CIRCULAR BUILDING DESIGN:

Strategies and Tools

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Brief summary

To accelerate and make the transition to acircular economy more effective it is crucial to have an overview of the various strategies, principles and possible tools, whose implementation can bring successful solutions to the construction industry.

This publication provides an overview of the principles of circular building design through the lens of the 10Rs, including design for disassembly, reversibility, adaptability, reconfiguration, and spatial transformability, as well as an overview of possible tools for circularity feedback. By using these principles in building design, buildings can be easily disassembled, repaired, or adapted for new use, reducing the need for new materials and minimizing construction waste generation.

This guide is primarily intended for construction professionals and stakeholders seeking to incorporate circular design, sustainability and environmental responsibility into their projects. By opening this guide, you will have access to awealth of information on circular design strategies and principles, making it avaluable resource for construction companies, architects and designers, investors and developers. With practical advice in checklists for different construction phases, this guide helps you incorporate new design techniques into your work, reduce waste, water and energy use. Together with other guidelines published under the scope of the CirCon4Climate project such as aguideline for low carbon material selection, it will support you during design and optimization of aproject.

1. Principles of circular building design

1.1. Circular economy as an opportunity

In constantly adapting to new sustainable development trends, the construction industry plays a vital role in global resource consumption and environmental impact. In this regard, the concept of circular economy emerged as a transformational approach to solving the problems associated with traditional linear resource production and consumption models. As a number of projects considered to be circular increase, the principles and their formulation is still evolving. There are more than a hundred different definitions of circular economy, but in the scope of this project we recognize circular economy as an economic model, which through closing economic loops aims at:

- optimizing resource usage within planetary boundaries;
- maximizing and retaining the value of assets in the economy;
- and minimizing waste.

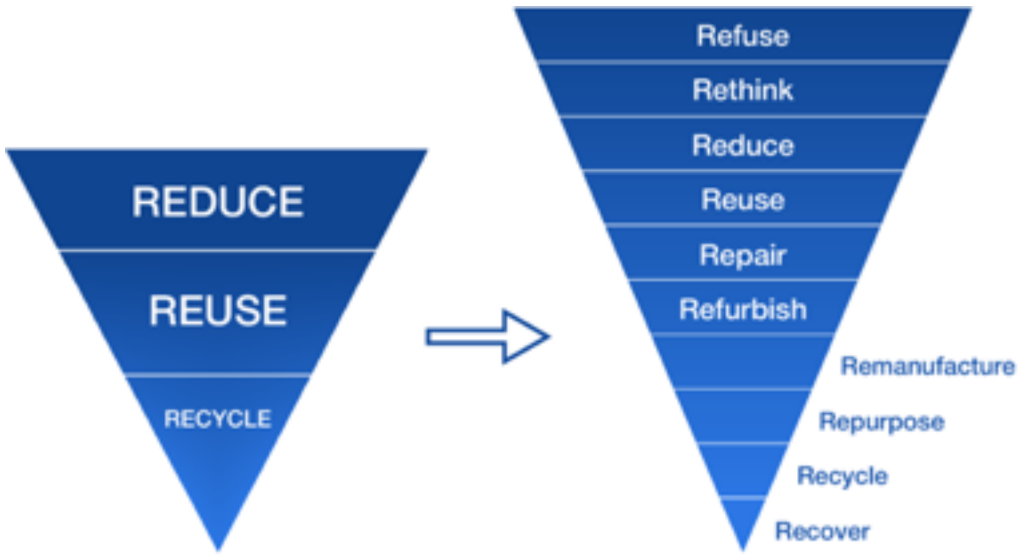
Circular economy perceives the entirety of value, taking into account environmental, social and economic benefits and costs in the entire lifecycle of assets.

In the construction sector, it does so by closing economic loops and consequently optimizing resource usage, maximizing value retention and limiting waste generation. To reach these general aims, it is possible to identify several approaches. In this guideline, they are called strategies, but it covers also actions that enable the retention of a construction value. Application of these strategies opens an opportunity to offer the same economic service with lower impact on the environment, in which we live.

1.2. 10R framework

The circular economy has often been identified with Recycling, which is only partially true. More precisely, the concept is more profound and, over time, has been smoothly transformed from Recycling to the well-known 3Rs principle and then to 10Rs (Figure 1). This concept includes vital principles such as Recover, Reduce, Reuse, Recycle, Repurpose, Remanufacture, Refurbish, Repair, Rethink.

Figure 1: Transformation of the 3Rs concept into 10Rs.



More about these strategies could be found in this guideline here: ***(Circular Building Strategies and 1.2 10R framework)***.

It’s essential to consider the 10Rs framework at the building level alongside the previously mentioned design strategies. Within these ten fundamental principles in Figure 1, one has the flexibility to select specific principles to guide new construction or apply them to existing buildings, tailoring the approach to the unique requirements of each project .

For example, **Refuse**: The first principle prompts us to challenge the necessity of new construction or superfluous components altogether. By evaluating whether a new build is essential, we minimize resource consumption.

Rethink: Embracing this principle encourages us to reevaluate traditional building approaches. By rethinking our methods, we can identify opportunities for more sustainable construction practices.

Reuse or Repurpose: Building on existing materials and structures is a fundamental aspect of circularity. By reusing structures and repurposing existing buildings, we extend the life of resources and Reduce waste, curb the use of virgin and non-renewable materials in new constructions. Repurposing buildings or their structure for alternative uses breathes new life into resources that would otherwise go to waste. This principle encourages creativity in finding novel applications for these elements.

Refurbish, Remanufacture: The „Refurbish” principle emphasizes the revitalization of building components and systems. It involves upgrading existing elements to enhance performance and extend their lifespan. Remanufacturing is a comprehensive process that restores a building to its original appearance using new, repaired or reused parts to replace obsolete components. Remanufacturing is a more costly process because it is more rigorous and meets higher standards than renovation.

Extending the life of products promotes circular economy strategies such as Recycle, Repair, Refurbish, Remanufacture and Reuse, resulting in reduced resource consumption and environmental impact and is considered a higher level of circularity [1], [2].

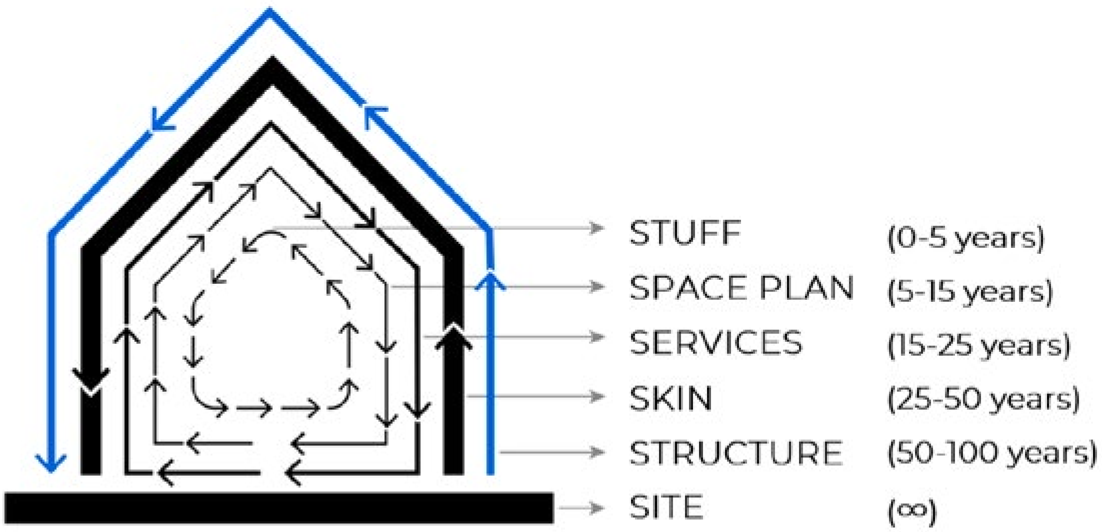
2. Circular building strategies

2.1. Design for Disassembly

The main focus of the principles outlined here relates to the end of the life cycle of a building, with a focus on the assemblies and the systems in the built environment. These facilities should be designed to allow dismantling at the end of life or during renovation, with the possibility of reusing their components for other purposes and potentially other facilities. The following principles should be considered:

- Each component must be independent on others.
- Prioritize the "building in layers" approach. According to the Brand's concept of "Shearing layers" buildings are seen as consisting of distinct layers that can change independently of each other [3]. This concept can be illustrated graphically as follows:

  Figure 2: Brand's shearing layers of change. Adapted from: [3].



  This means that these layers can transform at their own pace without affecting each other. For instance, a building's structural integrity typically lasts about 50 years, while certain services require replacement every 10 to 20 years. As a result, components such as heating, ventilation, and air conditioning systems need to be easily accessible for quick replacement or repair. Using prefabrication and modularity principles, dry connections make constructions easily assembled or disassembled.
- Implementation of the standardization of dimensions for the elements of the building - the height, the distance between the bearing walls, spans, etc.
- Simplicity should be prioritized in design, e.g., finishes or finished repairs should be avoided before occupancy, especially if different tenants will own the building.
- Use the business models that promote reuse and circular economy principles.

Benefits and challenges

By prioritizing these disassembly principles, benefits will be presented in minimizing carbon emissions, reducing material extraction over time, facilitating the reuse of building components in the future, and reducing costs throughout the life cycle of the building.

By implementing this design strategy, it is recognized that more materials might be required due to the use of different approaches to build the structure or a different method of connection between components, resulting in a correspondingly higher initial investment and a greater environmental impact [4]. However, this approach seeks to optimize the life cycle of the building, which will result in long-term benefits such as reduced waste and an overall environmental impact which will outweigh the initial costs ***(more about low carbon strategies/materials can be found in the guideline „Selection of circular and low-carbon building materials")***.

2.2. Design for Adaptability and Flexibility

Flexible design allows the building to adapt over time and meet the changing needs of users. The ability to adjust and change design elements ensures that the building remains functional and up-to-date even as operational requirements change, preventing it from becoming obsolete or irrelevant. This strategy may include the following principles:

- Design multifunctional spaces using active flexibility in spaces, such as the use of movable partitions or other elements.
- Use modular design and divide the building into modular components that can be easily rearranged or replaced as needed, allowing for flexible spatial configurations.
- Focus on spaciousness or expandability – e.g. large floor-to-ceiling heights and high-performance office spaces. This can include consideration of very fundamental design options, e.g. a circular building can easily be made larger or smaller by adding or removing a bay.
- Design accessible infrastructure by including accessible service routes and flexible utility connections to facilitate future modifications or upgrades.
- Implement principles of resource-efficient maintenance, repair, and flexibility in the use of space and systems.
- Consider Reversibility - Reversible buildings by design eliminate waste by using parts, which can be simply added and removed without damaging the building or its products, components or materials

Benefits and challenges

Adaptive design reduces waste, conserves resources, and mitigates the environmental impacts associated with new materials and buildings. However, it is considered that applying the principles of flexibility may result in additional costs at the design stage. For example, additional materials may need to be used as well as additional consultation to accommodate this flexibility. For this reason, it is essential to involve architects and planners from the conceptualization and design stages to develop an effective solution that meets your objectives and budget. In the long perspective it contributes to lower operating costs and overall carbon footprint over the life of the building as it reduces the need for major refurbishments the construction of new spaces because they will be able to adapt to new needs.

For a demonstration of applying this strategy in practice, please examine the following real-life example *(**5.1.1 Primary school building extension in Petrovice, Czech Republic** and **5.1.2 Gallery of Furniture, Brno, Czech Republic**)*.

2.3. Design for Durability

In the context of the built environment, sustainability implies designing buildings and building components that are built to last and can stand the test of time. The principles outlined here apply to all phases of the building lifecycle, as they minimize repairs from the first design phases and continue throughout the life of the building.

- Use durable materials, giving preference to those with a long lifespan, and use reliable construction methods and materials.
- Consider the resilience issues and resistance of materials to weather conditions, e.g., the roof and building envelope should be designed to withstand wind, rain, and temperature fluctuations, excluding possible corrosion and damage.
- Use of appropriate maintenance provisions - From the initial design stage develop a suitable and uncomplicated maintenance strategy. This should include the use of condition monitoring.

Benefits and challenges

By prioritizing durability in building design and construction, companies can reduce the need for frequent repairs, replacements, and renovations, which can help to reduce waste and conserve resources. Additionally, durable buildings and building components can be easily repurposed, reused, or recycled at the end of their useful life, further promoting circularity in the construction industry.

Durability can also help improve the overall quality of the built environment by ensuring that buildings are safe, functional, and comfortable for occupants or tenants. Durable buildings and building components can withstand extreme weather conditions, natural disasters, and other hazards, which can help protect the occupants and prevent damage to the built environment.

As with the previous types of design, it should be considered that this design strategy may require more materials or they could be more expensive due to improved properties, resulting in a corresponding increase in the initial investment and greater environmental impact in the initial phase. However, this approach focuses on long-term benefits and on optimizing and extending the life cycle of the building or its individual components, which will outweigh the initial costs in the future and reduce costs during its operational stage ***(More about low carbon strategies/materials can be found in the guideline "Selection of circular and low-carbon building materials")***.

2.4. Design for Reuse

Design for Reuse. The main focus of this strategy is reuse. An example could be to design a building, specifically its individual components, so that they can be reused - if, for some reason, the building needs to be relocated, rebuilt in a different location, or a completely different building can be constructed from some of its existing components. Or, when constructing a new building the reuse of a previously developed site or brownfields can be considered.

For a demonstration of applying this strategy in practice, please examine the following real-life example: 5.1.3 Office building Mercury as Example of (Re)molition, Prague, Czech Republic.

2.5. Design for Modularity

Another principle closely bordering the principle of reuse is **Design for Modularity or Modular design**, in which a system is divided into smaller parts called modules (from prefabricated structural elements to individual cells - rooms of an apartment) that can be independently created, modified or easily interchanged to other modules or between different systems.

For a demonstration of applying this strategy in practice, please examine the following real-life example: 5.1.1 Primary school building extension in Petrovice, Czech Republic

2.6. Design for Maintenance

The principles like **Design for Maintenance, Design for Repairability, Design for Upgradability and Design for Refurbishment** have been conventionally grouped because they have one purpose - to extend the life of a building or its components and to reduce the need to replace or disassemble. In other words, the goal is that elements can be easily modernized or adapted to changing needs or technologies through properly performed maintenance. For example, building façade construction can utilize wall panels with easily replaceable sections that can be maintained and repaired without significant intervention in the structure itself. If one section is damaged, it can be replaced with a new one or upgraded, extending the life of the entire wall.

Often, these strategies are used to preserve and adapt buildings of significant historic value. Such buildings require periodic maintenance and modification to preserve their historic significance and meet modern needs.

2.7. Design for Reliability

Design for Reliability in the context of circular economy includes methods aimed at ensuring reliability and safety throughout the life cycle or also involves improving the internal characteristics of the product, by which the life cycle and thus its useful life will be longer, e.g., through maintenance [5]. This strategy closely resembles the Design for Durability approach. In essence, both concepts aim to improve product performance and durability, but durability-based design focuses more on the physical aspects of the product and its resistance to wear and tear, while reliability-based design places more emphasis on ensuring that the product functions reliably without unexpected failures and breakdowns throughout its life cycle.

2.8. Design with Mono-materials

Design with Mono-materials in architecture and construction involves the use of a single material for most elements of a building or its structure in order to rethink the design and make it simple. Using the example of timber structures, it is emphasized that the main advantage of building with mono-material is that it can be easily disassembled and fully recycled as a one-piece structure since non-biologically based materials such as adhesives, metal fasteners, and insulation panels have not been used [6],[7].

2.9. Design with Recycled materials

Using **Design with Recycled materials** ***(More about recycled materials can be found in the guideline " Selection of circular and low-carbon building materials " and in "Information package for producers of building products on safe use of secondary materials ") and Design with Waste*** make a major contribution to reducing the consumption of primary resources by reusing previously used materials or diverting waste from different sectors - construction, industries or municipalities - to create new innovative building materials. For example, using construction products and materials such as alternatives to cement or aggregate in concrete or recycled asphalt pavement. Or when designing, using materials such as reclaimed wood, recycled steel, recycled glass and recycled plastic to create new products [7].

For a demonstration of applying this strategy in practice, please examine the following real-life example: 5.1.3 Office building Mercury as Example of (Re)molition, Prague, Czech Republic.

2.10. Design for Attachment and Trust

Creating products that will be loved, liked, and trusted for longer is what **Design for Attachment and Trust** is all about. Design the construction so that the user becomes attached to the product and thus encouraged to treat the product with care and is less likely to replace it. This is especially relevant for public buildings with cultural or social values, e.g. operas, churches.

2.11. Design with Circular business models

Design with Circular business models is a self-explanatory name, which prompts a rethinking of the existing business model used in the building industry. Even when we reference to a circular building design, the service provided by this product still remains linear. The building is designed – built – used – and finally disposed of. Design with Circular business models tries to suggest alternatives such as renting a construction or technology. An example can be renting lights in the building as a service specified using enlightened space. This kind of service moves responsibility for quality of the technology from users (owner of the building) to the producer. Although it is possible to imagine renting other parts of the building (e.g. building envelope), such an approach is limited by the very long service life of the construction and the unguaranteed existence of the company providing such a service. [1],[2].

2.12. Buildings as material banks

It is important to reuse individual building elements or materials at the end of their life. Instead of becoming waste, buildings will act as banks of valuable materials, so that the proportion of construction or demolition waste and the use of primary resources can be significantly reduced.

One of the first to promote this idea was the Horizon 2020 Buildings As Material Banks (BAMB) project [8]. In this design, the idea of „Buildings as a Material Bank" was interpreted in the direction of recycling to ensure that the elements are recyclable. Within the framework of this BAMB project, a pilot project „New office building" was designed. (Figure 3) The office building was constructed in Essen near the industrial complex of the Zeche Zollverein coal mine. The concept of the interior space allows the building to be converted into different uses. The building can either remain an office with different zoning, or it can become a hotel. Using the circular design aspects of the project, in the pilot case study 4,641 tonnes of waste was diverted from landfill, 91 tonnes of waste was not incinerated and a further 12,108 tonnes of material could be recycled into products of the same quality [8].

Figure 3: The New office building

source: https://www.bamb2020.eu

Such projects show us that the same circular strategies can operate at different scales – not only at the building level, but also at the product level. As all of the above-mentioned strategies are applicable during building design, the designers and building contractors can choose building products, which are designed to be circular and low carbon. For example, durability-oriented design can focus directly on materials, which involves selecting high-performance and durable materials (such as steel or concrete) whose life cycle extends beyond that of the building, reducing the need for frequent replacement and minimizing waste generation. It can also be considered holistically, at the building level, and include the development of appropriate and straightforward maintenance strategies. At the same time, circular design strategies have another goal that positively impacts sustainability: designing buildings and infrastructure to **minimize net operating costs** such as energy, water, and air quality.

2.13. Digitalization as a circular strategy

The integration of digital technologies is a powerful driver of circular economy in the construction industry [9]. The key to this transformation is the digital technologies' ability to provide and pass accurate information on product availability, location and condition, helping to slow down and close material loops, thus promoting circular economy business models. Digitalization also makes it possible to optimize circular business models, reduce waste, extend product lifecycles, and lower transaction costs.

The digitalization of processes in each design phase of building construction is often integrated through Building Information Modelling (BIM) as the most commonly used tool. ***This tool will be described in more detail in chapter 4.3***

Another approach to collect and store information about the building and especially about its components was defined by developing Material and Building Passports. ***This tool will be described in chapter 4.4.***

The use of other digital technologies, such as artificial intelligence or blockchain, is also enabling innovative ways to increase traceability and transparency throughout the product lifecycle. Smart, connected products enable manufacturers to continuously track, monitor, analyze, and optimize product performance by collecting valuable usage data.

Digitizing the real-time location of items using a Geographic Information System (GIS) increases the real-time availability of items, which greatly improves the ability to collect, recover, recycle, and dispose of end-of-life items. This way, a Material Cadaster can be created and can operate at a local or regional level. It provides an overview of the type, quantity and condition of materials used in a given area and serves as a basis for mapping the dynamics of material use in the residential environment of a city or region. This can be used to define "circular" building strategies in cities and regions to predict maintenance status, extend the life of both the whole building and individual components, and use materials for new construction. ***More information could be found in the Material Cadaster Guideline***. Finally, understanding product availability facilitates the creation of sharing scenarios through digital platforms and marketplaces, ultimately improving recycling practices.

2.14. Selective demolition

Selective demolition is one of the most important aspects of modern construction practices to minimize waste, resource consumption and environmental impact. Several activities can be covered by selective demolition:

- The deconstruction method involves carefully dismantling a building or structure piece by piece. The goal is to salvage and reuse as many components as possible in other projects.
- Selective demolition removes individual parts of a building while preserving the basic structure. This method is valuable in real estate re-modelling, preserving existing structures and reducing the overall environmental footprint of the project. Materials and products removed from the building can be subject to the national waste legislation and the contractor must keep in mind the waste hierarchy and other related requirements. ***More about these requirements can be found in Safe use of secondary building materials - Information package for producers***.
- Selective demolition prioritizes environmental responsibility throughout the demolition process. This approach includes minimizing waste generation, recycling of materials, using non-toxic building materials, and taking steps to ensure minimal environmental impact. Such demolition is consistent with the Sustainable Development Goals and helps protect the ecosystem.

For a demonstration of applying this strategy in practice, please examine the following real-life example: 5.1.3 Office building Mercury as Example of (Re)molition, Prague, Czech Republic.

3. Checklist for the initial design phase

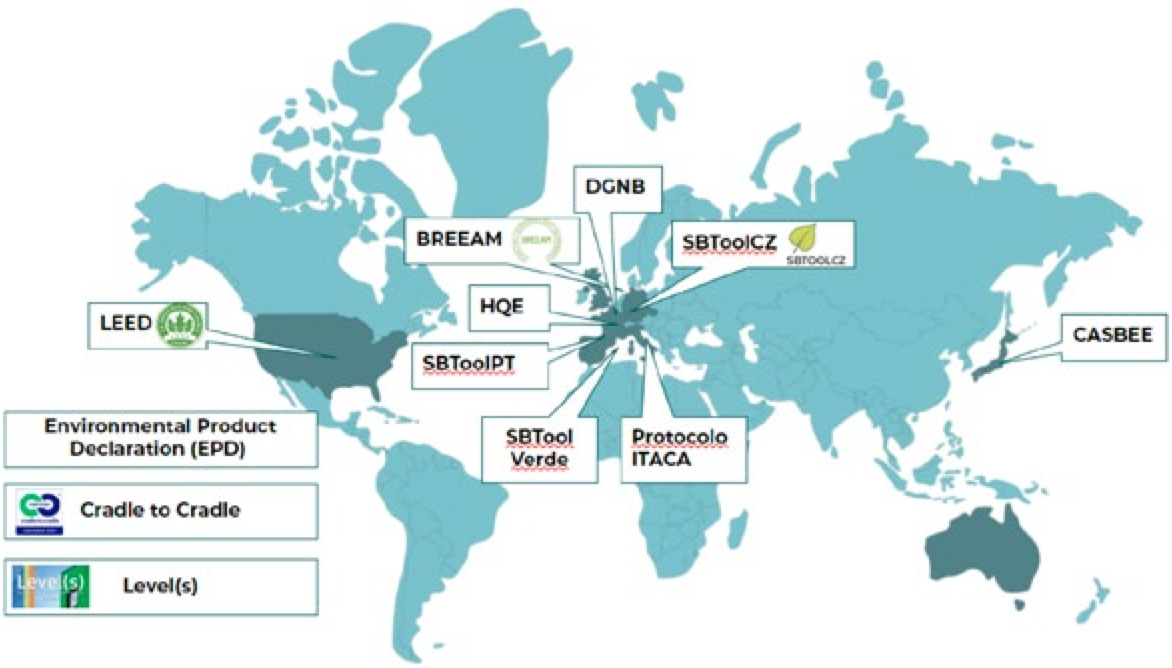
Influencing a construction project in the early stages of design can significantly affect the project's success. This checklist serves as an important tool offering valuable guidance to construction companies, planners, architects and designers, and stakeholders. Carefully categorized possible circular suggestions could help with choosing the right direction from the start and taking specific steps throughout the stages of project preparation - from the concept phase to the end of the life cycle. By utilizing this list, project participants can begin to act toward more circular, sustainable, and environmentally responsible construction.

Discover the checklist in the Annex of this guideline.

4. Tools for circularity feedback and measuring

Circularity in the construction industry can be considered from the perspective of the whole building, but also from the perspective of the individual materials used in its construction. For this reason, the focus of this section will be on tools that certify both - products and buildings. It should be noted that there are many ways to assess and certify the circularity of buildings and their parts in the world. The most common ones are presented in Figure 4.

Figure 4: Leading Circular Assessment Certification Schemes for Buildings and Products



4.1. Certification of products

Environmental labelling is a globally applied concept based on international standards (ISO14020 series), which are voluntary information tools. It is based on the evaluation of the characteristics of products (products or services) and their environmental performance.

It is the labelling of products with various labels, in some cases accompanied by brief information on the product's characteristics. The overall aim of eco-labels and declarations is to encourage demand and supply of products that cause less environmental pressure by communicating verifiable, accurate and non-misleading information on the environmental aspects of products, thereby stimulating the potential for continuous, market-driven environmental improvement.

There are three standardised (normative) types of environmental labelling and declaration:

Eco-labelling (Type I):

is a tool based on the labelling of products (and services) that have lower negative environmental impacts than comparable products, i.e. interchangeable in the use phase. Products that meet predefined environmental criteria within a defined product category and that are independently verified by a third party can be labelled.

Self-labelled environmental claim (Type II):

is defined as "a statement, mark or figure indicating the environmental aspect of a product, component or packaging". (e.g. biodegradable, recyclable, etc.). It is issued by the manufacturer, without third party verification or certification, but must be publicly verifiable (so-called second-party verification), based on information made available by the notifier.

Environmental Product Declaration (EPD) (Type III):

Provides quantitative information on the environmental performance of a product throughout its entire life cycle - i.e. from raw material extraction to disposal or recycling. This is based on the application of the Life Cycle Assessment (LCA) method. ***More aboutLCA method can be found in the guideline "Selection of circular and low-carbon building materials"***. In order to create comparable EPDs, they must follow the same methodological rules (EN 15804, [12]) and guidelines prepared by program operators called PCR. EPD is a technical information that provides quantifiable environmental data for construction products with a specified technical function on the building level. Standard EN 15804 defines the core rules for the creation of EPDs for construction products and materials. EPD enables to analyze the life cycle of products with regard to their environmental impacts and to display these analyses in a transparent and standardized way. The EPD Program is voluntary and covers all construction products as it is defined in Annex IV of the European Construction Products Regulation (No 305/2011, [13]) and open to all interested construction product manufacturers.

While certification undoubtedly adds value to products and buildings in the eyes of consumers and stakeholders, it is important to recognize the potential pitfalls. Product certification can attract professionals and companies looking to capitalize on the growing demand for sustainable solutions. Therefore, when selecting materials and participating in certifications, it is important to thoroughly research the information and the standards on which it is based, and to give preference to certifications that are established on the marketplace.

4.1.1. Carbon Footprint of products

The Product Carbon Footprint (PCF) is the sum of greenhouse gas emissions and sinks in the production cycle of a given product, expressed in CO_2 equivalents (CO2e). The calculation is based on a Life Cycle Analysis of the product and considers a single impact criterion, which in this case is total greenhouse gas (GHG) emissions. These emissions are produced and removed throughout the life cycle (e.g. "cradle to grave"), from raw material extraction through production, use and waste disposal. The procedure for calculating the carbon footprint of products is given in the PCF Technical Specification, which is under the ISO Standard 14067:2013.

Moreover, Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products, introduces an essential requirement 7 - sustainable use of natural resources. Its definition is as follows:

"A building must be designed, constructed and demolished in such a way as to ensure the sustainable use of natural resources and in particular:

a. the reuse or recyclability of structures, materials, and components after demolition;

b. the service life of the structures;

c. the use of environmentally friendly raw and secondary materials in construction." [13]

Building products must meet the limits for adequate indoor environmental quality while at the same time minimising the burden on the external environment. Also, building products incorporated into the building must respect the requirement for high functional quality over the long-term lifetime of the building. The design and optimisation of the structure must therefore consider the behaviour of the structure over its entire life cycle and consider the expected cycles of maintenance, repair, and replacement of individual components. ***More about related requirements and limits can be found in Safe use of secondary building materials - Information package for producers***.

4.2. Certification systems

4.2.1. Cradle to Cradle

The C2C Certified Products program, established in 2005, operates based on the Cradle to Cradle Certified Product Standard [14]. Its primary purpose is to evaluate the biological and technical recyclability of products – circularity aspects, their safety, and the responsibility of materials and products in five sustainability performance categories: Material Health, Product Circularity, Clean Air & Climate Protection, Water & Stewardship, Social Fairness. The certification Cradle to Cradle Certified™, is awarded to products that meet these criteria and receive a Bronze to Platinum rating in all 5 parameters. Each parameter is assessed independently, and if at least one of them meets the minimum level, the entire product will be awarded the minimum certification level, which is Bronze. This means that even if some parameters excel, the lowest-performing parameter determines the overall certification level.

The presence of this certificate for the material or product is also recognized when the building is assessed with sustainability certification schemes such as LEED (Leadership in Energy and Environmental Design) [15], BREEAM (Building Research Establishment Environmental Assessment Method) [16] and others. Based on that the credits are awarded, which affects the final score.

4.2.2. Level(s)

Level(s) is a widely known European framework, which provides a common language for assessing and reporting on the sustainability performance of buildings [17]. In addition to sustainability, this framework provides a simple starting point for embedding circular economy principles into the environment we are creating. Level(s) is a well-established system for evaluating and promoting improvements throughout the life cycle, starting from the design phase until the end of a building's life. It can be applied to different building types, such as residential or offices.

Level(s) uses fundamental sustainability indicators such as assessing carbon emissions, health and comfort factors, and climate change impacts over the building's life span. Regarding circular economy, relevant indicators could be found in it as well such as "Resource efficient and circular material life cycles". This part helps evaluate material use by using a Bill of Quantities (BoQ) and identify the approximate durability and service life of the materials and products used in relation to the expected lifespan of the building. The total volume of construction or demolition waste could be assessed, including how well building's design could face future adaptation and possible renovation. Level(s) framework includes an Efficient use of water resources evaluation.

4.2.3. LEED

Another certification scheme for sustainable buildings that includes circular indicators is LEED. Leadership in Energy and Environmental Design is a globally recognized green building certification system developed by the United States Green Building Council (USGBC) [15]. It provides a comprehensive framework for evaluating the design, construction and certification of sustainable buildings, spaces and even neighbourhoods, cities and communities.

The evaluation manual provides credits and requirements that will help evaluate circular aspects used in the building design. Inside each criterion a step-by-step guidance is provided to receive the highest score successfully. For example, credit that evaluates Construction and Demolition Waste (CDW) requires developing and implementing a CDW Management Plan through waste prevention and/or diversion. It is required to achieve at least 50 % of diversion of CDW. More specific steps are described throughout the manual and explained in more detail.

Further criteria that support and evaluate circularity can be found in the Materials and Resources part. For example, ensuring storage and the collection of recyclables to reduce municipal waste landfilling, building and material reusing, the use of the Environmental Product Declaration with all the necessary information about the product and only responsibly sourced materials, or if flexible design principles were implemented, etc. Also, separate attention is paid to water management for the reduction of water use.

4.2.4. BREEAM

BREEAM is the world's leading science-based suite of validation and certification system for a sustainable built environment [16].

Since 1990, BREEAM's third-party certified standards have helped improve asset performance at every stage, from design through construction, to use and refurbishment. Millions of buildings across the world are registered to work towards BREEAM's holistic approach to achieve ESG, health, and net zero goals. It is owned by BRE – a profit-for-purpose organisation with over 100 years of building science and research background.

The certificate includes several sections, each of which includes a different number of evaluation criteria. Points are awarded according to the degree to which specific sustainability and circularity criteria are met in the relevant section. These accumulated points form the basis of the BREEAM assessment process.

Strong alignment with and support for circular economy principles can be found in nearly every section of the certificate. This alignment is particularly evident in the Materials, Waste and Water sections. Here, the core principles of the circular economy are prominently integrated into the assessment criteria, as Designing for durability and resilience, which encourages to rethink the traditional design approaches; Material efficiency, where a higher score will be obtained for more efficient and smaller amounts of material used for building construction; Waste management, Recycled aggregates, Site selection and other assessment criteria.

4.2.5. SBToolCZ

SBToolCZ is a national Czech certification tool for expressing the quality level of buildings, in accordance with the principles of sustainable construction [18]. The certification process was officially introduced and launched in June 2010.

The objective of certification by the SBToolCZ methodology is the provision of a reliable certificate of compliance of the construction with legislative requirements and with the principles of sustainable construction:

- increasing the market value of buildings and reducing their operating costs,
- support for reducing the energy performance of buildings, in accordance with Directive 2010/31/EU of the European Parliament and the Council on the energy performance of buildings EPBD II,
- assessment of buildings within aspects in the field of sustainable construction,
- an optimization tool for designing buildings that better meet client requirements,
- mitigating the impact of buildings on the environment during the entire life cycle,
- supporting the creation of a good and healthy indoor environment in buildings,
- stimulating demand for sustainable buildings,
- stimulation of manufacturers to produce and market environmentally friendly products responding to the new basic requirement for construction according to Regulation of the EP and the Council No. 305/2011,
- an incentive for manufacturers to attach an EPD (product environmental declaration).

4.3. Tools for circularity assessment

4.3.1. Catalogue of recycled materials

A Catalogue of recycled materials has been developed to present the possible uses, risks and barriers to waste recycling in the construction industry. The catalog is divided into 2 sections, which present products with recycled content and the recycled materials themselves suitable for use in the construction sector with examples of good practice: from concrete to plasterboard.

In addition, the compilation contains legal requirements and relevant provisions of standards and test procedures for the practical application of recycled products in the specific conditions of the Czech Republic [19].

4.3.2. OneClick LCA

One Click LCA is the #1 easy and automated Life Cycle Assessment software that helps you calculate and reduce the environmental impacts of your building & infra projects, products and portfolio. OneClick LCA offers embedded algorithms for quantifying building circularity [20].

4.3.3. Madaster

Madaster is an online registry for materials and products. In Madaster, data are recorded on all materials and products that are incorporated in a real estate or infrastructure object, such as buildings and bridges [21]. Registering every component provides insight, for example, into the degree to which an object can be dismantled, its embodied carbon, or the toxicity of the materials and products used. It also enables determining whether materials and products can be reused after disassembling. Building in such a circular way means that we are drastically reducing the amount of waste and CO_2 emissions and are taking better care of our planet. ***More information about creation of material cadasters can be found in the Guideline for the compilation of a building material cadaster***.

4.3.4. CTI Tool

The CTI Tool was developed to help businesses in different industries worldwide to measure and improve their circular performance by supporting and guiding companies through the Circular Transition Indicators process [22]. The tool structures data and calculates outcomes, supporting businesses in taking concrete actions towards their circularity goals. It also supports users to reach out to internal stakeholders and value chain partners for data requests that avoid confidentiality issues.

Leveraging the power of digitization and smart software solutions, the CTI Tool enables companies to accelerate their transition towards a circular economy and fully understand their circularity baseline.

4.4. BIM

Building Information Modelling (BIM) is the most widely used digital tool for representing a building's physical and functional characteristics. It provides an accurate and up-to-date digital representation of building components and systems to support the design, construction, and operation of buildings [23].

There are several key points to consider when implementing BIM in the context of the circular economy. BIM can be used to track and manage the environmental impact of a building throughout its lifecycle - from design and construction to operation and subsequent demolition or renovation. This allows for a better understanding of resource consumption and waste generation. A plug-in to the OneClick tool mentioned earlier can be easily installed in Revit or Archicad software.

BIM tools can assist in the selection of sustainable materials and products that are in line with the principles of circular economy, such as those with a high potential for reuse, recycling, or disposal. Information on the environmental performance of materials can be incorporated into the BIM model, as well as extracted to produce Building or Material Passports.

Using BIM and creating a digital twin can support the design of buildings that consider the possibility of disassembly and reuse, facilitating the identification of building components for reuse in other projects, promoting the principle of circularity.

Similarly, it can track and manage resource consumption and waste generation during construction and operation, and facilitate the planning of maintenance, repair, and upgrades.

In addition, BIM facilitates collaboration and information sharing among various stakeholders, including architects, engineers, contractors, and owners. This collaboration can lead to more informed decisions in sustainable design and practice.

4.5. Material and Building Passports

To accelerate gaining insight into the properties of materials and their reuse potential, material passports need to be introduced. As one of the first examples they were used in the Horizon 2020 BAMB project and are defined as follows: *Material Passports (MP) are (digital) data sets describing defined characteristics of materials and components in products and systems that give them value for current use, refurbishment and reuse. MPs are an information and education tool that addresses issues that are often not provided by other documents or certifications of building products, especially in relation to product circularity. MPs do not assess or evaluate data. Instead, they provide information that supports assessment and certification by other parties and allow existing assessments and certifications to be written into the passport as uploaded documents [10].*

Passports have the potential to incorporate existing standards and tools. The material passports presented in the BAMB project and in general have the potential to incorporate existing mechanisms such as TDS - total dissolved solids, MSDS - Material Safety Data Sheet for the handling of hazardous substances and/or mixtures, EPD - Environmental Product Declaration, Bill of Materials - Bill of Materials as a list of all sub-assemblies, parts and starting materials from which the final product is made, including the Bill of Quantities (BoQs) required, and other information where relevant to support circulation claims.

Integrated through Building Information Modelling (BIM), allows the use of digital tools including Material or Building passports in this digital structure to create a comprehensive virtual representation of the construction project [11]. This allows for collaborative design, clash detection and visualization, a centralized repository of material data, sourcing information, resulting in fewer errors and more informed decisions.

5. Case studies

5.1. Czech Republic

Czech Republic

5.1.1. PRIMARY SCHOOL BUILDING EXTENSION IN PETROVICE, CZECH REPUBLIC

This case study is an example of the use of amodular construction process (Figure 5). An originally **modular** primary school needed more space for its growing number of students so 2 extra classrooms were attached to the building. The modular method allows aquick and easy construction or expansion of prefabricated standardized sections of buildings (modules) ensuring **flexibility and adaptability** with adesign focused on **reuse** right from the start [24].

Figure 5: Modular primary school in Petrovice, Czech Republic

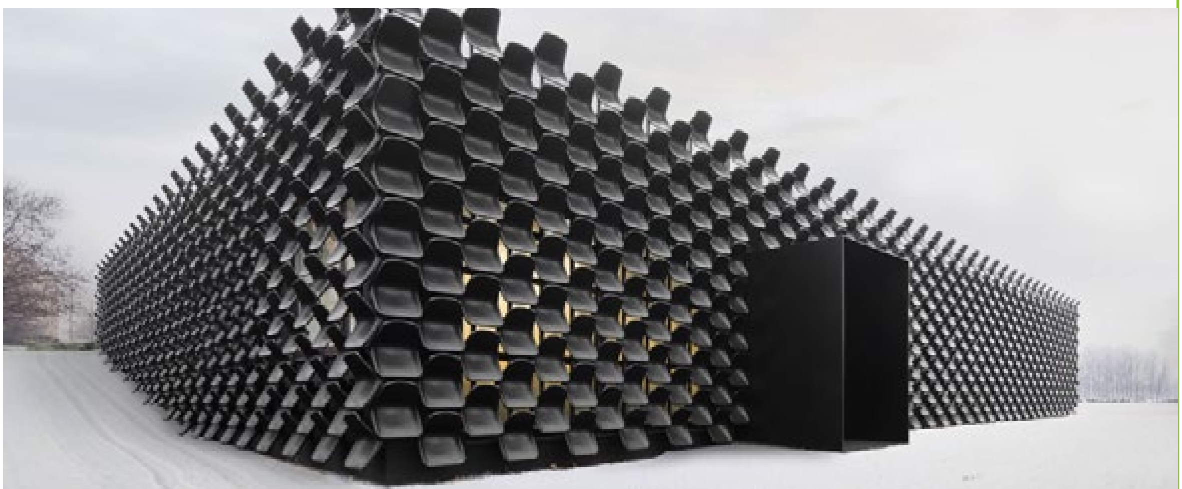
Source: *https://www.koma-modular.cz/reference/rozsireni-modularni-skoly-praha-petrovice, [24]*

Czech Republic

5.1.2. GALLERY OF FURNITURE, BRNO, CZECH REPUBLIC

Now a furniture gallery in Brno, this one-story building was originally a car show room (Figure 6). The architects decided to **repurpose** materials from plastic seats to construct an original façade, functioning as an advertisement for the furniture gallery as well. The interior was re-designed to have a more **flexible**, movable, and versatile space with a multi-purpose layout, optimizing utilization. Instead of building extra space, the existing structure was **reused, renovated, and repurposed**, saving materials and energy [25],[26].

Figure 6: Gallery of furniture, Brno, Czech Republic



Source: *https://www.chybik-kristof.com/projects/gallery-of-furniture, [25]* Czech Republic

5.1.3. OFFICE BUILDING MERCURY AS EXAMPLE OF (RE)MOLITION, PRAGUE, CZECH REPUBLIC

The Mercury office building on Figure 7 is the first office building in the Czech Republic to be built according to the principles of circular economy. Anew Mercury building will be constructed by **reusing** materials from its predecessor, which now stands in its place. In line with the philosophy of sustainable development, the previous building was **carefully dismantled** piece by piece and material by material - from the cladding to the load-bearing structures - so that as many materials as possible could be returned to the loop. This process of Remolition, as the company calls it, instead of demolition, will save up to 12,000 tons of concrete [27]. Much of the material will be used directly in the new Mercury building, while some will be used in other company projects [28].

Figure 7: Office building Mercury: new and existing building

Source: *https://cyrkl.com/cs/case-studies/166, https://www.skanska.cz/en-us/Expertise/development/commercial-development/projects-in-pipeline/mercury/mercury-story-cz/*

5.2. Germany

Germany

5.2.1. CRCLR HOUSE IN BERLIN-NEUKÖLLN, GERMANY

The Circular Economy House (CRCLR house) was built on the site of the former Kindl brewery in Berlin Neukölln (Figure 8). It is a combination of existing use and extension. The existing building of the former bottle warehouse is being **upgraded, renovated** and **extended** by two and a half storeys (new construction). The extension is built using sustainable timber constructions. When making decisions during the planning process, attention was paid to the use of **recycled building materials** and their **reusability**. In cooperation with the architects and users, ZRS Ingenieure developed the supporting structure for the existing building and the extension [29].

Figure 8: Renovation of the existing building and extension in timber construction

Source: *https://www.zrs.berlin/en/project/crclr-house-2/, [28]*

5.2.2. NEW BUILDING OF THE UBA (FEDERAL ENVIRONMENT AGENCY) IN DESSAU, GERMANY

In terms of construction, the new building is a solid concrete and reinforced concrete structure (Figure 9). Almost 3,000 cubic meters of concrete were delivered to the construction site for this purpose. 60 percent of the concrete delivered was **recycled concrete**. The recycled material in the concrete has a grain size of 8 to 16 mm and has been approved by the German Institute for Building Technology (DIBt) in Berlin [30].

Hemp will be used as an insulating material in the interior walls. Wood in the form of strip parquet will be used as a further **renewable** raw material. The building is a plus-energy building and was designed by the Berlin architectural firm Anderhalten Architekten.

Figure 9: Building of UBA – new construction with recycled concrete

Source: https://www.bvse.de/gut-informiert-mineralik/nachrichten-mineralik/2403-uba-erweiterung-mit-rund-60-recyclingbeton.html, (OPTERRA/Sven-Erik Tornow) https://www.umweltbundesamt.de

Germany

5.2.3. SPORTS HOUSE IN KOLKWITZ, GERMANY

For the new construction of the sports house (clubhouse in Figure 10) in Kolkwitz/Lausitz, the office “P. Jähne Ingenieurbüro GmbH” took over the object planning as well as the construction supervision [31]. It is a good example of demolition of old sports house, new construction of the sports house and **reuse** of reinforced concrete slabs PII from GDR slab construction in cooperation with BTU Cottbus (Chair of Contaminated Sites: Dr. Mettke Siemens-Halske-Ring 8 03046 Cottbus).

Figure 10: Sports House Kolkwitz – reuse of reinforced concrete slabs

Source: https://www.ib-jaehne.de/referenz/archiv/sportlerheim-kolkwitz.html

Germany

Germany

5.2.4. OFFICE BUILDING OBEREN WALDPLÄTZE 12 (OWP12), STUTTGART, GERMANY

The construction of this new office building (Figure 11) used **Cradle to Cradle design principles**. The project team focused on selecting **materials without harmful substances** and on a design for an easy **dismantling** during the planning and realization of the project. A **material passport** of all materials used was created to ensure high quality **recyclability** for a future demolition phase. OWP12 is an energy efficient building which has a highly insulated façade construction including a photovoltaic system, geothermal drillings, and a green façade. It generates more energy than it consumes and creates a pleasant microclimate [32].

Figure 11: Office building Oberen Waldplätze 12 (OWP12), Stuttgart, Germany

Source: https://www.dreso.com/at/projekte/details/neubau-buerogebaeude-obere-waldplaetze-12-stuttgart-1

Germany

5.2.5. RECYCLINGHAUS IN KRONSBERG, GERMANY

A prototype residential building (Figure 12) was **designed for disassembly** including **reused and industrially recycled materials** assuring considerable resource savings and reducing CO_2 emissions. Most of the interior is from second hand materials with an extra focus during planning on using locally sourced materials or materials from the already existing building stock of the client [33],[34].

Figure 12: Recyclinghaus in Kronsberg, Germany

Source: https://www.cityfoerster.net/projekte/recyclinghaus_-218-1.html

5.3. Slovenia

Slovenia

5.3.1. KNAUF INSULATION EXPERIENCE CENTER (KIEXC) IN ŠKOFJA LOKA, SLOVENIA

Designed from the start to serve as a case study for sustainable construction, the Knauf Insulation Experience Center showcases heat and acoustic insulation options of the company´s own design (Figure 13). Proper **building insulation** is key to energy efficient construction solutions as it **prevents energy waste**. The demonstrated building offers a high level of **flexibility** for all future potential functional/spatial changes. KIECX is also a pilot project of **Level(s)** - guidelines for sustainable construction [35].

Figure 13: Knauf Insulation Experience Center (KIEXC) in Škofja loka, Slovenia

Source: https://www.dgnb.de/de/zertifizierung/dgnb-zertifizierte-projekte/projektdetails/knauf-insulation-experience-center

Slovenia

5.3.2. INNORENEW COE RESEARCH INSTITUTE, SLOVENIA

A hybrid construction on Figure 14 is made of wood, concrete and steel and equipped with a **smart building management system** of over a hundred sensors in the building to monitor humidity, temperature and vibrations which will prove useful for future maintenance works and for the monitoring of its energy usage through **digitalization**. Through this monitoring the team is able to closely watch the aging of the wood and the wetting of the used wood materials which will allow better planning of wooden constructions in the future for enhanced **durability** of the buildings. During construction special focus was put on using **locally sourced materials** (natural resources), avoiding transportation induced pollution [36].

Figure 14: InnoRenew CoE research institute, Slovenia

Source: https://www.regionalobala.si/novica/innorenew-zakljucil-z-gradnjo-najvecje-lesene-stavbe-v-sloveniji-edinstven-primer-trajnostne-gradnje

Slovenia

5.3.3. SAXONIA FRANKE PRODUCTION WAREHOUSE, ŽIROVNICA, SLOVENIA

This building is an example of sustainable construction, it uses generated waste heat from production back into the heating system in a closed loop, providing for an **energy efficient** temperature management [37].

Slovenia

5.3.4. COFFEE SHOP LOLITA EIPPROVA, LJUBLJANA, SLOVENIA

During the refurbishment of an old unused building into a café the designers focused on using predominantly **second-hand, repurposed** or **recycled** materials for the interior design. Materials from the original building were checked and reused where possible [38].

5.4. Poland

Poland

5.4.1. NOVÝ RYNEK D OFFICE COMPLEX, POZNAN, POLAND

This **LEED certified** new office building was built using **recycled materials** and those with a **low content of volatile organic compounds** which are harmful for the environment as well as the residents (Figure 15). **Modern technologies** such as a photovoltaic system, a gray water and rainwater recovery system or low speed ventilation ensure the energy efficiency of this building, which is powered by 100% **renewable energy**. A special concrete sidewalk which reduces harmful car exhausts was included as well [39].

Figure 15: Nový Rynek D office complex, Poznan, Poland

Source: https://www.propertydesign.pl/dossier/132/nowy_rynek_d_doceniony_za_ekologie,40988.html

Poland

5.4.2. SKYSAWA BUILDING, WARSAW, POLAND

This commercial and office complex received the highest level of the **BREEAM certification** scoring high in categories such as location and transport links, **water saving** and the **development process management**. Sustainable options during the demolition phase as well as the construction phase were sought e.g. local greenery protection, use of certified materials for construction from **local production** where possible, focus on choosing only environmentally certified suppliers, implementing **recycled or reused construction waste**, energy efficient lighting, water-efficient sanitary fixtures or the use of sufficient native greenery (including a long-term plan of proper care of the chosen plants) around the whole complex [40],[41].

Poland

5.4.3. TEMPORARY PAVILION OF THE MUSEUM OF MODERN ART IN WARSAW

The Museum of Modern Art has been occupying the pavilion on the Vistula River, as could be seen on Figure 16, since 2017 until the museum will be moved to its final location in 2024. This temporary facility was lent to the museum free of charge by the Thyssen-Bornemisza Foundation. Previously, in the years 2008-2010, it was used to present art at the Castle Square in Berlin.

The Austrian architect Adolf Krischanitz's design with the objectives of meeting the deadline and staying within a limited budget. The pavilion has a structure that allows it to be quickly assembled and dismantled. Krischanitz opted for a structure made of ready-made wooden elements, filled with mineral wool on the inside and stiffened with fiber-blended cement boards on the outside so that the building could be built in a shell in just three weeks. The exterior of the building was designed to be used by artists as a canvas [42].

Figure 16: Temporary pavilion of the Myseum of Modern Art in Warsaw

Source: https://artmuseum.pl/en/muzeum

Poland

5.4.4. SOLACE HOUSE, POLAND

Solace House is an **adaptable prefabricated** house design with technology that ensures the **reduction** of operating costs, primarily in the form of lower energy costs (Figure 17). Currently, there are several implementations of this design and technology in Poland.

The Solace House building partitions are characterized by high thermal insulation, which translates into the energy balance of the building and the lack of heating costs. The low coefficient of transmittance, and thus low heat loss, is a unique feature of the Solace technology in the construction industry. Exceptional thermal insulation of the walls in combination with the building's cubic capacity and photovoltaic installation makes SOLACE buildings zero-energy buildings.

Prefabricated elements are built from a board designed for structural use in a humid environment, manufactured without the use of formaldehydes. Internal structural elements are made of glued laminated timber. The space between the prefabricated elements is filled with closed-chamber polyurethane foam [43].

Figure 17: Solace House, Poland

Source: https://solace.house/solace-double/

5.4.5. WAVE OFFICE BUILDING IN GDAŃSK, POLAND (STRATEGY: LIMITING INPUTS AND THEIR EXTERNALITIES)

The Wave office building in Gdańsk has given priority to the use of **recycled materials** and **local sourcing of raw materials** (Figure 18). Almost a quarter of the materials used to make Wave contained **recycled elements**. On the other hand, almost half of the products used came from **local** companies and suppliers. During the construction of the office building, products with a low content of volatile organic compounds were also used. The wood used in its construction was FSC certified, setting standards for responsible forest management [44].

Figure 18: Wave office building in Gdańsk, Poland

Source: *https://www.skanska.pl/en-us/offer/offices/our-offer/gdansk/wave/*

Poland

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Annex

	Concept of the project	Design	Procurement	Construction	Operation and maintenance	Deconstruction
Circular principles	• **Before starting a project, it is necessary to identify the intermediate and final objectives and their corresponding circular principle focuses.** · Analyze the National circular economy policies. · Implement new circular business models or rethink the existing ones. · Raise awareness of current principles of the circular economy for the team and stakeholders. · Consider using building certifications such as SBTool, LEED, etc., and individual criteria which will help to identify the gaps and implement circularity.	**Apply at least one of these design strategies:** · Design for Disassembly · Design for Adaptability and Flexibility · Design for Durability **Or the individual principles of the 9R framework:** · Refuse (building new and using existing instead). · Rethink (previous approaches, space zoning, integration of more functions to the elements). · Reduce (waste, primary sources, unnecessary elements). · Reuse (existing products, parts of the building). · Repair, Refurbish, Remanufacture (prolong the lifespan of building components, do the reconstruction of a building instead of demolition). · Repurpose (the existing buildings). · Recycle (recycled materials). · Recover(energy recovery/ composting). · Prepare the Operation and Maintenance plan including technical guidance for refurbishment.	· Organize the pre-procurement consultation. · Prepare a circular procurement plan with a definition of the aim that is relevant to your project. · Appoint to this stage a contract manager who is motivated to implement circularity . · Identify suppliers that may be most relevant at each subsequent stage and discuss new models or products that support circular manufacturing concepts. · Prefer manufacturers with take-back schemes experience or extended producer responsibilities. · Give preference to a local supply chain.	· Prepare a waste management plan for construction and separate construction waste on the site. · Prefer use of products and materials from suppliers, who can take back the unused products.	· Use the Operation and Maintenance plan, which includes technical guidance for needed refurbishment.	· Prepare a pre-demolition audit and create a demolition plan. · Use a selective approach for the dismantling of products and materials. · Follow the waste management hierarchy and prefer the use of dismantled products on other sites. It is also possible to use local business models for reusing or recycling of CDW. · Refuse to demolish the building at the end of its useful life so the existing structure could be reused for new purposes.
Construction and materials		· Prefer lean manufacturing and cleaner production of materials. · Prefer products with recycled content (concrete with recycled mixed aggregate). · Prefer materials with high recycling and reuse potential. · Prefer recyclable and reusable materials. · Prefer durable materials (steel/ concrete/stone). · Use digital material passports.	· Prefer local materials. · Consider the possibility of using waste/recycled materials from the surrounding area.	· Prefer easily dismantled structural elements (precast concrete elements with removable joints).	Use the Operation and Maintenance Plan.	Consider the use of dismantled materials and products on other sites.
Location		· Consider local conditions and give preference to a local supply chain, use materials from the site. · Prefer brownfield or previously developed site when choosing a new site to build on, its remediation can clean up contaminated land and return it to a cleaner state.	Support the use of local business models and supply chains.	· Provide the most optimal location and transportation plan of Construction waste.		· Use of mobile picking station for deconstruction on-site. · Provide the most optimal location and transportation plan of Demolition waste.

	Concept of the project	Design	Procurement	Construction	Operation and maintenance	Deconstruction
Water and energy		· Provide plan/measures to reduce the amount of water used, e.g. rainwater harvesting into storage tanks and further use of gray water, design water saving measures like dual flush toilets, pearl valves and shut-off valves for washbasins and showers, etc.	Use indicators from sustainability building certifications to increase quality.	· Implement innovative solutions like Utilizing heat recovery from wastewater to warm supply air. · Consider using Root Wastewater Treatment Plants to enhance pollutant removal and explore sustainable options for repurposing treated water in irrigation and cleaning the surrounding environment.	· Use water and energy monitoring connected to the building's Facility Management System to encourage reductions in consumption. · Use the wastewater treatment system - grey and drinking.	· Separate pipes and other installations for efficient recycling, and explore opportunities to recycle or reuse for example air handling units.
Waste (Construction and Demolition Waste & Municipal)		· Prepare the Operation and Maintenance plan including technical guidance for refurbishment to eliminate waste generation. · Prepare waste and financial forecast regarding the volume of predicted waste.	Prefer manufacturers with take-back schemes and extended producer responsibilities will have a positive effect on responsible waste management in the future.	Fill in the template for tracking waste with different waste categories and calculating potential recycling rates, including reuse, recycling, landfill, energy recovery and waste elimination rates.	Use the sorting containers for municipal waste.	· Prepare a pre-demolition audit to identify materials and components (hazardous and non-hazardous, reusable and non-reusable) that will result from demolition activities. · Use the EU Construction and Demolition Waste Protocol template for tracking waste with different waste categories and calculating potential recycling rates, including reuse, recycling, landfill, energy recovery and waste elimination rates.
		· Create Municipal Waste Management Plan · Learn about the possibilities of using municipal waste for the production of construction products.			· Equip waste collection sites, ensure sufficient number of containers for different types of waste (mixed, glass, paper, etc.).	
Digitalization		Use BIM and integrate material and building passports. The digitalization of processes in each design phase of building construction, often integrated through Building Information Modeling (BIM), allows the use of digital tools including material or building passports in this digital structure to create a comprehensive virtual representation of the construction project. This allows for collaborative design, clash detection and visualization, a centralized repository of material data, and sourcing information, resulting in fewer errors and more informed decisions. · Create a basic model for the demolition or substantial reconstruction of existing buildings, which will help to provide material inventory easily and define deconstruction steps.				
Biobased solutions		· Prefer biobased materials that can be composted at end-of-life · Consider biobased or wooden solution for construction.	Define requirements for use other Biobased products. In case of wooden products, certificates such as FSC and PEFC can be requested.	Consider use of biobased products from the construction site or enable their use for local community (e.g., wood from cutted trees, grass).	Use Operation and Maintenance plan, which should include technical guidance for maintenance of wooden and biobased products.	If applicable, consider use of waste management to enable the recycling closed to the nature (e.g. composting of waste plants, energy recovery using biogas plant).

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