The circular economy: an opportunity for the buildings and construction sector

Starting points for real-world projects

Current trends and recommendations – white paper

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Preface

The combination of global population growth and rapid urbanisation is resulting in a large and ever-increasing number of construction projects. By 2050, 70% of all people in the world will be living in urban areas. By 2070, the three largest cities in the world will be located in Africa. The buildings sector plays a key role in economic growth, but it also has a significant impact on the environment through soil sealing, resource consumption and high energy requirements. The buildings and construction sector accounts for 38% of all global greenhouse gas (GHG) emissions and over 40% of primary resource consumption.

Simply minimising GHG emissions or energy consumption is not enough to secure a liveable future, ensure a supply of materials and establish resilient societies. Adopting the principles of the circular economy and developing buildings that are designed to have a long lifespan and be suitable for flexible use is therefore becoming a matter of increasing importance in the sector.

Awareness of sustainability matters is increasing, not just at company level but also among governments. The buildings and construction industry is a key sector in the EU's Circular Economy Action Plan (2020) and the EU Taxonomy (4th environmental objective). Now is therefore the time for the sector to get to grips with approaches to the circular economy and to take them as an opportunity.

Companies need to identify and address their own areas of action, both to play their part in creating more sustainable communities and to enable efficiency gains throughout the entire life cycle of buildings.

This white paper aims to draw your attention to current trends and challenges, identify potential starting points in the value chain and use practical examples to illustrate their potential. We then take a look at various areas of action, with specific recommendations for companies that can help you to grasp the opportunities presented by the circular economy and embed appropriate approaches within your sustainability strategy.

We hope you have an inspiring read!

Emanuel Chibesakunda
Partner, Sustainability Services, PwC

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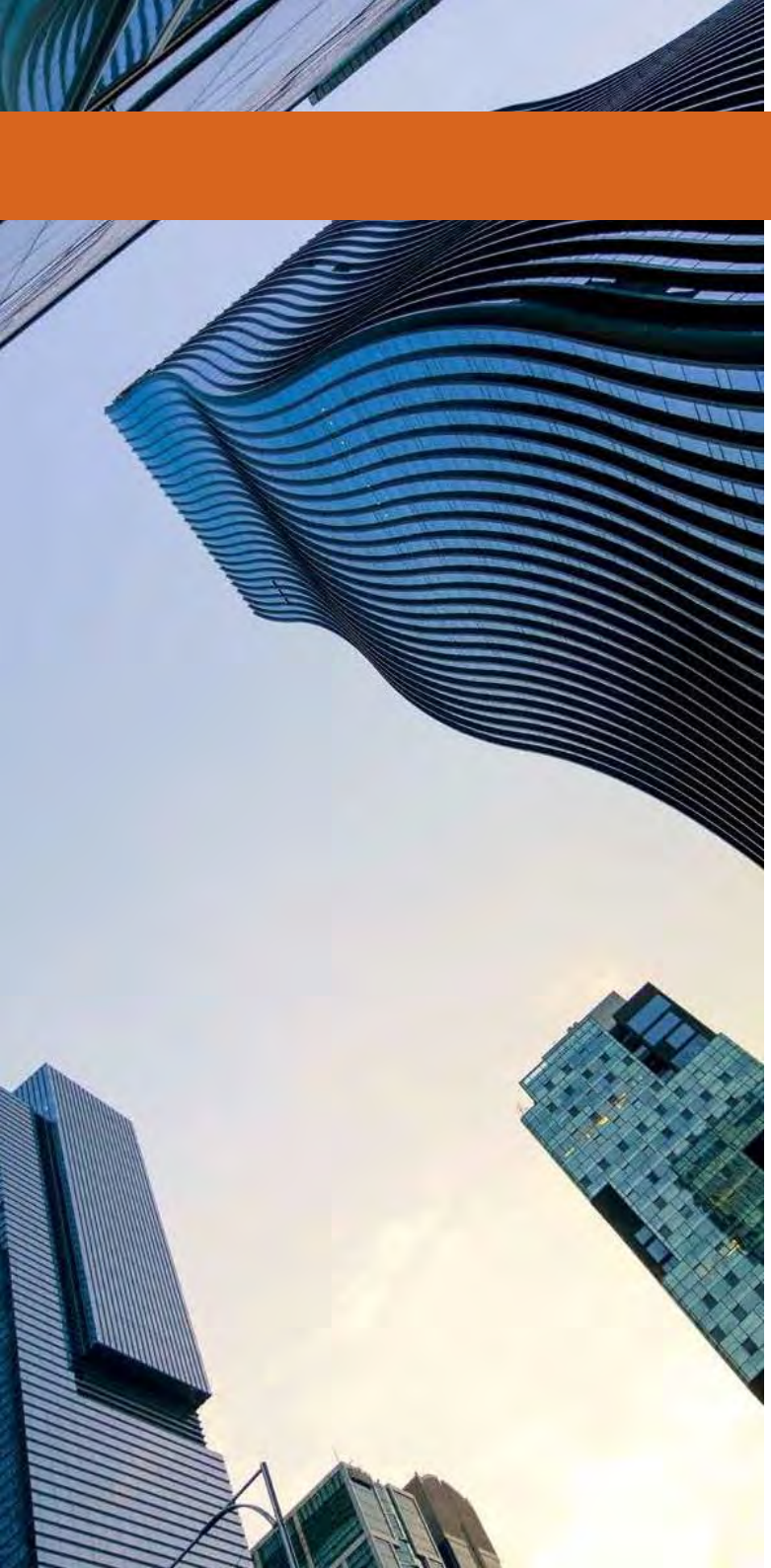
> A circular economy is based on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems.
>
> **Definition from the Ellen MacArthur Foundation**



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Overarching industry trends

- Wide-ranging use of digital technology and emergence of networked “smart cities”
- Prefabricated and modular buildings
- “Green” buildings
- Challenges due to shortages of materials
- Living, renewable building materials
- “Circulatable” buildings

Circular economy approaches in the sector

- Planning and designing buildings in line with circular principles
- Sustainable extraction and procurement of materials, use of reprocessed and biobased materials for new-builds
- Optimising and extending the usage phase of buildings
- Recovering and processing construction waste, components and materials for circular use
- Using digital technology to create transparency and ensure efficient use of materials throughout the life cycle of a building

Challenges to implementation

- High level of complexity (characteristics of recycled materials, differences in life cycles and ownership)
- Lack of efficient technologies for data management/processing and recycling
- High costs of switching to and procuring more sustainable alternatives
- Lack of confidence and knowledge within the industry and among clients
- Insufficient political commitment and funding systems
- Many existing properties are unsuitable for conversion (e.g. ceiling heights)
- No standardised database to present environmental criteria in a measurable way

Areas of action and recommendations for real-world projects →

- Increase measurability and transparency (e.g. using digital technology, life cycle assessments (LCAs))
- Create an effective circular system
- Carbon capture and storage in buildings for climate neutrality (e.g. timber housing)
- CO_2 budget for building portfolio and long-term analysis of GHG emissions throughout entire service life
- Consider use of low-resource, reusable alternative building materials and materials from the planning stage
- Promote more efficient usage by using hybrid construction techniques, designing in dismantling options and ensuring flexibility to repurpose buildings
- Adopt leasing and sharing paradigms (e.g. facades as a service)
- Treat documentation as an investment in the future (e.g. with building information modelling and material passports)
- Reprocess waste, components and materials and feed them back into the circular economy

> Circular doesn’t just mean considering ‘reusability’; it also includes dismantling and flexible usage in your thinking right from the start.

Margit Sichrovsky
LXSY Architects

Introduction

Buildings and infrastructure consume more than 40% of the world's primary resources. The sector accounts for just under 40% of global greenhouse gas emissions (UNEP 2022). New buildings covering an area the size of Paris are constructed every week, despite the fact that 80% of the building stock needed for 2050 already exists. Bearing in mind the global scarcity of resources and that the planetary boundaries have already been exceeded, the sector thus has a significant impact and could make a crucial contribution towards safeguarding resources and using them more efficiently (KNBau 2019). Transitioning global economies to a circular economic model – a model of production and consumption where available materials and products are jointly used, leased, reused, repaired, refurbished and recycled for as long as possible to extend their life cycles (EU Parliament 2023) – is one possible approach to kickstarting this transformation.

The idea of the circular economy first appeared in EU policy in the Circular Economy Action Plan 2015 (European Commission 2015; new edition 2020a). The buildings and construction sector consumes huge amounts of resources, and it has therefore been highlighted as a key industry in the transformation to a circular economy – both within Germany's circular economy strategy and in the Circularity Gap Report 2023.

The built environment, which includes residential and commercial buildings as well as infrastructure (e.g. roads, bridges, dams) could make a crucial contribution to reversing humanity's current overshoot on five of the nine most important planetary boundaries if we adopt specific circular approaches. This would help maintain the ecosystems necessary for life and restrict the rise in global temperatures to a maximum of 2°C above pre-industrial reference levels (Circularity Gap Report 2023).

These efforts are already starting to bear fruit in current trends in the sector. Although sustainability in construction is primarily understood only in terms of energy efficiency, and the number of buildings planned and implemented completely in line with circular economy principles remains low, innovative materials and business models such as sharing systems or multifunctional, modular paradigms are still becoming increasingly important.

Achieving a functioning circular economy is being promoted by international regulations, and is one of the aspects of the EU Taxonomy. Additional environmental goals are to be set this year, explicitly including the transformation to a circular economy. This issue is also at the heart of sustainability awards such as the German Sustainability Award (DNP 2022) and certification schemes such as the Assessment System for Sustainable Building (BNB) introduced by the German Government. Alongside the use of recycled materials, designing and manufacturing new building components and materials to be recyclable later on is also a key criterion for this certification (BNB 2023).

> The current DIN standards only provide limited support for the circular economy.
>
> **Dr Anna Braune**
> German Sustainable Building Council

Overall sectoral trends and starting points for the circular economy in the buildings and construction sector

Current trends in the buildings and construction sector

Innovative technologies and materials, prefabrication and digital networking are becoming increasingly common

Increasingly widespread use of digital, data-driven and smart technologies

1 **Building information modelling (BIM)**
Cloud computing and the latest BIM systems throughout the value chain provide centralised data management, smart collaboration and visualisation.

2 **Robotics and automation**
Use of construction robotics and automation (e.g. for welding) prevents errors, increases safety and precision, and saves time.

3 **Construction site monitoring using drones**
Drone technology allows monitoring and inspection of construction sites, with greater accuracy and fewer errors.

4 **Networked construction sites**
Networking using AR/VR, AI, robotics and wearables enables structured workflows and proactive logistics, improves health and safety and inventory management, saves costs, and provides real-time data.

5 **Digital project management**
Project management using cloud-based software helps maintain quality standards, deadlines and budgets – for example, using AI-based predictive algorithms to assess project feasibility or to help monitor progress in construction projects.

6 **Digital twins**
Use of digital twins beyond can go beyond the planning phase – e.g. virtual models, scenario simulation to improve decision-making, support with maintenance and repairs.

7 **Use of digital tools to improve occupational health and safety**
AI algorithms can be used to predict risks; staff can be trained using VR to reduce the likelihood of accidents; employee health status can be monitored with IoT sensors.

Prefabricated and modular buildings

- Prefabrication and modular, pod and panel construction methods speed up construction processes, and reduce waste, pollution and noise.
- 3D printing in construction (also known as additive manufacturing): a robotic approach that prints the design layer by layer using innovative building materials, working together with BIM.

Increased costs due to staff and material shortages

- Staff shortages and supply chain difficulties are making it more difficult to keep projects running smoothly.
- Renovation work and refurbishment/upgrading of existing properties is in demand.
- Demand for new buildings is steady, although residential property building is stagnating and prices remain high.
- Key materials are becoming more difficult to procure, which is driving up prices.

Green buildings

- There is currently a trend towards energy efficiency and climate-neutral buildings (e.g. solar panels, renewable building materials).
- Focus is increasingly moving to circulating products and materials and using resources efficiently.
- Various certifications are available to classify buildings as green or “sustainable” (e.g. LEED, BREEM).

Smart cities

- Smart mobility and transport management policies (e.g. transport as a service, autonomous vehicles) use real-time and historic data to improve mobility (e.g. to reduce congestion).
- This uses automated processes and data-driven planning.

Material and product passports

- Digital product and material passports can be used to create transparency on material characteristics and enable effective recycling.

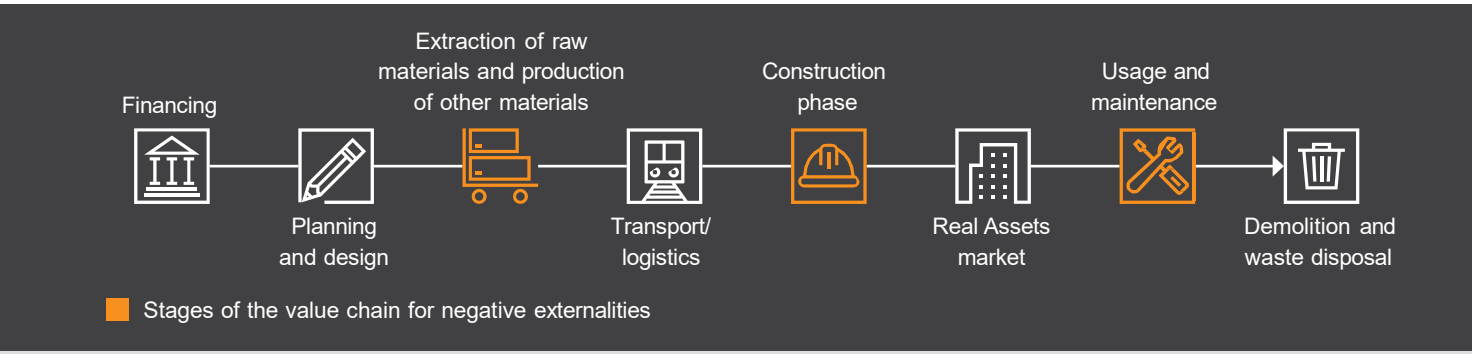
Innovative and living building materials

Innovative materials that are long-lasting, low-maintenance and energy-efficient becoming increasingly popular. These include:

- 3D-printed concrete or basalt;
- living building materials such as self-replicating concrete and self-mending bio-cement;
- sustainable materials and composites for construction, such as mycelium-based composites, bioplastics and biofoam;
- lighter materials with greater water storage capacity, such as aerogel, graphene, spider silk, carbon composites, hydroceramics and nanomaterials; and
- solid yet biodegradable timber and aluminium materials, such as bamboo, cross-laminated timber, transparent wood and aluminium foam.

The current value chain causes many environmental problems and poses multiple sustainability challenges for the buildings and construction sector

Sustainability issues in today's mostly linear value chain



Key adverse external effects of the linear value chain and the UN Sustainable Development Goals (SDGs) affected by it

Climate change and ocean acidification

- 38% of global GHG emissions are caused by producing and transporting building materials, constructing buildings, using them and demolishing them (Circularity Gap Report 2023).
- Large amounts of energy are used, particularly during the construction and usage phases.

Changes in land use, loss of biodiversity and depletion of resources

- The construction industry accounts for 40–50% of all extracted primary raw materials (CEAP 2020). This is often associated with deforestation, changes in land use, depletion of resources and loss of biodiversity.
- Large quantities of water are used in the extraction of sand and gravel and in the production of building materials such as cement, steel and glass.

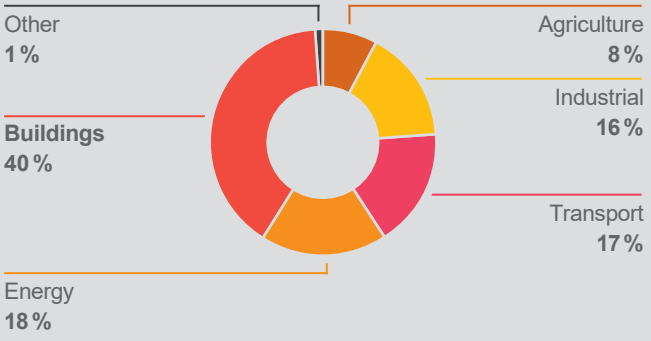
Contamination and waste

- 25–30% of all waste produced in the EU comes from construction and demolition.
- Changes in land use, domestic waste, sewage and rubble from demolition all cause soil pollution.
- Material extraction and construction reduce air quality, as do landfill sites.
- Construction can also cause contamination of river and coastal ecosystems.

Adverse external effects of material production, transport, construction, use, demolition and disposal

Large amounts of energy and natural resources are required during the building and in particular the usage phase of buildings. The manufacture of materials such as concrete, cement or asphalt causes huge amounts of GHG emissions. Since large amounts of gravel, sand, cement, water and lime are needed as raw materials in the manufacture of concrete, this stage of the value chain exacerbates the underlying depletion of resources. In total, the buildings and construction sector accounts for around 65% of global consumption of all non-metallic minerals, 15% of ferrous metals, 3% of non-ferrous metals and 25% of fresh water – proportions that are certain to increase even further in future with the rise in global population. Construction and demolition also produce large quantities of waste. The sector is responsible for over 35% of all waste generated in the EU (Eurostat 2016 quoted in CEAP 2020, p. 11). The often-unregulated extraction of scarce resources (e.g. river sand), the production and transport of building materials, construction operations, and the lack of waste management are accelerating a plethora of climate change-related adverse environmental impacts and mean that our planetary boundaries are increasingly being exceeded.

Global greenhouse gas emissions by sector



Source: BBSR online publication no. 17/2020.

The circular economy offers major potential savings and effective levers to help make the sector sustainable

Potential savings

The buildings and construction sector has a key role to play in the transformation to a circular economy, as there is still plenty of untapped potential for reducing material usage and emissions.

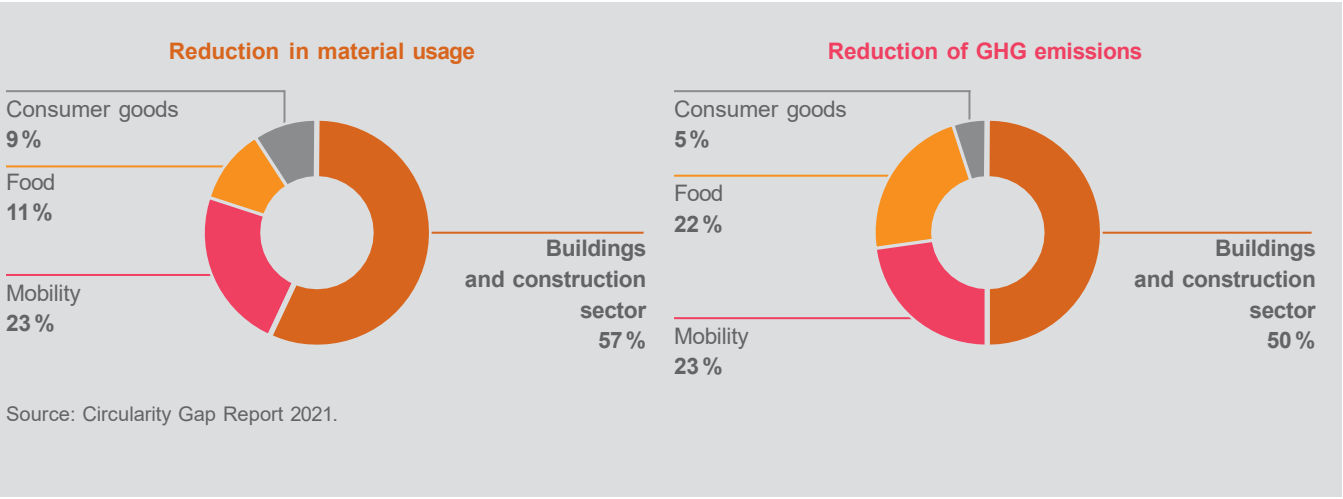
Implementing the principles of a circular economy will enable the construction industry to move towards a more sustainable future with more efficient use of resources, promoting economic growth while also minimising environmental impact.

According to the Ellen MacArthur Foundation, emissions associated with construction materials could be reduced by 38% by 2050 by adopting an approach based on the principles of a circular economy (Ellen MacArthur Foundation 2013). This is why this issue, alongside energy efficiency, is increasingly becoming a focus for governments and the use of secondary materials is becoming more important.

New taxes, mandatory standards, requirements in public sector construction projects or targeted incentive schemes (e.g. on the use of recycled materials, lower consumption of materials or energy or waste reduction) may follow in the near future.

Given the scarcity of resources, business models based on dismantling, renovation and recycling of old buildings and materials are also becoming increasingly attractive.

The construction sector offers the greatest potential savings from implementing circular strategies



Source: Circularity Gap Report 2021.

At a glance:
potential savings from the circular economy

–57 % Reduction in material usage

–50 % Reduction of GHG emissions

> Once they are extracted from the natural environment, building materials can be kept in circulation continuously.

Walter Feeß
K³-Kompetenzzentrum Kreislaufwirtschaft Kirchheim/T.

Kompetenzzentrum Kreislaufwirtschaft Kirchheim/Teck
powered by feess

Regulation: driving the circular economy

Regulatory pressure to drive circular construction is growing

The table below summarises the regulatory developments affecting the buildings and construction sector which need to be included in strategic planning right now:

Directives and regulatory frameworks						
		Area of application	Published by	Content/core issues	Focus	Details
Current	European Green Deal COM/2019/640	Europe	EU Commission	Policy with action plan on achieving the EU's climate plans	Cross-sector	50 actions for a climate-friendly, environmentally friendly Europe by 2050 (e.g. EU Taxonomy, Sustainable Finance Strategy)
	EU Taxonomy Regulation	Europe	EU Commission	Classification system for economic activities, proportions of green turnover, operational and investment expenditure	Reporting	Environmental objectives 1 and 2 cover relevant economic activities for the construction industry; environmental objective 4 (transition to a circular economy) is also particularly relevant
	Circular Economy Action Plan COM/2015/614 (COM/2020/98)	Europe	EU Commission	Measures to make the entire life cycle of goods more environmentally friendly, circular and energy-efficient	Cross-sector	"Construction and building" is the only topic with requirements relating to the circular economy
	Guideline for Sustainable Building	Germany	BMUB	Procedures, targets and recommendations to align planning, execution, use and operation of German federal construction projects with sustainability principles	Construction industry	Related to the Assessment System for Sustainable Building
Future	Thematic Strategy on the Sustainable Use of Natural Resources COM/2005/670 Final	Europe	EU Commission	Measures to mitigate the environmental impact of the use of resources, and indicators for efficiency and productivity in the use of natural resources	Cross-sector	–
	Roadmap to a Resource Efficient Europe COM/2011/571 Final	Europe	EU Commission	Roadmap to resource efficiency with a set of indicators	Cross-sector	"Improving buildings" chapter, with milestones on achieving a life cycle approach
	Proposal for a new Ecodesign for Sustainable Products Regulation COM/2022/142 final	Europe	EU Commission	Proposal for a new Ecodesign Regulation (specifying requirements for certain groups of products to improve potential for recirculation etc.)	Product-related	Complements the Ecodesign Directive Requirement for overall energy efficiency of construction components; system requirements
	Revision of monitoring framework for the circular economy COM/2018/29 (2022)	Europe	EU Commission	Revision of indicators to better cover the production phase of the circular economy and the connections between the circular economy, climate neutrality and zero pollution	Cross-sector	New indicators such as material footprint, resource productivity, consumption footprint, GHG emissions from production activities and material interdependency
	Strategy for a Sustainable Built Environment (2023)	Europe	EU Commission	Strategy to increase material efficiency and to reduce climate impacts of the built environment, particularly promoting circularity principles throughout the life cycle of buildings	Construction industry	–

Obligations/legislation						
		Area of application	Published by	Content/core issues	Focus	Details
	Ecodesign Directive 2009/125/EC (proposal: COM/2022/142 final)	Europe	EU Commission	Requirements for environmentally friendly design of energy-related products	Product-related	Requirements for products used in the construction industry
Future	Corporate Sustainability Reporting Directive (CSRD) and European Sustainability Reporting Standards (2022)	Europe	EU Commission	Follows on from the Non-Financial Reporting Directive (NFRD) and aims at putting sustainability reporting on the same footing as financial reporting	Reporting	ESRS E5 (resource use and circular economy) is particularly relevant and will apply to all large and listed companies that meet at least two of the three criteria (see CSRD regulations)
	Revision of the Construction Products Regulation (REFIT) COM/2022/144	Europe	EU Commission	Conditions for marketing of construction products, superseding the current Construction Products Regulation (CPR); aimed at making sustainable products the norm in the EU and boosting circular business models	Product-related	–

> A circular buildings industry should always be embedded in an overarching sustainable urban policy.

José Ignacio Lacomba Andueza
Valencia City Council

AJUNTAMENT DE VALÈNCIA

Alongside innovations for improving material efficiency, creating further efficiency gains and achieving climate neutrality, regulation is driving the integration of circular economy approaches into processes within the sector. For example, the EU's Circular Economy Action Plan 2020 sets out areas where action is particularly required for the circular economy. Although this has not yet been transposed into national law, companies should start preparing for new regulations now, and should already be considering their options and pursuing innovative approaches to bring construction projects and buildings into line with the circular economy.

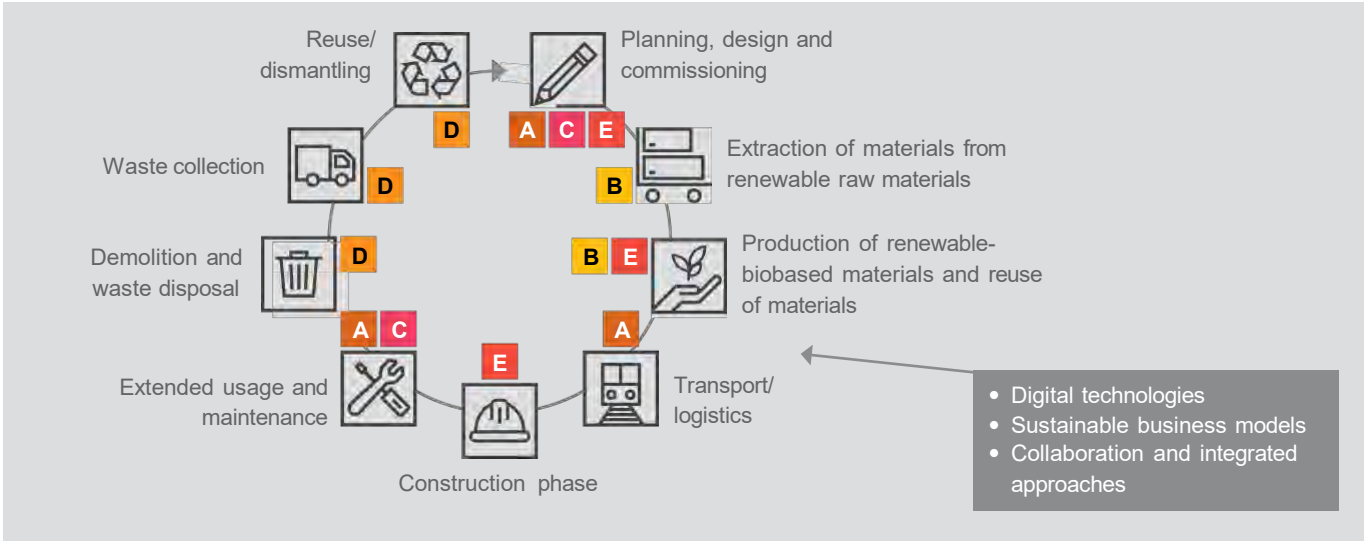
Circular economy strategies for the sector

At various points in the value chain, circular economy strategies offer opportunities to increase resource efficiency

The demand for innovative, efficient, long-life and digital building paradigms is high given the current challenges and the pressure from governments or other stakeholders. Seeking out resource-efficient alternatives and planning green buildings has now become a trend. Prefabricated, modular components and the use of BIM or drone technology and automated processes are already a routine part of projects in many European countries.

Circular building paradigms and business models are now gaining increasing attention in the sector, and many circular design strategies have been implemented in recent years. Modular buildings or sharing models could provide one potential approach towards sustainable design of urban spaces with different uses and repurposing options.

Focal points for establishing a circular value chain



Potential

- Reduced costs through smart reuse and lower energy consumption
- Lower emissions and reduction in use of resources/more efficient use of resources
- Making urban spaces more liveable and creating health and wellbeing benefits (e.g. use of less harmful materials)
- Contributing to the UN SDGs
- Maintaining value throughout a building's life cycle
- Increasing resilience (e.g. through technology or nature-based solutions)
- Potential for new, lucrative business models
- Solve supply chain problems and ensure compliance with regulations (e.g. Supply Chain Due Diligence Act, or LkSG) with local, recycled materials
- Create new jobs and business models in the renovation segment

A

Planning and design in line with circular principles

- Designing and developing buildings that allow maximum flexibility in use, have modular structures and are designed for a long service life, recyclability and dismantling (this includes prefabs)
- Taking account of the individual life cycle of construction materials and buildings

B

Sustainable extraction and procurement of materials and use of reprocessed and biobased materials

- Recycling and upcycling building waste, components and material offers an opportunity to retain value
- Use of renewable biobased materials
- Separating different structures and building materials based on length of life cycle
- Procurement in accordance with circular economy criteria/standards (e.g. with take-back option, zero-waste packaging)

C

Optimising and extending the usage phase of buildings

- Innovative business and value creation models (e.g. product-service systems for furniture and facades)
- Intelligent decisions on replacing components in existing properties can enable efficient use of buildings, avoid waste and help with maintenance
- Repairing, renovating and repurposing existing building stock

D

Recovering and preparing building waste, components and materials for circular use

- Reusing building waste, rainwater etc., recycling building waste and raw materials

E

Use of digital technologies to improve material efficiency and create transparency throughout the life cycle

- Smart management of material flows (e.g. using resource passports)
- Cooperation through digital project management systems, avoiding excess material procurement
- Extending life cycles through smart predictive maintenance

A

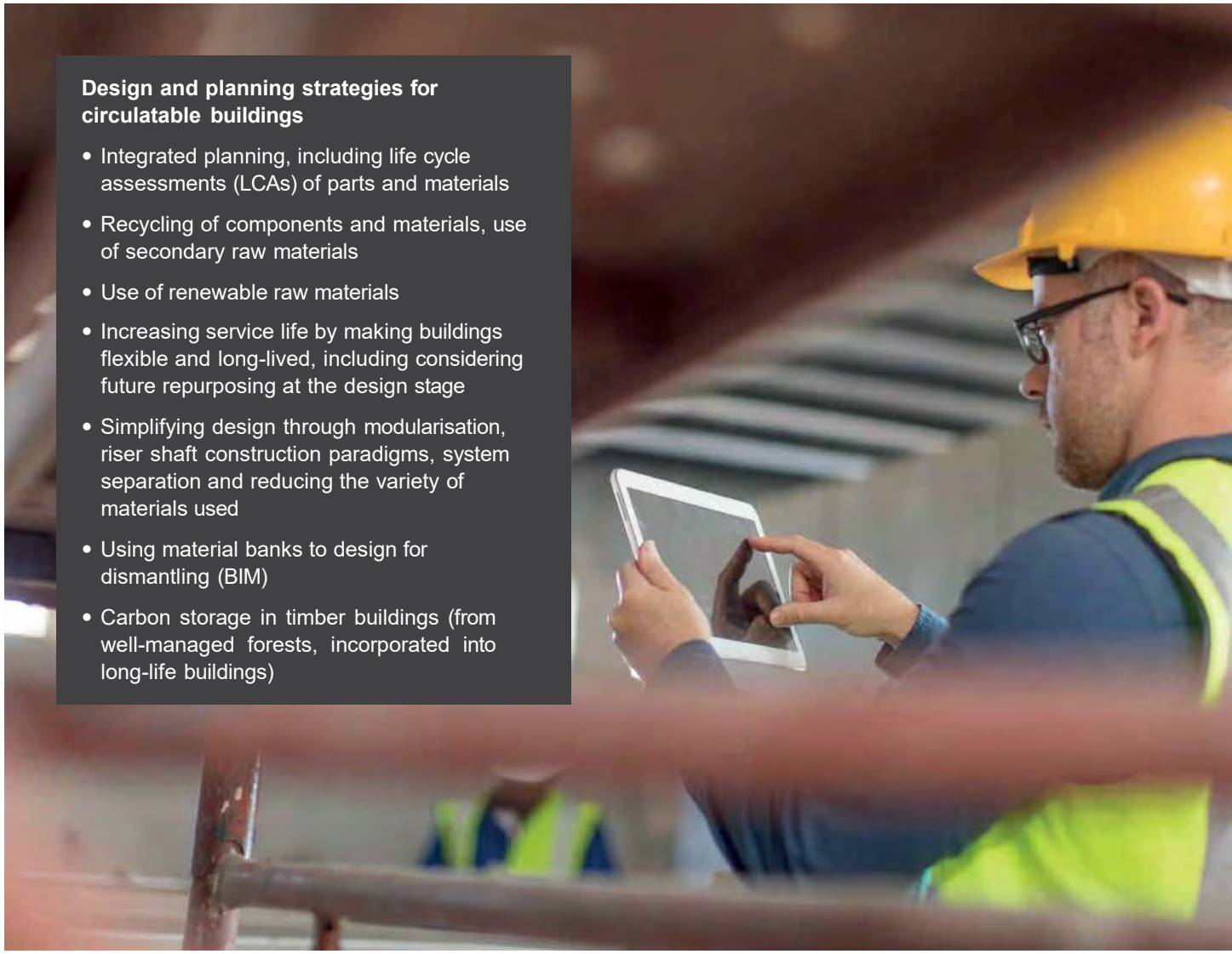
Rethinking buildings: planning and design in line with circular principles

Various design strategies use transparent monitoring and data management systems to drive circulation of materials by avoiding/intensifying use and reducing the quantities consumed.

There are numerous design strategies that can design buildings for long-term and flexible use, avoiding excessive waste and extraction of raw materials prior to construction. Alongside avoiding waste and hazardous substances, an integrated approach to planning can not only anticipate the usage phase, but also take storage of materials into account and record their characteristics to make it easier to replace components.

Flexible buildings, modularisation and reducing the range of materials used allow repurposing and easier dismantling and replacement to be factored in at the planning phase. Potential business models typically include sharing models where building blocks such as facades, ceilings, floor coverings or houseplants are purchased as a functional service, and maintenance and replacement is undertaken by the subcontractor(s).

Reusable or recycled materials are crucial for the transformation to building stock fit for the circular economy. Timber buildings designed for a long service life, made from wood from sustainably managed forests, can store carbon and thus make an important contribution towards achieving climate neutrality. Green roofs on buildings also help to improve air quality and increase biodiversity (De Graaf, D. and Schuitemaker, S., 2022; KNBau, 2019).



Design and planning strategies for circulatable buildings

- Integrated planning, including life cycle assessments (LCAs) of parts and materials
- Recycling of components and materials, use of secondary raw materials
- Use of renewable raw materials
- Increasing service life by making buildings flexible and long-lived, including considering future repurposing at the design stage
- Simplifying design through modularisation, riser shaft construction paradigms, system separation and reducing the variety of materials used
- Using material banks to design for dismantling (BIM)
- Carbon storage in timber buildings (from well-managed forests, incorporated into long-life buildings)

B

Extraction and procurement of materials and use of reprocessed and biobased materials

Depletion of primary resources can be reduced by using renewable, biobased and secondary materials.
Recycled materials can be used instead of new materials in some applications to make procurement of materials more sustainable. These reprocessed building materials (e.g. insulation materials, concrete) can sometimes be obtained from construction waste and rubble from demolition. However, more recycling technologies and bonding techniques need to be developed, as composites, contaminants and impurities currently preclude recycling of some materials. Another option is to use alternative materials. These innovative materials include substances such as self-replicating concrete or self-mending bio-cement, which will "heal" if they crack. Other sustainable materials and composites for construction include mycelium-based composites, bioplastics or biofoam, along with solid yet biodegradable wooden and aluminium materials such as bamboo, cross-laminated timber and transparent wood.

C

Optimising and extending the usage phase of buildings

Slowing down the circular economy and reusing, repairing and maintaining to extend building service lives.
Repair and maintenance, efficient heating and cooling with renewable resources, or (if necessary) renovation and refurbishment can significantly extend properties' service lives. Smart software solutions can be employed to ensure energy-efficient use of buildings. There are also multiple utilisation models that allow space to be used more efficiently, such as digital platforms. These include flexible, shared use of office buildings, or product-service system usage models where living or the space itself can be provided as a service. Lifespan can also be extended by repurposing existing buildings or planning smart, predictive maintenance.

D

Recovering and preparing building waste, components and materials for circular use

Closing the loop by recycling parts and materials and recovering energy
When a change of use or function ceases to be an option for a building and it has to be demolished, the circular economy strategy applies the idea of a closed loop. For recovery to be successful, however, the materials originally used in the construction phase must be capable of being reused for high-quality applications in the next cycle. The reusable building components can then be removed and material flows separated out on the construction site, using tailored recycling methods to allow targeted reprocessing of the materials ready for their return to the circular economy. For these processes to become established over the long term, however, more suitable processing methods and sites are needed, as well as knowledge transfer on material characteristics and options for reuse.

E

Material efficiency and transparency through digital technologies

Although many people are aware of the principles and theories of the circular economy, there are some barriers to implementation, including insufficient transparency and standardisation or lack of data sharing. This is where using digital technologies can be useful in many ways: for example, designing the construction process to make it more efficient and sustainable, increasing safety and transparency, or enabling reuse of buildings and their materials.

Examples of these include technologies applied in the construction phase to reduce material consumption, through efficient construction methods such as 3D printing or prefabricated components. For example, Europe's largest 3D-printed building to date, an IT server building, was erected in Heidelberg in May this year in 140 hours (Süddeutsche Zeitung 2023). Printing is typically carried out with materials such as concrete, geopolymers or sand, although biobased raw materials such as mud, earth or straw can also be used.

BIM systems have been in routine use in projects in many European countries for some time. BIM powered by a smart model and a cloud-based platform can be used to integrate structured, multidisciplinary data and visualise properties digitally throughout their life cycles.

Reviewing, recording and monitoring the life cycle of materials could ensure greater transparency in future (De Graaf, D. and Schuitemaker, S., 2022). Digital product or material passports also provide information on the materials, components and raw materials used in a building or product and where they are located.

These tools can be used to document and trace the value of an individual building or product. Materials need to be marked so that unmixed materials can be identified during demolition for reuse or recycling without additional time-consuming testing or analysis. The introduction of digital product passports is also being championed by the EU.

The quantity of waste can be reduced with smart management of material flows on site. Smart ordering and procurement tools also reduce transport and logistics costs.

Building information management can provide:

- data storage,
- monitoring of the complete life cycle of materials, and
- scenario analysis.

Digital material passports:

- are a crucial component of the circular economy and a core element of the EU's Green Deal (Berg et al. 2021, Götz et al. 2021);
- are a digital database in which objects in a building can be recorded;
- provide a quantitative and qualitative record of the materials that a building is made of, the construction methods used, and the location and ownership of some or all of the objects; and
- are key to circular construction, since they promote high-value reuse at material, product, element and building level.

Transparency through certification: summary of current building certification systems and labels

Building certificates are a way to make sustainability performance objectively measurable and include an increasing number of circular economy criteria

The following table provides an overview of the most common certification systems in Germany. Each one has been analysed to identify the aspects of the circular economy it covers. External market participants can use certification to a global or national standard to identify the extent to which a building meets sustainability requirements.

Certifications can provide a variety of information – for example, whether sustainable building materials were used during construction, the extent to which the use of the building is in accordance with local climate strategies, or whether energy-saving and water-saving plans have been implemented.

Certifier	BREEAM	LEED	DGNB	BNB	HQE	WELL
Area of application	Global	Global	Global	Germany	Global (mainly France)	Global
Scope of application	New buildings, existing properties (commercial and residential), renovation and fitting out, infrastructure	Design and construction, land use planning and construction, building operation and maintenance, neighbourhood development, residential buildings, cities	New buildings, existing buildings, renovation, buildings in use, city districts, interiors, dismantling	Public sector construction projects and legacy stock such as office and administration buildings, educational buildings, laboratory buildings, vocational education premises, outdoor spaces	New buildings, existing properties (commercial and residential), renovation, infrastructure	New and existing buildings (interior, core and envelope)
Coverage of core issues (based on CRSD)	• Governance and ethics • Climate change and CO_2 • Water • Resources • Ecosystems and biodiversity • Social concerns	• Governance and ethics • Climate change and CO_2 • Water • Resources • Ecosystems and biodiversity • Social concerns	• Governance and ethics • Climate change and CO_2 • Water • Resources • Ecosystems and biodiversity • Social concerns	• Governance and ethics • Climate change and CO_2 • Water • Resources • Ecosystems and biodiversity • Social concerns	• Governance and ethics • Climate change and CO_2 • Water • Resources • Ecosystems and biodiversity • Social concerns	• Governance and ethics • Climate change and CO_2 • Water • Resources • Ecosystems and biodiversity • Social concerns
Coverage of circular economy criteria	• Circular principles applied • Technical Working Group (BREEAM Circularity) • Circular strategy	• List of requirements includes a credit for "building life cycle impact reduction" under the "materials and resources" category	• Extensive criteria on the circular economy • Circular building is a core issue within the DGNB system	• Meets statutory requirements (Circular Economy Act, or KrWG)	• Guidelines on defining the circular economy in construction • Areas of action for integrating circular principles	• No data
Details	TÜV SÜD is the national office for BREEAM in Germany, Austria and Switzerland	Certification is carried out by Green Business Certification Inc. (GBCI) on behalf of the USGBC	When applied outside Germany, the DGNB system is adjusted to take account of local conditions	Tool for planning and assessing sustainable and mostly public sector construction projects, complementing BMUB's Guideline for Sustainable Building	Information only available in French	WELL certifications are aimed at consumer health and safety, and less at sustainability as normally understood

■ Topics form part of certification

The cradle-to-cradle product standard

A global standard for the safe and responsible manufacture of circulatable products

Cradle-to-cradle (C2C) is a method for designing products and processes based on natural circulation. Unlike the “take-make-waste” approach, which starts with extraction of new raw materials from the earth and ends with disposal, the focus with C2C is on safe and responsibly manufactured products that were developed for reuse, and can therefore be kept in circulation with as few restrictions as possible.

Designers, brands and manufacturers have already been applying the C2C standard to the development and manufacture of products for a number of years, all over the world and across sectors. The standard is regularly updated and expanded to reflect current developments. Certification involves an independent assessment process, comprising five criteria (see diagram on right). There are already many certified products in the building materials, fixtures and fittings, and furniture categories. As the certificate is issued in five stages, the barrier to entry is low, which makes it easier to carry out ongoing work on other measurable improvements and innovations.

C2C is an important element of the circular economy. The standard has great potential, particularly in the construction industry, since it makes it easier to locate products that can be used for low-resource and low-emission new-builds or renovation projects.

Evaluation criteria

Construction and buildings in line with circular principles: practical examples and pioneers

Practical examples part 1: inspiring pioneers throughout the value chain

Digital technologies enable efficient reuse of building materials

Use of digital technologies

B Procuring materials and using reprocessed and biobased materials

D Recovering and processing waste for circular use

E Material efficiency through digital technology

Image source: https://www.pwc.de/de/nachhaltigkeit/deutscher-nachhaltigkeitspreis.html

Concular

The Concular company provides a simple, economical and measurable way of closing the loop for materials, from building to building. Concular makes buildings digital using passports to keep materials and products in circulation, saving both time and costs. The circular value chain extends the service life of resources, significantly reducing demand for primary resources.

madaster

The online platform Madaster simplifies circular use of products and materials in the construction industry. It acts as a register of materials and products in the construction industry. The platform's algorithms and extensive database make it much easier to create a building resource passport based on a BIM or Excel model. This passport is used to document the extent to which a property complies with circular principles.

The German Sustainability Award: recognising pioneers in the transformation of the construction industry

In the "architecture" category, Germany's architectural prize for sustainability is awarded to buildings that "combine transformative impact, innovation and outstanding design quality". PwC Germany and Strategy& are once again supporting the German Sustainability Award this year as a partner.

Practical examples part 2: inspiring pioneers throughout the value chain

Innovative and living building materials form the basis for new “product-as-a-service” business models and reduce the number of repairs required

Innovative and living building materials

A Planning and designing in line with circular principles

C Optimising and extending the usage phase

Image source: http://www.c2c-centre.com/product/building-supply-materials/nortec-aurum; https://www.c2cplatform.eu/c2c-certified/

Lindner

Lindner LOOP aurum The Lindner Group is a pioneer in the field of circular products for interior design. An outstanding example of this is the raised access floor panel LOOP aurum, which has been awarded Cradle to Cradle Certified® Gold. The LOOP aurum is a used access flooring panel that is reconditioned by Lindner and given a new life cycle. For this purpose, Lindner offers a return or rental model for flooring systems and enables the reuse or further use of the building products or materials. In this way, the LOOP aurum can save over 70 percent CO_2 in the manufacturing process, as well as 98 percent gas and 93 percent water.

Image source: https://berlin.impacthub.net/about-us/coworking-space/

Image source: https://lxsy.de/de/projekte/impact-hub-berlin-at-crclr-house

Project partners

LXSY Architekten, TRNSFRM eG,
Die Zusammenarbeiter, Studio de Schutter

Practical examples part 3: inspiring pioneers throughout the value chain

Some of the first buildings developed and constructed entirely in line with circular principles provide an insight into the possibilities of circular construction

Green buildings

The circular economy and material and product passports

IMPACT HUB Berlin

A new community and coworking space built in line with circular principles: The new Impact Hub: Berlin community and coworking space in the CRCLR Haus in Berlin is a model project for circular construction. Impact Hub Berlin is a hub for a dedicated community of over 500 impact entrepreneurs. The Berlin community is part of the global Impact Hub network with over 25,000 members in 60+ countries.

The Circular Economy has played a central role in the Impact Hub Berlin's start-up funding and innovation programmes from the very beginning and gained further importance through the circular design of the new location, from the use of recycled materials and natural raw materials to the in-house "low-waste café".

Building management focuses on waste reduction and an efficient energy concept, as well as the use of modular, rented and reused furniture. The design process for the former warehouse in Neukölln took place in close cooperation with users, neighbours and experts.

During the planning process, special attention was paid to the use of recycled building materials and their reusability. Due to the modular construction method and with the help of material passes, potential deconstruction and reuse of the components in the future is already taken into account today.

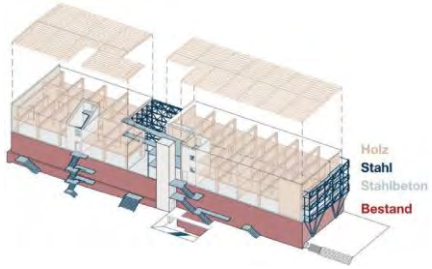


Image source: https://www.zrs.berlin/project/crclr-house-2/

Seeing the circular economy as an opportunity: areas of action for companies

The following recommendations can help the sector to prepare for current developments and take up the opportunities represented by the circular economy:

Challenges to implementing the principles of a circular construction industry

- Complexity of procuring[2], recycling and reusing materials (due to challenges such as composites, impurities, contaminants from material life cycles)
- Lack of confidence in reprocessed materials[2]
- Higher costs (e.g. for biobased recycled materials) than for primary materials[1]
- Longer construction times and more work/costs involved in circular construction[2]
- Insufficient regulatory incentives, funding or pressure to act on maintaining building substance and reprocessing materials, meaning that new-builds and using primary materials are still more profitable[3]
- Standards are insufficient, preventing a circular economy from becoming a reality[2,3]
- Ceilings usually too low for multiple uses, floor plans not flexible enough
- Long approval times are reducing acceptance of substitute building materials and delaying progress on construction and demolition[4]
- Life cycle assessments in the construction industry are currently not sufficiently representative, and there is no standardised dataset[4]
- Differences in life cycles and ownership structures make it difficult to introduce value creation/retention models (e.g. product-service systems)
- Potential rebound effect from increased material efficiency
- Lack of efficient, high-quality data management/ processing and waste recycling technologies

Ten key areas of action for real-world projects[1]

1. See detailed documentation as an investment in the future[4,2]
2. Create a more effective circular system
3. Use carbon capture and storage (CCS) to achieve climate neutrality
4. Select building materials and parts to conserve resources, in line with processing capacity[3,4,5]
5. Use hybrid construction techniques to design in dismantling options and flexible reuse[2,5]
6. Adopt leasing models and circular use models[5]
7. Introduce a CO_2 budget for building portfolios and long-term analysis[5,6]
8. Expand funding options[3]
9. Reprocess waste, components and materials[6]
10. Increase usage efficiency, dismantling options and flexibility to repurpose[5]

[1] Addressed by:
[2] Dr Anna Braune, DGNB.
[3] Walter Feeß, Heinrich Feeß GmbH.
[4] Stefan Schmidmeyer, BVSE.
[5] Margit Sichrovsky und Kim Le Roux, LXSY.
[6] Jesper Friis, Siemens Healthineers.

Detailing the recommendations:

1 See detailed documentation as an investment in the future

A C D E

- Use integrative planning and BIM to increase measurability and transparency.
- Create resource passports for buildings, including dimensions, environmental impact, circularity of building and potential for subsequent reuse.
- Record construction and material information in a central, shared-access digital model (BIM).
- Assess the (quantitative) difference between current contribution to circularity and potential future contribution.

2 Create a more effective circular system

Take measures to increase effectiveness at the material, component, unit and building level:

- Plan for long service life and efficiency.
- Promote adjustments to standards and regulation.
- Make building levels and ceiling heights suitable for flexible use.
- Use prefabricated elements/standardised parts for construction.
- Use connections that can be dismantled – e.g. with shapes that lock together instead of using cement.
- Create material and building passports.
- Use digital twins.

C E

3 Use carbon capture and storage (CCS) to achieve climate neutrality

- Store CO_2 in products through cascade systems, e.g. wood: stores CO_2 > wood pulp > chemical industry > burned to generate heat.
- Increase percentage of timber in new buildings and replace concrete/cement.
- Increase regional availability.
- Redesign buildings to become urban carbon sinks.

B

4 Select building materials and parts to conserve resources, in line with downstream processing capacity

- Use biobased, recyclable (building) materials.
- Use reprocessed building materials such as “R-concrete”.
- Work with partners in international raw material supply chains/value chains and set up collaborations.

B D

5 Use hybrid construction techniques to design in dismantling options and flexible reuse

- Design buildings for multiple uses and factor in different forms of use.
- Use prefabricated parts.
- Use modular components to make replacement easier.
- Use technology to minimise consumption of building materials, fresh water and energy.
- Prioritise maintenance and repairs over replacement.

C

6 Adopt leasing models and circular use models

- Apply leasing, sharing and second-use models to buildings, spaces and their components – i.e. see them and source them “as a service” (e.g. lighting, houseplants, facades or floor coverings).

C

7 Introduce a CO_2 budget for building portfolios and long-term analysis

- Carry out life cycle assessments and identify the status quo of the building portfolio.
- Specify a CO_2 budget in accordance with climate strategy and develop an action plan.
- Ensure long-term analysis of CO_2 throughout entire service life of property.

8 Expand funding options

Demand action from politics, educational institutions and standards bodies on the following issues:

- Creating reprocessing jobs on urban fringes
- Including the circular economy as a subject in tertiary education (including alternative materials following circular principles)
- Drawing up adequate standards
- Financial support and incentives for circular economy activities
- Creating a legal framework for circular economy activities
- Creating (international) collaborative ecosystems and platforms for coherent transformation and to coordinate initiatives

D

9 Reprocess waste, components and materials

- Collect waste at designated collection points.
- Speed approval procedures to simplify interim storage.
- Recycle and separate materials on site during demolition.

10 Increase usage efficiency, dismantling options and flexibility to repurpose

- Prioritise retention and repurposing of existing stock over constructing new buildings.
- Include modularity, flexibility and long service life in the planning process.
- Plan to keep materials separate during demolition as a proactive recycling measure.

A. Planning and designing buildings in line with circular principles

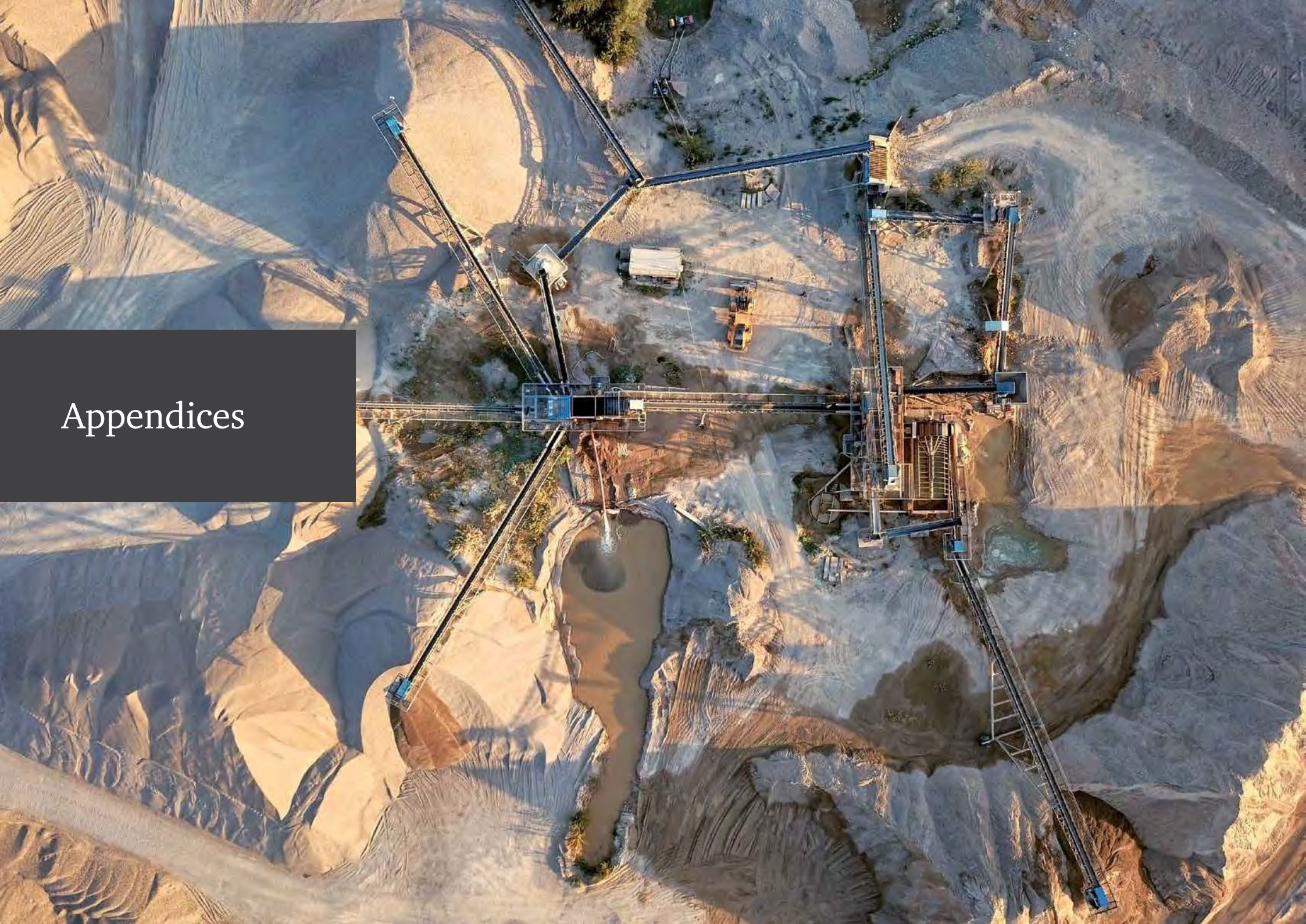
B. Sustainable extraction and procurement of materials, use of reprocessed and biobased materials for new-builds

C. Optimising and extending the usage phase of buildings

D. Recovering and processing construction waste, components and materials for circular use

E. Using digital technology to create transparency and ensure efficient use of materials throughout the life cycle of a building

Recognise and promote the potential of the circular economy for sustainability transformation



Appendices

Glossary

Building information modelling (BIM)	Building information modelling (BIM) refers to the consistent digitalisation of all planning and construction-related building information in the form of a virtual building model. This method uses significantly more information than conventional IT models and creates a synchronised dataset which can be accessed by everyone involved.
Circular economy	The circular economy is a model of production and consumption where existing materials and products are jointly used, leased, reused, repaired, refurbished and recycled for as long as possible. This extends the life cycle of products.
Digital product passports (DPPs)	The European Commission defines a “product passport” as a product-specific data set which can be accessed electronically via a data storage medium to register, process and share “product-related information” electronically between companies in the supply chain, authorities and consumers.
Digital twins	A digital twin is a digital representation of real-world entities or processes. Digital twins use real-time and historic data to represent the past and the present, and numerical models to simulate future scenarios.
The rebound effect	Sustainable use of resources necessitates efficient use of energy, raw materials and water. Increased efficiency allows products to be manufactured and services to be performed using fewer resources, and often at a lower cost. This in turn influences purchasing habits and how products are used, and this change is known as the rebound effect.

References

Scientific literature

Berg, H., Bendix, P., Jansen, M., Le Blévennec, K., Bottermann, P., Magnus-Melgar, M., Pohjalainen, E. and Wahlström, M. (2021)
Unlocking the potential of Industry 4.0 to reduce the environmental impact of production (Eionet Report ETC/WMGE 2021/5). European Environment Agency, European Topic Centre on Waste and Materials in a Green Economy. Available at: www.eionet.europa.eu/etcs/etcwmge/products/unlocking-the-potential-of-industry-4-0-to-reduce-theenvironmental-impact-ofproduction/@@download/file/Final%20for%20website.pdf.

Ellen MacArthur Foundation. (2013)
Towards the circular economy (Vol. 2). Available at: https://doi.org/10.1007/b116400.

Gerbens-Leenes, P., Hoekstra, A. and Bosman, R. (2018)
The blue and grey water footprint of construction materials: Steel, cement and glass. Water Resources and Industry, 19, 1–12. doi:10.1016/j.wri.2017.11.002.

Götz, T., Adisorn, T. und Tholen, L. (2021)
Der digitale Produktpass als Politik-Konzept: Kurzstudie im Rahmen der umwelt-politischen Digitalagenda des Bundesministeriums für Umwelt, Naturschutz und nukleare Sicherheit (BMU) (Research Report No. 20). Wuppertal Report. Available at: https://doi.org/10.48506/opus-7694#.

Hertwich, E., Lifset, R., Pauliuk, S. and Heeren, N., (IRP) (2020)
Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future.

Thyberg, K. L. and Tonjes, D. J. (2016)
Drivers of food waste and their implications for sustainable policy development. Resources, Conservation and Recycling, 106, 110–123. doi:10.1016/j.resconrec.2015.11.016.

Internet

European Parliament (2023, 22. Februar)
Circular economy: definition, importance and benefits. Available at: www.europarl.europa.eu/news/en/headlines/economy/20151201STO05603/circular-economy- definition-importance-and-benefits?&at_campaign=20234-Economy&at_medium=Google_Ads&at_platform=Search&at_creation=RSA&at_goal=TR_G&at_audience=circular%20economy&at_topic=Circular_Economy&at_location=DE&gclid=Cj0KCQjwsIejBhDOARIsANYqkD0Hz-jhnvMUZYvR187wzqMAdtU_W_t46C6RycWnmc76xir_OhswV0AaAhQQEALw_wcB (accessed 23 May 2023).

BRE Group (2023)
Available at: https://bregroup.com/products/breeam/ (accessed 11 May 2023).

C2C (2023)
Available at: https://c2ccertified.org/the-standard (accessed 18 July 2023).

U.S. Green Building Council (2023)
Available at: www.usgbc.org/leed (accessed 12 May 2023).

Deutsche Gesellschaft für Nachhaltiges Bauen (2023)
Available at: www.dgnb.de/de/index.php (accessed 12 May 2023).

Bundesministerium für Wohnen, Stadtentwicklung und Bauwesen (2023)
Available at: www.bnb-nachhaltigesbauen.de/ (accessed 8 May 2023).

Alliance HQE (2023)
Available at: www.hqegbc.org/ (accessed 8 May 2023).

International WELL Building Institute (2023)
Available at: www.wellcertified.com/ (accessed 8 May 2023).

UnternehmerTUM GmbH (2023)
Available at: www.unternehmertum.de/en/topics/sustainability/circular-economy-startups (accessed 23 May 2023).

Umweltbundesamt (2023)
Rebound effects. Available at: www.umweltbundesamt.de/en/topics/waste-resources/economic-legal-dimensions-of-resource-conservation/rebound-effects (accessed 23 May 2023).

European Commission (2023)
European Digital Twin of the Ocean (European DTO). Available at: https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and- open-calls/horizon-europe/eu-missions-horizon-europe/restore-our-ocean-and-waters/european-digital-twin-ocean-european-dto_en#:~:text=A%20digital%20twin%20is%20a,models%20to%20simulate%20future%20scenarios (accessed 23 May 2023).

Bundesministerium für Digitales und Verkehr (2023)
Digitales Planen, Bauen, Infrastrukturmanagement. Available at: https://bmdv.bund.de/DE/Themen/Digitales/Building-Information-Modeling/BIM/building-information-modeling.html (accessed 23 May 2023).

Revolutionized (2023, 1 November)
Top 12 Trends in the Construction Industry for 2023. Available at: https://revolutionized.com/trends-in-the-construction-industry/ (accessed 25 May 2023).

Startus Insights (2023)
Discover the Top 10 Construction Industry Trends & Innovations in 2023. Available at: www.startus-insights.com/innovators-guide/top-10-construction-industry- trends-innovations-in-2021/#:~:text=The%20major%20construction%20industry%20trends,to%20worker%20safety%20and%20regulations (accessed 25 May 2023).

Tequma AG (2023, 22 March)
9 key trends in the construction industry. Available at: https://morethandigital.info/en/9-key-trends-in-the-construction-industry/ (accessed 25 May 2023).

Concular (2023)
Available at: https://concular.de/ (accessed 25 May 2023).

Madaster (2023)
Available at: https://madaster.de/ (accessed 25 May 2023).

Lindner Group (2023)
Available at: https://www.lindner-group.com/de_DE/ausbauprodukte/boden/doppelboden/nortec-aurum/ (accessed 10 May 2023).

Basilisk Concrete (2023)
Available at: www.basiliskconcrete.com/en/ (accessed 12 May 2023).

ZRS Architekten Ingenieure (2023)
Available at: www.zrs.berlin/project/crclr-house-2/ (accessed 25 May 2023).

LXSY Architekten (2023)
Available at: https://lxsy.de/de/projekte/impact-hub-berlin-at-crclr-house.

Circular Economy Action Plan CEAP (2020)
Available at: https://op.europa.eu/en/publication-detail/-/publication/45cc30f6-cd57-11ea-adf7-01aa75ed71a1/language-en/format-PDF/source-170854112 (accessed 25 March 2023).

Other publications

Bosman, R. (2016)
Water footprint of widely used construction materials. Available at: https://essay.utwente.nl/69751/1/MA%20thesis%20Bosman,%20R..pdf.

Circle Economy (2023)
The Circularity Gap Report 2023. Available at: www.circularity-gap.world/2023.

Deutscher Nachhaltigkeitspreis e.V. (2022)
Der 15. Deutsche Nachhaltigkeitspreis (programme). Available at: www.nachhaltigkeitspreis.de/media/4-Preisverleihungen/Programmheft_DNP.pdf.

European Commission (2021, 14 July)
Proposal for a Regulation of the European Parliament and of the Council, Establishing a Carbon Border Adjustment Mechanism (Document 52021PC0564). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021PC0564&from=EN.

De Graaf, D. and Schuitemaker, S. (NL Branding Circular Buildings) (2022)
Circular Buildings: constructing a sustainable future. Available at: https://circulareconomy.europa.eu/platform/sites/default/files/nl-branding-circular-buildings.-f.pdf.

European Commission (n.d.)
Circular Economy: Environmental and Waste Management: The reference document for the Construction sector. Available at: https://susproc.jrc.ec.europa.eu/activities/emas/construction.html (accessed 23 May 2023).

European Commission (2020)
Circular economy action plan: For a cleaner and more competitive Europe, Publications Office of the European Union. Available at: https://data.europa.eu/doi/10.2779/05068.

Kommission Nachhaltiges Bauen am Umweltbundesamt (KNBau) (2019)
Position der Kommission Nachhaltiges Bauen am Umweltbundesamt (KNBau): Schonung natürlicher Ressourcen durch Materialkreisläufe in der Bauwirtschaft. Available at: www.umweltbundesamt.de/publikationen/schonung-natuerlicher-ressourcen-durch.

OECD (2018)
Global Material Resources Outlook to 2060: Economic drivers and environmental consequences. Available at: www.oecd.org/publications/global-material-resources-outlook-to-2060-9789264307452-en.htm.

IRP (2017)
Assessing global resource use: A systems approach to resource efficiency and pollution reduction. Bringezu, S., Ramaswami, A., Schandl, H., O'Brien, M., Pelton, R., Acquatella, J., Ayuk, E., Chiu, A., Flanegin, R., Fry, J., Giljum, S., Hashimoto, S., Hellweg, S., Hosking, K., Hu, Y., Lenzen, M., Lieber, M., Lutter, S., Miatto, A., Singh Nagpure, A., Obersteiner, M., van Oers, L., Pfister, S., Pichler, P., Russell, A., Spini, L., Tanikawa, H., van der Voet, E., Weisz, H., West, J., Wiijkman, A., Zhu, B., Zivy, R. A Report of the International Resource Panel. United Nations Environment Programme. Nairobi, Kenya. Available at: www.resourcepanel.org/reports/assessing-global-resource-use.

IRP (2017)
Resource Efficiency: Potential and Economic Implications. A report of the International Resource Panel. Ekins, P., Hughes, N., et al. United Nations Environment Programme. Nairobi, Kenya. Available at: www.resourcepanel.org/sites/default/files/documents/document/media/resource_efficiency_report_march_2017_web_res.pdf.

One Planet/International Resource Panel (2020)
Analysis of the Construction Value Chain Understanding the value chain & identifying hotspots. Draft 10 December 2020. Available at: www.oneplanetnetwork.org/sites/default/files/value_chain_analysis_construction_-_draft_201210_-_for_inputs.pdf.

UNEP (2016)
Global Material Flows and Resource Productivity. An Assessment Study of the UNEP International Resource Panel. H. Schandl, M. Fischer-Kowalski, J. West, S. Giljum, M. Dittrich, N. Eisenmenger, A. Geschke, M. Lieber, H. P. Wieland, A. Schaffartzik, F. Krausmann, S. Gierlinger, K. Hosking, M. Lenzen, H. Tanikawa, A. Miatto, and T. Fishman. Paris, United Nations Environment Programme. ISBN: 978-92-807-3554-3.

UNEP (2022)
Available at: https://www.unep.org/resources/publication/2022-global-status-report-buildings-and-construction (accessed 25 May 2023).

Video

Süddeutsche Zeitung (2023, 5 May)
In 140 Stunden fertig – Europas größtes 3D-Druck-Gebäude. [Video]. Available at: www.sueddeutsche.de/wirtschaft/in-140-stunden-fertig-europas-groesstes-3d-druck-gebaeude-1.5841761 (accessed 23 May 2023).

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[8] Period of consultation: May to June 2023.

Contact us

Are you interested in developing and implementing strategies in line with circular principles for your company, or preparing for new regulations on sustainability? We would be happy to help with our extensive experience and expertise in sustainability management for the real asset sector, advising and assisting you with your transformation based on a holistic approach. Feel free to get in touch!

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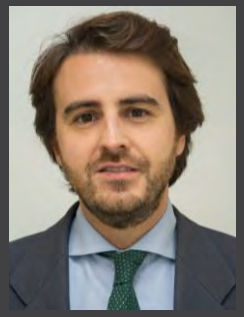

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