Building for the Future

2

A Knowledge Product Collection
by Bauhaus Earth

Series 2 — Regenerative Buildings

Building with Reused and Recycled Materials

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What to Expect:

Achieving a regenerative built environment requires a fundamental shift towards the use of bio-based materials. However, this shift alone is not enough. We need to consider how we approach the use of materials. The second Knowledge Product of Series 2 "Regenerative Buildings" highlights the importance of reusing and recycling materials.

Explore the impact of circular economy on the construction sector and the immense potential of circular building practices. Identify the barriers that prevent their extensive adoption and discover strategies for overcoming them.

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Towards Reduced Resource Consumption and a Post-Waste Economy

The built environment is the single most energy- and emission-intensive sector. In fact, the construction and demolition of buildings and infrastructure accounts for around 60% of global resource use and 50% of global waste[1]. This not only has a significant effect on climate change and the environment but also leads to the depletion of building materials. It is therefore crucial that we rethink the way we use materials and transition towards a sector that promotes a truly regenerative built environment.

Circular building practices offer an alternative approach to construction. This includes moving towards predominantly bio-based and renewable materials (see Knowledge Product 1 of Series 2), keeping materials in use for as long as possible, minimising the extraction of new resources, and ensuring that resources are wasted as little as possible. This can be achieved through intelligent design and manufacturing methods, such as design for flexibility and disassembly, and the principles of reuse and recycling, which help to extend the life cycle of building materials and components.

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There is no single agreed definition of circular construction. It can be understood as an approach to construction that aims to overcome the current linear process of take-make-consume-dispose and instead close the loop of building materials by reusing, repairing, refurbishing, and recycling. The aim is to maximise the life and usability of buildings or materials. Circular construction explicitly includes the use of bio-based building materials wherever possible (see Knowledge Product 1 of Series 2) and is understood as an essential contribution to a circular economy.[2] Circular economy implies an ideal system in which material and energy flows are cyclical rather than linear, replacing the notion of a product's 'end of life'[3]. A closely related idea is the cradle-to-cradle concept, which describes a design approach that views the materials in a product as resources rather than waste[4], supporting the notion of a circular economy.

Circular Building Practices in a Nutshell

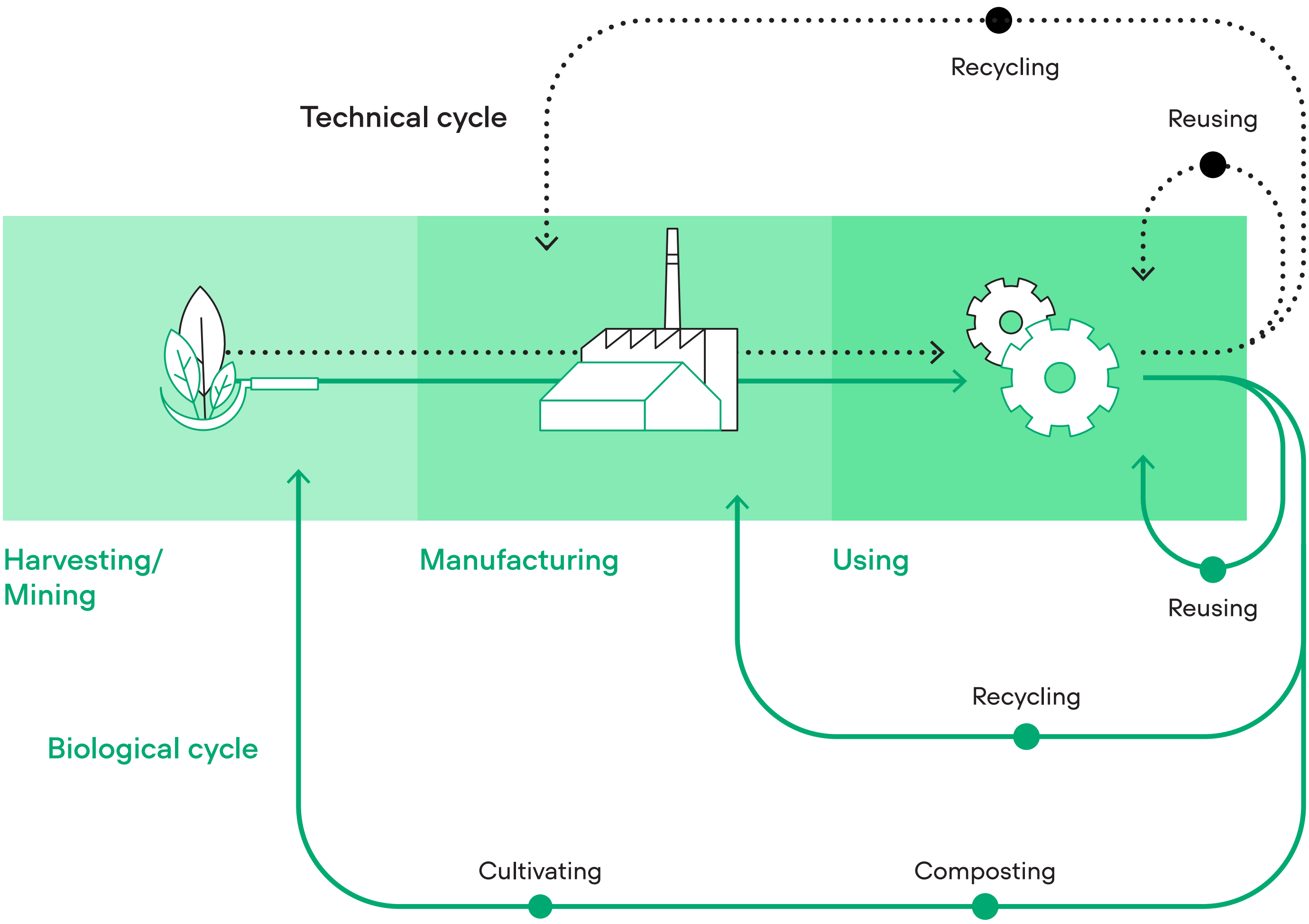
To understand circular construction, it is helpful to distinguish between biological and technical material cycles. The biological cycle includes the circulation and flows of bio-based and biodegradable materials.

Carbon is removed from the atmosphere and stored in plants during their natural growth process. Now, by using bio-based materials such as wood, buildings can effectively store the carbon in the wood within the building. While these buildings store carbon, other plants continue to grow and remove even more CO_2 from the atmosphere. In this way, buildings can offset the emissions related to their construction or operation and thus act as carbon sinks (see Knowledge Product 1 of Series 2). Keeping bio-based materials in the cycle of use of buildings for as long as possible is important, as disposing of them prematurely would release the carbon back into the atmosphere. Thus, the longer carbon is stored in buildings and the more bio-based materials are replenished, the greater the benefit. In particular, fast-growing materials with short harvest cycles (hemp, bamboo or straw) can have a significant impact.

After their period of use in buildings, bio-based and biodegradable materials can be reused or returned to the environment to decompose naturally and start a new cycle.

The technical cycle involves all finite materials, such as metallic-, mineral- and fossil-based materials. These are generally non-compostable and therefore cannot be easily returned to the environment. Once extracted, these materials should be kept in use for as long as possible through reuse and recycling to minimise harmful environmental impacts.[5]

Fig. 1: Technical and Biological cycle. Graphic based on EPEA (n.d.)[6]



The prospect of completely eliminating resource extraction and waste generation is considered unachievable in the near future[7], simply because of the lack of technological recycling solutions and the wear and tear of materials. To enhance resource use and minimize waste, it is therefore crucial to reduce our need for new materials and prolong the life cycle of materials or products through reuse and recycling wherever possible[8].

At the core of increasing resource efficiency and reducing waste are the so-called R-Strategies[9]. While they vary slightly in definition and specifics depending on the context in which they are applied, the following four are generally recognized as fundamental principles in the construction context[3]:

'Refuse': Avoid unnecessary components, details, and new construction. Before using or building something new, it is important to think critically about its necessity.

'Reduce': Reduce the amount of virgin material used in a product by optimising supply chains and minimising waste in the production process, as well as through efficient design. For example, digital technologies allow a tree to be turned into timber with minimal waste.

'Reuse': Reuse a product or material in its existing function, such as a window that can be reused in its function in another building or for another purpose, usually with a loss of quality. For instance, bricks that are reused in paving from a load-bearing structure.

'Recycle': Use a material as a raw material for another product, such as a steel column that is melted down to be used in another form. For some materials, such as steel, the recycling process allows the same quality to be achieved in the new product, whereas in the case of glass, the quality is reduced during the process of recycling. Recycling requires new energy inputs and should therefore only be considered after reuse options have been exhausted.

For those who would like to delve deeper into this topic, a far more differentiated and detailed representation of these strategies is offered, for example, in the 9R Framework by Potting et al. (2017)[10].

Fig 2: The 9R-Framework by Potting et al. (2017)[10]

SMARTER PRODUCT USE AND MANUFACTURE	R0 - Refuse	Make product redundant by abandoning its function or offering the same function with a radically different product
	R1 – Rethink	Make product use more intensive, (e.g. through sharing products, or by putting multi-functional products on the market)
	R2 - Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials
EXPAND LIFESPAN OF PRODUCT AND ITS PARTS	R3 - Re-Use	Re-use by another consumer of discarded product which is still in good condition and fulfils its original function
	R4 - Repair	Repair and maintenance of defective product so it can be used with its original function
	R5 - Refurbish	Restore an old product and bring it up to date
	R6 - Remanufacture	Use parts of discarded product in a new product with the same function
	R7 - Repurpose	Use discarded product or its parts in a new product with a different function
USEFUL APPLICATION OF MATERIALS	R8 - Recycle	Process materials to obtain the same (high grade) or lower (low grade) quality
	R9 - Recover	Incineration of materials with energy recover

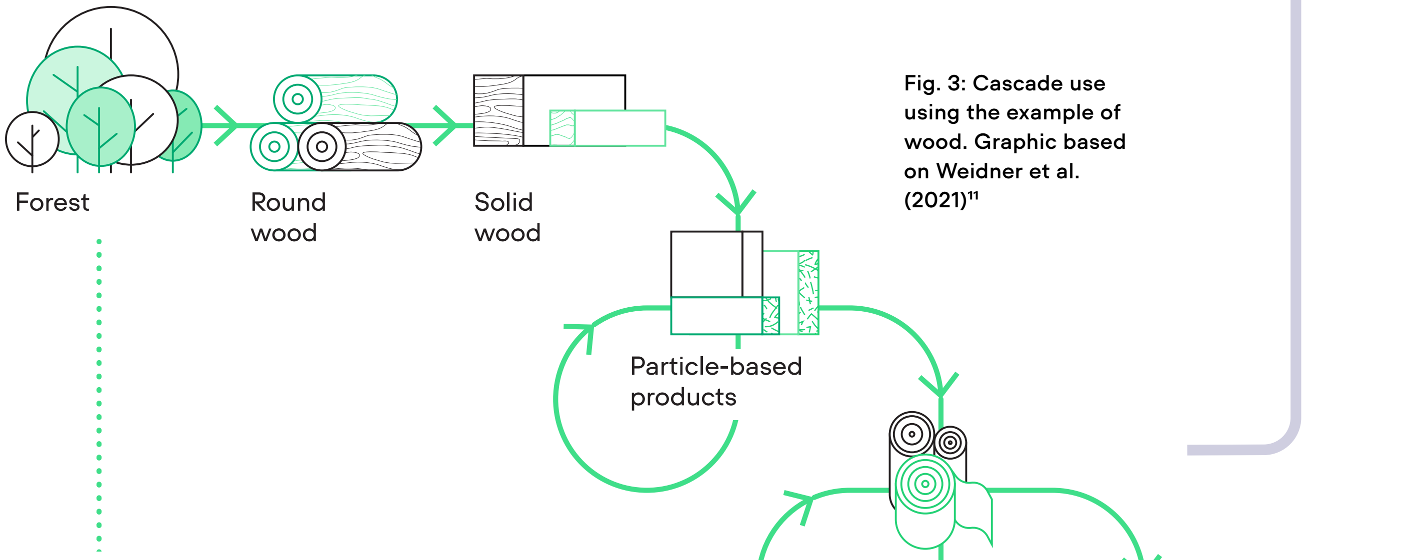


Fig. 3: Cascade use using the example of wood. Graphic based on Weidner et al. (2021)[11]

The principle of cascading is often mentioned when discussing bio-based materials. This concept entails that at the end of its first life, a product is not simply discarded but instead repurposed with the highest possible value. For instance, suppose a timber component has served as a load-bearing element in a building for 80 years; it can then be reused to create high-quality furniture. Later in its life, it may be recycled into plywood panels and only after multiple product life cycles should it be burned for energy. Ideally, a bio-based product will go through as many cascades as possible to ensure the most efficient use of the resource.[11]

Realizing Circular Buildings: Best-Practice Examples

The Circularity Gap Report 2020 found that for the first time in history, more than 100 billion tonnes of materials entered the global economy[12]. Without urgent action, the outlook for resource use is bleak, with 190 billion tonnes per year by 2060[13]. This is an increase of 110 per cent compared to 2015 levels of global material use[14].

> “As the single largest consumer of resources and accountable for half of the world’s waste, the built environment holds considerable power to influence the worldwide resource extraction.”

This negative trend has gone from bad to worse. According to the Circularity Gap Report 2019, our global economy was 9.1 per cent circular – 8.4Gt of materials were recycled input, while 84.4 Gt came from extracted resources[15]. Subsequent reports show a downward spiral – falling further to 8.6 per cent in just two years, and to a new low of 7.2 per cent in the latest 2023 report[16].

As the single largest consumer of resources and accountable for half of the world’s waste[1], the built environment holds considerable power to change these statistics. While many of the above-mentioned strategies may seem straightforward, their application to the built environment is complex. The following guidelines are an attempt to translate them specifically for the construction sector. Together with showcases of already constructed buildings, these examples and guidelines present opportunities for enhancing circularity in construction.

Prioritising Adaptive Reuse Over New Construction

Research shows that a new building that is 30 per cent more energy efficient than an average existing building takes 10 to 80 years to offset the CO_2 emissions associated with its construction[17]. Therefore, adaptive reuse and retrofitting of existing buildings is in most cases a better choice for meeting climate targets than building new energy efficient buildings. Despite this, it is estimated that the number of buildings demolished in the European Union is five times higher than the number of buildings retrofitted[18].

> Adaptive reuse is the process of reusing an existing building or structure for a purpose other than that for which it was originally built or designed. Examples include converting a former grain silo into a museum, an old church into office space, or a windmill into a home. This type of repurposing is an effective strategy for extending the life of a building.

A growing number of experts in the field are therefore calling for the use and renovation of existing buildings to be prioritised over new construction. A recent example is the demolition moratorium signed by hundreds of leading scientists and professionals in Germany. In an open letter to the German Building Minister, the initiative calls for a legal ban on demolitions, with demolition only allowed after a social and environmental impact assessment[19]. In addition, examples from around the world show how existing

Fig. 4: The Cosmopolitan

— Architects: &Bogdan (former Bogdan & Van Broeck)
— Completion: 2019
— Location: Brussels, Belgium

structures can be creatively reused and repurposed.

For example, many office buildings have been vacant at least since the rise of home offices following the COVID 19 pandemic. In Germany, more than 12 per cent of total workspace is underutilised[20]; it is estimated that converting these office buildings could provide almost 2 million new homes by 2040[21]. Conversion of office buildings offers enormous potential – not only to address the housing shortage but also to revitalise monofunctional city centres by creating additional residential spaces.

Originally built in the 1960s, an office building with a former trading port near the Brussels Canal has been converted into apartments. The 130 apartments range from studios to three-bedroom flats. The conversion involved the complete removal of the facades, fixtures, and fittings, while retaining the supporting structure and main circulation cores. Among other benefits, this reduced the transport emissions of the old materials by half. The project, known as The Cosmopolitan, is an example of innovative strategies for bringing office buildings back to life.

Reusing and Recycling Materials in Retrofitting and New Construction

Exploring and maximizing the potential for reuse and recycling of building materials is crucial in both retrofit and new construction. Although this task can be challenging, there are numerous projects that showcase the diversity of applications and the unique architectural and spatial qualities that can be achieved.

Fig. 5: CRCLR House

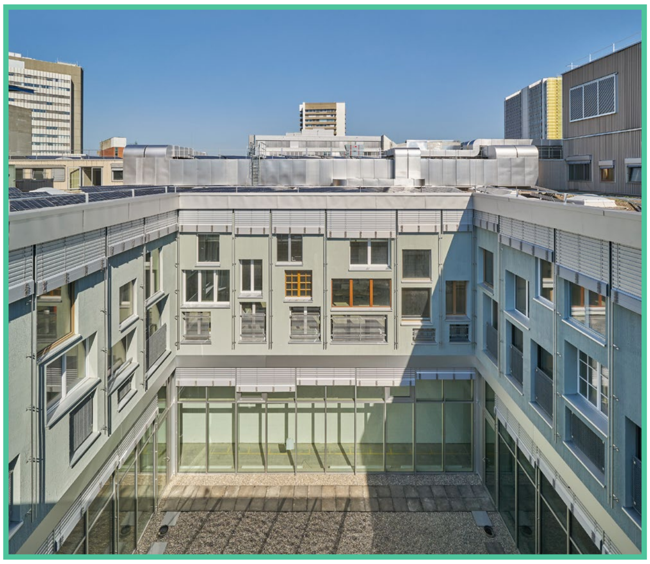
— Architects: LXSY
— Completion: 2021
— Location: Berlin, Germany

While the interior of the CRCLR House in Berlin shows how reused and recycled materials can be used in a coherent, high quality design concept, the refurbishment of the ELYS Kultur- & Gewerbehaus deliberately installed reused windows as distinctive design elements that showcase a new aesthetic. Similarly, the use of coloured glass bottles in the Silindokuhle Nursery creates a unique atmosphere using locally available materials that are not commonly used in construction. Such projects create a new architectural language that makes building with reused materials accessible to the public, highlighting its qualities and overcoming prejudices about its inferiority.

On the site of a former brewery, a 3500 square metre community and co-working space has been opened for entrepreneurs in the fields of circular economy, inclusion, sustainable food, and green technologies. Exploring circular construction methods, LXSY designed the interior by considering the possibilities of reusing building components, flexibility of spaces, recycled materials, and reversibility of connections. Product and material passports were used to document the process and facilitate reuse at the end of the building's life.

Fig. 6: ELYS Kultur- & Gewerbehaus

— Architects: Baubüro in situ
— Completion: 2021
— Location: Basel, Switzerland



ELYS Kultur- und Gewerbehaus is a mixed-use development in a former logistics centre in Basel, Switzerland. In addition to incorporating the existing building structure, repurposing of original construction materials was a central theme of the redevelopment. For instance, all approximately 200 windows installed

> "A Building can also function as a mine of materials."

during the redevelopment were sourced from within a radius of 100km. Within a grid pattern, the façade responds to the different sizes and shapes of the windows, making them a central design element. In total, preserving the building and reusing materials saved over 7000 tonnes Carbon dioxide equivalent (CO_2 eq).

Fig. 7: Silindokuhle Nursery

— Architects: Kevin Kimwelle
— Completion: 2015
— Location: Gqeberha (previously Port Elizabeth), South Africa

The Silindokuhle Nursery was developed after carefully assessing the needs of the community. The design challenge was to create a space that was flexible enough to cater to different urgent needs, including a pre-school, a paediatric clinic, and a community meeting place. Local citizens played an integral role in identifying these needs and actively participated in developing strategies. Locally available reclaimed materials that were already in use in the community were utilized in the design. Notably, the project used 2500 old wine bottles to create unique lighting effects while wooden pallets adorn the rest of the structure. This unusual combination of materials adds character and charm to the overall aesthetic of Silindokuhle Nursery.

Design for Future Reuse and Recycling

From the very beginning, buildings need to be designed and constructed with deconstruction in mind; their materials and components should be reused, recycled, or composted in the future. While complex geometries and designs often require components that limit the potential for reuse, standardised elements can greatly increase this potential. The design should allow components to be disassembled for reuse or recycling.

Reversible connections between components and materials, such as screws, nuts, and bolts rather than nails and ties, allow for easier disassembly when a building is no longer functional. In this sense, a building can also function as a mine of materials. This design approach is known as 'design for disassembly' and is exemplified by the Triodos Bank headquarters in the Netherlands. In this respect, prefabricated elements offer advantages because they are already proven to be transportable compared to, for example, walls that are cast on site.

Fig. 8: Triodos Bank

— Architects: RAU Architects
— Opened: 2019
— Location: Driebergen-Rijsenburg, Netherlands

The new headquarters of Triodos Bank is a building that can be dismantled and completely rebuilt elsewhere. The entire building, from the ground floor up, is a timber structure - giving the building a very low carbon footprint.
All products used in the construction have a documented identity, with information on both origin and processing, as well as possible future reuse.

Design for Longevity and Flexibility

In both new construction and adaptive reuse architecture, it is essential to aim for a long life for individual building components. Designing for disassembly promotes the longevity of a building by making it easier to remove and replace individual components as required. However, it is also beneficial if the design incorporates aesthetic quality and easily adaptable spaces to increase the potential for a building to be used over a long period of time. For example, a load-bearing structure that allows

Fig. 9: La Borda

— Architects: Lacol
— Completion: 2018
— Location: Barcelona, Spain

for the re-division of internal spaces, or is designed to adapt apartments on demand, as seen in La Borda, creates greater flexibility for future needs.

La Borda is the first co-operative housing development in Barcelona. It includes 28 units and communal areas, with a communal kitchen, guest rooms, and terraces. The design of the building makes it easy to rearrange the different apartments. Each unit has a size of approximately 40 square metres but can be extended to 60 or 75 square metres by flexibly adding rooms. This flexibility allows the flats to be temporarily adjusted to the needs of the residents, such as accommodating a growing family or adapting once the children have moved out.

Challenges and Barriers to Circular Building Practices

Circular construction is indeed possible – and not only that; numerous practical examples have shown that it is also ecologically and economically beneficial. However, there are still many barriers preventing its widespread adoption. These barriers include financial and regulatory challenges, as well as a lack of awareness and commitment. To address these challenges, several innovative strategies and initiatives have been developed. The following table summarizes key challenges in circular building practices, along with novel approaches and initiatives on how to overcome them.

TYPE OF CHALLENGE	DESCRIPTION OF CHALLENGE	INNOVATIVE APPROACHES AND INITIATIVES
FINANCING	Circular buildings often incur higher initial costs due to the additional time and effort currently required to work with reused materials, such as the need to guarantee individual components or material sourcing logistics.	Evaluating buildings from a life-cycle perspective, and taking into account not only the construction phase but also the maintenance and deconstruction of buildings, can result in economic savings of up to one third. High-value materials and adaptive construction techniques reduce the costs for maintenance. Further, the reuse and sale of building components at the end of a building's life cycle reduces the cost of deconstruction.[22]
LIABILITY	Currently, the legal standpoint is mainly concerned with the single use of materials and components. The main challenges are the lack of information on the quality and use of materials, which hampers the ability to implement necessary measures for high quality reuse, as well as addressing warranty and liability issues for reused components. It is imperative to bridge the current information and exchange gap between key stakeholders in the construction sector.	Material passports offer standardised and reliable information on the quality, origin, and location of materials. While it is easiest to collect this information during the design phase, material passports can also cover materials in already constructed buildings. Digital platforms like Madaster offer a service for storing and managing this information.[23] Extended producer responsibility is an approach that addresses the lack of warranty. Suppliers like Mitsubishi's M-Use provide building components, in this case lifts, in a 'products-as-a-service' model[24]. They retain ownership of the product, maintain it, and retrieve it for reuse. As a result, they have a vested interest in its longevity and reparability.
POLICY AND REGULATORY ENVIRONMENT	Although a circular economy policy framework has been adopted at EU level, including for the construction sector, it has yet to be translated into national legislation and policy. Where they do exist, they encourage recycling and reuse in the future, but neglect to deal with the existing stock and materials that are currently available.	Some countries are in the process of introducing policies. The Netherlands, for example, is planning to introduce digital material passports on a large scale to turn the building stock into a material stock[25]. There is also increasing pressure from civil society on policy makers to take the necessary steps, as evidenced by initiatives such as the demolition moratorium in Germany[19].
AVAILABILITY	The market for logistics and distribution of recycled building materials is still largely undeveloped.	Several platforms, such as Concular in Germany or Re-Sign in Italy, have digitized materials and components in existing structures, matching supply and demand for reclaimed building materials by listing them on a database for sale when they are deconstructed. Concular is also involved in the Urban Mining Hub, a pilot project for temporary storage of reclaimed materials. The aim is to align different planning schedules and requirements, which has proven challenging for stakeholders given the high costs of construction delays.[26].
PERCEPTION AND CULTURAL ACCEPTANCE	Reused and recycled materials are often associated with lower quality and inferior aesthetics.	Awareness campaigns and pilot projects could help change negative attitudes towards reused and recycled materials. For example, Future-Built, a collaboration between several Norwegian municipalities, aims to complete 100 pilot projects that reduce carbon emissions by at least 50 per cent, accompanied by workshops and various communication formats[27].
KNOWLEDGE AND SKILLS	The design process for building for reuse or with recycled and reused components differs from the conventional process. It involves the 'design for disassembly' approach and material passports, as well as adapting to the availability of reused building components - neither of which is the current practice, resulting in a lack of knowledge and skills among many professionals in the field.	In collaboration with the Ellen McArthur Foundation, Arup has launched a 'Circular Buildings Toolkit' that provides architects and professionals with valuable technical information and case studies on circular building practices[28]. In addition, educational initiatives such as the Natural Building Lab at TU Berlin[29] or the Chair of Circular Engineering for Architecture at ETH Zurich[30] have begun to integrate training in circular building practices into standard architectural curricula, training the next generation of architects.

Moving towards Circularity

In the face of the climate crisis and our depleting resources, a more responsible approach to materials is essential. Many challenges can only be addressed by political leadership, such as revising legislative and regulatory requirements, while others require the attention of each individual, especially industry professionals, in fostering awareness, commitment, knowledge, and capacity. Combined with a transition to bio-based materials where possible, meaningful steps can be taken towards a regenerative built environment.

However, per capita demand for space and resources is increasing – and if this trend continues, even the most effective reuse and recycling approaches will not be sufficient to reduce the extraction of new resources. The upcoming Knowledge Product 3 of Series 2 "Regenerative Buildings" discusses the concept of sufficiency as a solution for more responsible consumption and the equitable distribution of resources.

KEY TAKEAWAYS

→ Embracing the principles of 'refuse', 'reduce', 'reuse', and 'recycle' serves as a roadmap to greater circularity.

→ Adopting circular building practices can help reduce resource consumption and waste production, while playing a vital role in mitigating climate change.

→ Adaptive reuse and retrofitting of the existing building stock should almost always be prioritized over demolition and new construction.

→ Reused materials and building components should be favoured over new materials both in retrofitting as well as in new construction.

→ Recycling materials should be explored after reuse opportunities are exhausted.

→ Designing buildings with their future use in mind is key to facilitate a high degree of reuse at the end-of-life.

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About Bauhaus Earth

We envision a future where buildings, cities, and landscapes proactively contribute to climate restoration and have a positive impact on the planet and its inhabitants. Our mission is to transform building and human settlements from a driver of climate and societal crises into creative forces for systemic regeneration.

Only a complete systemic overhaul of our built environment will prevent a global climate catastrophe.

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