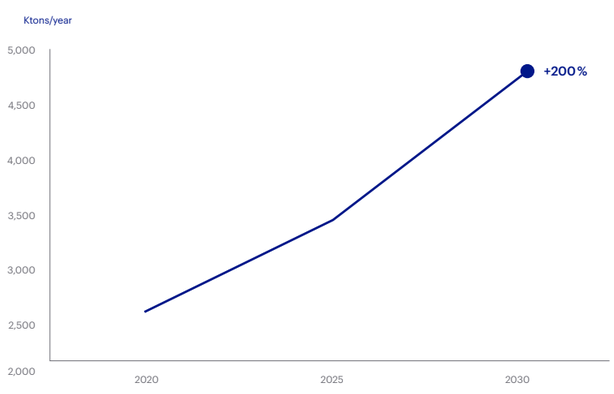
FIGURE 9:

Expected growth of waste materials generated by the clean-energy infrastructure

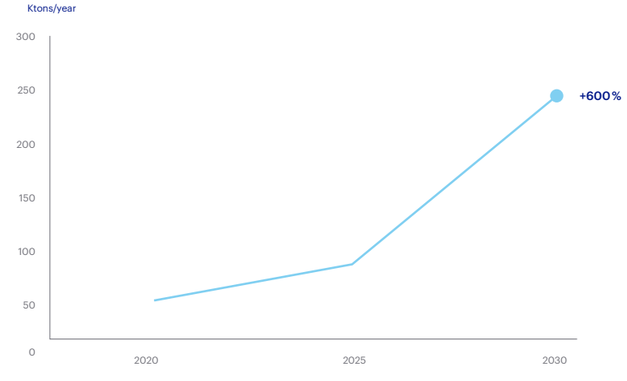
PHOTOVOLTAIC



WIND ENERGY



BATTERIES FOR ENERGY STORAGE & MOBILITY



Source: Photovoltaics – Carrara et al. (2020); IRENA (2020), Wind energy – Carrara et al. (2020); IRENA (2020), Energy Storage & Mobility – Stahl et al. (2021).

FOCUS 3

Facing the coming surge of waste with technologies 4.0

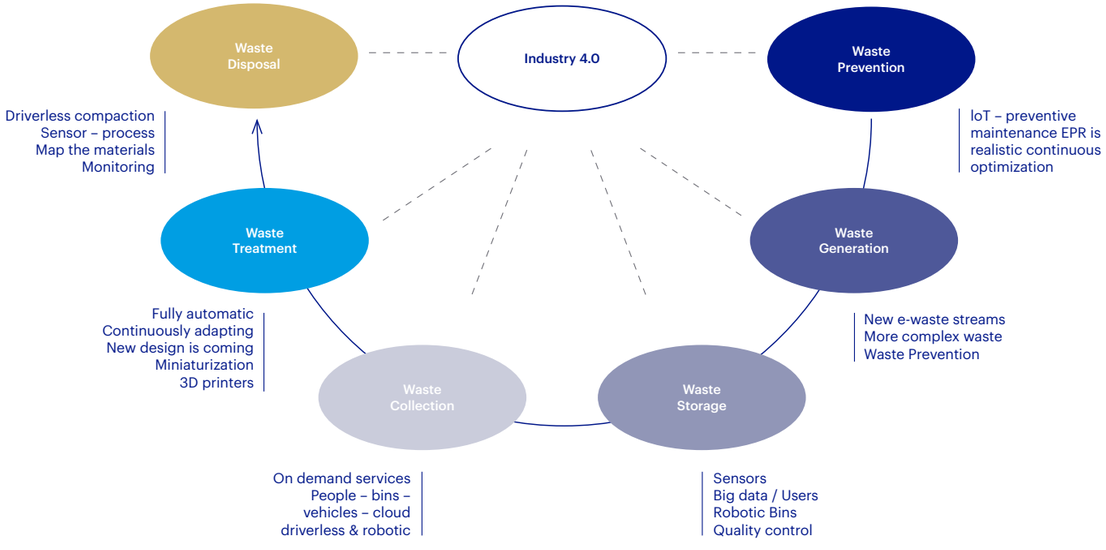
The waste industry is currently disrupted by advances in digital technologies, which are profoundly changing the "waste management stages" toward more efficiency. This more efficient management is a real necessity, since, according to Eurostat, in 2020 each European produced 505 kilos of waste, 38 more than in 1995[68]. The widespread use of digital technologies shall enable "smarter" waste management: artificial intelligence (AI), remote monitoring and control, the Internet of Things (IoT) and blockchain ensure the recyclability and traceability of waste, from collection to treatment, allowing waste management to be fully digitalized and integrated with more control and cost efficiency (Figure 10).
Given ongoing advancements, it appears increasingly probable that the field of waste management will evolve into an industry heavily reliant on data-driven approaches.

[68] Eurostat, "Municipal waste generation up to 505kg per person", February 2022.

FIGURE 10:

Waste management stages and the impact of industry 4.0

Source: ISWA, 2019



CASE STUDY 1

PAPREC: the crucial role of waste managers in the circular transition

A

As a company present in the whole waste management chain and employing more than 13,000 people, PAPREC's infrastructure propels the transition to more sustainable economic models through its four-stage process of collecting, sorting, recycling, and recovering waste. By giving waste a second life and extending material lifespans, PAPREC embraces the principles of the circular economy, backed by firm commitments and innovative initiatives.

Through continuous investment in cutting-edge technologies like AI-powered sorting robots and precision optical sorting lines, PAPREC drives improvements in waste recovery rates, fostering environmental protection and the responsible management of natural resources. In 2019, PAPREC invested in advanced sorting lines to recycle new materials like plastic films and yoghurt pots, to minimize final waste proportions.

IT'S NOT JUST ABOUT "RECYCLING"

Although recycling is an essential part of a circular economy, **a full "transformation" will not be achieved on its own without reductions in production and consumption.** Not only do end-user behaviors need to change, but infrastructure investments can also focus on upstream activities and data and logistics systems targeted at reducing resource consumption rather than just on recycling. In this respect, "infrastructure for circularity" also refers to infrastructure which reduces resource use and waste, by lowering demand for new goods, through the reuse, repurpose and remanufacture of products such as reuse and takeback centers.

To make this case, the think tank Green Alliance and the Resource Recovery from Waste of the University of Leeds outlined three scenarios for England's future with varying degrees of circularity by 2030. The work conducted aimed at identifying infrastructure that would be required under each of these scenarios for three high impact material streams from household waste: plastics, textiles and electrical equipment. Regarding plastics, the "transformation" scenario assumes that a more circular economy could cut plastic waste amount from households by half compared to the "high recycling" scenario, while increasing the amount of plastic collected by nearly 60% compared to business as usual.

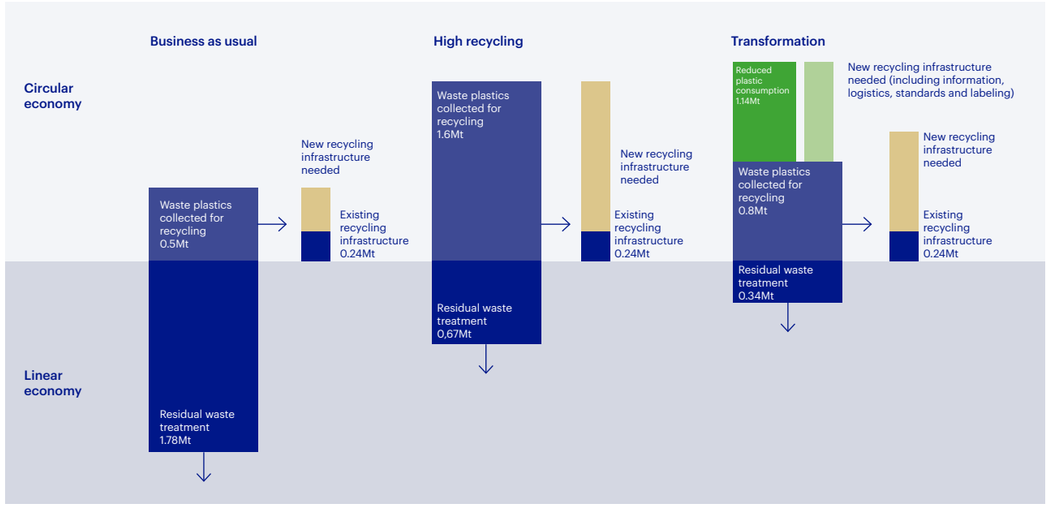
Based on these much lower waste amount, beyond new recycling facilities, **additional infrastructure and systems are therefore needed beyond recycling facilities:** a reconsideration of the suggested deposit return scheme is being proposed, with the aim of promoting the return of beverage containers for refilling rather than solely focusing on recycling. Additionally, there is a push for the implementation of a standardized, separate collection system to guarantee that higher-quality plastic materials are channeled into the recycling system. More infrastructure and logistics for refilling containers will be also required to encourage less consumption of packaging[69].

[69] The Green Alliance, Building a circular economy: How a new approach to infrastructure can put an end to waste, 2021.

FIGURE 11:

England's infrastructure requirements for a circular economy in three scenarios (for household plastic waste)

Source: The Green Alliance, Building a circular economy: How a new approach to infrastructure can put an end to waste, 2021



Business as usual – This scenario assumes that the current pattern of investment will continue, based on existing policy. Some limited additional recycling infrastructure might come online for plastics.

High recycling – This scenario is basing the transition to a circular economy on greater investment in recycling facilities.

Transformation – Recycling would still be a prominent activity, but only after other options to improve resource value have been maximized by other means. Change would start with production and consumption, which would be overhauled in a way that benefits both progressive businesses and consumers.

Water treatment systems, underside of development

A CRITICAL NEED FOR RELIABLE AND RESILIENT WATER INFRASTRUCTURE

Within the scope of "infrastructure for circularity", water treatment infrastructure also contributes "by design" to the circular transition it aims at **bettering water quality by removing contaminants,** such as bacteria, viruses, or other toxins, to make it usable for specific purposes, like drinking or bathing.

In this respect, the **quality and accessibility of water infrastructure will be critical** to ensure clean water availability, especially in developing countries: according to the IEA, more than 2bn people in the world live in water-stressed countries where access to clean drinking water is limited and, at this stage, around 80% of wastewater worldwide goes untreated, though in many cases, treating it would be technically possible[70].

While a 50% rise in urban water demand is anticipated within the next three decades, there is an immediate need for investments in wastewater infrastructure. These investments should encompass various approaches, including traditional "gray" infrastructure, nature-based solutions, or a blend of both. They should also encompass a range of scales, from large, centralized systems to smaller, decentralized water supply and sanitation solutions. Furthermore, investments in water-related infrastructure may extend to multifunctional purposes, such as supporting urban development, with examples like green roofs and permeable surfaces designed to mitigate rainwater runoff, thereby contributing to effective water management (see section 4)[71].

FOCUS 4

City Water Circles: reforming outdated urban water infrastructure

The City Water Circles (CWC) project aims to assist municipalities in revamping obsolete urban water infrastructure systems by adopting a circular economy approach, providing numerous economic and environmental benefits. The project's outputs will aid European cities in implementing effective water management practices within their territories.

The project's objective is to modernize urban water infrastructure systems through circular principles by promoting water conservation practices. Techniques include incorporating urban rainwater harvesting and utilization, along with gray water recovery measures at the city level. The pilot action will showcase the potential of using treated wastewater and rainwater to produce construction products based on secondary raw materials for road maintenance purposes.

EXPERT POSITION 8

Circular infrastructure strategies: shift countries, build countries

"There are different circular economy strategies that would be applicable for different parts of the world. On the one hand, shift countries have to adapt and transform their existing infrastructure, and promote reusing strategies. On the other hand, build countries should be more focused on the design phase of infrastructure."

Martijn Lopes Cardozo,
CEO of Circle Economy

A SNOWBALL EFFECT ON DEVELOPMENT

Highly performant water management facilities and processes can be powerful enablers of "circular synergies", especially in urban areas. Figure 12 presents a simplified view of components of a municipal water system to show how urban water systems interface with industry, energy systems, agriculture, food production, and the wider environment.

Scaling up that infrastructure therefore provides a reliable water source often at lower investment costs and with lower energy use. On the contrary, costs of inaction could be massive, especially in developing countries: in India, the cost of not treating wastewater, has been estimated as USD 54bn, mainly due to unreliable energy supplies[72].

Strengthening those infrastructures will also have additional positive outcomes as **performant wastewater treatment fosters environmental, energetical and health co-benefits:**

— Adequately treated wastewater can be reused for irrigation without harming the soil, ensuring a healthy harvest;

— Wastewater treatment can reduce the scarcity issue by balancing safe and hygienic water demand and supply while minimizing the waste volume released into the ecosystem;

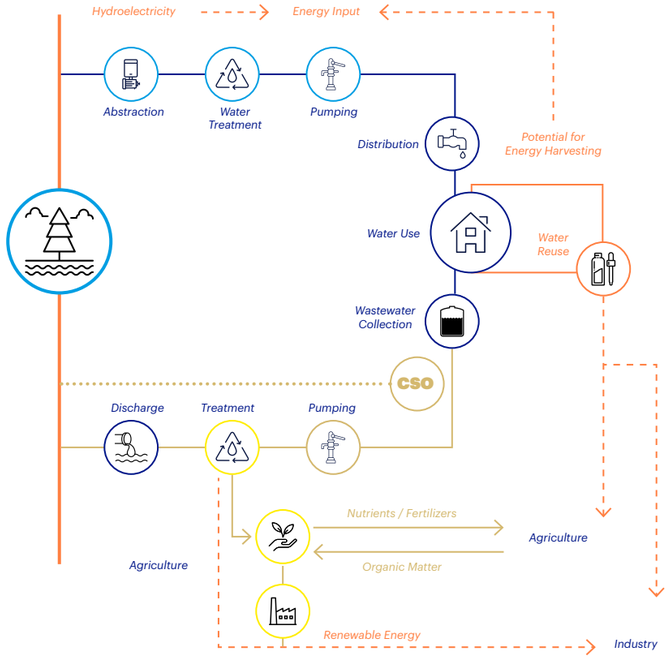
— During the treatment process, a vast amount of energy is produced whose excess can be reused;

— Performant infrastructure provides clean and safe water that protects the environment and safeguards human and animal life and health.

FIGURE 12:

Simplified urban water system with inter-sector interfaces

Source: Tahir, S.; Steichen, T. Water and Circular Economy: White Paper. 2018



[70] International Energy Agency, *Energy has a role to play in achieving universal access to clean water and sanitation*, 2018.
[71] OECD, Financing a water secure future, Policy highlights, March 2022.
[72] P. Amerasinghe, *Urban Wastewater and Agricultural Reuse Challenges in India*, International Water Managment Institute, 2013.

Circularity of infrastructure, a sustainable and profitable move

The need for a lifecycle approach

A SYSTEMIC VISION OF CIRCULARITY

Circular economy for infrastructure is rooted in a systemic approach.The transition to environmental sustainability requires circular economy practices implementation across the whole lifecycle of infrastructure following a series of five objectives: avoiding consumption at most; keeping resources in use for as long as possible; extracting the maximum value from resources while in use; embedding circular economy principles in asset operations; and recovering and regenerating products and materials at the end of life.

In this context, moving from a linear to a circular economy entails two-speeds for infrastructure operators: (i) the deployment of "quick wins" to help move the dial in terms of energy efficiencies and sobriety; and (ii) longer-term strategies to maximize the amount of materials recovered and subsequently reused, repaired, refurbished and recycled.

DESIGN & SOURCE WITH A CIRCULAR MINDSET

Infrastructure operators (transport, energy, telco, heating networks, etc.) can be part of the circular transition by **transforming their internal processes, starting with infrastructure design andmaterial sourcing.** By minimizing material usage and sourcing from renewable and biodegradable sources, such as urban mines and existing building stock, "circular design" pre-integrates circularity considerations at every stage of the project.

When designing a large-scale structure, such as a highway or a viaduct, applying circular principles requires that aspects such as the desired lifespan, is considered the future (re)use of all parts and materials and the usage of various types of materials[73]. For infrastructure to embrace a circular approach right from the start, two major imperatives must be followed:

– **Promote the use of durable products and services that are made from secondary, non-toxic, sustainably sourced,** or renewable materials, and focus on monomaterial solutions (reduction of material mixing and layering)[74];

– **Give priority to longevity, resilience, durability and reparability** of the building or infrastructure: locking assets into stocks not only extends their lifespan but also reduces the long-term demand for materials, effectively narrowing the flow of resources. To this extent, infrastructure serves as both a reservoir of reusable materials and a source of new construction, further driving circularity by enabling the reuse of resources in future projects[75].

Overall, better and streamlined infrastructure design, planning, and implementation could significantly alleviate material demands in construction, resulting in a reduction of over 50%[76].

Margin of progress is high in the renewable energy sector, especially in terms of assets' life extension. For instance, lithium-ion batteries are initially engineered to prioritize performance and cost-effective mass production, often overlooking considerations for extending their lifespan; as a result, the design tends to neglect strategies that would facilitate easy and affordable repair, refurbishment, and remanufacturing processes. Regarding photovoltaic plants, the case is also compelling. While the sturdy and weather-resistant design of the panels ensures their long-term functionality for decades, they are not designed for refurbishment: considering the significant amount of waste projected by 2030-2050, a better balance between durability and repairability must be sought to address those issues effectively[77].

[73] V. Gruis, *Circular Infrastructure: the road toward a sustainable future*, Rijkswaterstaat, January 2022.
[74] European Circular Economy Stakeholder Platform, Circular buildings and infrastructure, 2021.
[75] Circle economy, *Circularity gap report*, 2023.
[76] Material Economics, *The Circular Economy: A powerful force for climate mitigation*, 2020.
[77] Green Purposes Company, *For a circular energy transition*, February 2023.

EXPERT POSITION 9

Circularity: a new paradigm for infrastructure operators

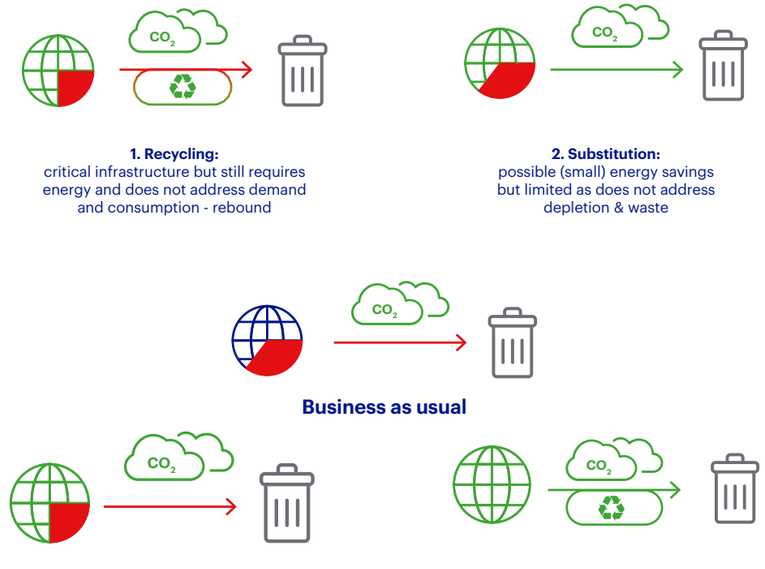
"Long summarized as the improvement and generalization of recycling, circularity is in fact a new paradigm, integrating the circulation, reuse and traceability of materials between different production chains, optimized material consumption and new, more sober uses. The circular model must find its "rightful place" in a global economy that operates on the theory of comparative advantage, and which is likely to create synergies, for example in terms of waste recycling and recovery. There is an emergency for the infrastructure sector to embrace this new paradigm."

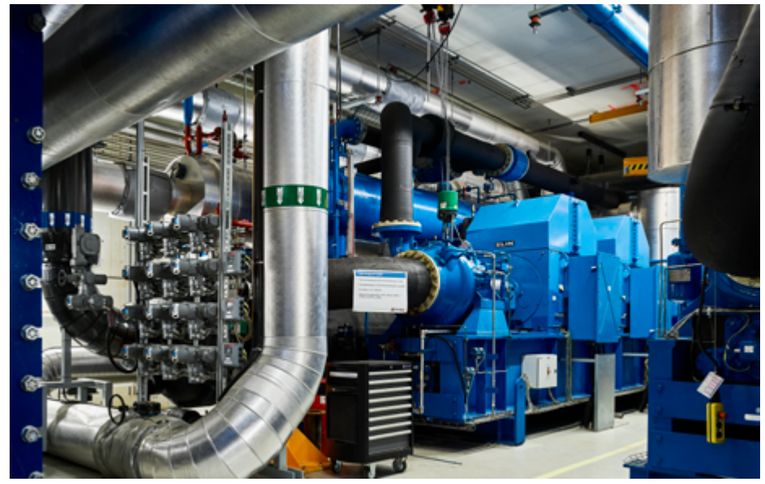
Gwenola Chambon, CEO of Vauban Infrastructure Partners

FIGURE 13:

A systemic approach of circularity of infrastructure

Source: Phil Purnell





CASE STUDY 2

Circular economy at the heart of Telefónica's climate targets and ambitions

Acknowledging the challenges posed by limited recycling rates worldwide, Telefónica has set ambitious objectives in terms of circular practices. Telefónica showed recently strong commitment to circularity through the publication of a "Climate Action Plan" (published in July 2023). Intended to set ambitious sustainability and circularity objectives, this plan includes a vast array of strategic levers to achieve Telefónica's long-term climate-related targets. For example, since 2019 the achievement of emission reduction targets is linked to the variable compensation of employees.

With the potential to substantially reduce global GHG emissions by 39% and cut resource consumption by 28%, Telefónica's dedication to increase reuse and recycling rates illustrates its determination to drive positive change on a global scale with the ultimate objective of achieving Zero-Waste to landfill by 2030. Telefónica's specific targets are:

— 90% of refurbished and reused customer-premises equipment (routers, decos) by 2024;

— Reuse 500,000 mobiles per year by 2030;

— For network equipment: 100% reuse, resale and recycling by 2025 (aligned with the GSMA sector target).

In pursuit of the circular economy's vast opportunities, Telefónica embraces a multifaceted approach. By focusing on reuse to minimize environmental impacts, extending product lifespans, and recovering valuable raw materials, the company redefines sustainable business practices. Through the adoption of digitalization, cloud services, IoT devices, and the design of smaller, lighter devices, Telefónica exemplifies how circularity is not only environmentally responsible but also strategically advantageous.

To increase circularity in network equipment, the initiative MAIA enables OpCo's to display their equipment for sale within a marketplace platform, where Telefónica operators can select which products they would like to purchase. This facilitates and promotes internal reuse. When internal reuse is not possible, the platform enables operators to connect with technological partners to facilitate equipment sales and therefore extend its useful life. The MAIA project began at the end of 2020 and is currently present in all of Telefónica's OpCos. Thanks to this initiative, Telefónica has managed to reuse more than 180,000 pieces of equipment to date.

Also Telefónica uses blockchain and big data to foster the circular economy of customer-premises equipment thanks to the VICKY and APOLLO initiatives that enable it to achieve greater traceability throughout the value chain of modems, routers and TV set-top boxes and increase their recovery rates.

"The telecom industry is wholeheartedly embracing sustainability, moving beyond mere ambitions. At Telefónica, we have already set our objectives for 2030 and made specific commitments. For instance, we have announced that all our clients will be transitioned to fiber-based services starting next year. We are close to achieving this goal, which will lead to substantial savings and increased efficiencies thanks to the closure of our copper network. We take sustainability seriously and are actively working toward tangible and impactful outcomes."

Sergio Oslé,
CEO of Telefónica in Spain

FOCUS 5

A circular concrete viaduct: a circular design mindset

In 2019, a circular viaduct was developed in collaboration between the Netherlands Government and the private sector as part of its ambition to halve the country's use of natural resources by 2030 and achieve a fully circular economy by 2050. The viaduct has a span of 20 meters and consists of 40 concrete elements, all manufactured at Spanbeton's factory in Koudekerk aan den Rijn. Overall, the viaduct proves it is possible to build a circular bridge with only 1% material wastage, thanks to a series of key features – modularity, traceability, and reuse:

— Based on modular precast, elements can be disassembled, moved, and reused to rebuild a completely new viaduct, which shall therefore have a very low CO_2 footprint;

— The behavior of the viaduct is monitored with highly sensitive sensors embedded into the elements giving information about the materials in the built environment and when they would be available [78].

FIGURE 14:

A circular viaduct in the Netherlands

Source: Bridge Design & Engineering (2020) [79]

[78] Consolis, "First circular viaduct in the Netherlands", 2022.
[79] H. Russel, "Full circle", *Bridge Design & Engineering*, March 2020.

CASE STUDY 3

SACYR: reusing materials

As a committed highway operator with a presence in more than 20 countries, Sacyr has showcased cutting-edge expertise in circular economy through multiple rehabilitation and construction projects. Recently, Sacyr successfully completed the first sustainable asphalt-paved stretch of a highway in Spain. This was achieved by incorporating rubber powder from used tires using the innovative RARx technology, a product developed and manufactured by CIRTEC, a company of the Sacyr Group. 60% of RARx consists of used tire powder, making it an environmentally friendly solution for reusing discarded tires. The use of RARx in the asphalt plant not only enhances roadbed durability and reduces noise pollution but also provides a sustainable approach to managing unused tires.

Sacyr also showcased its cutting-edge expertise in the circular economy through a pioneering road rehabilitation project in the Canary Islands. Facing limited construction materials, the company recycled 50% of milled materials from the roads they are repairing. Collaborating with Cabildo de Tenerife, Sacyr's sustainable approach reduced waste, curtailed quarry dependency, and lessened the ecological impact. This transformative endeavor not only addresses scarcity but also cements Sacyr's position as an industry leader, shaping a greener future.

"We operate in more than 20 countries and most of them are based in Latin America. There, we have to start a road from the very beginning: we design, build and operate with a more holistic approach. We have finished 2022 with a level of use of 50% of recycled materials in all our activities and we reuse or upcycle more than 85% of our waste. When we start a new project, we design a circularity plan with all the initiatives we can carry out. For us the main challenge has to do with collaboration throughout the whole value chain because in the end we are only managers of other assets."

Marta Gil de la Hoz,
Chief Strategy, Innovation and Sustainability Officer at Sacyr

CREATE "INTEGRATED" SUPPLY CHAINS

Beyond design and sourcing, circular infrastructure must aim at **maximizing resource utilization and minimizing waste all along the value chain** of industrial processes. In search of circularity, infrastructure operators must **build "integrated" supply chains**[80] as circular supply chains can only be conceived and implemented if all suppliers prioritize circularity over linear approaches. This requires all stakeholders to contribute toward an outcome that achieves the best value for all parties, using components that retain the highest value throughout the lifecycle and minimize losses from the system.

In this respect, "R-ladders" strategies (see section 1) are increasingly put in perspective with the growing appearance of **the principle of "whole system approaches"**[81]. In the pursuit of a sustainable circular economy, R-ladders can serve as a valuable tool for mapping out potential scenarios to optimize the management of resource stocks and flows. However, determining the most suitable approach for a supply chain context should be based on a comprehensive evaluation of the entire system[82].

The task is not easy and circular supply chains today remain elusive and difficult for businesses to implement, especially as they are a continuous process within which production systems must adapt and not an ideal end state which would not change anymore once it has been achieved[83].

In this context, **reverse logistics can be a powerful enabler** by overhauling supply chains for the advancement of circular economy models: this type of supply chain management relies on a backward move through the supply chain to the distributor or from the distributor to the manufacturer (Figure 15). Reverse logistics can also include processes where the end consumer is responsible for the final disposal of the product, including recycling, refurbishing or resale. While it has been mainly deployed for goods production, the construction industry can benefit from reverse logistics by moving upward salvaged materials to new sites.

[80] Arup, *Circular Business Models for the built environment*.
[81] A. Velenturf, P. Purnell, "Principles for a sustainable circular economy", *Sustainable Production and Consumption*, vol. 27 July 2021.
[82] Ibid.
[83] A. Velenturf, P. Purnell, "Principles for a sustainable circular economy", *Sustainable Production and Consumption*, vol. 27 July 2021.

EXPERT POSITION 10

Driving efficiency and waste reduction in telecommunications

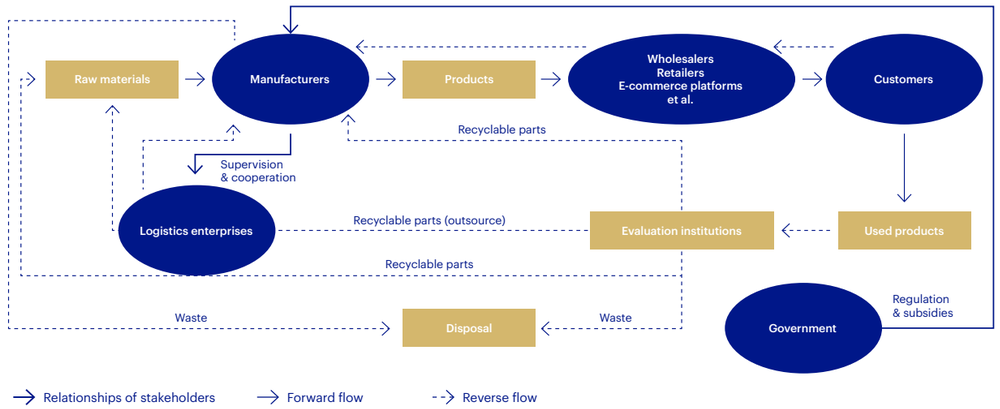
"Having a strategy to reduce carbon emissions and adopting a more responsible approach to business is no longer optional; it must be an integral part of our overall strategy. For nearly a decade, we have implemented phone recycling strategies for our customers, seamlessly integrating it into our commercial processes. When a client purchases a new phone, we offer to buy back their old one and recycle it. For instance, last year, we bought back and recycled almost 300,000 smartphones from our customers. Additionally, we sell second-hand smartphones, and we see a positive response from customers willing to purchase these devices."

Benoît Torloting,
CEO of Bouygues Telecom

FIGURE 15:

Reverse logistics process

Source: F. Zhang and Y. He, Study on the effective way to convert waste into resources – Game analysis of reverse logistics implementation based on value chain, 2022)



Circularity, a business opportunity

A RISK-MANAGEMENT STRATEGY

For infrastructure operators (transport, energy, telco, etc.) dealing with physical materials and products, the transition from linear to circular means profound operating, technological and organizational changes: a major shift from primary to secondary material production, new business models to reduce and re-use materials and products, and different end-of-life treatment practices. The business case must therefore be strong for them to fully embrace the needed circular revolution.

More circularity within infrastructure operating models can create sustainable value by helping companies meet their climate change commitments, get ahead of government regulations – for instance to protect biodiversity – and reduce exposure to an unstable environment (geopolitical tensions, changes in consumer preferences, etc.).

For companies, implementing a circular mindset can therefore help hedge against short-term and long-term risks directly linked to a linear business model. For instance, reusing materials, and assets, and reducing waste can have an immediate financial benefit for an organization and protect against inflationary and scarcity-driven supply chain pressures. In this perspective, Circle Economy, PGGM, KPMG, WBCSD and EBRD built a linear risks matrix companies can be exposed to if they continue to follow a "business as usual strategy"[84], combining linear economic business practices and market, operational, business and legal risks (Figure 16).

FIGURE 16:

Linear Risks Matrix

Source:Circle Economy, PGGM, KPMG, WBCSD and EBRD, "Linear Risks", 2018

		Linear business practices			
		Utilize non-renewable resources	Prioritize sales of new products	Fail to collaborate	Fail to innovate or adapt
Risk factors	Market	Scarcity of primary resources Volatility of resources prices	Bans on trade of waste Volatility of resource prices	Limited opportunities to expand to new markets	Scarcity of primary resources Volatility of resource prices
	Operational	Internal process failures	Worker safety issues	Supply chain inefficiencies	Inability to hire new talent
	Business	Changing demand for sustainable solutions Decreasing cost of renewables	Disruptive business models Decreasing margins from commoditization	Disruptive new technologies	Disruptive new technologies Disruptive business models
	Legal	Fines for legal violations More stringent environmental laws	Requirements for extended producer responsibility	Fines for legal violations	More stringent environmental laws

[84] Circle Economy et al., *Linear risks: how business as usual is a threat to companies and investors*, 2018.
[85] C. Scheel, "Transforming Linear Production Chains into Circular Value Extended Systems", *Sustainability*, 14(7), April 2022.
[86] European Economic and Social Committee's Employers' group, *The Circular Economy: Beneficial for All The Threefold Challenge: Climate Change, Competitiveness & Dependence on Raw Materials*, 2016.
[87] Ellen MacArthur Foundation, "What is the linear economy?", 2020.

A STRONG BUSINESS CASE BEHIND CIRCULARITY

From a bottom-line point of view, circular investments, processes and practices present wide-ranging benefits for infrastructure operators both in the short and long term as more circularity within infrastructure operating models can increase asset performance and cost-efficiency and open new avenues of revenues. The value creation is by essence grounded on **keeping the economic value embedded into infrastructure** after their use to reduce costs and generate new types of service offerings[85].

During planning and operations, the optimization of infrastructure design and sourcing with recycled and renewable materials can massively **improve cost efficiency** keeping in mind the need to reduce waste all along the supply chain and anticipate end of life. According to the European Economic and Social Committee's Employers' group, the potential cost benefits of a circular economy are huge: raw materials typically account for 30% to 50% of production costs, thus improving resource efficiency by 30% could lead to annual savings exceeding EUR 600bn for European industry. Additionally, significant cost efficiency can be achieved through water and energy savings, reaching up to 8% of turnover[86].

Applying the circular economy model to infrastructure can **create additional revenue streams** as well: as explained by the Product Lifecycle Extension model, by repairing, upgrading, and maintaining assets, infrastructure operators can maximize value beyond the initial end of life of their assets, avoiding waste and generating income. On the contrary, a linear model leaves sustainable value untapped by focusing on a short-term approach and disregarding the lifecycle dimension of products and materials which are generally not used to their full potential[87].

LEVERS TO ACCELERATE AND SCALE THE CIRCULAR TRANSITION OF INFRASTRUCTURE

Key takeaways

→ Beyond traditional R-ladder strategies, new and the most innovative circular business models have emerged and are particularly relevant for the circular economy: infrastructure as a service, sharing economy, track & trace digitally, infrastructure retrofit and industrial symbiosis.

→ A series of key business levers can be activated to accelerate the spread of circular business models, including cutting-edge innovations (new materials, digital technologies), industrial collaborations and training for a circular-oriented corporate culture.

→ To scale the circular transition of infrastructure, a clear and strong support from the financial community and the insertion of new incentives within procurement schemes and contractual arrangements will be critical.

Speeding up the adoption of circular business models

The need to move toward more advanced circular models

INNOVATIVE APPROACHES EMERGING

To maximize the business opportunities offered by the circular transition, infrastructure asset operators must design their **business and operating models with a circular economy mindset** from the outset. Those "circular" business models deliver new ways of providing value to stakeholders, systemically boosting resource efficiency and effectiveness along the infrastructure lifecycle.

Figure 17 visualizes a range of business model strategies available for infrastructure operators wanting to move to a circular economy model, according to the lifecycle of the asset and the optimal material loop approach (closing, narrowing, slowing the loop). **Five innovative business models** are emerging and are particularly relevant to speed up the transition toward more circular infrastructure: infrastructure as a service, sharing economy, track & trace digitally, infrastructure retrofit and industrial symbiosis.

FIGURE 17

Circular business models for infrastructure

Source: Altermind

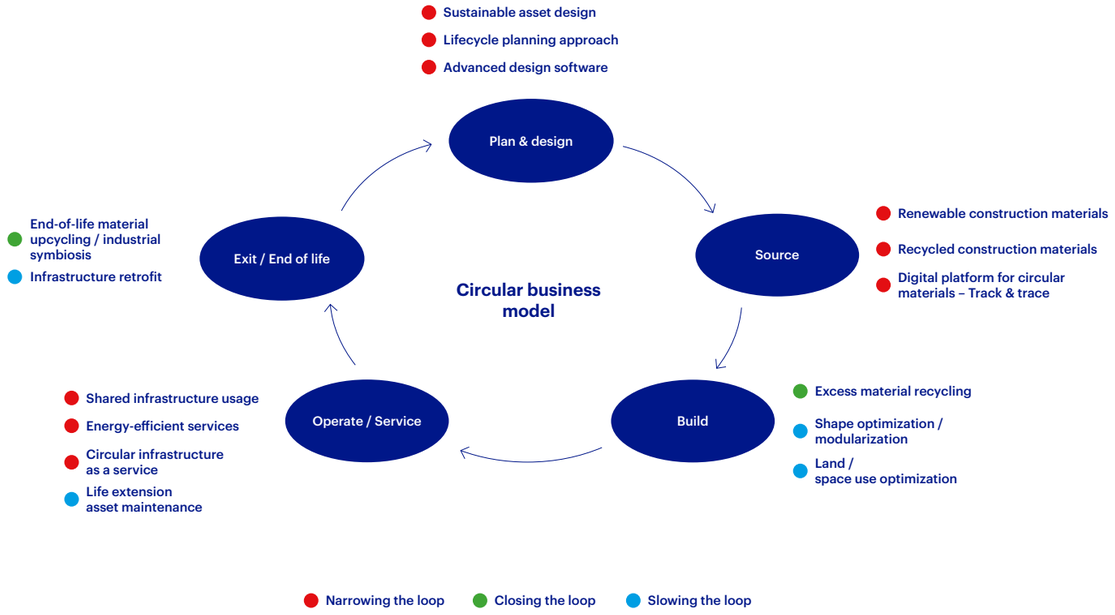


TABLE 1:

Features of 5 most innovative circular business models

Source: Altermind

TYPOLOGY	VECTOR	MATERIAL LOOP	VALUE CREATION LEVER	EXAMPLES
Infrastructure as a service	Delivers access to an infrastructure and retains ownership (functionality economy) to internalize benefits	Narrowing the loop	Optimizes costs all along the project Increases energy efficiency according to real needs	Road as service such as electric highways that charge electric vehicles while they are in motion (see section 3.2.)
Industrial symbiosis	A process- oriented solution, concerned with turning waste outputs from one process into feedstock for another process	Closing resource loop	Cost reduction and potential creation of new business lines based on former waste streams	Straw residue to produce bioethanol
Track & trace	Uses software and databases for planning, simulation, dimensioning	Narrowing the loop	Facilitates traceability, resource optimization and monitoring	Platformization of raw materials Circular digital materials passport
Shared infrastructure	Enables or offers shared use/access or ownership to an infrastructure	Narrowing the loop	Increases flexibility and utilization rate of the infrastructure with digital platforms Decreases OPEX / CAPEX Easy migration to other sharing platforms	Mobile telecommunications networks, such as Active RAN sharing, enabled by network function virtualization
Infrastructure repurposing	Extend the useful life of infrastructure	Slowing the loop	Reuse of future stranded assets Opens new areas of revenues for stranded assets	Oil & gas pipelines retrofit into CCUS or hydrogen transport

CASE STUDY 4

Indigo adapting its business model to a constrained environment

In the pursuit of long-term sustainability, the car park operator Indigo has showcased remarkable adaptability, transforming its core business models to generate lasting value and set a bold precedent by committing to carbon neutrality by 2025 (scopes I and II) focusing on waste and water management, reducing energy consumption, and slashing GHGs emissions.

Beyond their vital role in the energy transition, car park operators are faced with the challenge and opportunity of the mobility revolution as parking lots could be considered as stranded assets given the nature of the ecological transition. To deal with this complex equation, Indigo has revolutionized its underground spaces, collaborating with last-mile logistics services and providing essential amenities at the heart of bustling cities to minimize overall environmental impact.

Strategically located in urban centers, Indigo car parks leverage vast partially unused areas in the face of scarce new construction and urban land. This situation may create opportunities for alternative usages, like offering storage spaces for booming e-commerce and at-home delivery services, providing essential infrastructure for last-mile logistics players. Additionally, unused areas can be transformed into data centers, fitness clubs, dark stores, dark kitchens, healthcare platforms, automobile repair shops, cultural facilities, or even urban farms.

With car park spaces converted into logistics centers, as seen in Paris for mon-marche.fr and in different cities with delivery and pick-up points for Rexel, the world expert in the distribution of electrical equipment, Indigo is proving its commitment to sustainable and circular growth, playing a vital role in shaping the urban landscape of the future, and reducing the number of trips and carbon emission.

MULTIPLE BARRIERS TO BE OVERCOME

Overall, despite the growing interest for circular economy, **multiple barriers are yet to be overcome at all levels of the economic system** – cultural, technological, market and regulatory, but in different intensities – **making the adoption of circular business models complex**. Interestingly, according to an evaluation of business and policy leaders[88], **cultural barriers emerge as the main impediment** regarding a transition toward a circular economy with three out of the five most pressing barriers identified being cultural ones: company culture, consumer interest, and current operating model (Figure 18).

Innovation, collaboration & education: the key "accelerators"

SUPPORT TECHNOLOGICAL INVENTIVENESS

To enable the integration of circularity principles across the infrastructure lifecycle, **innovation and research will be critical**: among the most valuable innovations required for a technological and structural change, are using digital technologies – especially those from the industry 4.0 – to capture, store, share and analyze data related to the design and condition of an asset and improving access to materials by re-imagining waste streams (Figure 19).

For instance, materials passports – i.e. digital database recording the objects in buildings or infrastructure in both qualitative and quantitative terms – promote high-value reuse at the material, product, element, and building levels. **The case studies in this section illustrate how entrepreneurs in the circular economy are making progress in all those areas, with business ingenuity and creativity.**

[88] J. Kirchherr et al. "Barriers to the circular economy: evidence from the European Union", *Ecological Economics*, 2018.

FIGURE 18

Heatmap of circular economy barriers

Sources: *J. Kirchherr, Barriers to the Circular Economy: Evidence From the European Union (EU), 2018*

Cultural	Technological	Market	Regulatory
Company culture	Circular design	High upfront investment costs	Obstructing laws and regulation
Willingness to collaborate in the value chain	Willingness to collaborate in the value chain	Limited funding for circular business models	Limited circular procurement
Consumer interest and awareness	Ability to deliver high-quality remanufactured products	Low virgin material prices	Lacking global consensus
Operating in a linear system	Too few large-scale pilot projects	Standardization	

Intermediate pressing barriers

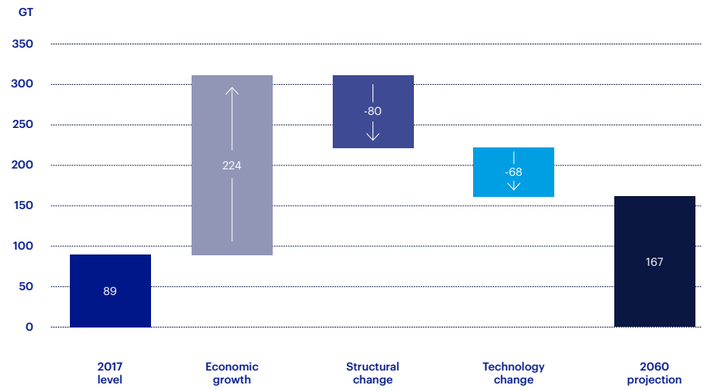
Most pressing barriers

Least pressing barriers

FIGURE 19

Structural and technology change impact on amount of materials used (Gt)

Sources: *OECD, Global material resources outlook to 2060*



CIRCULAR START UP 1

Néolithe

CREATED IN 2019 AND LOCATED IN THE LOIRE VALLEY, Néolithe combines the traditional knowledge of minerals and craftmanship with cutting-edge industrial technologies to revolutionize the treatment of non-recyclable waste materials, thus avoiding landfilling and incineration. Néolithe innovated to bring ordinary industrial waste into the loop of circularity, using a fossilization process.

A new life is given to non-recyclable, non-inert and non-hazardous waste through three stages:

→ Sorting out waste to collect fossilization-compatible waste; such as plastics, textiles, wood, plaster and insulation materials;

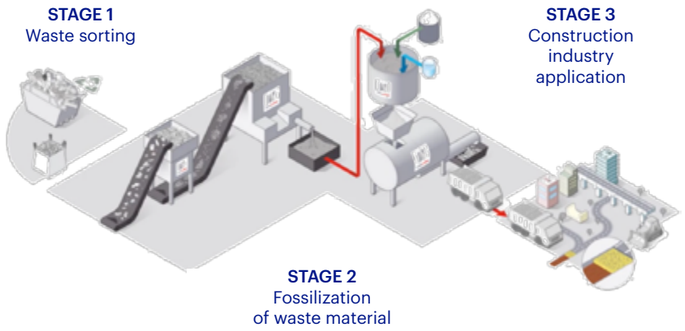
→ Fossilizing waste requires waste to be shredded and to create a coherent mineral structure with a low-carbon binder. With a shredding line able to process 3 tons of waste per hour;

→ The new mineral called "anthropocite" has the same technical and mechanical features as traditional aggregates, which are the most widely used raw material in France (450 mn tons per year). Anthropocite can be used in road sub-bases and concrete. Néolithe's approach enables waste processing facilities to embrace sustainable practices without major infrastructural modifications. By eliminating the need for dedicated land, the fossilizer opens up new possibilities for municipalities and waste management companies to adopt eco-friendly solutions within their current setups.

FIGURE 20

Néolithe's waste processing stages

Sources: *Néolithe*



CIRCULAR START UP 2

Concular

CONCULAR IS AT THE FOREFRONT OF URBAN MINING, simultaneously reducing material extraction and recycling infrastructure. The start up aims to transform the construction industry through intelligent data-based and new construction projects, and live eco-balancing, to make circular construction easier and more economical. Concular has successfully led 250 projects in Germany, Austria and Switzerland, and works with over 55 partners, including the European Commission, from all stages of infrastructure's lifecycle.

Concular disrupts the construction industry with an AI-driven platform that connects buyers' demand for construction material with suppliers offering circular materials. Construction projects can submit their material requirements through the platform, while circular materials from demolition projects can be registered using a digital material passport. Concular conducts its projects following three stages:

→ Digitalization of materials: Concular assesses the existing building through data collection and surveying focusing on the materials characteristics;

→ Setting-up a Life-cycle Passport: all data are stored in a digital database, enabling Concular to upload the building's information over its entire lifecycle. Buildings become circular as the passport shows their compliance to ESG and Taxonomy, the optimization of their CO_2 footprint, and their level of circularity;

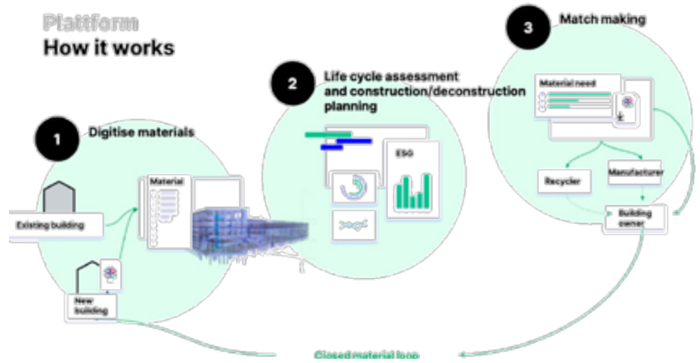
→ Matchmaking: Concular uses its platform to match material demand to supply coming from recycling old buildings.

Concular creates a value opportunity for building owners, while aiming to reduce by 20% the GHG emissions from the construction industry. Its biggest project already showed the potential of matching platformization with the circular economy: assessing Stuttgart's Mercedes Benz Arena's lighting, windows, stairs, etc. allowed 135 tons CO_2eq to be saved.

FIGURE 21

Concular's business proposal

Sources: *Concular*



CIRCULAR START UP 3

Fairmat

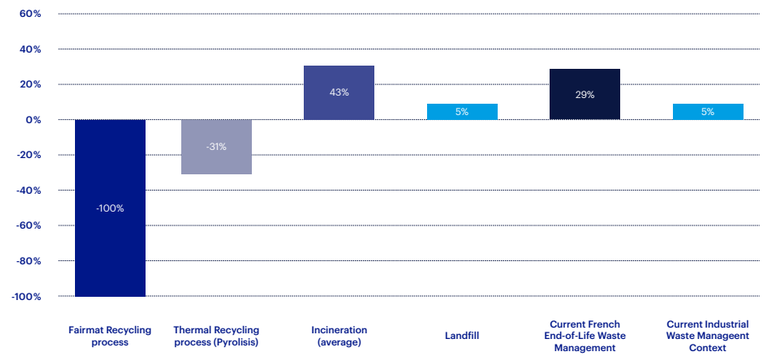
FAIRMAT DEFINES ITS MISSIONS AS "building the manufacturing ecosystem that puts second-generation materials at the heart of forward-thinking manufacturers worldwide".
Focusing on carbon fiber waste, Fairmat implements the principles of recycling and circular economy to reduce GHGs emissions through providing an alternative to incineration and landfills of carbon waste emissions.
The solution consists of a mechanical treatment rather than a conventional highly energy-consuming technique like pyrolysis or solvolysis.
The process results in optimized compound layouts reusable in manufactured parts that can replace aluminum and glass fiber composite.
While 190 million tons of carbon fiber representing USD 10tr are expected to be landfilled in the next 50 years, Fairmat's value proposal is critical.

Today, Fairmat recycles important quantities of waste from over 30 clients in aeronautics, wind energy, or also manufacturing and provides recycled materials for over 15 clients in sporting goods, automotive and electronics, desiring to manufacture sustainably.

FIGURE 22

GHG emissions of Fairmat's recycling process, compared to other end-of-life scenarios, accounting for "avoided impacts"

Sources: *Fairmat*



CIRCULAR START UP 4

Resourcify

RESOURCIFY IS A DIGITAL PLATFORM FOR CIRCULAR WASTE MANAGEMENT AND RECYCLING.
By digitizing day-to-day operations, the platform enables companies to manage, track and improve their recycling, while reducing administration and saving up to 40% of costs compared to traditional waste management.
Resourcify helps companies to optimise their recycling processes, set up take-back programmes and connect them to its network of over 450 recyclers. These are the first steps toward the circular economy.
Launched in 2018, the platform is trusted by leading companies across Europe, including Johnson & Johnson, Rewe, Hornbach, Syntegon and Frankfurt Airport.

Resourcify's customers benefit from:

→ Increased efficiency through digitization of day-to-day operations and more time for optimization and sustainability projects;

→ Cost savings through better recycling, onsite handling and contracts;

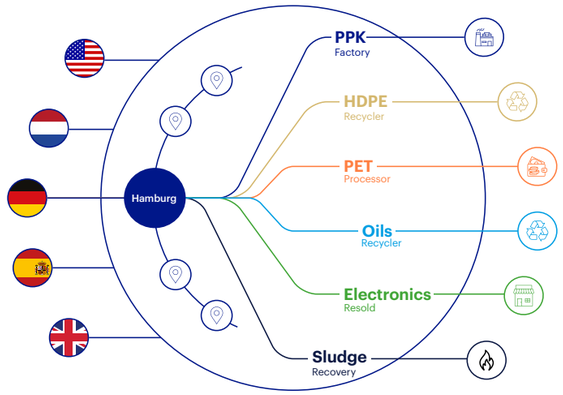
→ Competitive advantage through improved decision making with data-driven information.

Resourcify works with companies across a range of industries, with proven results in retail, healthcare, logistics and manufacturing.
At Frankfurt Airport, waste managers were able to identify a waste stream that was too expensive to dispose of and move it from incineration to a fully closed loop.
The University Hospital in Bonn has seen a 40% reduction in administration after digitizing its waste management, and its take-back programme with Johnson & Johnson has already saved 6,454 kg of CO_2.

FIGURE 23

Resourcify offer

Sources: *Resourcify*



Companies

All-in-one circular service
One point billing and contact

Cost reduction
Up to 10% lower costs

Waste Diversion
Up to 3x more revenue from recyclables

Operational Visibility
Up to 80% less admin:

↑
Resourcify
↓

Recyclers

Cost reduction
Up to 15% processing cost reduction

Win more waste volume
Directly work together with large clients

Earnings improvement
Up to 30% higher margins per client

Gain customer access
Get hands on valuable materials

For infrastructure operators, in particular the cement and construction sector, innovation can also be derived from **engineered industrial processes and solutions such as additive manufacturing:** instead of a process where layers are removed to get the right shape, and in the process creating waste, layers are added in the precise shape needed using computer-aided design (CAD) software and 3D printing.

Carbon capture, utilization and storage (CCUS) also shows promising potential to control and reuse CO_2 emissions. CCUS technologies rely on a network of multiple interconnected infrastructure assets – to transform CO_2 captured in an input to create products and services: the CO_2 can be used, for example as a feedstock in synthetic fuels, or it can be permanently stored to achieve negative emissions.

Widespread deployment of CCUS will mean emitting plants need transport and storage capacity to convey large volumes of CO_2 to distant sites where it can be stored or used in other industrial processes. For many this may mean a pipeline, rail-link or shipping route, with the significant funding needed coming from public sources[89]. In the path toward Net Zero, CCUS deployment is expected to reach 5.6 Gt of CO_2 according to the Global CCS Institute, accounting for a fifth of emissions reductions needed by 2050[90].

Overall, an "innovation ecosystem perspective" will be necessary to help deliver technological innovation at scale[91]. In this respect, three main priorities have been identified by the Global Infrastructure Hub:

— Support incubation of technologies: circular infrastructure technologies are already being developed by the private sector but on a sporadic and ad-hoc basis. More incentives of incubation, for example through direct fiscal support, dedicated funds or blended finance are needed;

— Procure and apply new technologies: Governments can assist through the aggregation of market demand for circular infrastructure solutions and by being early adopters of technologies across their infrastructure portfolios;

— Scale technology adoption by aggregating demand and sharing data from early deployments can help establish marketplaces for technological solutions.

PROMOTE INDUSTRY COLLABORATION

To implement a circular approach in business models, which is an economic model affecting more and more sectors and industries, it is key to **perform collaborative efforts across the whole value chain**, to leverage on network, technologies, resources, needed for scaling solutions and business models. Managing this change collaboratively demands greater levels of communication, negotiation, coordination, and cooperation to systematically change the behaviors of networks of actors.

For instance, while telcos need to focus their procurement efforts on equipment that has longer lifespans, modular designs (for less wasteful upgrades) and incorporate reusable materials, they must also forge new partnerships to incentivize vendors to provide products that meet this requirement. Large inter-company associations such as Global System for Mobile Communications (GSMA) in the telecoms sector show that industry collaboration is growing and turning toward the circular economy.

[89] Global Cement and Concrete Association, "Providing the infrastructure for circular and net-zero manufacturing".
[90] International Energy Forum, "The circular carbon economy", 2022.
[91] J. Konietzko, *Business innovation toward a circular economy - An ecosystem perspective*, TU Delft, 2021.
[92] PAPREC, Groupe Guillin, "PAPREC Recyclage et Groupe GUILLIN s'associent pour accélérer le recyclage des barquettes alimentaires plastique", Communiqué de presse, 2018.

CASE STUDY 5

PAPREC-Guillin: the REUSAL project

Determined to keep up with plastic recycling, PAPREC and European leader in food packaging solutions Guillin, launched in 2018 the REUSAL project to speed up the sorting and recycling of PET plastic trays and reinforce the eco-design of the products they market to comply with emerging regulations.

The two companies have decided to pool their research and development resources to work on the launch of a specific recovery, processing and regeneration unit for food-grade plastic and food packaging, based on the "tray to tray" principle.

In this regard, PAPREC and Guillin Group are following three development programs: (i) develop regeneration technology for these selective collection flows; (ii) reinforce the eco-design of food packaging; (iii) optimize the incorporation of food-grade materials derived from recycling[92].

Driven by the introduction of a bonus-malus system to encourage manufacturers to eco-design their products and use more recycled plastic, these two French companies have embarked on a transition to circularity in the recycling of their packaging to meet the growing regulation of these issues.

CASE STUDY 6

PAPREC and TotalEnergies joining forces to retrofit stranded assets

B

Based on a strong partnership between two key players of the circular transition, the Grandpuits in Seine & Marne (77) transformation project is a perfect example of "infrastructure for circularity", dedicated to the recycling and reuse of materials, but also of "circularity of infrastructure". Processed by PAPREC at its Plastique plant in Amiens (80), the agreement between both industrial groups will enable TotalEnergies to secure supplies for its Grandpuits chemical recycling plant for plastic waste, turning it into a zero-carbon platform.

Scheduled to come on stream in 2024, the pyrolysis process will convert nearly 15,000 tons of waste per year into virgin plastics that can be used in contact with food, thus closing the loop. TotalEnergies (Grandpuits) and PAPREC (Amiens) plants are both working on existing industrial estate that has been converted and revitalized.

"We are in an era of creating new infrastructure for making materials more circular and having more energy from waste."

Sébastien Petithuguenin,
CEO of PAPREC

CREATE A CIRCULAR MINDSET TO BREAK THE CULTURAL BARRIER

All external stakeholders involved should be included, notably operations, support, procurement, partners, suppliers and management, with the broadest possible vision. It is also vital to **involve employees as early as possible**, from the pre-diagnosis phase onwards, so that they can take ownership of the circular transition and cooperate best under these conditions. The Circular Economy Institute (CEI) offers innovative and practically oriented labels, certificates and training targeted to the needs of various professionals like designers, managers, and consultants (Focus 5).

FOCUS 6

The Circular Economy Institute (CEI)

The CEI was created in 2016 and operates a base of experts offering training on the circular economy and on Circular Economy Clubs, of which there are 280 across the globe.
The Institute's mission is to promote the highest standards of practice in the circular economy field to build the strong leadership needed internationally to shift from linear to circular. The CEI also offers sector-specific workshops and webinars for companies, public authorities, and startups.

"The CEI offers three levels of certification: Basic, Specialist and Trainer. Managers come to learn the tenets of the circular economy so that they can infuse them into their businesses. The aim is to have circular economy specialists in every industry."

Dr David Greenfield,
Vice President of the Circular Economy Institute

EXPERT POSITION 11

Pedagogy: a key role for the waste management industry

"The recycling industry also has a responsibility to inform the required design of products for easier recycling and reuse, and for longer-lived products to reduce production and consumption.
Beyond their core activities, waste managers must teach design and manufacture and educate communities to make sure products can be reused, repaired and ultimately recycled with minimal energy."

Dr. Phil Purnell,
Professor of Materials and Structures in the School of Civil Engineering
University of Leeds

EXPERT POSITION 12

The Global Circular Economy Chair of ESSEC

Founded in 2021, the ESSEC Global Circular Economy Chair aims to train young generations so they can contribute to the circular transition of the industry.

"Looking forward, education and training of young generations will be key. The ESSEC Business School has therefore created the first international chair on circular economy – the Global Circular Economy Chair- to train students so they can act positively across the entire value chain of companies.
With new talents ready to take up the circular economy challenge, consistent regulations both at the European and the national level, and forward-looking firms, we can be confident in the fact that our industry will be able to succeed in the transformation toward a more circular economy."

Dr. Wilfried Sand-Zantman,
Academic Director
of the ESSEC Global Chair
of Circular Economy

Going forward to scale the circular transition: foward looking incentives and more investment needed

Adapt policy tools to better integrate circularity

PUSH FOR A PARADIGM SHIFT IN PUBLIC PROCUREMENT

Public procurement can be a very effective enabler of the transition toward a circular economy. Public contracts, by which public authorities purchase supplies, services and works, amount to approximately 14% of the European GDP (more than €2,000bn). Public authorities are the principal buyers in many sectors, including of course infrastructure sectors (energy, transport, waste management, social protection, health, education, etc.)[93].

In the EU, public procurement is subject to EU regulations to create a level playing field for businesses. Historically, public procurement has been governed by a "neutrality" principle, promoting free movement of services and competition as well as budgetary and financial considerations. However, this "neutrality" principle is giving way to **the use of public procurement to fulfill environmental, social and innovation policies.** The focus on price is being replaced by a global cost approach, which also considers the positive and negative externalities of products, services and works through their lifecycle. Circular practices should therefore be valued more under this approach.

This new approach materializes in general obligations as well as specific requirements. As an example, in France, which is one of the most advanced Member States, the Public Procurement Code now provides that "public procurement participates in achieving the objectives of sustainable development, in their economic, social and environmental dimensions". Public buyers shall have the obligation to take environmental aspects into consideration during the tender process and as a performance condition in 2026 and, for some sectors currently under discussion, even in 2024. With respect to circularity, more specifically, the Anti-waste and Circular Economy Law of February 10, 2020 has introduced an obligation for the State and local authorities to purchase goods that are reused or contain recycled materials, in proportions ranging from 20 to 100% depending on the type of product (office supplies, textile items, electronic devices, etc.).

Nevertheless, **there are still some issues to address to make these principles and obligations effective.** Public buyers may face legal uncertainties, as it is not always easy to define objective environmental criteria or to follow their implementation, and often face cultural and operational obstacles. Economic studies show that Green Public Procurement is hampered by the quest for minimum cost, the ignorance of sustainable purchasing, the complexity of evaluating bids, the lack of will on the part of managers/supervisors, the lack of political will, the resistance to change, the lack of external assistance, the increased risk of unsuccessful bids, etc.[94]

In order to make public procurement a powerful lever for the circular economy, it is therefore critical to accompany regulatory changes through information campaigns, training as well as designing specific tools to help public buyers assess the environmental and social value, in a lifecycle perspective (labels, scoring, etc.).

EXPERT POSITION 13

Public procurement and circularity

"Even if 55% of OECD countries are actually implementing green procurement, much needs to be done on circularity. There is no harmonized indicator or criteria measuring the level of circularity. Some targets or requirements have been established in respect of waste recycling or certain types of material use but they fail to appropriately measure lifecycle impacts. They do not close the loop. Sometimes public buyers fear that including green and circular criteria in tenders will result in more expensive bids. Therefore, it is key to have a more comprehensive approach of "value" including green and circular criteria in addition to the price."

Dr. Oriana Romano,
Head of Unit
Water Governance
and Circular Economy at OECD

[93] European Commission, *Sustainable Europe Investment Plan European Green Deal Investment Plan*, 2020.
[94] F. Testa, F. Iraldo, M. Frey et T. Daddi, "What factors influence the uptake of GPP [green public procurement] practices ? New evidence from an Italian survey", *Ecological Economics*, 2012.

CASE STUDY 7

Vinci Autoroutes: road as a service as an innovation catalyzer for highway concession companies

Among infrastructure, road transport – responsible for around 20% of global CO_2 emissions – is both a participant and an onlooker in a linear economy, which is struggling to make the leap into the circular economy. Yet, from preserving natural capital to optimizing natural resources and reinforcing system efficiency, road operators have been taking part in the general move toward a more circular world. The "road-as-a-service" model approached by Vinci Autoroutes is, for instance, a visionary approach aimed at enhancing circularity in the transport sector. The focus is on utilizing roads not only as mere infrastructure but as dynamic platforms that offer additional value and services.

A prime example of this concept is in freight transport, where the advent of electric trucks is transforming the industry. To address the need for larger batteries to ensure sufficient autonomy, after winning a tender, Vinci Autoroutes is conducting an experiment of "electric motorway": instead of relying solely on charging stations, the road itself becomes an energy provider, charging trucks while they are in motion. This innovation could significantly reduce the size of truck batteries, thereby curbing the demand for lithium and cobalt, reducing costs, and contributing to zero-carbon targets by 2050.

The company is experimenting with rail and induction technologies, which could also be adapted for light vehicles. The implications of such a development would be far-reaching, revolutionizing battery usage and promoting a circular economy.

The envisioned infrastructure would not only deliver energy to vehicles but would also generate it with large solar farms, forming a fully integrated circular economy service.

"The infrastructure can have a major role far beyond the road itself with the proper use and equipment, for instance in freight transport. In the years to come, electric trucks should constitute the main decarbonized vehicle to carry the freight on motorways. This technology requires large batteries to ensure sufficient autonomy. Building an electric road infrastructure can help in this matter: instead of having a truck that is charging its energy at a charging station, then driving for a few hundred kilometers and having to charge again in another charging unit, we are working on a road that can provide energy while the truck is moving. So, the energy will fill up the battery – which can be smaller – and provide the sufficient momentum so that the truck can drive."

Christophe Hug,
Deputy CEO of Vinci Autoroutes

[95] Ademe, *Study of a waste performance contract to reduce the production of household and business waste*, 2018.
[96] Grand Montauban Communauté d'Agglomération and SUEZ sign France's first performance contract designed by ADEME for the collection of household and similar waste and the management of waste and recycling centers. The-year contract, known as the Contrat de Performance Déchets Ménagers et Assimilés (CPDMA), is a first in France. Created and supported by ADEME, the CPDMA aims to integrate prevention, recycling and lifestyle improvement objectives beyond waste collection alone.
[97] European Commission, *Sustainable Europe Investment Plan European Green Deal Investment Plan*, 2020
[98] P. d'Aprile et al. *How the European Union could achieve net-zero emissions at net-zero cost*, McKinsey & Company, 2020.
[99] Ellen MacArthur Foundation, *Financing the circular economy*, 2020.

PROMOTE MORE "CIRCULAR" CONTRACTUAL ARRANGEMENTS

Infrastructure contracts shall be designed to accelerate the transition toward the circular economy, by promoting "infrastructure as a service" and other circular business models and be more favorable to innovation.

First, contractual arrangements should incentivize infrastructure operators to provide services with the aim of making the most of limited resources.

Interestingly, **the concept of "infrastructure as a service"** is embedded in one of the most prominent contractual schemes in infrastructure sectors: concessions. These contracts indeed entail a global mission, favoring an integrated approach of projects over a long duration: the mission of the private partner generally includes financing, conception, construction of infrastructures or public works, as well as their maintenance and their operation, and delivering services to final users. The operator is thus encouraged **to favor an integrated approach to these missions** in a consistent manner and to optimize costs over the duration of the contract. **These contracts also often set out performance targets** the infrastructure operator has to comply with, to ensure the quality of delivery. Highway concessions provide a good example of this.

However, fully integrating a circular economy approach represents a challenge insofar as the remuneration of the infrastructure operator is based on the volume of resources consumed by final users. This requires **finding new contractual and financial arrangements** in order to decouple volumes from the operator's remuneration. It can be achieved through various mechanisms: performance-based remuneration, price adjustments based on quantities sold (landscape clauses) or conditional contract duration tied to the operator's revenue. Global performance contracts or availability-based contracts (instead of concessions) also favor this decoupling.

As an example, **performance contracts are emerging in the waste management sector.** These contracts rely on an integrated prevention & management solution, enabling stakeholders to cooperate, bypassing the volume-based logic on which the waste management business model is historically based and giving more value to prevention actions[95]. The first contract of this kind has been signed in France in 2021 between Grand Montauban and Suez for a seven year period beginning in 2022. It aims to integrate prevention, recycling and lifestyle improvement objectives beyond waste collection alone, with a goal of reducing waste production by 10% by 2028[96].

Second, to move faster toward the circular economy, **infrastructure contracts must be more favorable to innovation.** Public contracts are often too rigid. The promotion of innovation implies substantial changes in contractual practices before and after the conclusion of the contracts:

— Prior to the conclusion of the contract, and even before competition, public authorities should consult private operators in order to better define their needs and have a clear view of existing solutions (a practice called sourcing). They should also favor procedures enabling them to consult with candidates, so that they can make the most innovative proposals;

— During the performance of the contract, public authorities should make the most of the possibilities to modify their contracts in order to integrate innovations which help improve the quality of service and reward positive environmental impacts.

INVESTMENT: THE LIFEBLOOD OF THE CIRCULAR ECONOMY

The transition toward circular infrastructure requires massive investment. According to the European Commission, to achieve the goals set out at the European level by 2030, the overall **environmental sustainable investment gap can be estimated at between €100bn and €150bn per year** (while social investment needs amount to €142bn per year)[97]. Experts have estimated that reaching Net-Zero emissions by 2050 in the EU27 would require total capital expenditure of around €1 trillion per year in the period 2021-2050[98]. As far as the circular economy is concerned, as described in section 2 of this report, investment in new industrial facilities, waste and water management facilities or engineered industrial solutions such as CCUS will be key.

The investment community and the private sector will have a major role to play to meet this challenge. Between 2016 and 2020, there has been a tenfold increase in the number of private market funds, including venture capital, private equity and private debt, investing in circular economy activities (from 3 to 30)[99]. But there is still a long way to go. The rise of investment in the circular economy will therefore be supported by the critical role of ESG criteria in investment strategies, since the circular economy helps to deliver on ESG goals and manage associated risks – notably promoted by the EU Green Taxonomy (see section 1).

Business prospects and profitability are also a key driver of investing in the circular economy. According to the Ellen MacArthur Foundation, public equity funds with the circular economy as a sole or partial investment focus on average performed 5.0 percentage points better than their benchmarks in H1 2020.

Last, but not least, **investment in the circular economy needs more public support**. Public subsidies, tax incentives or other financial instruments (public guarantees, soft loans, equity, etc.) are essential to generate a training effect on the private sector in sectors which are considered risky or not profitable enough. While it is mostly focused on carbon emissions, the American Inflation Reduction Act (IRA) of 2022 contains USD 500bn in new spending and tax breaks, which are directed toward domestic manufacturing capacity, procurement of critical supplies, leading-edge technologies such as CCUS (such support goes with "Buy American" provisions). This has led other regions, and in particular the EU, to react by adapting its State aid rules, rely upon the Recovery and Resilience Facility's dedicated climate subsidies and adopt a Net-Zero Industry Act, which is currently under discussion.

EXPERT POSITION 14

Closing the circular investment gap

"The financial investment community needs to jump in to enhance the transition. Planning the future of construction is about aligning efforts and closing critical gaps. Despite the €11bn currently allocated to foster the transition to the circular economy through the Recovery and Resilience Facility – including €2bn for research and innovation toward the circular economy – the EU funding won't be sufficient. The Commission estimates that the investment gap for the transition to the circular economy is between €13bn and €28bn per year. That is why the private sector needs to step in and through the development of the EU Environmental Taxonomy, we have set out concrete criteria to guide private finance into circular economy investments."

Florian Flachenecker,
Policy Officer at
DG Environment
of the European
Commission

EXPERT POSITION 15

The role of venture capital in the circular transition

"In addition to industry and policymakers, investors have a unique and important role to play in guiding the allocation of societal resources to the right ventures with the greatest short- and long-term returns. Several of the most exciting circular technologies are still nascent."

David Greenfield,
Vice President of the
Circular Economy Institute

EXPERT POSITION 16

Expectations from industrials

"The US IRA constitutes a huge aspirator of industrial projects, with very strong incentives that must not be underestimated. In order to preserve our industry, the EU needs to help the whole transition rather than jumping right at the last step. For instance, CCUS has long been recognized in the US while there are not enough policy incentives at the EU level at this stage. Yet, we are going to need this carbon capture and work on recycling the CO_2 into H_2 to produce, for instance, efuel."

Gabrielle Gauthey,
Senior Vice President
for European Public Affairs
TotalEnergies

BUILD "CIRCULAR CITIES" TO SEAL THE DEAL

Key takeaways

→ Considering the ongoing urbanization wave, which should lead to 80% of people living in cities by 2050, the transformation of the way we design, build, operate and govern infrastructure in urban areas will be a key trigger of success or failure of the circular transition.

→ As epicenters of innovation, infrastructure, investment and culture, urban hubs are where circularity can get scaled up: cities can be seen as circular cradles in which circular solutions are developed, and as circular catalysts since city authorities can effectively drive the transition.

→ Circular cities of the future will be multifunctional embedding the principles of a circular economy across all its functions, establishing an urban system based on low-carbon, restorative (even regenerative) and inclusive infrastructures.

→ Building circular cities requires a systemic approach engaging all stakeholders – policymakers, elected officials, industrials, end-users – and can rely on digital technologies, smart urban planning and circular public procurement.

Urban areas, where it gets tricky... and scalable

Cities: the key trigger of the circular transition

WHERE THE CHALLENGE GETS REAL

Given that 80% of the global population will live in urban areas by 2050, cities will be the key triggers of the success or failure of the circular revolution. Cities have traditionally functioned within a global economic framework that relies on a linear model of resource consumption — where resources are extracted, used, and discarded. The urban economy mirrors and amplifies the challenges of this model: as of today, **cities consume 60 – 80% of natural resources globally, produce 50% of global waste and 75% of carbon emissions**[100].

In this context, missed opportunities to develop circular infrastructure will likely **lock cities into non-sustainable material management pathways** and deprive citizens of the future opportunities brought by the circular transition. A quantitative analysis of global resource requirements carried out by the International Resource Panel (IRP) estimates that under business-as-usual circumstances material consumption by the world's cities will grow from 40 bn tons in 2010 to about 90 bn tons by 2050.

The characteristics of urban areas and infrastructure makes the task even harder, as they concentrate a series of systemic inefficiencies and imbalances (Figure 24):

— **Demand for infrastructure** is expected to rise as approximately 50% of the urban environment needed by 2050 is not yet built: urban land is estimated to grow from about 1.1 mn to 3.6 mn km² by 2100, representing roughly 1.8 to 5.9 times the global total urban area occupied in the year 2000 (0.6 mn km²)[101];

— **Infrastructures in cities are interconnected**, which requires to align stakeholders (businesses, public sector, knowledge institutes, citizens, and communities) with sometimes conflicting interests toward a common goal;

— **Urban infrastructures are constrained** by space, which compels to maximize spatial efficiency and limit urban sprawl;

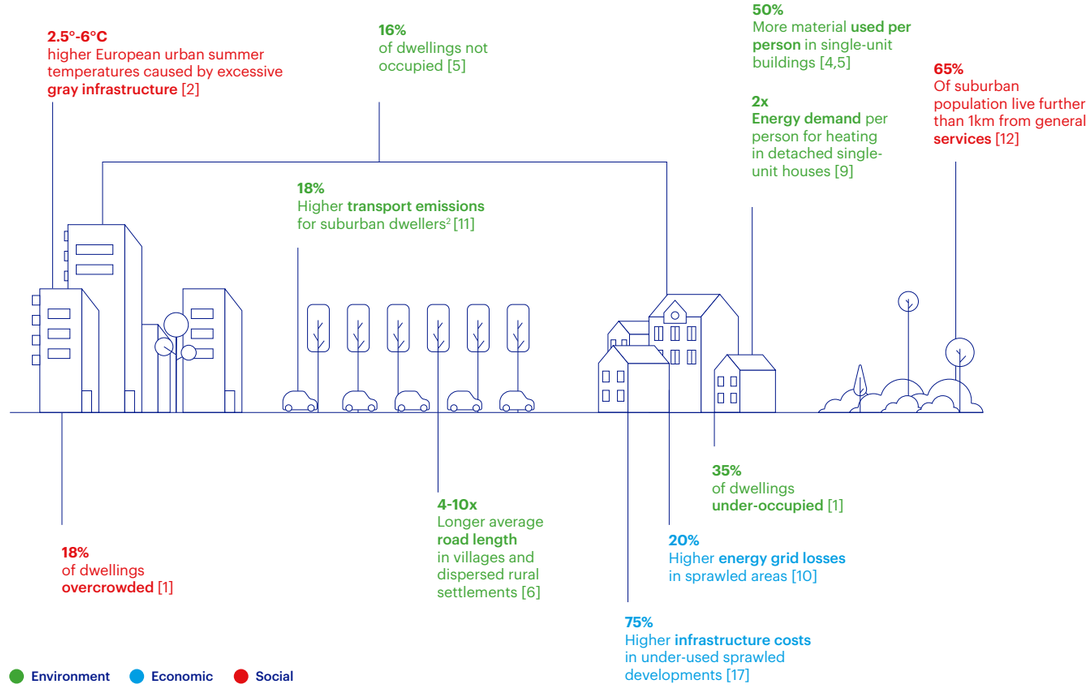
— **Cities are prone to systemic risk in diverse forms**, such as access to energy and water pollution but also catastrophic events such as storms and flooding[102].

[100] Ellen MacArthur Foundation, Cities and circular economy.
[101] J. Gao, and B.C. O'Neill, "Mapping global urban land for the 21st century with data-driven simulations and Shared Socioeconomic Pathways", *Nature Communication*, 2020.
[102] A. Wijkman, "Circular Economy in Cities requires a Systems Approach", Background paper for an OECD/EC Workshop on July 5, 2019 within the workshop series "Managing environmental and energy transitions for regions and cities, 2019.

FIGURE 24

Urban areas: a concentration of systemic inefficiencies and imbalances

Sources: *Janez Potočnik*



Illustratrion of inefficiencies and imbalances in urban space use - illustrative only, usually not all challenges contained in one single city
Sources: [1] Eurostat, "Eurostat-European Statistics". [2] Intergovernmental Panel on Climate Change, "IPCC Sixth Assessment Report - Mitigation of Climate Change", 2022. [4] International Resource Panel, "Resource Efficiency and Climate Change : Material Efficiency Strategies for a Low-Carbon Future", 2020. [5] Eurostat, "Eurostat-European Statistics". [6] Lewis Dijkstra, Hugo Poelman, and Linde Ackermans, "ROAD TRANSPORT PERFORMANCE IN EUROPE", WP 01/2019 (European Commission, 2019). [9] London School of Economics and Political and EIFER, "Cities and Energy", London School of Economics and Political Science, 2014. [10] Johansson et al, Global Energy Assessment (GEA), 2012. [11] Munoz et al - The impact of urbanization on Austria's carbon footprint, 2020. [12] Kompil et al - Mapping accessibility to generic services in Europe: A market-potential based approach, 2019. [13] Mueller et al - Health impact assessment of cycling network expansions in European cities, 2018. [15] Gies et al - Parking standards as a streering instrument in urban and mobility planning, 2021. [16] Joint Research Centre (European Commission), "What Drives Car Use in Europe?", JRC Publications Repository, 2017. [17] Example Finland, excluding parking, based on Kurvinen & Saarti - "Urban Housing Density and Infrastrcture Costs", 2020.

EXPERT POSITION 17

Transforming infrastructure to reshape urban areas

"As urban populations are growing and people seek new ways of life, it is critical to redefine how we share urban space. Operators in the heart of cities manage infrastructure designed long ago. Are all these structures still useful? If not, how can we repurpose them? For instance, Paris has vast underground carparks equivalent to 14 Montparnasse towers. Many of these spaces are often unused or rarely occupied. We therefore need to find solutions that allow cities to rebuild autonomously: in this perspective, adopting a circular approach will be vital to transform existing infrastructure for new activities and foster sustainable urban evolution."

Sébastien Fraisse,
Chairman of Indigo Group

"TRANSFORMING" EXISTING INFRASTRUCTURES

In the transition toward a circular economy in urban contexts, **the transformation of existing infrastructure holds immense importance**. While building infrastructure in cities is getting harder due to limited space and constrained areas, adapting existing ones to meet modern needs is both critical and massively challenging considering changing expectations and standards. Transformation, retrofitting and repurposing existing structures yields notable reduction potential in terms of resource consumption and waste generation but **requires clear steps to implement a generic method** for circularization of cities:

— **Assess the circularity potential of dormant assets:** map and evaluate underutilized buildings, infrastructure, and capital equipment for possible repurposing to meet current needs;

— **Identify opportunities to reconnect unused assets with current demands:** repurpose assets in alignment with local needs and circular economy objectives;

— **Identify and engage relevant stakeholders:** establish connections across governments departments and non-government actors to extend asset lifespans effectively;

— **Develop maintenance plans and budgets for asset longevity:** properly planned and budgeted maintenance is crucial to prevent asset deterioration and extend their useful life. Execute maintenance tasks promptly to ensure optimal results[103].

By implementing these strategies and fostering collaboration, cities can successfully transition toward a circular economy, fostering sustainability and resilience for a better future.

Where most valuable circular opportunities are

CRADLES & FACILITATORS

Although cities are part of the overshoot problem, **they also embed massive "circular value" potential.** Cities can be seen as circular cradles in which circular solutions are developed, and as circular facilitators since city authorities can effectively drive the transition by defining a strategy and a roadmap, optimizing infrastructure and logistics networks, mobilizing key stakeholders, providing the relevant incentives, etc. (Figure 25).

Cities, owing to their **high concentration of resources, capital, data, and talent** within a relatively compact geographic area, are in an advantageous position to promote and facilitate the adoption of exemplary circular practices and to bolster the growth of innovative infrastructure-related business models. Densely populated cities operate in a resource-constrained environment where implementing circular practices can result in immediately visible benefits, such as cost savings in the private sector.Furthermore, physical proximity in cities makes them more agile and adaptative and eases the implementation of policy changes and pilot initiatives[104].

Overall, **the positive outcomes derived from the implementation of circular strategies could be huge:**

— By applying a circular city model, Europe's GDP could increase by 7%, with yearly savings of €600 bn, benefits of €1.8 tr each year, and the creation of 170,000 jobs by 2035[105];

— Carbon dioxide discharges could drop by 48% by 2030 and 83% by 2050[106] and raw material utilization can be decreased by 32% and 53%[107];

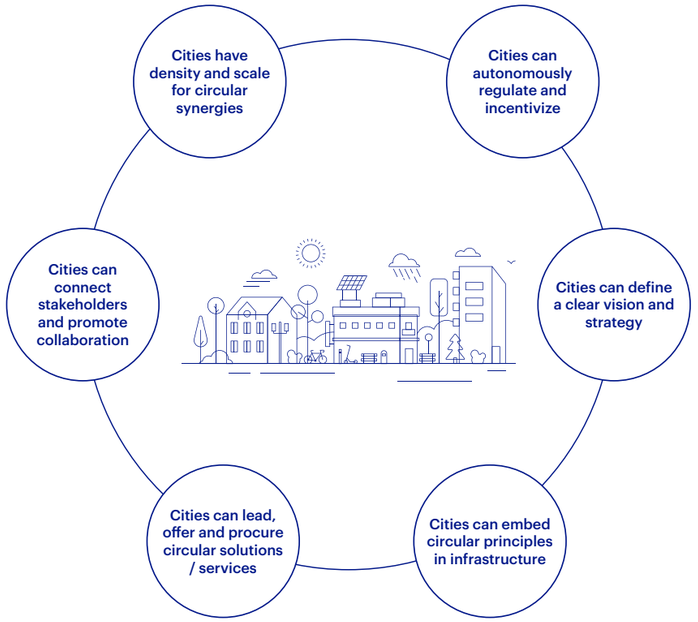
— Deep refurbishment can cut building-related energy consumption in Europe up to 80%, saving the EU over 30% of its total energy use (equivalent of 4 bn barrels annually)[108].

While circularity may appear quite complex to scale, **synergies can emerge between players** as cities are operating within a network of systems designed to eliminate or handle waste, circularize supply chains & materials, and build eco-friendly infrastructure to fit in urban ecosystems.

FIGURE 25

Cities: cradles and facilitators of the circular transition

Sources: *Altermind, European Investment Bank*



FOCUS 7

Urban mining: "value underground"

Urban mining refers to the process of extracting valuable resources and materials from the urban environment, including buildings, infrastructure, and waste streams. It involves recovering and reusing resources that have been previously utilized in cities, rather than relying solely on traditional mining methods that extract raw materials from nature. This concept is spreading rapidly to reduce the demand for virgin resources, decrease waste generation and minimize the environmental impact of waste extraction. Some examples include the recycling of construction and demolition waste, electronic waste, or the recovery of materials from sewage sludge but also urban agriculture to grow food in urban spaces such as rooftops or abandoned lots.

Zurich acted as a cradle and catalyst for an urban mining initiative using Cargo-trams and E-trams to recycle household waste. This transport-based circular innovation to recycle the 3,000 tons of garbage disposed illegally in the city. This service enables car-free residents to easily recycle electric appliances, glass, bulky goods, plastic bottles, and other waste. The recycling trams follow scheduled routes, operating on existing public transport lines year-round from Monday to Saturday with 11 pick-up sites.

[103] European Investment Bank et al., The 15 circular steps for cities, February 2022.
[104] World Economic Forum and PwC, *Circular Economy in Cities Evolving the model for a sustainable urban future*, 2018
[105] D. Bourguignon, *Closing the Loop: New Circular Economy Package; European Parliamentary Research Service*, 2016
[106] Ellen MacArthur Foundation, *Growth Within: A Circular Economy Vision for a Competitive Europe*, 2015.
[107] Ellen MacArthur Foundation, *Toward a Circular Economy: Business Rationale for an Accelerated Transition*, 2015.
[108] European Parliament, *Boosting building renovation: what potential and value for Europe?*, 2016.

LABS FOR CIRCULAR SOLUTIONS

Circular economy solutions are complex, but often **a few key changes or "nudges" can lead to a "virtuous circle"**. Cities possess a distinct advantage in moving toward a circular economy as they concentrate resources and can function as labs for innovations and experimentations. They can leverage their roles as innovation hubs, economic centers and accessible spaces to set an example of how to design out waste, regenerate natural systems and keep resources in use. For instance, Amsterdam has launched a Smart City's Circle Lab, an open innovation platform promoting collaboration and fostering innovation by helping translate Amsterdam's circular goals from theory into practice – while mobilizing other cities, businesses and citizens to "learn by doing".

EXPERT POSITION 18

Using digital technologies to scale the circular transition in cities

Future Cities Laboratory (FCL) is an inter-university collaboration between Switzerland and Singapore, led by the Singapore-ETH Centre (SEC). The center, established in 2010, aims to strengthen Singapore's and Switzerland's capacity to actively research, understand and respond to the challenges of global environmental sustainability. The current research phase of the FCL has been structured around three inter-disciplinary, problem-based research "scenarios" that link science, design and specific places. In this dynamic, the circularity of cities is seen as a keystone: in this regard, the Circular Future Cities (CFC) project brings together civil and environmental engineers, materials scientists, architects, urban planners and computer scientists, who will work closely together to develop a common modeling framework and digital platform to inform the design of sustainable housing.

"We need to extend the life of existing buildings; the most sustainable building is no building. If we do construct something we have to increase the use of sustainable and reuse materials. Transition needs to rely more on digital prefabrication methods, reducing waste and improving research management by collaborative and integrative approaches. Developing machine learning algorithms will help data sharing, creating the perfect matchmaking of needs between all stakeholders. In the CEA lab, we try to look at digital technologies that exist in other sectors and bring them to the construction sector to foster this transition from a linear to a circular economy. For e.g., when we talk about community involvement, we want to involve citizens in the decision-making process, to do so we use extended reality and strategy gaming so that we can have a discussion about the impact of the action we want to take with them."

Dr. Catherine de Wolf,
Assistant Professor of Circular Engineering for Architecture at the Swiss Federal Institute of Technology Zurich (ETH Zurich)

A glimpse into the future: circular cities by 2050

Circular city: low-carbon, livable and resilient

MULTIFUNCTIONAL CITIES

A circular city "embeds the principles of a circular economy across all its functions, establishing an urban system that is regenerative, accessible and abundant by design". Everything is operating within an interconnected network of systems that are designed to eliminate waste and pollution, circulate products and materials, and regenerate nature. According to the Ellen MacArthur Foundation[109], a circular city shall include:

— **A built environment that is designed in a modular and flexible manner**, sourcing healthy materials that improve the life quality of the residents, and minimizing virgin material use;

— **Energy systems that are resilient, renewable, localized**, distributed and allow effective energy use, reducing costs and having a positive impact on the environment;

— **An urban mobility system that is accessible, affordable, and effective;**

— **Production systems that encourage the creation of "local value loops".**

With **a shift toward "service models"**, cities have the opportunity to reduce energy and product demand by changing citizens' relationships to material ownership and consumption. Those service-based models, notably sharing infrastructure, can extend to a vast variety of applications (shared living spaces – as 40% of the year homes remain empty – and car use, etc.) **enhancing more sobriety and energy savings.**

Several cities have already taken the leap of circularity. In 2020, Amsterdam took a groundbreaking initiative by becoming the first city to commit to establishing a circular economy that aims to eliminate waste.

[109] Ellen MacArthur Foundation, "Circular cities: thriving, liveable, resilient", 2023.

CASE STUDY 8

Equans: the role of service providers in circular cities

A

As a provider of energy optimisation solutions and maintenance services, Equans offers sustainable solutions for electricity, heating, and cooling, with a strong emphasis on renewable energy sources. Through their innovative energy solutions, Equans prioritizes sustainability, resource optimization, and waste reduction, contributing to a greener, more sustainable future.

In Brussels, Equans partnered with BNP to outfit a new office on top of an old building with six levels of car parking. By installing smart heat pumps and two large tanks for hot and cool water on the 6th level of the underground car park, interseasonal storage has been organized, allowing to have almost free cooling during the summer and heat storage for most of the winter. This solution divided the energy consumption of the building by more than 10.

"In areas with relatively balanced energy needs throughout the year, we still consume significant energy for cooling and heating. However, by storing excess energy in the soil during summer, we can meet these requirements with a very efficient interseasonal storage system."

Jérôme Stubler,
CEO of Equans

By 2030, Amsterdam aims to reduce its reliance on new materials by half, and by 2050, the city plans to achieve full circularity. Consequently, Amsterdam initiated a series of pilot projects focused on recycling demolition waste and renovating old buildings and infrastructure to enhance material and energy efficiency. Bogotá is also a pioneer of the circular economy in South America: circular principles are at the core of its Climate Action Plan for the next three decades, encompassing various governance tools and initiatives such as eco-design and the utilization of recycled materials.

RESTORATIVE INFRASTRUCTURE: BASES OF CIRCULAR CITIES

According to the IPCC, more than 3.5bn people worldwide are highly vulnerable to multi-factorial climate impacts – particularly in major cities and developing countries. To mitigate the risks, circular economy can be a powerful lever for public authorities and operators ready to create restorative infrastructure, intended to make local systems more circular but also to **bring nature back into urban ecosystems** thus improving resilience and promoting more sustainable ecosystems[110]. Urban areas are well positioned to deploy those solutions and maximize their benefits through different channels:

— Applying circular design choices in urban areas can strengthen climate adaptability with modular flood defenses, retrofitted protection against extreme weather, or renovations;

— With biomimicry methods (i.e. design and production of materials, structures, and systems on the basis of biological entities and processes), **external facades can address anticipated climate risks** by absorbing nitrogen, sulphur dioxide, and particulates as well as preventing heat stress by providing a cooling effect;

— The collection, storage and use of rainwater (rain-proof gardens) and the reuse of gray water in "Sponge Cities" can act as umbrellas for cities in case of climate hazards, such as floods.

The next step, more prospective at this stage, relies on the development of **regenerative infrastructure**, i.e., infrastructure that has a net-positive impact on the climate and biodiversity (environment) and improves the long-term capabilities and well-being of communities (society).

FOCUS 8

Sponge cities in China

Sponge Cities is a revolutionary urban planning concept in China that was developed by Kongjian Yu (Peking University's College of Architecture) in response to the country's rapid urbanization and increasing vulnerability to floods and water scarcity. This innovative approach seeks to replace impermeable 'gray infrastructure' and engineering-based solutions like reservoirs, pipes and dams by green areas, flood lands, wetlands and meandering natural waterways. This sponge infrastructure allows the infiltration, retention and storage of rainwater, natural purification, and slowing down of water flows.

In 2013, the Chinese government launched a national "Sponge City" pilot program. This program selected 30 cities as demonstration projects for implementing water management and ecological restoration measures. The central government allocated substantial funds and policy support and there is now an obligation to implement sponge city elements in all cities with the goal to achieve 80% of spongy urban areas that recycle 70% of all rainwater by 2030[111].

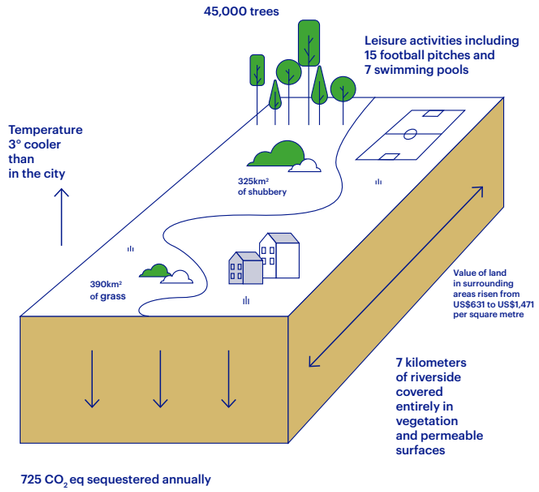
One example of this policy is the city of Wuhan where the "Sponge City" initiative has constructed 38.5 km² of 389 separate sponge projects like extensive permeable pavements and sidewalks throughout the city, or urban gardens. For example, the Yangtze River Beach Park spans over 7 km, with an extensive green area of 700,000 m² that includes 45,000 trees and rain gardens and provides flood protection, contributes to CO_2 absorption and has improved the local microclimate[112].

[110] E. Elobeid, "Bridging the adaptation gap: can the circular economy help?", Ellen MacArthur Foundation, June 2023.
[111] A. Walsh, "China transforming cities to stop flooding ", *DW*, April 2022.
[112] L. Oates, L. Dai, A. Sudmant, A. and A. Gouldson, *Building Climate Resilience and Water Security in Cities: Lessons from the sponge city of Wuhan, China*. Coalition for Urban Transitions, University of Leeds, 2020
[113] *Ibid.*
[114] R. Schjødt Larsen, *"Largest Beach Park Serves As Flood Defence"*, Global Opportunity Explorer, March 2019.

FIGURE 26

Award-winning example of sponge design: Yangtze River Beach Park[113] [114]

Sources: *Oates et al., 2020 ; Schjødt Larsen, 2019*



CASE STUDY 9

idverde: building restorative infrastructure to enhance resilience and adaptation in urban areas

idverde is Europe's leading provider of grounds maintenance services and landscape construction projects operating throughout the UK, France, and the Netherlands. idverde has expertise in professional open space management, landscape design and build, civil engineering, grounds maintenance, tree surgery, outdoor facilities management, biodiversity management, and waterways management.

With its 'Nature active' concept, idverde is integrating nature as an active asset to address climate change. idverde is invested in changing the view on urban green spaces from passive assets mainly used for aesthetics and wellbeing toward an active tool to adapt to climate change and make cities more resilient.

For example, sewage systems in most cities are old and not equipped for the heavy rainfalls caused by climate change. In contrast, green spaces like raingardens can absorb the water, thereby protecting a city's assets like sewage systems and reduce the need for more investment in infrastructure hence contributing to a more circular economy. Another example are green rooftops with soil and grass that can absorb heat in the summer and thereby reduce energy use in those buildings.

Following this approach, in its work for green spaces in community areas with the public sector, idverde includes measures to enhance biodiversity and promote nature restoration, pollinator-friendly plants and water-saving planters.

EXPERT POSITION 19

Activating green spaces for more circularity and resilience

"Activated green spaces have the potential to conserve water, addressing the growing realization of the critical balance between water consumption and availability even within urban areas. To achieve this, green spaces must no longer rely on potable water for maintenance. Instead, they should harvest rainwater for their upkeep or employ gray water and reclaimed water. By actively reducing water consumption in cities, these green spaces become essential contributors.

— With more than €1bn of annual revenues, idverde is Europe's leading provider of grounds maintenance services and landscape construction projects operating throughout the UK, France, the Netherlands, Denmark, Germany and Switzerland.

— For example, sewage networks in most cities are old and were never designed to deal with the new heavy rainfalls caused by climate change.

When activated, green spaces can absorb rainfalls and offer multiple benefits Traditional urban infrastructure, often ill-equipped to handle intense rainfall, requires costly expansion and renewal. In contrast, deploying permeable overground green spaces, including trees, gardens, and permeable pavements, protects sewers and assets from flooding and pollution. This circular approach not only safeguards against investment but also makes the economy more sustainable."

Olivier Brousse,
CEO of idverde

A systemic approach to succeed

URBAN PLANNING

As urban infrastructure systems and their operations are becoming highly interconnected and interdependent due to their complex and dynamic nature, it has become nearly impractical to isolate these systems and address issues within one system without affecting others[115]. The traditional silo-based approach of planning, designing, and operating infrastructure systems individually and in isolation potentially misses vast opportunities to make infrastructure more sustainable and resilient.

It is therefore important to **see the urban structure as a whole** – which requires more visionary, holistic planning. In this respect, spatial and land-use planning will be key to build multifunctional cities and the consideration of circular economy aspects in the **planning of unavoidable new land uses can help reduce the consumption of resources.** Densification in proximity to mass transit lines can serve as a strategy to prevent unnecessary expansion of paved areas and decrease the distances people need to travel, thereby leading to reduced emissions from traffic and fostering a more sustainable urban environment[116].

By incorporating circular economy principles from the outset of urban development, planners can establish a strong basis for urban mining in the future. This proactive approach will help create infrastructure that facilitates the efficient and effective reuse, collection, and redistribution of resources. It is projected that global urban areas could be reduced by approximately 14 mn hectares globally with the adoption of such circular economy measures[117].

This "systemic" approach can be achieved using digital tools, especially building information modeling (BIM). Indeed, some pioneer cities are experimenting intelligent modeling for city development to link urban planning and urban design with BIM and therefore accelerate smart planning and connectivity for more circular, livable, sustainable, and interconnected cities.

CIRCULAR PUBLIC PROCUREMENT IN CITIES

In cities, public procurement accounts for 15-20% of global GDP[118], and sub-national governments are responsible for more than 50% of procurement decisions in OECD countries[119]. City governments therefore have an important role in shaping local circular economies by applying circular economy principles and criteria to purchase products and services[120].

— The city of Lisbon has taken steps to implement circular economy principles in a structured way across the municipality in the areas of goods procurement and infrastructure by developing a Procurement Planning Platform (PPP);

— In Salvador's Climate Action Plan, the city has set its commitment to incorporating circular economy principles in its public procurement procedures. This involves assessing factors such as the proportion of biodegradable, recycled, or repurposed materials used, the presence of mechanisms for reverse logistics within companies, and the consideration of lifecycle costs associated with materials.

— While Phoenix remains early stage in the circular procurement journey, circular economy principles have been integrated into the citywide "Sustainable Purchasing Policy" (SPP).

To further the case, the Ellen MacArthur Foundation, with the European Circular Economy Stakeholder Platform, has established a **circular procurement framework** that provides municipal authorities with an overview of the "intervention points" to make more circular choices and engage in collaborative circular partnerships[121]. It assists cities in transitioning toward a more circular approach, spanning from the initial decision-making stage to the implementation and expansion phases. This support aims to promote circular public procurement by facilitating business innovation, pushing for regulatory changes, and fostering a culture of circularity.

STAKEHOLDER ENGAGEMENT AND BEHAVIORAL CHANGES

Building circular cities requires an inclusive approach, **engaging all stakeholders including policymakers, elected officials, industrials, and end-users.** The adoption of a stakeholder engagement strategy based on principles such as involvement, dialogue, and effective fulfillment of stakeholders' expectations is therefore becoming increasingly relevant. **Changes in behaviors are also critical:** circular economy calls for more willingness to share spaces, resources, and infrastructure instead of pursuing individual ownership, thus reducing overall resource consumption.

TABLE 2:

The circular transition of Copenhagen

Source: Altermind

ACTIONS	KEY LEVERS	RATIONALES	TOOLS	EXAMPLE IN COPENHAGEN
Urban planning and infrastructures	Incorporate circular design principles into infrastructure projects with a holistic and integrated perspective	Cities have the authority over urban planning, energy and material use, infrastructure, building and construction, mobility and transport, and waste management	Modular infrastructures, the creation of networks for circular procurement, sustainable supply chains, transforming existing infrastructures	New method of waste collection with electric vehicles, testing of autonomous and small electric vehicles
Community engagement	Develop and diffuse circularity enabling knowledge	Cities benefit from high level of public awareness and engagement	Joint development of circular solutions, workshops for residents	Waste sorting information campaigns to improve the collection of household waste for recycling
Innovation and technology	Create a dynamic environment and provide a fertile ground for innovation and accelerate the transition	Cities are innovation hubs that can pool resources to lead societal transformation	Bring together start up, venture capitals and talents to develop and scale innovative circular solutions or business models	Establishment of a dedicated innovation platform, providing a test facility for a robot-based sorting of plastics
Collaboration and partnerships	Leverage on collective knowledge, resources, and expertise	Cities benefit from a variety of businesses and industries that can rethink their relationships to embrace circular principles and close the loop	Public-private partnerships, academia & research institutions, NGOs, International collaboration	Public-private partnership on the repair and sale of electronics from recycling centers

[115] P.A. Jayasinghe, S. Derrible, L. Kattan, "Interdependencies between Urban Transport, Water, and Solid Waste Infrastructure Systems", *Infrastructures*, 2023.
[116] European Environment Agency, ETC CE Report 2023/7, Circular Economy and Biodiversity, June 2023.
[117] *Ibid.*
[118] European Commission, "International public procurement", 2023.
[119] OECD, "Size of public procurement", 2021.
[120] Ellen MacArthur Foundation, "Circular public procurement: a framework for cities", 2022.
[121] Ellen MacArthur Foundation, "Circular public procurement: a framework for cities", 2022.

VAUBAN IP'S CIRCULAR STRATEGY: FIRST CONCLUSIONS FROM THE RESEARCH

Key takeaways

→ Vauban IP is committed to developing a circular approach framework in response to evolving infrastructure challenges. This framework, under development, aligns with circular economy principles, offering guidance rooted in best practices and KPIs.

→ In the pre-investment phase, Vauban IP shall initiate this journey by identifying projects that align with circular economy principles, focusing on waste and water management activities, as well as waste to energy facilities. This phase would assess eco-label certifications, zero waste commitments, and circularity potential.

→ Post-investment, Vauban IP aims to (i) establish tailored indicators to track resource efficiency, waste management potential, and economic impacts; (ii) provide external circular economy support to portfolio assets; and (iii) facilitate peer collaboration and engage circular industry associations among portfolio companies.

Pre-investment phase — Apply Vauban IP's circular approach framework

In the ever-evolving landscape of our industry, it is imperative that Vauban IP stays ahead of the curve, adapting our strategies and methodologies to address emerging challenges linked to circularity effectively.

Over the course of the upcoming year, our aim is to develop a robust and adaptable framework that aligns with the unique intricacies of Vauban IP's field and circular economy. This set of criteria will serve as a compass, helping Vauban IP navigate and ensuring that our decision-making process is both informed and focused on circular economy core principles. It will encompass a holistic perspective, drawing from the best practices, industry insights, and KPIs, ultimately leading to a more circular and sustainable approach.

The propositions presented in the following sections are, at this stage, paths awaiting further exploration and formalization. They are signposts marking the direction Vauban IP intends to pursue during our journey to framework development. These propositions are not cast in stone; rather, they are the initial stepping stones toward a refined, evidence-based strategy that will empower Vauban IP to meet the challenges and opportunities of the infrastructure industry and circular economy.

Implement a circular approach at the inception of investment cycle

In the initial assessment phase, Vauban IP will focus on identifying projects that could align with circular economy principles and pinpoint specific areas where Vauban IP could establish a strategic presence, in particular in waste and water management activities, as well as waste to energy facilities.

During this evaluation, Vauban IP's strategy consists in flagging assets with high circularity potential and risks, at the earliest screening stage:

— Highlighting best practices, recognizing eco-label certifications and assessing companies' communication on their commitment to achieving zero waste targets.

— Spotting wasteful construction practices, non-sustainable transportation infrastructure, habitat destruction and infrastructure obsolescence.

Conduct thorough assessments and due diligence with sustainable and circular criteria

For the due diligence phase, Vauban IP will design a framework/audit to evaluate the impact of the project through a short Life Cycle Assessment, notably for greenfield projects. Relying on experts, this process will integrate a series of key criteria:

— How does the project **incorporate sustainable and recycled materials** in its construction or operation?

— Is there a plan for **efficient resource use,** such as reducing materials waste, energy consumption, or water use, throughout the project's life cycle?

— Does the project **consider the potential for reuse, repurposing**, or **recycling** of materials and components at the end of their life? How does the project promote circular supply chain practices, such as **sharing or reusing resources** within the project or its ecosystem?

— Are there measures in place to **minimize environmental impacts**, such as emissions, pollution, or habitat disruption, associated with the project's construction and operation?

Enforce circular economy commitments

Vauban IP intends to enforce circular economy commitments in the closing phase, in order to benefit from governance rights, ensuring that project developers are committed to upholding circular economy principles and share the objective to integrate circular economy clauses in their relevant contracts.

These governance rights aim to:

— Recall explicitly to the management of the investee companies, the core tenets of circular economy principles.

— Participate (through committees) in the definition of key terms related to circular economy principles to ensure clarity and alignment with the intended objective;

— Ensure that the management of project developers is committed by a set of actions, notably: integrating an R-ladder strategy; reducing material consumption; minimizing waste generation; maximizing the use of recycled materials; including review clauses and anticipating future stages of contract re-evaluation to ensure circular economy commitments remain relevant and effective;

— Define key performance indicators (KPIs) related to these circular economy objectives to be reached by the project developers.

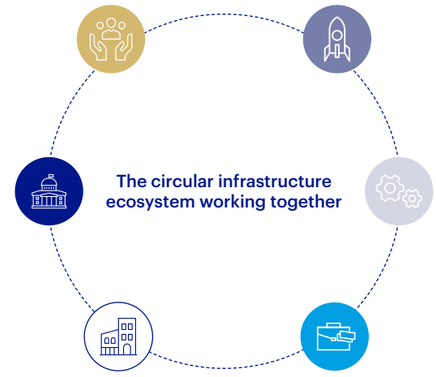
—Insert related KPIs in top management compensation.

On their side, investors should consider financial incentives such as grants, subsidies, or preferential terms to projects that demonstrate innovative circular economy practices. Conversely, measures should be defined in case the specified targets are not met.

FIGURE 27

A multistakeholder and collaborative approach to accelerate the circular transition of infrastructure

Sources: *Altermind*



CIVIL SOCIETY AND END-USERS

Push for a bottom-up change

- Spread circular awareness with NGOs
- Adopt more circular and sober behaviors in everyday life

PUBLIC POLICYMAKERS

Set up the right circular incentives

- Make regulations consistent and comprehensive, beyond waste management
- Facilitate the development of the "innovation ecosystem"
- Respond to industrial expectations
- Guide the financial community toward more circular investments (EU Taxonomy)
- Create more circular contractual options

START UP ECOSYSTEM

Develop powerful catalysts for the industry

- Develop circular innovation *(AI, modular materials, etc.)*
- Participate actively in the innovation ecosystem

INFRASTRUCTURE INVESTORS

Implement circularity for and in infrastructure

- Look for industry collaboration
- Transform internal processes
- Implement more circular business models, including track & trace, modular design, service-oriented offers, shared infrastructure
- Discuss with policymakers regarding expectations

URBAN PUBLIC AUTHORITIES

Facilitate the emergence of *"circular cities"*

- Integrate circular criteria, in cities public procurement
- Focus urban planning on circular infrastructure
- Adopt digital technologies in urban planning (BIM)
- Promote "restorative" urban areas

INVESTORS

Finance and guide the circular transition

- Invest in infrastructure for circularity (waste and water management)
- Push for more circular practices in asset portfolios
- Integrate circular criteria in investment strategies
- Support the development of the "innovation ecosystem"

Post-investment phase — Enhance circular practices and initiatives

Adapt monitoring and performance evaluation to circularity

In the monitoring phase, the prerequisite is to establish a comprehensive set of KPIs that are applicable across all projects, while also tailoring specific KPIs to individual sectors or projects.

For some projects, accurate targets will be directly linked to the objectives outlined in their respective contracts. In cases involving tangible assets, a thorough review of potential impacts and opportunities shall be conducted, and if necessary, an audit shall ensure compliance with circular economy principles and goals.

A non-exhaustive list of areas to assess through these KPIs could include:

— KPIs related to **resource efficiency;**

— KPIs focused on **waste management;**

— Evaluation of **supply chain** and local sourcing practices;

— Analysis of cost savings and the **economic impact of circular economy initiatives.**

By consistently monitoring these KPIs, it becomes possible to track progress, pinpoint areas for improvement, and ensure the effective integration of circular economy principles into the ongoing operations of the projects.

Support circular economy engagement for continuous improvement

In the pursuit of continuous improvement, it is essential **to provide portfolio companies with the necessary support to advance their efforts in addressing circular economy challenges:**

— **Keep a heightened awareness** through various means, including organizing webinars and workshops, faciliating access to relevant reports, and conducting case studies;

— **Propose external support from circular economy consultants to conduct audits,** deliver training programs, and develop strategic roadmaps for circular economy initiatives;

— **Review circular economy goals** at least annually with portfolio companies;

— **Maintain open and regular communication** with portfolio companies at Board level;

— **Foster innovation and development** by financing initiatives and action plans.

Collaborate with peers

In the pursuit of promoting knowledge sharing and collaboration in the domain of circular economy, several strategies should be employed to share experience:

— **Promote collaboration with peers** by facilitating networking opportunities, organize events or establish platforms where these companies can connect and work together on circular economy initiatives;

— **Integrate industry associations** that are aligned with circular economy principles. These associations can provide valuable resources, guidelines, and connections to further support portfolio companies in their circular economy endeavors;

— **Recognize best practices** of portfolio companies that excel in implementing circular economy principles.

FOCUS 9

The Circle Economy

Since 2023, Vauban IP has been supporting the Circle Economy – a global impact organization with an international team of passionate experts based in Amsterdam. The practical and scalable approach of the Circle Economy aims at empowering decision-makers from the public and private sectors to develop and implement circular economy strategies and business models, by combining research, data, and digital tools for the greater good. The Circle Economy notably publishes every year a best-in-class report called The "Circularity Gap Report", which measures the level of circularity (see section 1).

Among the organization's initiatives, the Circle Economy's Cities Programme accelerates the transition toward circular cities throughout five core services:

- **Scan circular innovation process that identifies opportunities to foster a circular economy and presents practical and scalable strategies to begin implementation**
- **Implement circular business solutions by providing tools, capacity building modules, best practices and on the ground support**
- **Measure and monitor progress toward achieving the cities environmental, economic and societal policy targets**
- **Scale circular practices by creating an open-access digital platform with tools and gauges to support and empower them to accelerate the circular transition**
- **Initiate thought leading projects and programmes to drive the transition toward a circular economy.**

APPENDIX 1

BIOGRAPHIES OF EXPERTS

DR. CATHERINE DE WOLF
Dr. Catherine De Wolf is Assistant Professor and Director of the Chair of Circular Engineering for Architecture (CEA) at ETH Zurich. Her work explores digital innovations such as reality capture and AI to advance the built environment toward a circular economy. She has a dual background in civil engineering and architecture from Brussels and obtained her PhD at MIT. She continuously applies her research and teaching on circular construction to renowned projects, such as the reuse of materials like glass from the Centre Pompidou in Paris (Elioth) and timber from the Huber pavilions in Zurich (Baubüro in situ). Catherine actively collaborates with both government entities like the European Commission and engineering design offices such as Arup. Throughout her career, she has gained international experience working at institutions like the University of Cambridge, TU Delft, EPFL, Nanjing University, Kuwait University, and the African Urban Metabolism Network. She is on the steering committee of the Centre for Augmented Computational Design in Architecture, Engineering and Construction (Design++) as well as a faculty at the AI Center, EMPA, the Future Cities Lab, and the National Centre of Competence in Research on Digital Fabrication (DFAB).

DR. PAUL EKINS
Dr. Paul Ekins is Professor of Resources and Environmental Policy at University College London and previously co-directed the UK Energy Research Centre from 2004 to 2019. He was a member of the European Resource Efficiency Platform, and is a member of the UN Environment Programme's (UNEP) International Resource Panel, leading on its report on resource efficiency for the G7. His work has repeatedly concluded that, with strong and appropriate policy, environmental sustainability and economic growth are compatible.
In 1994 he received UNEP's Global 500 Award.

DR. FLORIAN FLACHENECKER
Dr. Florian Flachenecker is a Policy Officer in the Directorate-General for Environment at the European Commission, working on the circular economy and in particular on the Waste Framework Directive. Florian is also an Honorary Lecturer at University College London. Previously, he worked in the Recovery and Resilience Task Force of the Secretariat-General that directly reports to the European Commission President Ursula Von Der Leyen on the design and implementation of the green transition under the Facility. Florian started his career at the European Commission at the Joint Research Centre researching the effects of environmental innovations. Before joining the European Commission, Florian was an Economist at the Organization for Economic Co-operation and Development (OECD) developing and harmonizing environmental data and policy. Florian holds a PhD in Economics from University College London, an MA in Economics from the College of Europe and a BSc in Economics from the University of Mannheim.

DR. DAVID GREENFIELD
Dr. David Greenfield is a recognized circular economy expert, having been involved in resource and waste management policy making at local, regional and government levels in his early career, to developing circular economy businesses such as SOENECS and Tech-Takeback, that demonstrate the possibilities of circularity in the last decade. David is author of many circular reports and papers and is a regular speaker at a diverse events and conferences. In September 2022, David co-founded etsaW Ventures, a venture studio that accelerates circular material and waste innovation into game changing impact. Since 2020 David has been Vice President of the Circular Economy Institute (CEI) and Circular Economy Club (CEC) responsible for External Affairs. In September 2021, David was appointed as Professor of Circular Economy at the University of Brighton to lecture and work with academics to incorporate circular economy into the curriculum. In June 2023, David was elected by the membership to be Junior Vice President of the CIWM, this is a four-year appointment and will culminate in David becoming President in 2025.

MARTIJN LOPES CARDOZO
Martijn Lopes Cardozo is a serial entrepreneur with successful ventures in software, mobile, and digital media in California. As the CEO of Black Bear between 2014 and 2019, he led a circular economy company that extracts valuable materials from end-of-life tires. Martijn was also board member of Parkbee, an innovative digital parking lot operator, between 2014 and 2021. Today, he is an entrepreneur-in-residence with YES!Delft and the CEO of Circle Economy, a not-for-profit that offers practical and scalable solutions to accelerate the Circular Economy. Martijn holds an MSc in Applied Physics from TU Delft and an MBA from Harvard Business School.

DR. JANEZ POTOČNIK
Dr. Janez Potočnik is an economist and a Slovenian politician who served as European Commissioner for Environment from 2009 until 2014, which resulted in the adoption of the first European Circular Economy Package. He currently acts as co-chair of the International Resource Panel (IRP) at the United Nations Development Program (UNEP), a forum of scientists and experts working on natural resources management. For his visionary contributions and leadership, he has received many awards such as the Champion of the Earth by the UNEP or the Twelve Stars for the Environment Award by the European Environmental Bureau (EEB). Dr. Janez Potočnik holds a Ph.D. in Macroeconomics from the University of Ljubljana's Faculty of Economics.

DR. PHIL PURNELL
Dr. Phil Purnell is a Professor of Materials and Structures in the School of Civil Engineering, University of Leeds, and Deputy Head of the School of Civil Engineering. From a background in concrete technologies, Phil Purnell has developed new methods that enable the analysis of the whole lifecycle of resource flows. His research includes the role of robots in infrastructure, low-carbon action plans for infrastructure and alternative finance mechanisms.

DR. ORIANA ROMANO
Dr. Oriana Romano is the Head of Unit, Water Governance, Blue and Circular Economy, Urban Policies, and Sustainable Development Division of the OECD Centre for Entrepreneurship, SMEs, Regions and Cities. She leads the OECD Water Governance Programme, which she joined in 2013, as well as the OECD Programme on Circular Economy in Cities and Regions, which she created in 2018. Before joining the OECD, she was a lecturer in Environmental Economics at the "Centre for International Business and Sustainability" (CIBS), London Metropolitan University and the Department of Social Science of the University "L'Orientale", Naples, Italy. She holds a Ph.D. in "Institution, Economics and Law of Public Services".

PIERRE-EMMANUEL SAINT-ESPRIT
Pierre-Emmanuel Saint-Esprit co-founded ZACK, a startup dedicated to giving a second life to unsold, used, and unused electronic products from businesses, fighting against waste. ZACK became a subsidiary of the Manutan Group in February 2022, where Pierre-Emmanuel now leads circular economy initiatives. He is also the founder and executive director of the ESSEC Global Circular Economy Chair and president of the Club des Entrepreneurs Alumni at ESSEC. With a background from ESSEC and the University of California, Berkeley, he is considered a pioneer in the field and actively engages in discussions on circular economy challenges and progress in France.

DR. WILFRIED SAND-ZANTMAN
Dr. Wilfried Sand-Zantman is professor of Economics at ESSEC Business School where he heads the Economics Department and a research associate at the Toulouse School of Economics. He holds a Master in Statistics and Economics from ENSAE and a Ph.D. in economics from the University of Toulouse. His research interests include industrial economics, market regulation and, more generally, information economics. His articles have been published in leading international academic journals such as the Journal of European Economic Association, the Journal of Law, Economics and Organization, Management Science and the Rand Journal of Economics. Wilfried is a former Board member of the Autorité Nationale des Jeux and gave several lectures on regulation at the Conseil d'Etat and at the Autorité de Régulation des Transports. He was also involved in consulting and executive education for several firms as EDF, Orange, SFR and Telefónica. With Altermind, Wilfried has been working on leading competition and regulation cases.

BENOÎT THIRION
Benoît Thirion has joined Hoche Avocats as a Partner in 2023 to head the Public Law practice. Benoît practiced law for 8 years in the Public Law departments of Hogan Lovells (2010-2013) and Clifford Chance (2013-2017). From 2017 to 2023, he was a partner in the Infrastructure and Services practice of Altermind, a strategy consulting firm. Benoît advises public and private clients on all aspects of public law, in respect of strategy definition, project implementation and litigation. He specialises in public contract law, public sector law, regulatory law and public competition law. He is senior advisor at Altermind.

APPENDIX 2

GLOSSARY

AI	**Artificial Intelligence**
BIM	Building Information Modeling
CAD	**Computer-Aided Design**
CCUS	Carbon Capture, Utilization and Storage
EPR	**Extended Producer Responsibility**
ESG	Environmental, Social and Corporate Governance
EU	**European Union**
GDP	Gross Domestic Product
GHG	**Greenhouse Gases**
GSMA	Global System for Mobile Communications
IEA	**International Energy Agency**
IoT	Internet of Things
IPCC	**Intergovernmental Panel on Climate Change**
IRP	International Resource Panel
ISWA	**International Solid Waste Association**
KPI	Key Performance Indicator
OECD	**Organization for Economic Co-operation and Development**
SPP	Sustainable Purchasing Policy
WEF	**World Economic Forum**
USD	United States Dollar
USEPA	**United States Environmental Protection Agency**

APPENDIX 3

MAIN BIBLIOGRAPHIC REFERENCES

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APPENDIX 4

LIST OF FIGURES, EXPERT POSITIONS, FOCUS, CASE STUDIES AND TABLES

FIGURES

EXPERT POSITIONS

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