Circular Construction In Regenerative Cities

Insights from the CIRCuIT project

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Acknowledgments

The *Circular Construction in Regenerative Cities* report presents the key learnings, tools, methodologies and recommendations generated by the Circular Construction in Regenerative Cities (CIRCuIT) project from 2019 to 2023 across the cities of Copenhagen, Hamburg, London and Vantaa/ Helsinki region.

This report was produced by members of the 31 partner organisations that were involved throughout. It shares a body of work that was made possible thanks to the time and expertise provided by numerous individuals who helped to support the project across its lifespan. This includes local decision makers and built environment stakeholders from each of the CIRCuIT cities, as well as the European Commission's Horizon 2020 programme.

All of the resources presented in this report, along with the accompanying technical report, are available at circuit-project.eu/post/latest-circuit-reports-and-publications.

Glossary of terms

Adaptive Reuse
The process of reusing a structure or building for a purpose other than the original purpose for which it was built or designed.

Business as Usual (BAU)
Shorthand for the continuation of current conventional construction process practices as if the intervention under consideration were not to happen. Usually used as a benchmark to compare interventions.

Circularity Indicator
A piece of information that can be used to measure performance within the built environment to guide decision making and enable the industry to communicate their circular economy actions in a consistent way.

Design for Adaptability (DfA)
An approach to planning, designing, and constructing a building so it can be easily maintained, modified and used in different ways or for multiple purposes throughout its lifetime, extending its practical and economic life cycle.

Design for Disassembly (DfD)
Approach to the design of a product or constructed asset that facilitates disassembly at the end of its useful life in such a way that enables components, materials, and parts to be reused, recycled or, in some other way, diverted from the waste stream.

Downcycling
A form of recycling that repurposes materials into a substance of lower value than the original.

Life Cycle Assessment (LCA)
A methodology developed to assess the environmental impacts of a building, component or material. The assessment compiles and evaluates the inputs and outputs of the material system throughout its life cycle and assesses the relevant environmental impact.

Life Cycle Cost Analysis (LCC)
An analysis of all the costs that will be incurred during the lifetime of the product, work or service. LCC may also include the cost of externalities such as environmental degradation or greenhouse gas emissions.

Meanwhile Use
A range of strategies to make under-utilised spaces and places productive, both economically and socially, often for a shorter length of time until a long-term use for the space is determined.

Pre-demolition Audits (PDAs)
A systematic and comprehensive assessment conducted before the demolition or deconstruction of a building or structure which results in the inventory of materials and components arising from the building. The reusability and recyclability of the materials can also be assessed during this process.

Pre-redevelopment Audits (PRAs)

A systematic evaluation conducted before the redevelopment or repurposing of a property or site, typically with the aim of assessing and addressing potential environmental contamination and regulatory compliance issues. The potential to reuse or incorporate existing structures on site into the new plans can also be assessed during this process.

Recovery

The process of systematically and intentionally collecting, salvaging and reusing materials from a building or construction site to extend their life cycle and reduce waste.

Recycling

Any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes.

Return on Investment (ROI)

The quantifiable returns and advantages derived from embracing specific construction methods. This encompasses financial gains, environmental benefits and enhanced social value resulting from the project's design choices.

Reuse

The repeated use of a product or component for its intended purpose without significant modification.

Transformation

In architecture transformation is used as an umbrella term to refer to a wide range of potential changes to a building from a subtle change of appearance to a complete change of use.

Upcycling

A form of recycling that repurposes waste, products or materials into a substance of higher value than the original.

Urban Mining

The process of recovering and reusing the raw materials that are already in the environment, cities or everyday products, in the resource cycle.

Introducing the CIRCuIT project

The way we currently build our cities is wasteful and inefficient with resources extracted, manufactured into components, and constructed into buildings only to be demolished and discarded as waste well before the end of their useful life.

Estimates suggest that 11% of global emissions are linked to manufacturing construction materials such as steel, cement and glass[1]. In the EU alone, the built environment accounts for 36% of carbon emissions, 40% of material use and 50% of landfill waste[2].

Accommodating for the expected population growth within cities will mean constructing additional buildings and infrastructure equivalent to a city the size of Milan (1.5 million people) every week until 2050[3]. There is, therefore, an urgent need to transition from a linear construction model to a more sustainable and regenerative one based on circular economy principles.

In a circular model, rather than continuing the traditional take-make-consume-dispose process, building material loops are closed through reuse, sharing, leasing, repair, refurbishment, upcycling or recycling. This radical reimagining of construction considers how the lifespan and reusability of entire buildings can be maximised at the very start of the design process and thereby ensures that usable materials are not discarded as waste.

Cities hold the keys to this transition. Working collaboratively with industry, they can find new ways of confronting the climate impact of construction and develop a new urban agenda. This also gives rise to co-benefits as embedding circular principles also supports wider policy goals such as net zero targets, climate resilience and adaptation in cities.

Further, this regenerative approach has economic and social benefits as more adaptable and flexible cities are better able to serve the changing needs and interests of residents and circular solutions often also bring cost savings over a building's life cycle.

It is, therefore, crucial that cities and their stakeholders have the support, resources and tools needed to create change and drive circular construction practices locally.

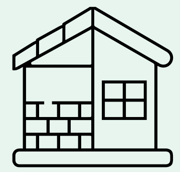
Turning theory into practice

Many circular construction techniques, tools and approaches have been developed and tested around Europe, but circular practices are yet to be scaled up effectively to a city or regional level. To explore how the circular economy can be effectively embedded in cities across Europe, and bridge the gap between theory, practice and policy, CIRCuIT – Circular Construction in Regenerative Cities – was established.

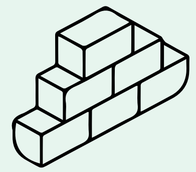
CIRCuIT was a collaborative project funded by the European Commission's Horizon 2020 programme. The project involved 31 partners across the entire built environment supply chain in Copenhagen, Hamburg, Helsinki Region and London.

1 Global Status Report for Buildings and Construction 2019 | IEA
2 Internal Market, Industry, Entrepreneurship and SMEs | European Commission
3 Circular economy in cities: Opportunity & benefit factsheets | Ellen Macarthur Foundation

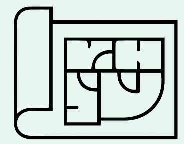
The project's goal was to support the mainstreaming of circular construction practices in the built environment focusing on three key thematic areas:



Transformation and building life cycle extension



Urban mining and material reuse



Design for disassembly and adaptability

Over the course of the project three key results emerged:

1. It is beneficial: Circular practices can improve both the financial and environmental outcomes of construction projects. As part of the project, 36 demonstrators were developed that provide evidence of the carbon and economic implications of adapting conventional construction methods to more circular approaches. The results show that the environmental benefits are great: in all three thematic areas there can be significant carbon emissions reductions and resource savings. Cost benefits are also evident within the context of a circular approach and have been explored in the business cases within chapters 1, 2 and 3. Shifting to circular practices requires use of long-term thinking and seeing buildings as investments to be examined by legislation, integrated collaborations, and new financial models.

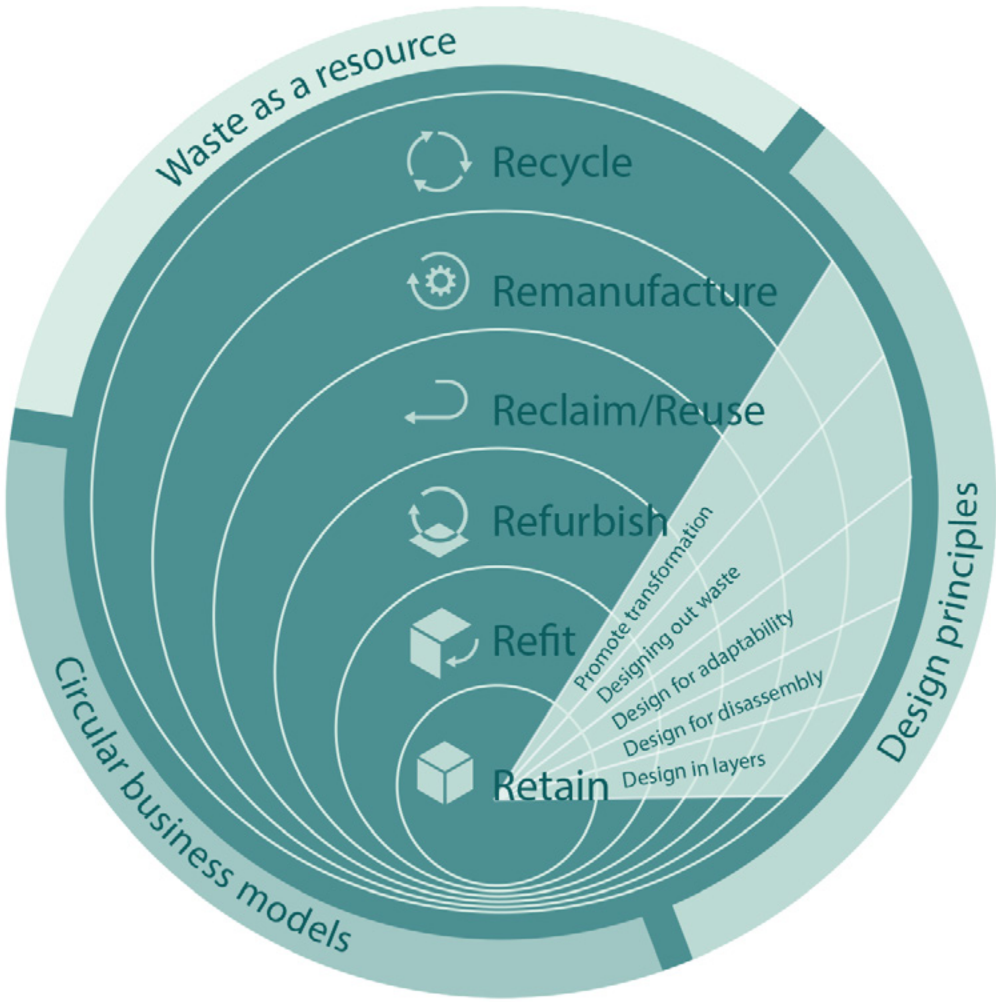
2. It can be done: Real changes are possible by defining a common agenda and applying tools that enable cities to work smarter given the same resources. CIRCuIT has developed tools that can help cities and their stakeholders embed circular economy practices, such as the transformation tool which supports the identification of buildings at risk of demolition, or the dialogue tool which ensures that conversations about circularity start early in the planning process. The CIRCuIT project also developed adaptable procurement requirements in collaboration with the construction industry (see chapter 5). Each of these tools will help to create changes within the landscape, processes, and behaviours.

3. It has scale-up potential: Circular practices are achievable at a building, neighbourhood, city or even country level. To generate the maximum impact of circular construction practices, each of the cities in the CIRCuIT project developed roadmaps that illustrated how best practices could be effectively embedded into city policy (chapters 3 and 5). The project also created working proof of concepts for digital tools such as the Material Reuse Portal that support the delivery of material exchange work and thereby enable increased uptake and the scaling of benefits (see chapter 6).

A call to action

Cities now have the opportunity to connect an ambitious circular economy transition to their sustainability goals. However, to achieve success, cities must also work with professionals from across the entire built environment value chain, from urban planners to material manufacturers, from demolition specialists to residents, and urge them to come together and transform the sector using circular economy principles.

Changing the way that the industry designs, constructs and transforms buildings and infrastructure is critical in the fight against the climate crisis. Thanks to the wide array of tools, case studies and datasets developed by the CIRCuIT project, stakeholders across the value chain are better equipped to turn ideas into reality.

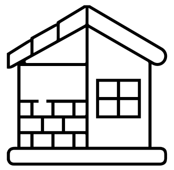


Principles of circular construction

The Handbook to Building a Circular Economy, David Cheshire, AECOM, 2021

Chapter 1: Extending the lives of buildings through transformation and refurbishment

Transformation and refurbishment of existing buildings is the first principle of circular construction. Applying a transformation-first approach will be key to meeting climate targets. Reducing the instances of demolition can keep resources that have already been refined in use for longer, reducing the need for new materials.



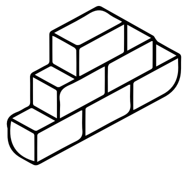
Key findings:

- Methodologies to identify buildings at risk of demolition
- Policy drivers to encourage decision makers and built environment professionals to extend the lives of existing buildings
- 12 demonstrator projects showcasing design transformation strategies.
- 10 business cases for building transformation.

Chapter 2: Increasing the reuse and recycling of building materials

Reusing and recycling building materials is a highly effective way to reduce the resource use and carbon intensity of the built environment by closing material loops. But many challenges are preventing cities from adopting this circular construction approach including issues with cost, adoption and the demolition process.

The CIRCuIT project explored these challenges and suggested ways to embed practical solutions on how cities and the building sector both build and demolish, from policies to Pre-Demolition Audits.

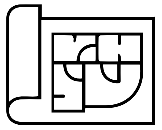


Key findings:

- Recommendations to increase the reuse and recycling of building materials
- Recommendations for embedding pre-demolition audits (PDA) in city policy
- Methodology for developing an optimised PDA
- 12 demonstrators illustrating material reuse and recycling techniques
- 9 business cases for driving the reuse and recycling of building materials.

Chapter 3: Futureproofing cities: designing for disassembly and adaptability

Design for disassembly (DfD) and design for adaptability (DfA) are two construction approaches that can help cities meet their future housing and infrastructure needs while ensuring circular economy principles are adopted. Currently, the technical solutions needed to adopt these approaches exist but take up throughout the construction industry is low. The CIRCuIT project explored what DfD and DfA looks like in practice, how these approaches can be embedded in cities, and how the environmental and economic benefits of DfD and DfA can be calculated to help increase adoption.

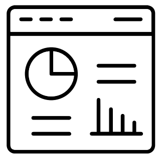


Key findings:

- Methodology for assessing the return on investment (ROI) for DfD and DfA across three areas: monetary cost, carbon use and material use
- Methodology to assess whether a DfD or DfA concept is likely to be scaled up across a city
- Roadmaps for DfD and DfA for Copenhagen, Hamburg, London and Vantaa
- 12 DfD and DfA demonstrator projects
- 7 business cases for DfD and DfA approaches.

Chapter 4: Data and indicators for a circular built environment

A consistent and comprehensive approach to data collection, analysis and management is fundamental for a city to accelerate circularity in its built environment. As part of the CIRCuIT project, partners explored the data available in cities, how data capture can be improved and which indicators are key to supporting circularity.

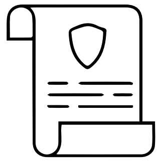


Key findings:

- Two methodologies and template for carrying out a circularity data mapping exercise and assessment of accessible data in a city
- Set of data templates to improve the capture and sharing of data relating to components, spaces, buildings and areas
- Recommendations to help a city address gaps or weaknesses in their data
- Set of 37 indicators that focus on circularity at a city, building and materials level.

Chapter 5: Using policy to power circular construction

Two significant areas where cities can support a transition towards circular construction is through their planning and procurement policies. To help decision makers take effective action in these areas, the CIRCuIT project developed practical guidance on policy interventions, working with developers, criteria for public tenders and city-level circular economy strategies.

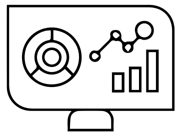


Key findings:

- Policy interventions to embed circular approaches in cities
- Checklist to support circular construction dialogue with developers on city projects
- Recommended circular economy criteria for public sector tenders
- Circularity policy roadmaps for Copenhagen, Hamburg, London and Vantaa

Chapter 6: Supporting circular construction with online tools

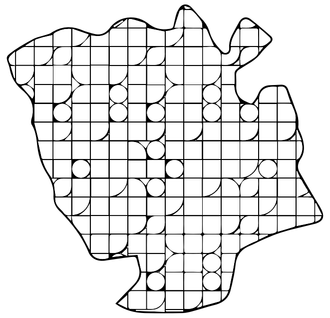
If cities are to increasingly transition to circular construction, it's critical that decision makers and built environment professionals have access to tools that can help them turn circular construction theory into practice. As a result, CIRCuIT's project partners developed five online tools to improve professional knowledge, increase acceptance of this way of building and ultimately, accelerate adoption of circular construction.



Key findings:

- Material Reuse Portal
- Circularity Dashboard
- Circularity Atlas
- Citizen Engagement Portal
- Circular Economy Wiki.

Overview of the four CIRCuIT cities

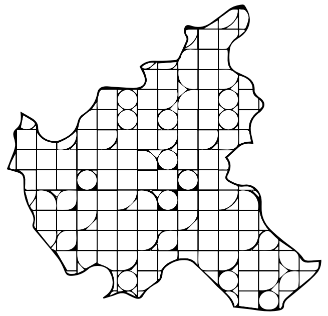


Copenhagen

Copenhagen is internationally renowned for its innovative approach to the climate and the environment. It has a reputation as the world's best city for cyclists. It is a living showcase for Danish architecture. But, most important of all, Copenhagen is a good place to live.

None of this came about by chance. It is the result of years of planning and development based on the needs of Copenhageners – everybody who lives in, uses, visits, works with or runs a business in the city. It is based on the life between the buildings.

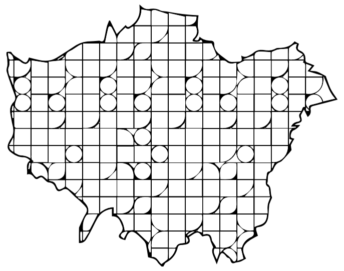
Copenhagen sets ambitious climate goals, aiming to be the world's first carbon neutral capital. It will achieve this through a city-wide transition toward sustainable energy supply, building retrofits, circular waste management, sustainable public infrastructure and mobility, as well as other key initiatives to support the transition.



Hamburg

The Free and Hanseatic City of Hamburg is one of the 16 states of the German federation and the second largest city in Germany. As a member of Eurocities and the City Science Initiative, Hamburg supports European cities and regions, facilitating knowledge sharing across networks, forums and workshops.

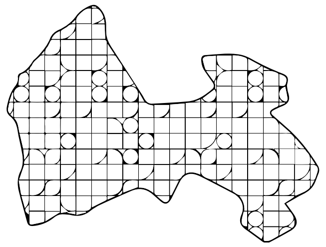
It is currently delivering several EU-funded Interreg and Horizon 2020 projects on urban development, circular economy and smart city elements, harnessing the power of innovation to progress towards its circular goal. In addition, in recent years Hamburg has set up ambitious climate transition targets in line with its industrial composition and socio-economic prospects, and it has introduced sectorial targets, including carbon reduction targets for each sector.



London

London is the engine of the UK economy, accounting for more than a fifth of the country's economic output. Over many centuries London has evolved, resulting in an extraordinary web of distinctive residential streets, squares, markets, parks, offices and industrial and creative spaces.

London aspires to be a zero carbon, zero waste city, and to transition to a low carbon circular economy. This is part of a wider strategy promoting 'Good Growth', which is about working to rebalance development in London towards more genuinely affordable homes, to deliver a more socially integrated and sustainable city.



Vantaa/Helsinki Region

One of three cities in Helsinki metropolitan area, the city of Vantaa is the fourth biggest city in Finland. It has a total area of 240.35 km^2 and a population of 223,000, rising by 2,400 citizens every year. The population is expected to reach over 300,000 by 2050.

Vantaa has a new comprehensive environmental programme called the Roadmap to Resource Wisdom 2030. It focuses on the circular economy and Vantaa's ambition to be carbon neutral by 2030. The circular economy goals consist of reusing materials (including during a demolition), establishing circular economy as part of planning and execution and improving the model for circular economy areas.

CIRCUIT

1

Extending the lives of buildings through transformation and refurbishment

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821201.

Why buildings need to last longer

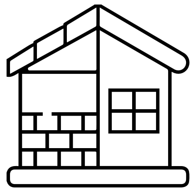
Extending a building's life is the first and foremost principle of circularity in the built environment due to the carbon savings it can deliver.

It's a common perception that building new, highly energy efficient buildings will reduce a city's carbon emissions. However, while increased energy efficiency will help deliver carbon savings in the future, we urgently need strategies that can reduce emissions today.

New building construction is responsible for a great deal of emissions due to the extraction of raw materials, processing into products, transport, and construction. Transforming or refurbishing an existing building prevents demolition and can keep resources that have already been processed in use for longer. This reduces the need to extract and process additional virgin materials reducing carbon emissions as well as minimising waste.

One of CIRCuIT's findings is that building preservation generally results in lower emissions compared to new construction. This is exemplified by results from demonstrator 19, the Korso school in Helsinki illustrating that even an extensive refurbishment without the addition of façade insulation showed a 26% better carbon performance over 50 years compared to conventional demolition and rebuild.

Where possible, extending the life of existing buildings must always be considered before demolishing a building and reusing components or recycling materials as it results in greater environmental benefits.



Where possible, extending the life of existing buildings must always be considered before demolishing a building and reusing components or recycling materials as it results in greater environmental benefits.

To help make the practice mainstream, decision makers and built environment stakeholders need to be able to easily identify buildings at risk of demolition with the potential to be transformed. They also need to understand how and why they should drive greater transformation and refurbishment .

This chapter outlines practical ways cities can identify buildings at risk of demolition by highlighting learnings informed by the CIRCuIT project's process. This includes showcasing a variety of examples that demonstrate what successful transformation looks like in practice. The resulting strategies enable and encourage more refurbishment and transformation in cities around the world.

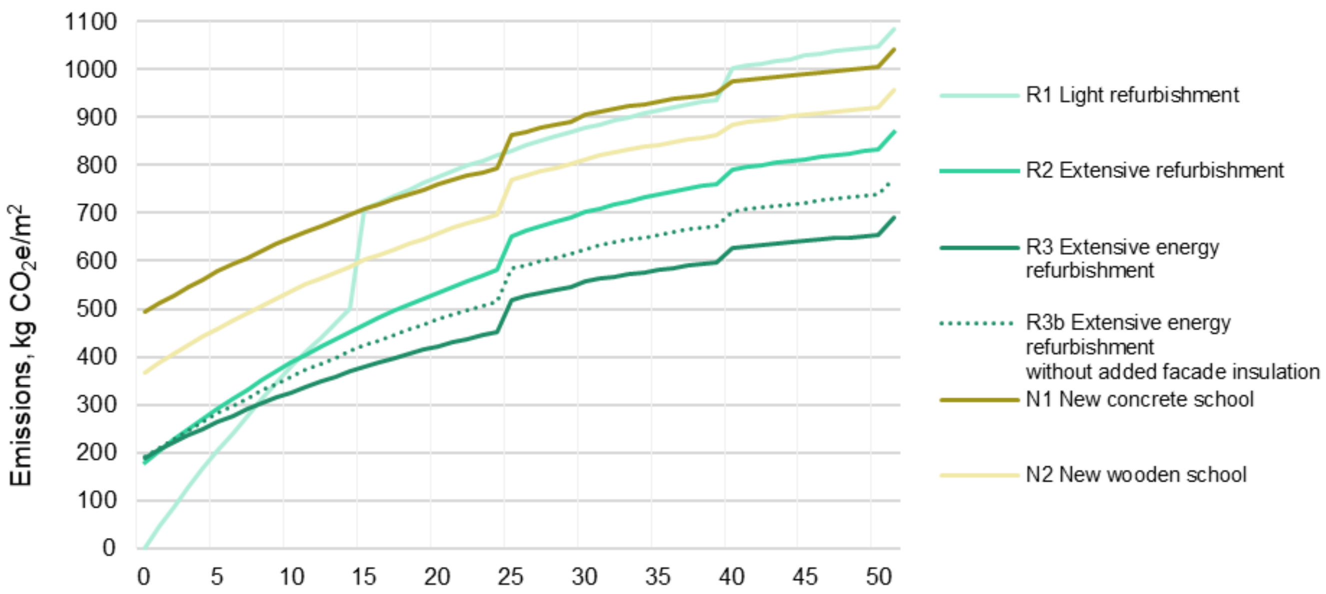


Figure 1.1: Accumulation of emissions in the different refurbishment and replacement scenarios, showing how building preservation results in lower emissions than new construction in most cases in demonstrator 19, Korso school.

How to identify buildings at risk of demolition

It is crucial that the construction sector makes significant changes to conventional practices and begins to prioritise resource conservation.

Presently, when the needs of a city change, built environment professionals – in particular building owners and asset managers – often choose to demolish rather than rethink existing buildings. In some cases, this is due to a lack of integration of refurbishment principles in city development practices, or a perception that it is a more expensive option.

Driving change starts with ensuring stakeholders can easily identify buildings that can be refurbished rather than demolished.

CIRCuIT project partners worked with local built environment stakeholders to develop three 'big picture' strategies for identifying endangered buildings. The strategies apply across different building types and can be adapted or developed to fit local data, allowing circular economy practices to become an integral part of a city's sustainable urban planning and policymaking.

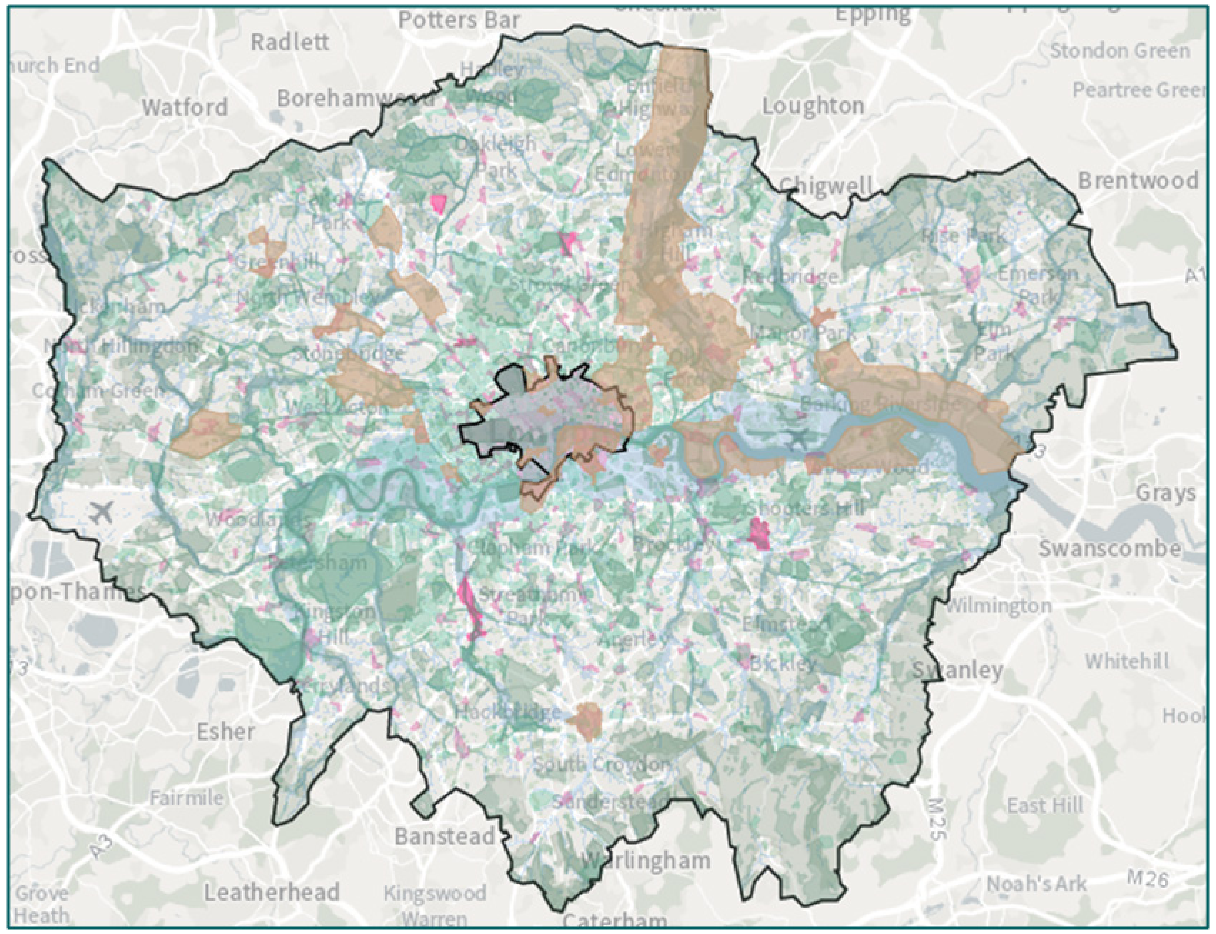


Figure 1.2: Map of London outlining planning areas of interest that could inform demolition trends. Key: opportunity areas (brown); intensification areas (pink); town centres (pale pink); central activities zone (pale pink);conservation/ designated open space (greens); flood risk (blue)

1. Analyse building stock patterns

Building stock data helps identify the kind of buildings typically demolished along with their replacements. This can help decision makers understand what buildings are at risk of demolition.

Data can be analysed by: using maps to extract geographical demolition data, using a building registrar to analyse replacement patterns or using text databases to identify demolition and replacement.

a) Use maps to extract geographical demolition data

This can work for cities that don't have a building register. It uses maps from different points in time to identify demolished buildings by analysing their footprints. Maps can provide an overview of upcoming demolition and allow targeted demand for transformation through urban planning.

Key steps

1. Acquire at least two maps of the city that showcase the location from different points in time, with at least a five-year difference.
2. Overlay the maps in a geographical information system (GIS) or by other means.
3. Compare building footprints manually or using computer software to detect changes.
4. Analyse the changed footprints to identify whether they indicate demolition or something else (like building extension).
5. Use additional data (for example Google Street View) to identify the key characteristics of demolished buildings, such as function and height/number of storeys.
6. Compare the key characteristics, including location, to new builds to identify opportunities for retention. This can include where similar buildings are demolished and built, or where buildings with potential for adaptive reuse are demolished.
7. Analyse existing buildings for key characteristics of demolished buildings to identify those at risk of future demolition.

b) Use a building register to analyse replacement patterns

This is recommended for cities with a building register that retains information about demolished buildings. In addition to a simple register analysis, cities with registers containing information about building location (e.g. coordinates) can supplement the analysis on demolitions and other building stock patterns with a geographical analysis similar to the first approach. A geocodable building register can substantially speed up the analysis as it can contain key characteristics of buildings, such as function, floor area, height, number of floors or building year.

Key steps

1. Get access to, or an extract from, the building register.
2. Make a simple descriptive statistical analysis of the demolished and built buildings, highlighting their quantities and key characteristics.
3. Compare the key characteristics of the two stocks to identify similarities and differences in (for example) functions or sizes of demolished and new buildings.
4. If the register is geocodable, transfer the register information to GIS to analyse locations of demolished and new buildings to identify simultaneous occurrence in the same neighbourhoods or plots (like replacement).
5. Using the same approach, analyse the existing building stock for key characteristics of demolished buildings to identify buildings at risk of future demolition.

c) Use text databases to identify demolition and replacement

This approach is suitable for cities that don't keep track of demolished buildings in a building register and are too vast to analyse with maps. If the city has a non-indexed text database on building and/or planning permits, search the database text for 'demolition'.

Key steps

1. Get access to, or an extract from, the city's database on permits.
2. Search the database for the terms of interest (for example 'demolition', 'deconstruction', 'replacement' etc).
3. Analyse the identified permits for key characteristics of demolished buildings, such as location, function, floor area, building year etc.

2. Identify external factors

Many factors can play a decisive role in determining whether a building becomes obsolete, and so influence the risk of being demolished. These can include the surrounding neighbourhood, the owner's aims and expectations and whether the construction sector leans towards transforming existing buildings or building new ones.

To identify what external factors may play a role in determining whether a building is at risk of demolition, cities can a) analyse locational factors and b) analyse key stakeholder perspectives.

Analysing locational factors

Supplementing method one with a closer look at neighbourhood-level factors, like access to transport, facilities and services, can help identify urban characteristics that contribute to demolition.

Key steps

1. Establish where demolition has taken place in the city over a set period (outlined in method one above).
2. Collate data on locational factors that could play a role in increasing or decreasing a building's risk of being demolished. These could include:
    - transport access (proximity to motorways, public transport, airports etc)
    - distance and quality of facilities and services
    - historical and architectural characteristics
    - safety
    - land use
    - land and property value
    - planning zones and rezoning potential
    - density of occupation

Geographically compare your demolition activity data with locational data to identify common trends. For example, that a high percentage of demolitions over the past five years took place in areas with poor transport links, or particular issues in a neighbourhood.

Analysing key stakeholder perspectives

Understanding how the real estate and construction sector operates, how key stakeholders view building retention, and which factors are important to them in making demolition decisions, can be useful. It can also complement any available building and/or urban data.

Key steps

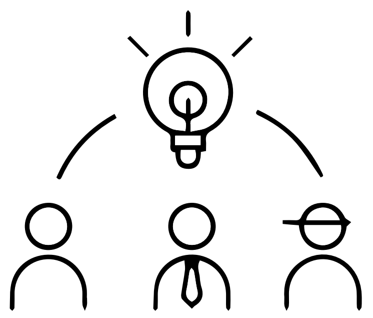
1. Speak to colleagues or other planning professionals to understand how planning decisions around redevelopment and demolition are made. Decisions made by built environment stakeholders can greatly influence whether a building is transformed or demolished.

2. Conduct interviews and workshops with stakeholders to discuss the most influential factors.

Questions could include:

- What are the key factors that guide decisions to demolish or refurbish?
- What do your short-term and long-term cost analyses include as assumptions?
- Is the impact on social value and communities included in your analyses?
- What (or who) might change a decision to demolish or retrofit? For example, tax incentives, legislative requirements, improved guidance, technological development, site context (location, building type).
- Do you have any insights on how the decision to refurbish or demolish has come up in existing projects? Are there case studies?

3. Market research into current and future built environment trends could help identify types of buildings or areas at risk of becoming obsolete now and in the future. Discussions with built environment stakeholders may shed light on these. Additionally, review reports and articles on relevant topics.



3. Adopt a multi-method approach

This approach is recommended if there is access to the right data and stakeholders to provide a broader perspective.

Key steps

1. Use building stock data to identify what kind of buildings are typically demolished in a city and what they are replaced with. See method one on page 1-7.

2. Geographically compare demolition data with data on key external factors that may influence whether a building becomes obsolete and at risk of demolition. Identify common trends that may help predict where at-risk buildings are likely to be located in the future and the amount of floorspace that may be demolished. See method two on 1-8 and 1-9.

3. Hold discussions with built environment stakeholders to gain valuable insights about planning decisions, redevelopment and demolition that may not be publicly available. See method two on page 1-10.

Recommendations

Urban planners and policy makers should use a circular perspective on all city development

Consider transformation possibilities when identifying land for development in the city. Overprovision of new space will vacate and drive premature demolition of already existing buildings with life cycle extension potential. For example, the list of 'at-risk' buildings could figure in these decisions.

- Tax empty buildings to prevent them becoming underused, vacant and falling into disrepair.
- Establish a lighter and quicker route to change the urban plan or deviate from a building's stated function to help transform buildings temporarily, before the long-term plan is implemented.
- Design transformation projects for circularity ensuring transformed spaces can be adapted for another future use, or structures can be easily disassembled.
- Try to engage early on to create a common understanding between building permit and heritage protection departments and developers.
- Reserve funds for systematically developing life cycle extension in all branches of city administration.

Practical ways to extend a building's life

This section outlines transformation strategies and drivers that encourage decision makers and built environment stakeholders to extend the lives of buildings as opposed to demolishing and building new.

Renovation projects usually save between 50–75% of embodied carbon emissions compared to constructing a new building[4]. As we must reduce emissions quickly and sharply, ensuring we extend the life of existing buildings and do not need a large influx of new materials is critical.

Cities often focus on preserving or transforming buildings with heritage value. Transitioning to a circular economy means shifting this focus to include more everyday buildings like workplaces and housing, such as post-war era stock, where preservation is typically not mandatory or even encouraged by public policy.

Assess transformation potential

CIRCuIT recommends municipalities focus on identifying which buildings are suitable for transformation. It is important that cities are proactive in being informed and informing others on the potential for preservation through transformation a long time before any demolition is scheduled. Depending on the case, this could mean identifying harmful substances, investigating possibilities for extensions, or finding the best transformation strategy based on a building's existing layout.

When rezoning already developed areas with existing building stock, cities should consider the transformation potential of the area's buildings. They should also consider the positive environmental impacts and devise city plans that enable maximum retention of buildings with preservation potential. Cities must also proactively inform and negotiate with current and future building owners about preservation potential through circular design principles.

Review financial and environmental factors

Most CIRCuIT transformation demonstrators showed there are financial savings from transforming buildings rather than demolishing and building new. However, there are still other conditions or considerations, such as risk management. They can make the transformation more expensive, less profitable, or less attractive to business decision makers.

CIRCuIT recommends reviewing processes in municipalities or applicable locally around how transformation projects are taxed compared to new construction. Legislation should be streamlined so that transformation projects are equalised or prioritised financially compared to new construction.

Removing financial barriers to transformation projects can make it cheaper or more profitable to preserve rather than tear down and build new. This can also help remove some of the risks in transformation projects. These include uncertainty on an existing building's technical condition – which investors say is the main reason why many buildings are demolished rather than preserved.

4. Embodied carbon: What it is and how to tackle it | RPS Group

Factor in resource savings

CIRCuIT's demonstrator projects show large material savings thanks to the circular retention strategy, particularly where the structure and foundation are preserved. Transformation is less material intensive than new construction because most of the existing building parts are preserved. This means there are potentially big carbon savings from the reduced need to produce new building materials.

CIRCuIT recommends current or future environmental preservation value should be implemented in the municipalities' work with urban development and handling applications for demolition.

Embed transformation priorities in procurement policies

Procurement processes and public tenders are an impactful way for cities to drive their circularity priorities. For transformation, procurement recommendations are particularly relevant in the design stages of the project. To that end, draft designs should be procured for both alternatives– renovation and replacement, and both alternatives should be supplemented with LCA and LCC calculations to facilitate informed decision-making. Subsequently, detailed design and construction can be procured based on the selected alternative, where further environmentalcriteria can be requested (e.g. related to energy efficiency).

To read more about procurement see Chapter 5: Using policy to power circular construction.

Construction strategies to promote life extension

These different strategies can be used by cities to encourage extending buildings' lives.

Refurbishment and renovation

The most direct way to promote life cycle extension is simply taking care of built structures by regular and timely refurbishment and renovation. This includes upgrading buildings' technical aspects, such as energy consumption and insulation.

Transformation and adaptive reuse

Transformation can include everything from changing structural and spatial properties or expression to changing functions (sometimes both). 'Adaptive reuse' refers specifically to change of function.

Densification or infill

This means adding more built square metres into an already built-up area with new construction. It may seem contradictory that new construction is a strategy for life cycle extension. Yet construction comes with additional income which may fund renovation or transformation. Making the space viable with a small addition saves the need for total demolition and rebuild.

Listing

Heritage listing is an effective way to save buildings from demolition. More inclusive listing strategies could consider wider building categories that value existing buildings for their embodied carbon intensity.

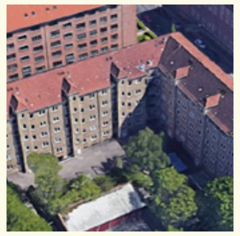
What successful building transformation looks like

Working with each other and local built environment stakeholders, partner organisations in the four CIRCuIT cities developed and evaluated and the benefits they can deliver, four are highlighted here.

Each of the demonstrators illustrated a range of buildings often at risk of demolition in the CIRCuIT cities and beyond and the typical challenges when trying to transform these buildings. These examples bridge the gap between theory, practice and policy. They don't just prove that cities can embed circular construction techniques – but that these activities are scalable and replicable.

> **Full overviews including detailed carbon and cost assessments of all demonstrators can be found at circuit-project.eu/post/latest-circuitreports-and-publications**

Copenhagen



Transforming a 1930s commercial site into student housing

Virtual Demonstrator

Overview

Buildings on the commercial plot were originally developed for manufacturing, including production of timber, soda water and cast metal products.

Currently, the site houses businesses including auto repair shops, a night club, musicians' studios, start-up companies and education services.

Threat of demolition

Industrial buildings account for the vast majority of demolished area in Denmark. Typically, a site like this is sold to a developer that will demolish it as far as possible so new housing can be built. The huge demand for housing in Denmark and soaring residential prices means the developer is likely to build at high density.

Transformation project

CIRCuIT partners in Copenhagen and local built environment stakeholders investigated how the site could be transformed into affordable student housing. Overall, the circular intervention's lower material consumption resulted in a potential CO_2 saving of 23%.

Key findings

Public data has an important role in assessing transformation potential. A publicly available database made it possible to create static calculations and a 3D model of the building's construction and layout to support the design process.

Hamburg

Gröninger Höf Parkhaus – Giving new life to a heritage-listed building

Physical Demonstrator

Overview

This building is in a popular resort on the Baltic coast of Schleswig-Holstein, about 85km north-east of Hamburg city centre.

It was built as a one-storey car dealership in the mid-1950s and extended several times in the following years. In the early 2000s parts of the structure (sales areas) were heritage-listed because of the curved glass façade. In the last years before conversion, the building was briefly vacant during planning and project development. .

Threat of demolition

Gaining heritage-listed status meant the building could never be demolished. However, analysis of demolished buildings in Hamburg showed it exhibits many characteristics typical of demolished buildings. This includes the commercial-industrial function, distant location and small, low-rise character. These buildings are often demolished without second thought to give way for denser and higher development – especially buildings without a heritage listing. A significant problem with buildings like this is how to use them and the land they stand on effectively while retaining spaces and components with preservation potential.

Transformation project

Transformation and extension of the existing heritage-listed building into a gym and vacation apartments was completed in 2020.

By strengthening the structure's load-bearing capacity three extra levels for vacation apartments were made possible. This resulted in savings of 321 tonnes of materials, 186 tonnes of waste and 74 tonnes of CO_2 emissions. The cost of the circular intervention was 4.2% less than demolishing and building new.

Key findings

Early collaboration with heritage protection authorities was key for success. It helped precisely identify areas for preservation, alongside those that could be modified and by how much.

Increased density and a new future-oriented use was achieved through revised room layouts and structural strengthening to enable three new floors above the original building. Close collaboration with architects helped harmoniously integrate modern, high-quality features people would expect with the original heritage look.

Figure 1.3: Illustration of suggested redevelopment of Groninger Höf Parkhaus

Vantaa/Helsinki Region

Transforming 1970's public rental housing to accommodate more people

Virtual Demonstrator

Overview

This transformation covers two blocks of flats (one with three floors and one with five floors) in the Hakunila district of Vantaa. Both buildings were completed in similar Modernist style with precast concrete panels in 1979. The buildings have always been social rental housing.

Threat of demolition

There is no particular threat of demolition for the flats. However, there is pressure to demolish existing housing in the area as the urban population rises.

Social rental housing is particularly prone to demolition due to factors like:

- typically having only one institutional owner, which eases decision-making on demolition
- physical degradation of buildings or lacking necessary flat properties, e.g. in accessibility or demand on flat size
- socio-economic environment with precarious groups, neighbourhood image issues
- vacancy issues, mismatch of flat size with demand
- city's policy targets for urban densification and social mix/gentrification and the potential value of the plot with a renewed urban plan featuring substantially increased building rights (in m2)

Transformation project

Instead of demolition and replacement, urban densification targets were pursued through a retention and extension approach, with additional floors added on top of the existing buildings. Through consultation with the owner, it was decided there was no need to change the flat or room layouts. They serve the needs of renters well, as evidenced by the low vacancy rate. Instead, it was decided to balance out the flat-size offerings in the buildings with the help of additional floors to house smaller flats. The facades, building services and interiors of existing floors (including flats and shared facilities) were renovated as part of the overall transformation.

Additional floors were designed to be added on top of the existing buildings with the help of steel beams, running from cross-wall to cross-wall. This provides freedom for the placement and sizes of the new flats, as the new walls will not need to coincide with the underlying load-bearing walls.

The wooden load-bearing frame of the additional floors is lighter than concrete and helps to avoid the need to reinforce foundations, but also results in shorter spans. This fact, together with creating smaller flats, means that layouts may not be particularly adaptable in future.

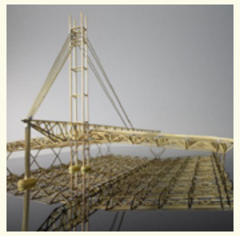
Key findings

If a city has a densification target, extending housing blocks with additional floors can be a technically, economically and environmentally viable alternative to demolition and new build.

The approach is particularly viable in social housing, as there is only one owner who can easily make the decision to transform. Because the building is non-profit, the project's demonstrated cost saving is more relevant than the potential profit from demolition (a factor that can limit the interest of for-profit housing providers). As public actors, social housing companies could set an example for other types of housing providers.

Depending on the size and shape of the site and its location, a densification target may only be achievable if new buildings are constructed on the site as well as adding additional floors to existing buildings. The terrain and soil of the site may influence whether this is possible and what the cost implications will be.

London



Extending the life of a 1980s commercial shopping outlet

Virtual Demonstrator

Overview

The subject of the transformation is a large commercial shopping outlet, which was completed in 1987 and functioned as a Do-It-Yourself store.

The structural scheme was created to be column-free through a structural steel spine truss along the length of the building. This is supported at an intermediate point by steel tension cables. The building is clad with sheet metal and sits on a concrete podium deck.

Threat of demolition

A developer recently acquired the outlet and surrounding land. The plan for the site is to build high-rise residential properties and retail outlets on it. This is because of the huge demand for residential properties in London. As a result, the large shopping outlet is at high risk of demolition.

Transformation project

In an attempt to save it, CIRCuIT partners in London explored options for retaining and transforming the whole building. The sectors these options covered included retail, multifunctional/cultural, healthcare, transport, industrial/manufacturing, agricultural, sport and research/educational.

After considering the different options and the potential environmental and economic benefits, the developer decided none of the transformation options were suitable.

However, dismantling and re-erecting the entire structural frame on another site was chosen as an alternative option.

This circular intervention (retaining the substructure, steel frame and roof) would save up to 1.2 million kg of CO_2 compared to a new building alternative.

Key findings

This kind of project could potentially be replicated across other out-of-town retail units. This could result in a reduction in whole life carbon emissions of 400,000 tonnes of CO_2 across Greater London.

Making the case for building transformation

A 'business case' makes the case for change. It is directed at a specific audience who can make the proposed change and describes actions to be taken outside of BAU and expected outcomes.

Each business case includes five perspectives presented under the headings: strategic, financial, feasibility, risk and scalability. Together these commentaries and the demonstrator templates provide evidence on the benefit of investment in the proposed changes for both the decision maker and the community.

> **A full list of all business cases developed from demonstrator results can be found in appendix A1.2**

B. Public and private asset owners can identify the optimum cost and carbon approach to projects by commissioning assessments of different degrees of retaining and transforming existing assets.

Strategic: Public and private asset owners can improve projects' costs and carbon profiles by commissioning early-stage assessments of different degrees of retention and transformation to meet future needs. This is rather than just comparing default demolition or a façade retention-only approach against minimal refurbishment of existing buildings.

Financial: In the demonstrator projects on which this case is based, life cycle costing found the total costs of optimal approaches to existing buildings result in savings of 7% and 26-41% compared to default new build or façade retention only. The savings range from €1m to €5.5m, indicating a strong case for investment in assessments.

Feasibility: Skills exist to implement assessments of various approaches to building retention. The benefits should be considered at the start of projects and consultants appointed on the basis of proven abilities and their willingness to interrogate the best use of existing assets.

Risk: Regulations might change during a development project. Setting out early on with evidence of the optimal approach to existing assets minimises the risk of developing a BAU approach and creating abortive work that's non-compliant under new regulations.

Scalability: This approach would not work on sites where city planning allows significantly taller new buildings than can be achieved through retention and extension of existing buildings. Nevertheless, the demonstrator cases are widely applicable across many other sites and building types. While the Korso School project showed significant economic advantage in carrying out various levels of refurbishment, North Row was more marginal. In marginal projects, making the economic case for building retention may require new financial incentives such as (in a UK context) charging VAT equally on new build and refurbishment.

Related demonstrators: Demonstrator 19 – Korso School, Demonstrator 24 – North Row

D. Public and private asset owners can activate a neighbourhood and support new businesses by retaining existing assets for temporary use during long-term, phased regeneration projects.

Strategic: Public and private asset owners can activate a neighbourhood and support new businesses and job creation by assessing masterplans to identify existing assets to retain for temporary use during long-term, phased regeneration projects.

Financial: In the demonstrator project on which this case is based, construction costs for adapting and upgrading an existing building were 6% less than providing an equivalent new building. The projected return on investment over a fifteen-year temporary use period was enhanced by 8% compared to the new build alternative. Compared to a scenario in which the existing building is demolished, not replaced, and the land is rented out, the building retention option creates significantly higher net revenue, more jobs and a greater net total Gross Value Added.

Feasibility: Building retention to support temporary use is a familiar concept and skills exist to achieve it. The challenge is to recognise opportunities early on, assess their merit in terms of placemaking and social as well as economic value, and place sufficient weight on these benefits when briefing for design and phasing. Triple bottom line assessments should inform the approaches taken towards existing buildings.

Risk: Temporary uses can be seen as a risk for landowners in terms of safety and logistical reasons or delays in getting vacant possession when the site is due to be developed. A building or site will not always be suitable for temporary uses – for example if access blocks construction vehicles – but this can be considered in the early planning stages. Vacant possession can be ensured by establishing lease arrangements and maintaining clarity about the temporary use period.

Scalability: Large-scale redevelopment of industrial areas, such as the project that provided this demonstrator, are common in expanding urban areas where there is high demand for housing. With long redevelopment timeframes, there is good scope to treat existing buildings as assets that can provide income and social benefits through temporary use.

Related demonstrators: Demonstrator 23 – Block F

N. Private asset owners, investors and developers can gain recognition and achieve market differentiation by assessing whole life carbon when deciding between retrofit and demolition.

Strategic: Private asset owners, investors and developers should include results of whole life carbon assessments in strategic decision-making over retention and retrofit versus demolition and new build. This will help them meet changing legislation and public perception.

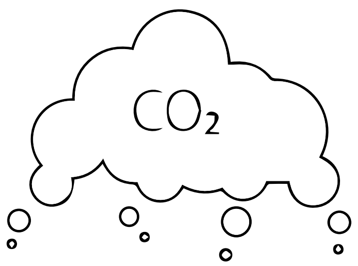
Financial: In the demonstrator projects on which this case is based, life cycle costing over a 50-year period found the total costs of retrofit scenarios to be 37%, 36%, 25% and 4% lower than new build.

Feasibility: There is growing capacity among consultants including access to software to enable whole life carbon assessments. In the demonstrator projects, the whole life carbon of retrofit scenarios was found to be 23%, 19% and 6% lower than those of new build. Giving the results of assessments sufficient weight in strategic decision-making, beyond meeting statutory minimum requirements, will be a matter of developers' setting their own policies and targets.

Risk: Gaining recognition for transforming underused buildings and exploiting opportunities for creating new housing in existing assets minimises businesses' exposure to the risk of demolition becoming an unacceptable approach in many contexts. Developing the capacity to work efficiently with existing assets builds businesses' resilience to shifts in policy and taxation that incentivise retrofit over demolition and limit whole life carbon.

Scalability: There are few barriers to introducing whole life carbon assessments and taking them into account when deciding between demolition and new build. The demonstrator projects indicate economic and environmental benefits as well as reputational benefits in doing so. The ability to scale retrofit as a solution requires greater familiarity working with existing buildings across the construction value chain and innovation in surveying methods to de-risk and generate better information about existing buildings.

Related demonstrators: Demonstrator 13 – Godewind Park, Demonstrator 18 – 1930s commercial plot, Demonstrator 21 – Vantaa office building



In the demonstrator projects, the whole life carbon of retrofit scenarios was found to be 23%, 19% and 6% lower than those of new builds.

Y. Citizens can form cooperatives and create new affordable homes and workspaces by identifying and transforming underused assets.

Strategic: Citizens can form cooperatives to work with municipalities to identify underused assets that are otherwise a blight on the urban landscape and at risk of demolition, and transform them into productive buildings.

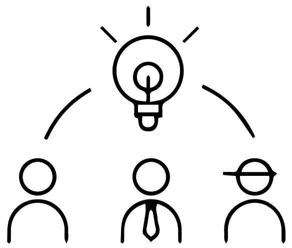
Financial: In the demonstrator project on which this case is based, transformation of an underused multi-storey car park into housing resulted in a saving in demolition costs of around 15%. It also led to a total construction cost reduction of around 5%, compared to demolition and new build.

Feasibility: A key step for citizen-led cooperatives is to form relationships with city planners and collaborate in identifying underused assets suitable for transformation. The demonstrator project found that there is increasing appetite among cooperatives to invest in alternative residential-led mixed use developments.

Risk: Early investigation of existing structures is critical to ensure any hazardous materials or historic contamination can be remedied and the associated costs and risks are understood.

Scalability: The demonstrator focused on a multi-storey car park. Many cities are aiming to reduce car use and keep cars out of inner-city areas. This means reuse and transformation of car parks is one opportunity to scale creation of valuable living, social and commercial spaces in inner cities. In Hamburg, nearly 10,000 parking spaces in multi-storey car parks are expected to be suitable for transformation in the next twenty years. Municipalities can support cooperatives by systematically identifying these and other assets at risk of demolition to maximise the likelihood of their transformation and the social, environmental and economic benefits shown in this demonstrator.

Related demonstrator: Demonstrator 15 – Gröninger Hof Parkhaus



Citizens can form cooperatives to work with municipalities to identify underused assets that are otherwise a blight on the urban landscape and at risk of demolition, and transform them into productive buildings.

Further reading

For further information about these outputs and the work behind them, please read the following reports, which were published by members of CIRCuIT partner organisations during the lifetime of the project.

- D5.1 How to identify buildings for life-cycle extension? Guide for case selection via the mapping of transformable neighbourhoods and buildings
- D5.2 Developing and applying replicable strategies and design principles for keeping buildings and neighbourhoods in circular use
- D5.3 Policy brief and business case of building transformation

All these reports can be downloaded at circuit-project.eu/post/latest-circuit-reports-and-publications

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CIRCUIT

2 Increasing the reuse and recycling of building materials

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821201.

Inspiring the reuse and recycling of building materials

The construction industry, and the materials it uses, are responsible for more than a third of global resource consumption. This has significant repercussions on carbon emissions and ecosystem degradation. Reusing and recycling construction materials is an effective way to reduce the resource use and carbon intensity of the built environment.

It was once common to reuse materials in new buildings – but it's now the exception, not the rule. When reused or recycled materials are used, it's usually at a superficial level that doesn't approach the scale necessary to have meaningful climate impacts.

There are many reasons reused materials aren't more widely used. One is the mismatch between supply and demand of reusable and recyclable materials. This means upcoming projects cannot rely on availability of reused or recycled material – which can disrupt timelines. A limited or inconsistent supply means there is no demand for materials at scale.

Another reason is a lack of trust in the quality and reliability of reusable and recyclable materials compared to new. This perception limits their applications and potential for use, with insurance providers often declining to underwrite reused materials. There are real but manageable challenges to overcome around limits in structural applications and potential contamination by hazardous materials.

There's also a lack of standard practice on how to identify and report materials suitable for reuse and recycling. Many contractors are unaware of, or unable to implement, the demolition processes that document and preserve building materials.

A better system is possible

In the face of these challenges, it can be difficult to highlight the potential environmental and economic benefits of using reused and recycled materials. Without consistent and standardised reporting, measuring cost and carbon footprint benefits is a costly exercise in itself.

Improving this system is possible. Urban mining means recovering and reusing cities' building materials – high-quality reusable and recyclable materials can be extracted from existing buildings if the right demolition techniques are used. This can play a key role in helping built environment stakeholders reduce their environmental impact, costs and waste.

A secondary material reuse market can be created by applying standardised documentation, using digital and physical infrastructure, establishing behaviour change mechanisms and sharing case studies highlighting benefits – as well as supporting city-wide policies.

This chapter looks at practical steps to achieve these goals. It reviews CIRCuIT's findings on pre-demolition audits supporting city-level policies, shares practical demonstrators and business cases that can be taken from them.

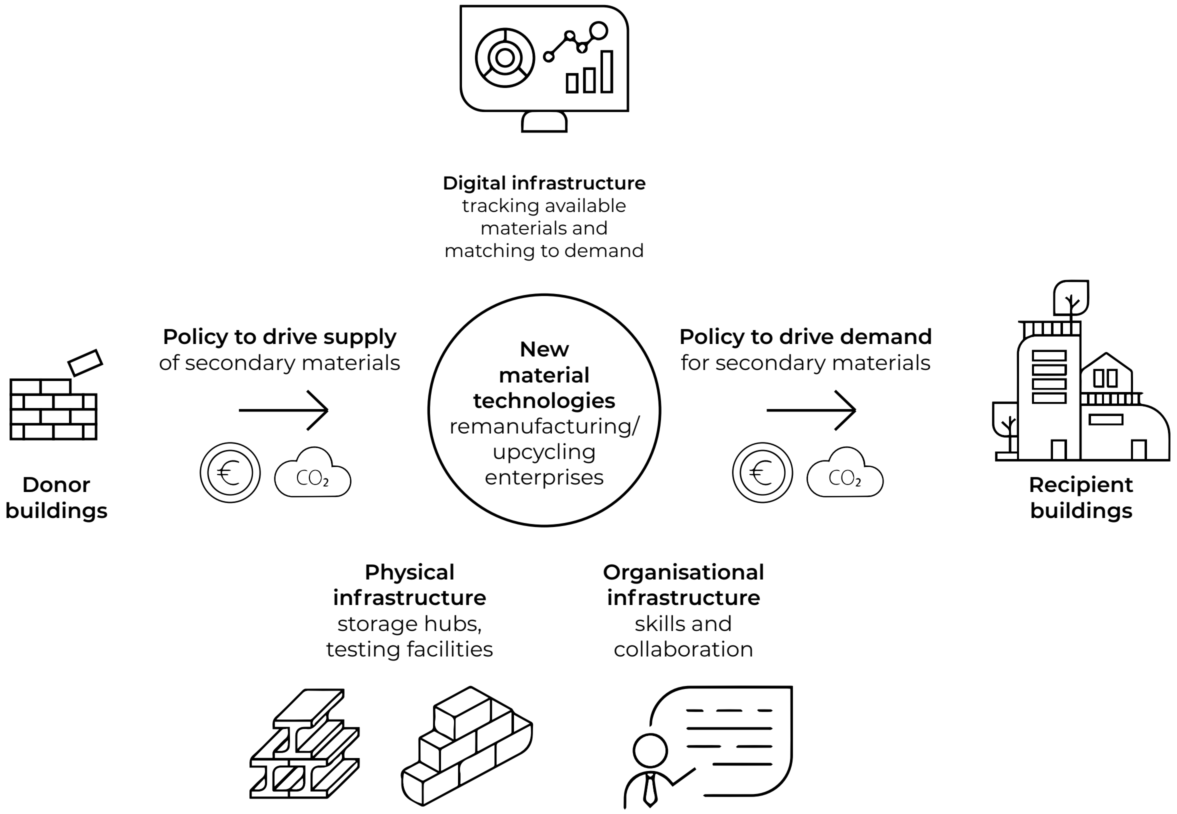


Figure 2.1: Material Reuse Landscape

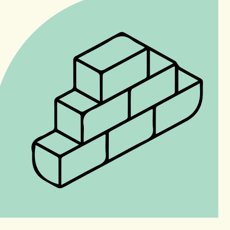
Urban mining in action – examples of material reuse and recycling

Working with each other and local built environment stakeholders, partner organisations in the four CIRCuIT cities developed and evaluated 12 demonstrator projects to showcase urban mining strategies and the benefits they can deliver. Four are showcased here.

Below is an overview of each project, the techniques used and key learnings.

Full overviews including detailed carbon and cost assessments of all demonstrators can be found at circuit-project.eu/post/latest-circuitreports-and-publications

Copenhagen



Gladsaxe school / The Swan - Selective disassembly

Physical Demonstrator

Overview

The Gladsaxe school is an interesting case for PDA assessment because it represented two types of buildings – it was built in 1937 and extended in 1967.

Materials from the school were used to construct a new kindergarten on the same site, making it easier to plan for urban mining (see page 2-10). This included wood recovered from demolition in the kindergarten's entry hall, wooden trusses, steel sheets, pantiles, masonry and specific fixtures and accessories such as lamps and sinks.

Reuse of the wooden trusses was the main focus of the project, with six forming the load-bearing roofing elements in the new kindergarten's entrance hall.

Nearly 6,000 tonnes of concrete were also crushed and used for the kindergarten's foundations and site backfilling.

Key actions taken

The pre-demolition audit involved an interdisciplinary team, with stakeholders from the entire construction value chain. Timber rafters from the roof were carefully cut free according to predefined and agreed cutting lines. Three types of steel cladding were dismantled from the building and bricks were taken down using a Cat digger and cleaned manually from mortar. Roofing tiles were also selectively dismantled from the school.

Key findings

The pre-demolition audit of a building should be a process that involves stakeholders from the entire construction value chain to ensure the highest possible level of recycling and reuse. In particular, the demolisher of the existing building and the architect/developer of the new building should go through the existing building together to discuss and agree on reusable/recyclable items.

It's crucial to use expert reuse consultants for the initial building mapping who can steer cross-disciplinary processes so circular practices are used rather than linear approaches. An open house at the demolition site, a virtual open house or a digital model, could be used early on to connect built environment stakeholders with each other. They can then explore how they would work together to reuse or recycle materials from the existing building.

Storage of extracted materials should be a consideration. For example, the timber extracted from the Gladsaxe school needed to be stored in a place where it was covered and ventilated, so it didn't rot.

If a developer includes the reuse of building materials in their tender, it will be calculated in project finances from the beginning. That means it's less likely to be overruled later in a project due to economic or practical reasons.

If building materials are initially regarded as reusable products rather than waste, regulations may state they don't have to be checked for hazardous substances. As a result, it's important that an initial screening for hazardous substances takes place along with the PDA to ensure materials that could harm the environment or people don't remain in the built environment.

Reusing timber is an opportunity to extend the carbon storage of wood. Growing trees store carbon, which is then released when wood is burned. However, assessing wood for reuse is relatively simple, if standards are followed. Reusable wood may be deformed or crooked, which should be considered when designing a new building.

Hamburg

Die Musterbude – Testing the performance of recycled concrete mixtures

Physical Demonstrator

Overview

Die Musterbude is an innovative project that involves the construction of a small cabin using seven types of recycled concrete. Recycled concrete has been used for decades – but this project tested new mixes featuring materials like recycled sand and waste materials from demolished buildings against conventional concrete. The project aimed to assess the technical and environmental qualities of the recycled concrete mixtures against a standard concrete mixture that uses new aggregates.

The recycled concrete, which is derived from crushing and reusing excess concrete from demolished structures, is the primary construction material for the Musterbude.

The project allows a deeper understanding of how recycled concrete performs in real-world applications and its potential benefits in terms of sustainability and material circularity.

By demonstrating the successful use of recycled concrete aggregates, the project sets a compelling case for sustainable construction practices that advance the circular economy in construction.

Key actions taken

The project produced various aggregates from construction and demolition waste. They were tested for optimal screening and washing both in the lab and in the finished construction. Out of this process, seven new recycled concrete recipes were developed. Life cycle assessment and costing was carried out.

Key findings

The project team found mixtures with a higher percentage of recycled concrete have a lower environmental impact. However, mixtures with a higher percentage of recycled concrete lead to more water consumption because of the porosity of recycled aggregate. The amount of water could be reduced by using polycarboxylate superplasticizers (PCEs) in the concrete mix (a chemical admixture) and pre-washing aggregates.

The Hamburger Mische mixture, which contains 100% mixed construction and demolition waste, achieved good concrete strength and surpassed expectations.

Because of these positive results, the mix will be further improved and used locally in Hamburg

Vantaa/Helsinki region

Tikkurila school warehouse – Reusing red clay bricks

Physical Demonstrator

Overview

Reclaimed red clay bricks, including from the National Theatre of Finland, were reused to construct a small storage building in the yard of the Tikkurila Pavilion School. Bricks were identified as a prevalent and reusable building material in the pre-demolition audits of two demolition cases in Vantaa.

The aim of the demonstrator project was to develop cost-effective methods to investigate the quality of deconstructed bricks (and potentially other materials). It was also to assess the environmental and economic performance of reused bricks against virgin bricks.

Key actions taken

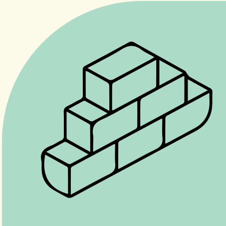
Bricks were deconstructed with hand-held power tools and an excavator. An assessment was carried out between material properties acquired with indirect (non-destructive) methods and those acquired with direct (destructive) methods. There was also an assessment of the environmental and economic performance of reused bricks in comparison to virgin bricks. Recommendations were noted about appropriate methods and sample sizes. Ultimately, reclaimed bricks were used to build the storage building.

Key findings

Indirect methods to study the material properties of reclaimed bricks include assessing the colour of a brick and its pitch when struck to sort into different categories. Compression strength and freeze-thaw durability of a reclaimed brick can be evaluated with ultrasonic pulse velocity. Both are rapid, low-expense tests that can be performed at a demolition site. This contributes to the cost-effectiveness of the reuse process. However, only laboratory tests can determine compression strength and freeze-thaw resistance accurately.

Reused bricks must be selected carefully for the right area of a building to ensure an 'attractive' side of the brick is visible. This selection takes more time than using new bricks.

London



Glulam from secondary timber

Physical Demonstrator

Overview

The London demonstrator investigated the technical and logistical feasibility of upcycling reclaimed timber into new building components.

This involved retrieving timber from demolition sites, characterising and quality-testing the material, preparing it for manufacture and fabricating new glued-laminated timber building components.

Key actions taken

Timber was reclaimed from building demolition sites. The reclaimed timber was characterised, visually and mechanically, to prepare it for the manufacturer. New laminated timber building components were manufactured from reclaimed timber.

Bending tests and shear tests were carried out on the glulam beams. Test results were compared with benchmark results of glulam fabricated from virgin timber. Finally, recommendations were provided on deconstruction, regrading and manufacture in relation to secondary timber laminated building components.

Key findings

There was good correlation between non-destructive and destructive testing of the stiffness of manufactured secondary timber glulam beams. As stiffness is a good indicator of strength, this suggests that secondary timber glulam beams could be commercially tested using non-destructive methods (as is the case with virgin glulam products) to verify product performance.

The glulam beams made of secondary timbers performed to structural glulam standards.

No additional time is needed for removal of timber compared to business-as-usual demolition practices. If it takes no longer to remove the timber then there isn't a cost premium on accessing the material.

Identification and removal of screws, nails and staples is crucial to avoid damaging the tools used in the glulam manufacturing process.

Longer secondary timber lengths, ideally 1.5m or longer, enable a cost-effective manufacturing process by minimising the number of finger joints required.

Optimising the pre-demolition audit

Pre-demolition audits (PDAs) are critical to driving recycling and reuse in construction.

Why PDAs?

A PDA is a comprehensive and systematic assessment of the quantity and quality of elements and materials left after a building's demolition. It can be used as a tool to identify potentially reusable and recyclable components. When completed well ahead of demolition this information can be fed into a digital platform where professionals can see what materials will become available for upcoming designs.

Implementing PDAs in policy

Currently, PDAs are not required as part of the demolition process in most cities.

Where they are required or encouraged, they are often not compulsory, standardised or set up to support circularity. Existing policies and demolition auditing methodologies also typically focus on hazardous materials and their waste codes. This frames outgoing materials as waste rather than usable resources. Even when detailed information is collected, it's not standardised. This doesn't allow for the aggregation necessary to share material information at scale. Making sure planning policy requires PDAs in a standardised format would overcome these challenges.

Recommendations to successfully embed PDAs in city policy

Establish digital system to capture PDA data

Ensure city planning data systems can capture the material data included in PDAs. This will allow the collected data to be used to support secondary material reuse.

Standardise PDA format and guidelines

Align PDA reporting with local best practice, in discussion with industry, to ensure data can be transferable.

Make PDAs mandatory

Once a digital system can actively use and support PDA submissions, the PDA should be made mandatory. Efforts should be made to give the PDA a legal basis and make it part of a corresponding law. The current voluntary nature of the PDA does not create incentives for increased use. Due to the country-specific legislation in the construction sector there isn't an EU-wide consistent way of integrating the PDA into legislation. Accordingly, it cannot be recommended to make the PDA mandatory on a European level. Instead, it is recommended to make the PDA mandatory at the national or local level.

Expand PDAs to include pre-redevelopment audits

To fully capture all the potential material flows in the city, PDAs should also be carried out for retrofit or renovation projects.

Frame PDAs as part of the building life cycle

Rather than viewing the PDA as a standalone procedure dealing with 'waste' it is recommended to integrate it into the building life cycle. It is recommended to perform the PDA as early as possible and to frame the identified materials as resources. Doing this will enable long-term planning processes and more transparency in intended handling of building stock.

Make PDAs more understandable and intuitive

The title 'Pre-demolition audit' can be unnecessarily confusing for some people. Changing it to something like 'Urban mining audit' or 'Circular material audit' could help spread awareness.

Update PDA tools

The tools used to complete the audits should also be updated to be more intuitive and user-friendly than the current Excel models.

Make PDA information accessible to all stakeholders

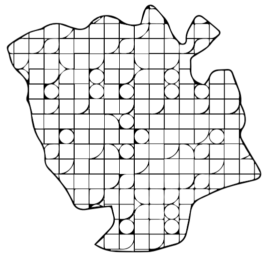
To capitalize on all the benefits of completing PDAs, the data must be accessible to the industry at large: collectively they provide a database of building components that will soon become available.

Incorporate the PDA steps into contracting

For public tenders: Perform the first step of the PDA: element and material assessment before issuing the tender and use it to make a detailed performance description. The demolition contractor will then respond with the second step of the PDA: management options as part of the offer. The contract will make the procedure legally binding.

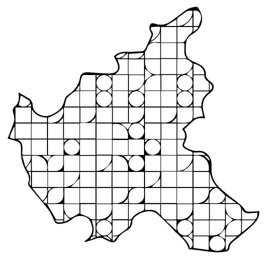
How cities are embedding pre-demolition audits

Though not formally required, the CIRCuIT project cities have already implemented PDAs in some policies to varying degrees. The range of approaches illustrates the various ways cities can embed PDAs into current practices.



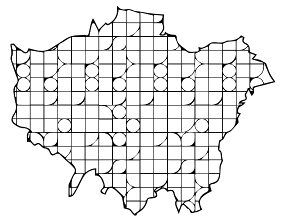
Copenhagen

For most projects, hazardous waste screening is already mandatory in Denmark, while PDAs mapping material quantities and quality is voluntary. The city has made PDAs mandatory for their own projects. Work is being done to create a national standard for both environmental mapping and PDAs. This includes standardising reporting and a basic training programme that is required so that only trained auditors can have their work approved. In the meantime, the municipality is working on creating a standard procedure for PDAs in owned buildings in which a digital platform can handle all the steps and gather data in one place.



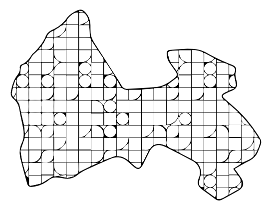
Hamburg

PDAs are not yet required or recommended in Hamburg, but there are requirements for hazardous waste screening and separation. Demolitions are often completed on short notice. This means there's limited time to realise the benefits of PDAs. The City of Hamburg is examining if they can make a digital PDA available as an open data source through the city's website for construction projects. At the same time, future integration of PDAs in public tenders is being discussed.



London

PDAs are not the norm in London. However, in recent years there has been an increase in their use on larger developments. Most PDAs are completed to earn Building Research Establishment Environmental Assessment Method (BREEAM) credit or to fulfil Circular Economy Statement (CES) requirements. These were introduced in 2020 and came into effect in 2021. Policy on PDAs will most likely continue to be addressed through the CES policy at city and borough level.



Vantaa

PDAs are currently conducted in all demolition projects owned by the city of Vantaa. To support developing demolition data collection in the current registers of the city, Vantaa has joined the national Green Deal on sustainable demolition, which requires systematic use of PDAs. The Green Deal is with the Ministry of the Environment and sustainable demolition agreements are valid until 2025. PDAs are currently voluntary in Finland. The new and reformed Building Act will come into effect at the beginning of 2025. It will oblige a waste and demolition material estimate before a demolition permit can be granted, and a waste and material statement after the demolition has been finalised.

Developing an optimised pre-demolition audit

The CIRCuIT project developed an easy-to-understand methodology, template and checklist to support built environment stakeholders to carry out PDAs and increase material circularity in their local area.

These outputs were tested in 12 demolition demonstrator projects: three each in Copenhagen, Hamburg and London (Please see page 2-4 for more information).

Pre-demolition audit methodology

Follow these steps when using the PDA template and checklist developed by CIRCuIT partners.

Step 1 – Desk study

Analyse relevant documents to collect information about the building's history. The age of building and/or past works are essential information and related to the presence of hazardous materials such as asbestos or heavy metal-contaminated materials. Carry out initial inventory of materials.

Step 2 – Field survey

The auditor should visually inspect all parts of the site to be demolished. This phase is important to verify quantities of materials, evaluate their condition and potential for reuse, and estimate the amount of waste from demolition. Inventory of materials is completed with the field survey.

Step 3 – Inventory completion

The inventory happens during the desk study and field survey. It includes the type and quantification of reusable and recyclable materials and components, as well as hazardous materials and eventual waste fractions. Record through photos, comments or advanced scanning approaches that allow a faster execution of the audit and easier interpretation.

Step 4 – Recommendations

The audit provides recommendations on how to:

- preserve valuable components and materials during the demolition activities
- safely remove hazardous and/or waste fractions
- manage waste logistics and operations.

Step 5 – Report

The report must include information on the project, the information collected during the desk study and field survey, and any information that can be useful for the owner, contractor or any other stakeholder involved.

Pre-demolition audit template

The optimised PDA template developed as part of the CIRCuIT project is available to download at circuit-project.eu/post/latest-circuit-reportsand-publications

Recommendations to increase reuse and recycling of building materials

Digitize planning process and allow open access to data

Improved material data transparency and material information improves market confidence, reduces risk and provides opportunities for long-term planning. Improved material information should facilitate improved quality assurance and consumer material choice to compete with virgin construction materials and enable more opportunities for closed loop reuse and recycling of materials.

Relevant stakeholder(s)

Public stakeholder(s)

Establish materials exchange platforms for city and/or region

Material exchange platforms provide the data infrastructure necessary to facilitate material exchanges showing the material supply and demand.

Relevant stakeholder(s)

Building industry

Connect data collected during planning with material exchange platforms

To take advantage of the high-quality data collected during the planning process, connect this data with material exchange platforms where possible. This will allow information coming from planning requirements, such as the PDAs, to be used practically on existing networks without delay.

Relevant stakeholder(s)

Public stakeholder(s)

Develop alternative quality assurance methods

Develop alternative non-destructive methods for quality assurance of reused materials

Relevant stakeholder(s)

Building industry

Develop alternative funding options for pilot projects

Provide alternative funding schemes for ambitious circular projects in public building projects to meet increased up-front costs related to innovative secondary material use.

Relevant stakeholder(s)

Public stakeholder(s)

Temporary urban storage facilities

Establish temporary storage facilities for reuse materials from private or public demolishing sites.

Relevant stakeholder(s)

Building industry | Private stakeholder(s) | Public stakeholder(s)

Standardised secondary materials

Pursue and develop standardised secondary building materials and components for large-scale market uptake.

Relevant stakeholder(s)

Building industry | Public stakeholder(s)

Establish training on improved selective demolition

There is room for improvement in selective demolition technologies and workforce skills. Lack of industry knowledge and/or experience on damage-free disassembly leads to degradation of materials which severely reduces circular opportunities. Skilled and experienced contractors to guide circular processes are crucial.

Relevant stakeholder(s)

Building industry | Public stakeholder(s)

Promote and educate on material reuse and recycling

Addressing lack of knowledge about the value and benefits of material reuse and recycling requires awareness and educational initiatives. Industry associations, government agencies and construction companies can collaborate to raise awareness about the environmental advantages, cost savings and sustainability benefits. This can be achieved through workshops, seminars, training programmes and information campaigns highlighting successful case studies and showcasing the positive impact of material reuse and recycling.

Relevant stakeholder(s)

Building industry | Public stakeholder(s)

Develop alternative disassembly practices

Time-consuming manual handling is often required for the high precision tasks of removal and cleaning building elements and components. Innovative technology and equipment is needed to reduce labour-intensive practices.

Relevant stakeholder(s)

Building industry

Making the case for reusable and recyclable building materials

A 'business case' makes the case for change. It is directed at a specific audience who can make the proposed change and describes actions to be taken outside of BAU and expected outcomes. Four of the business cases that were developed drawing on the carbon and cost analysis of the CIRCuIT urban mining demonstrators projects, are shared here.

Each business case includes five perspectives presented under the headings: strategic, financial, feasibility, risk and scalability. Together these commentaries and the demonstrator templates provide evidence on the benefit of investment in the proposed changes for both the decision maker and the community.

> **A full list of all business cases developed from demonstrator results can be found in appendix A1.2**

A. Public and private asset owners can assess cost and carbon saving opportunities from reuse across projects and asset portfolio by commissioning and acting on pre-demolition audits.

Strategic: Public and private asset owners can identify opportunities to make cost and carbon savings through reuse of materials across projects and assets in their portfolio. They can achieve this by commissioning PDAs in the early design stages of major redevelopment and building upgrades.

Financial: The cost of commissioning a PDA is small in the context of construction costs. One demonstrator found a 12% saving in construction costs through on-site use of recycled aggregates. A demonstrator comparing deconstruction and component resale to demolition and scrap value of a structural steel frame found that the cost premium involved in deconstruction is £50/tonne and additional resale value is £80/tonne. However, if it is assumed that 20% of the deconstructed steel is lost to cutting, the deconstruction option becomes 8% more expensive than BAU. A demonstrator reusing timber trusses on site also reported increased costs, largely due to additional handling, processing and fitting costs compared to BAU. A demonstrator comparing reclamation of bricks laid in cement mortar using hand-held power tools and an excavator found that using hand-held tools produced reusable bricks at a higher cost than other reclaimed bricks on the market. However, using an excavator produced reusable bricks that were cheaper than other reclaimed bricks (by 48%) and cheaper than virgin bricks (by 24%).

Feasibility: There is increasing familiarity with PDAs in industry and capacity for carrying them out in early design stages, in line with CIRCuIT recommendations. However, many secondary material supply chains remain in their infancy and do not have the economies of scale enjoyed by conventional supply chains.

Risk: CIRCuIT policy recommendations include making PDAs mandatory for all projects or all government projects. Building this into procedures now, demonstrates leadership from local authorities and enables forward-thinking developers to stay ahead of legislation.

Scalability: The potential impact of PDAs increases as more are carried out. With more reusable materials identified and made available through digital platforms, data collection will reach a tipping point where it becomes a fertile place for specifiers and procurers to source materials they need. That scale will reduce the costs of deconstruction, processing and testing. Across a portfolio, there may be timely opportunities to direct components from one project to another. Local authorities can also offer materials at low cost to projects that achieve other goals such as social value. In the medium term, aggregated findings from PDAs provide data that can be used to support future policymaking. Innovative surveying methods could improve the quality of information generated and/or reduce the cost of PDAs.

Related demonstrators: Demonstrator 2 – Offakamp, Demonstrator 4 – Gladsaxe School / The Swan, Demonstrator 6 – Hyltebjerg skole, Demonstrator 7 – Hevoshaka school, Demonstrator 8 – Vantaankoski school, Demonstrator 10 – Component reuse of retail unit, Demonstrator 11 – Leadenhall

G. Local authorities can help to create circular supply chains by driving demand for novel remanufactured secondary materials and adopting their use in public projects.

Strategic: Local authorities can reduce embodied carbon emissions in line with their own carbon reduction objectives by taking a leading role in briefing design teams to specify secondary materials. This will also help break down barriers to wider adoption of novel materials.

Financial: New remanufacturing initiatives may not be able to deliver like-for-like materials cost neutrally when compared to existing manufacturers that operate with significant economies of scale. In the demonstrator project on which this case is based, the time involved in deconstructing timber framing was estimated in general to add 15% to the demolition contractors' costs. This would lead to more expensive feedstock for glulam production than using primary timber as usual. However, there is a holistic economic benefit to the area if more construction spend is retained in the local economy. This spend also helps new businesses expand and reduces their costs, increasing the competitiveness of circular supply chains in the longer term.

Feasibility: Adopting novel materials requires strong impetus from those commissioning construction to set a 'direction of travel'. Officers in development and regeneration roles will need to understand the reasons for the policy and act as custodians as it is enacted in briefs and challenged through the course of a project's development. Appointed design teams will be asked to specify materials in a way that differs from their normal practice. Likewise, contractors will be asked to build with materials that may vary from those they are familiar with. Clarity of rationale and awareness of carbon and circularity will be key to resisting pressure to revert to BAU.

Risk: Association with innovative, circular businesses can enhance the reputation of a local authority among staff, residents and industry. The opportunity cost of achieving carbon savings or other environmental benefits should be weighed against other options for achieving the same benefits. The starting point is to understand the scale of benefits. In the demonstrator case, using secondary timber in glulam manufacture was found to achieve a 40% reduction in embodied carbon (cradle-to-gate), and almost a 200% increase in the biogenic carbon stored in wood (grave-to-cradle-to-gate).

Scalability: The ability to scale this business case depends on availability of novel secondary materials ready to be supplied to major projects. The emergence of these supply chains can be supported by developing physical and digital infrastructure that creates a more effective market for secondary materials. It should also make available materials more visible and reachable by remanufacturing businesses. Organisational infrastructure will develop workforce skills and capacities for deconstruction, testing and recertification and form links in supply chains. Greater demand for secondary materials from across the market, driven by progressive purchasing, tighter regulation of whole life carbon or carbon pricing will create more opportunities for new circular businesses.

Related demonstrators: Demonstrator 12 – Glulam from secondary timber

P. Local authorities can help to create supply chains for secondary materials by establishing circular economy construction hubs closer to city centres.

Strategic: Local authorities can reduce embodied carbon emissions of their own buildings, and other developments under their jurisdiction, by allocating sites for circular economy construction hubs and facilitating partnerships to establish and manage them.

Financial: Circular economy construction hubs improve the likelihood of retaining value from materials in the local economy. This can reduce the length of supply chains, minimising exporting waste and importing materials, and increasing local employment. Reuse opportunities are sometimes missed due to lack of available space to store materials or inflated costs because materials need to be taken to remote storage.

Investigating potentially reusable materials was found to be a time-consuming exercise that requires significant effort from the design team. In one demonstrator this accounted for around 10% of the total cost involved with reusing glulam beams (although total costs were 12% less than new glulam). As the reuse process becomes more visible in cities through hubs, and more familiar to teams, the transaction costs involved with new ways of sourcing materials will come down.

Feasibility: Leveraging existing skills, capacity and experience through partnerships with organisations already involved in managing related sites will be key to establishing them. This could include demolition contractors, reclamation yards, builders' merchants, construction consolidation logistics centres, developers, universities and colleges and production facilities.

Risk: Temporarily using disused brownfield sites earmarked for long-term redevelopment may provide opportunities to road-test circular economy construction hubs. This can activate sites that are otherwise providing no social value and detracting from the urban environment.

Scalability: This case can be seen as a step in evolving urban waste management infrastructure to circular economy infrastructure. Policy targets for net waste self-sufficiency (e.g. the London Plan policy of the equivalent of 100% of London's waste being managed within the city by 2026) should be established to support development of such sites. In the demonstrator projects on which this case is based, local recirculation of materials achieved carbon emissions reductions of 2-6%, 8%, 40% and 47%.

Related demonstrators: Demonstrator 1 – Luruper Hauptstraße, Demonstrator 3 – Musterbude, Demonstrator 5 – Stablen / The Stack, Demonstrator 12 – Glulam from secondary timber.

U. Demolition contractors can achieve new revenue streams by becoming retailers of recovered materials.

Strategic: Demolition contractors can rebrand as urban mining specialists and open up new revenue streams by recovering more materials and finding markets for their reuse, remanufacturing or high-quality recycling.

Financial: Demolition contractors already seek to minimise disposal costs by identifying materials that can be sold by reclamation yards. But this is usually limited to high-value goods for heritage projects. There is growing demand for other secondary materials, such as structural steel. In one demonstrator project on which this case is based, the time involved in deconstructing a steel frame was estimated to add £50/tonne – but additional resale value is currently around £80/tonne. If it's assumed that 20% of the deconstructed steel is lost to cutting, the deconstruction option becomes 8% more expensive than typical demolition and scrappage. For brick laid in cement mortar, a demonstrator found that costs were heavily dependent on the deconstruction method. Using an excavator, despite breaking more bricks, produced reusable bricks at a cost 48% lower than other reclaimed bricks on the market, and 24% lower than virgin bricks.

Feasibility: Improving skills and technology will simplify deconstruction and reduce time and cost. Greater familiarity with markets for secondary materials will simplify identification of materials that can be resold and reduce transaction costs.

Risk: Shifting from demolition to deconstruction and urban mining minimises businesses' exposure to the risk of demolition becoming an unacceptable approach in many contexts. Supplying materials directly to other construction projects may require the development of testing procedures and warrantying. Demolition contractors could integrate these operations or supply to specialists who prepare products for resale.

Scalability: Greater demand for secondary materials from across the market, driven by progressive purchasing and tighter regulation of whole life carbon or carbon pricing, will increase margins between deconstruction costs and resale prices. This will allow more material types to be profitably recovered.

Related demonstrators: Demonstrator 5 – Stablen / The Stack, Demonstrator 8 – Vantaankoski school, Demonstrator 9 – Tikkurila School Warehouse, Demonstrator 10 – Component reuse of retail unit.

Further reading

For further information about these outputs and the work behind them, please read the following reports, which were published by members of CIRCuIT partner organisations during the lifetime of the project.

- D4.1 Documentation with audit result, inventory and demolition guide for execution
- D4.2 Achieved reuse, refurbishment and recycling quota energy and resource balances and cost analyses for the demonstrator cases
- D4.3 Recommendation for improving the use of recycled materials and reusable elements

All these reports can be downloaded at circuit-project.eu/post/latest-circuit-reports-and-publications

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CIRCUIT

3 Futureproofing cities: designing for disassembly and adaptability

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821201.

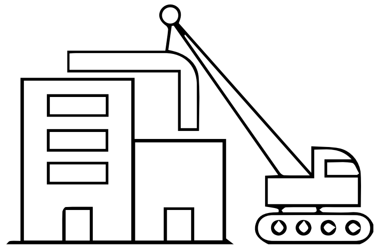
Design for disassembly and adaptability: why it matters

By 2050, another 2.5 billion people are expected to live in urban areas. To accommodate these people and meet their needs, it's estimated that buildings and infrastructure equivalent to a city the size of Milan (1.5 million people) will need to be constructed every week until 2050. As a result, it's critical that the construction of necessary new buildings involves less resources, uses more reused and recycled materials, and reduces the need for demolition and further construction in the future.

Two circular construction approaches that can play a key role in achieving these goals are design for disassembly and design for adaptability:

Design for disassembly (DfD) is an approach to planning and designing a building so it can be easily dismantled. This allows the building to be moved or for components to be directly reused in other projects in the future.

Design for adaptability (DfA) is an approach to planning, designing and constructing a building so it can be easily maintained, modified and used for multiple purposes throughout its lifetime, extending its practical and economic lifecycle.



DfD and DfA can help cities meet their housing and infrastructure needs while ensuring circularity in the future

These two approaches can be broken down further into:

Multifunctionality – being able to adapt a space for different use or needs without any disassembly of components.

Transformability – being able to reconfigure and adapt an internal or external structure through partial disassembly of components to suit different use or needs.

Demountability – being able to fully disassemble a space and its components so that they can be reused or recycled elsewhere.

When a new building is designed and constructed using DfD and DfA, it could solely focus on multifunctionality, transformability or demountability, or it may involve a combination of these practices.

Historically, DfD and DfA approaches have been used for centuries. Yet DfD and DfA are not mainstream in the construction industry today, despite the technical solutions needed to carry them out already existing. This lack of adoption is mainly due to the fact that these solutions come at a slightly higher upfront cost in monetary, carbon and material terms compared to conventional construction.

Looking to the future, it's vital that decision makers and building environment professionals think beyond short-term gains and take action that will help to meet long-term climate goals. As shown in this chapter, DfD and DfA can help cities meet their housing and infrastructure needs while ensuring circularity in the future. These approaches will help cities minimise waste, reduce carbon and save money by keeping materials, components or entire buildings in use for longer.

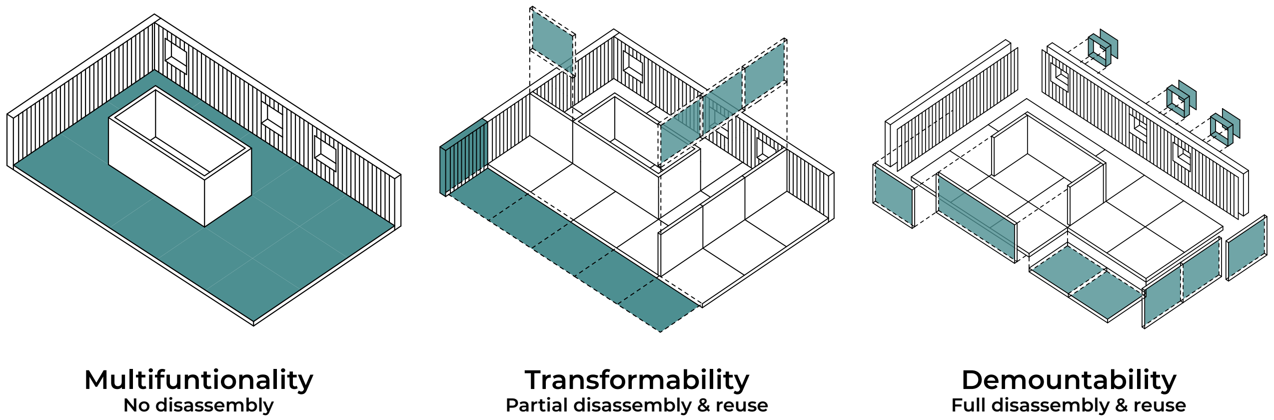


Figure 3.1: Multifunctionality, Transformability, Demountability illustrated

What does design for disassembly and design for adaptability look like in practice?

Working with each other and local built environment stakeholders, partner organisations in the four CIRCuIT cities developed and evaluated 12 demonstrator projects to showcase design for disassembly and adaptability strategies and the benefits they can deliver. 4 are showcased here.

> Full overviews including detailed carbon and cost assessments of all demonstrators can be found at circuit-project.eu/post/latest-circuitreports-and-publications

Copenhagen

Adaptable housing

Physical Demonstrator

City context

In Copenhagen, new residential buildings tend to be designed to the same specifications. In fact, 66% of apartments have three rooms and the floor area of the flat is between 85–115m2, not including outside areas such as storage space, a balcony, etc.

Currently, prefabricated concrete construction with loadbearing walls are the norm in Danish construction. In this approach, structural concrete elements are cast together to form internal and external walls and floor slabs. However, this limits flexibility, both horizontally and vertically, and the structural elements are difficult to modify without major interventions. Services like underfloor heating, drainage and electricity are often integrated into the concrete. This makes them difficult to access for maintenance or replacement without demolishing part of the structure.

Projections show an increasing need for smaller one and two-room apartments in Copenhagen. But because of the way Danish buildings are currently constructed, it's unlikely a simple layout shift alone could meet future demands. This means buildings are at risk of being prematurely demolished in favour of new dwellings.

DfD and DfA approach

The adaptable housing demonstration project in Copenhagen aimed to show how apartment blocks that use DfD and DfA principles could meet future housing demand and deliver significant environmental and economic benefits.

The demonstrator showcased an alternative structural system based on frame construction. It included a frame system without loadbearing walls. Slabs could be removed to significantly increase adaptability, both horizontally and vertically.

In addition, including mechanical fixings and lime mortar instead of cement allowed components to be dismantled. Design enabling disassembly of building layers, avoiding cast-in services and replacing concrete screed with sand enabled services to be replaced or maintained easily without major interventions.

The demonstrator also included standard prefabricated elements such as concrete columns, concrete core, steel beams and hollow core slabs.

Figure 3.2: 1:1 Model of DfD floor slab

Key findings

Compared to a business as usual (BAU) case study, the DfD and DfA approach had a substantially higher reuse potential (85%).

Results also indicated that the embodied carbon of the BAU approach and the DfD and DfA approach were almost the same after a single building lifecycle. However, if the DfD and DfA buildings were redeveloped, there would be an embodied carbon saving of 37% after the first redevelopment and 50% after the second.

Constructing the alternative buildings and disassembling them would be 25–28% more expensive than using the BAU approach and demolition. However, if the alternative buildings were redeveloped, there would be a 27% cost saving after the first development, and 45% after the second.

Adopting DfD and DfA principles may require a higher upfront investment, but by extending the lifecycle of a building and its elements, there can be substantial environmental and economic benefits after just one redevelopment.

Hamburg

The Klassenhäuser structure – slab construction

Physical Demonstrator

City context

In Hamburg, several schools were built using comparable design concepts. This demonstrator aimed to compare the impact of conventional construction floor slabs against three DfD versions.

DfD and DfA approach

The BAU case for this design was a conventional floor slab made using an in-situ concrete method. Three different types of DfD floor slabs were made using pre-stressed concrete cast elements, pre-stressed concrete cast elements with seam and joint and a bolted timber-concrete construction method to aid disassembly and reuse.

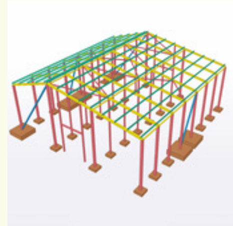
Key Findings

The demonstrator found that the DfD slabs could be dismantled completely and sorted by material type. The DfD floor slabs used 40% less concrete, representing significant material savings and associated carbon impacts. Additionally, the DfD slabs interlocked, which meant, unlike traditional methods, no gaps needed to be sealed.

Using the pre-stressed concrete slab with seam and joint did result in dimensional differences. The DfD school building was 50cm higher than the comparable BAU building, which affected wall heights, staircase and railing lengths, pipe lengths and the distance between the building's columns. These had to be reduced, resulting in more columns and fewer open spaces, which is a drawback that would need to be considered when weighing up the benefits of using this method.

Overall, the demonstrator showed that using DfD slabs could lead to a 70% cost saving over multiple lifecycles of the building, as well as significant carbon savings.

Vantaa/Helsinki region



Design for disassembly warehouse

Virtual Demonstrator

City context

Traditionally, warehouses are designed to remain in a fixed location, be in use for around 20–40 years, then demolished, typically a long time before their technical lifespan is complete. Demolition is more likely to occur because of economic redundancy than technical limitations.

DfD and DfA approach

A single-storey steel framed DfD warehouse was designed that could be dismantled and reused in another location. The warehouse used demountable concrete foundations to allow for disassembly. All connections in the steel and concrete structure were bolted. The columns were also given the option of variable heights, allowing the warehouse hall to be either 5 metres or 3 metres tall. This DfD warehouse was then compared to a conventionally built warehouse in terms of environmental and economic impact.

Key findings

Almost 100% of the DfD warehouse materials could be reused or recycled at the end of life.

Lifecycle assessment (LCA) calculations showed that over three lifecycles (relocating the DfD warehouse compared to building a new conventional warehouse) there were carbon savings of around 40%. Over two lifecycles, calculations showed that the DfD warehouse had significant cost savings, and over three lifecycles the cost saving was 41%.

Overall, it was found that applying DfD methodologies to a warehouse can be challenging because of compliance with regulations for factors such as loads, fire class and building purpose. This challenge should be taken into account in the early stages of DfD design.

London

Albion Street (The Hithe) – Flexible temporary building

Physical Demonstrator

City context

In London, some local authorities have small parcels of centrally located but underused land that currently only host low-value uses such as storage. To trial new uses for the space, 'meanwhile use' construction can be valuable to provide amenities for residents.

DfD and DfA approach

A two-storey affordable office building was designed and constructed using DfD and DfA principles. The building was intended to be disassembled and relocated after 10 years, due to the lease terms for the land it was built on.

The DfD and DfA design was compared against a BAU case study in terms of its environmental and economic impact. A key difference between the two designs was that the DfD and DfA design used modular demountable structural insulated panels (SIP). The BAU design used a traditional steel frame with low-tech timber rainscreen cladding.

Key findings

The economic impact assessment found that the DfD and DfA approach resulted in a 6% increase in construction cost compared to the BAU approach. However, there was a 23% reduction in overall whole life costs.

The results of the LCA study showed an initial 6% increase in whole-life embodied carbon over the BAU base case after the initial construction and use cycle. After the first redevelopment cycle, there was a 30% overall saving in whole-life embodied carbon against the BAU case study. After the second redevelopment cycle, this increased to an overall saving of 46%.

The demonstrator showed that its lifetime could be prolonged by at least 30 years. This was a 200% increase over the BAU case study. It is based on a functional need (use cycle) of 10 years and an ability to accommodate at least two additional use cycles.

The demonstrator targeted a 100% demountable design. However, general wear and tear will likely lead to replacement of materials in a redevelopment. Therefore, a waste allowance of 5% loss during disassembly and 5% loss due to wear and tear was assumed. This means 90% of the building elements for the DfD and DfA approach are estimated to be demountable/reusable.

Embedding design for disassembly and design for adaptability in the heart of cities

Guides and tools to help policymakers embed DfD and DfA approaches in future city strategy, planning policy and city-led projects are lacking. CIRCuIT partners across Copenhagen, Hamburg, Vantaa and London worked with city officials and built environment stakeholders to develop a DfD and DfA Circular Building Roadmap for each of their cities. These roadmaps outlined the best starting point towards DfD and DfA in each city and can serve as inspiration for other cities looking to embed DfD and DfA approaches in their actions.

Following the development of the four roadmaps, CIRCuIT partners identified that roadmaps are usually best integrated into or used for steering existing tools, policies or other roadmaps. If the roadmap remains a standalone resource, it may receive less attention and be less effective.

To make a roadmap a viable tool, it's essential that stakeholders know it exists. Therefore, the roadmap must be promoted to those who can integrate it into existing practices and other tools.

Below, two approaches for a DfD and DfA Circular Building Roadmap are shared. The first is for Copenhagen and features city-driven actions. The second is for London and features design-focused actions.

> **Complete roadmaps for all four CIRCuIT cities are available in the report D6.5 Four city case roadmaps for implementation. Download it at circuit-project.eu/post/latest-circuit-reports-and-publications**

Copenhagen DfD and DfA Circular Building Roadmap: Defining the city's role

City context

Copenhagen is a rapidly growing city. Its municipal plan for 2019 to 2030 proposes the construction of 60,000 new dwellings (around 4.4 million m2). Meanwhile, around 32,000 dwellings are being demolished across Denmark, primarily within the social housing sector.

Most of these dwellings were constructed between 40–50 years ago and their structural materials are still technically sound. The reasoning behind the demolitions is a complex social, political and urban planning issue. However, the fact remains the premature demotion of the dwellings will result in an enormous amount of carbon and materials being wasted.

Using learnings from the CIRCuIT project, there's a great opportunity to influence the approach to the thousands of new dwellings being constructed in the city. The local authority is restricted in the criteria it can set for private developers to increase DfD and DfA. However, it can influence dwellings within the social housing scheme and dwellings built on municipal land.

Of the 60,000 dwellings to be constructed up to 2030, 15,000 (25%) will be social housing. Of these, 8,500 (around 567,000m2) will be delivered by 2030. The steps outlined in the roadmap below put the milestones in place that will increase DfD and DfA within social housing and highlight the city's role in embedding DfD and DfA. The result will have a significant impact on the future circularity of the city.

Actions for implementing Copenhagen's DfD and DfA Circular Building Roadmap

Develop principles and tools for implementing DfD and DfA in social housing

Step 1 – Outline a 'cost pyramid' of use cases that could deliver DfD and DfA in social housing
Use cases outlined a specific situation in which DfD and DfA approaches could add value. These use cases could then be classified in a 'cost pyramid' ranked with cost neutral uses cases at the bottom to more expensive ones at the top. Professionals could then decide which to use, depending on the project.

Step 2 – Develop design criteria and tools for DfD and DfA in social housing
These included guidance on DfA and DfD integration in maintenance plans for social housing and structural, fire and acoustic impact and considerations.

Step 3 – Develop procurement criteria and tools for DfD and DfA in social housing
Circular procurement guidelines have been developed in Denmark. The criteria focuses on a specific percentage target by weight for DfA. Project teams were invited to propose solutions to achieve that target within the budget.

Develop and agree on financial models and incentives for DfD and DfA in social housing

Step 1 – Agree methodology to integrate DfA and DfD in lifecycle costing (LCC)
All social housing in Copenhagen requires a lifecycle cost analysis. But this doesn't cover factors like reuse and adaptability as ways to reduce costs for a building's lifecycle. As a result, a new methodology should be developed covering elements like deconstruction, transportation and adaptation costs.

Step 2 – Investigate integration of LCC in budget allocation and funding for social housing
Budget allocation for social housing is based on a fixed upfront cost, plus a fixed percentage to cover future maintenance and replacement. There's currently no way to increase budget for upfront costs, even if it means savings over the life of the building. Changing this is complex and requires a specialist group to influence funding.

Step 3 – Develop circular financial models for social housing
Based on use cases, there's huge potential to develop new circular financial models for social housing. This could include portfolio-based renovation strategies with material flows between assets. Once tools are in place, financial models should be developed by social housing developers and promoted by Copenhagen Municipality.

Create a city strategy to support DfD and DfA in social housing

It is crucial that the city of Copenhagen communicates its ambitions relating to circularity in housing to inspire change in the industry. A city strategy can help achieve this.

Step 1 – Create and promote a vision for DfD and DfA in social housing
As part of the city vision, it is suggested to include targets for DfD and DfA amongst new construction and for the city to also develop 'future use' scenarios of development areas which might see a change of use in the coming 50-100 years.

Step 2 – Develop pilot projects and showcase to engage industry
Copenhagen Municipality has the potential to support pilot projects through funding, but also by leading the projects in areas where they are the developer alongside social housing associations. Two areas suitable for pilot projects have been identified: By Strømmen and Gammelby.

London DfD and DfA Circular Building Roadmap: Applying DfD and DfA principles to modern methods of construction (MMC)

City context

London has an Affordable Homes Programme (2021–2026) with £4 billion funding to support local authorities and registered providers of social housing to deliver new affordable homes. Projects in London funded through the Affordable Homes Programme must maximise their use of modern methods of construction (MMC). A quarter of all buildings delivered through the programme must use some form of MMC.

The Greater London Authority (GLA) and Be First, the London Borough of Barking and Dagenham's development company, have convened a Buyers' Club to support delivery of high-quality sustainable homes. Its members are largely recipients of funding under the Affordable Homes Programme.

A primary instrument of the Buyer's Club collaboration is a Housing Pattern Book. It provides guidance on designing apartment blocks up to 10 storeys while using design for manufacture and assembly (DfMA) principles.

The main focus of the roadmap for London is to drive demand for MMC and circular construction by influencing the construction approaches and procurement processes of Buyers' Club members. This will primarily be done by suggesting changes in future iterations of the Housing Pattern Book and engaging with supply chains. The steps below emphasise the role that industry can take in promoting and embedding DfD and DfA within cities.

Actions for implementing London's DfD and DfA Circular Building Roadmap

Facilitate greater consideration of full building lifecycle

Step 1 – Set direction of travel
Normalise the consideration of disassembly by adjusting terminology in the Housing Pattern Book and, in due course, in the wider industry. Ensure design teams consider circular economy design principles and approaches by requiring the preparation of circular economy statements across Buyers' Club developments.

Step 2 – Assess the value of circular economy strategies over a building's lifecycle
Given that councils often hold a long-term interest in sites that they develop, make investment decisions based on lifecycle costing (LCC) in preference to capital cost alone.

Step 3 – Digitise information on assets
Being 'digital first' helps make it easier to effectively use and manage building assets through their lifecycle. Tools like material passports (a digital document listing all the materials that are included in a product or construction during its lifecycle) help make DfD and DfA simpler.

Drive appropriate application of circular principles

Step 1 – Design for internal flexibility
Needs of residents and the city's housing mix may change over time. To improve the chances of buildings continuing to meet housing needs, consider the potential for flexibility in apartment sizes and layouts.

Step 2 – Design for adaptability
Changes to demand on building stock are very difficult to predict. However, measures like extra structural capacity, e.g. allowing storeys to be added, will help buildings to adapt.

Step 3 – Design for disassembly
Designing for disassembly helps maximise the reusability of a building's components at the end of its lifecycle. Shorter life building elements should be removable and replaceable.

Step 4 – Set key performance indicators (KPIs) at a building level
Include indicators to measure material use, current material end-of-service-life scenarios, intended future material end-of-service-life scenarios and embodied carbon.

Build the capacity to deliver circular MMC

Step 1 – Create comprehensive guidelines for DfD
Build capacity to deliver circular MMC and increase familiarity with design for adaptability and disassembly among design teams and supply chains.

Step 2 – Engage supply chain with the developed KPIs and DfD guidance
The Housing Pattern Book contains a strong section on circularity and DfD. The guidelines provide technical criteria for design teams to apply through the design process and can frame conversations with suppliers.

Step 3 – Standardise more building elements in the Housing Pattern Book
The Housing Pattern Book already proposes standardisation of bathroom pods and utility cupboards, and it lists additional elements with potential for standardisation: cores, risers, façades and balconies.

Based on RightSizer, one of London's demonstrator projects, floor, ceiling and partitioning systems could also be developed with suppliers to increase internal flexibility, building adaptability and component disassembly. Progressively address standardisation potential of each building element.

Calculating return on investment (ROI) for design for disassembly and design for adaptability

Applying DfD and DfA principles to building design often leads to higher upfront costs compared to a more conventional linear approach. This is typically due to more expensive less often used materials and techniques being used at the outset. However, as shown by CIRCuIT's demonstrator projects (see page 3-5), DfD and DfA often results in economic and environmental savings over the whole life of a building or material.

To increase awareness of this fact and adoption of DfD and DfA approaches, it's critical built environment stakeholders have access to the tools they need to clearly assess and demonstrate ROI when using DfD and DfA. As a result, the CIRCuIT project created a robust methodological framework for assessing the ROI for DfD and DfA across three areas: monetary cost, carbon use and material use.

A second methodology was further developed to assess whether a DfD or DfA concept is likely to be scaled up across a city on the back of its ROI assessment.

> **Both methodologies are covered in more detail in the report D6.4 Part 1 Threefold ROI assessment of building concepts and threefold ROI urban plan – preliminary report. This is available to download at circuit-project.eu/post/latest-circuit-reports-and-publications**

Return on investment methodology for DfD and DfA

In the context of applying ROI to DfD and DfA, the investment refers to the money, carbon or materials going into a project over its lifetime.

For this methodology, the 'net income' is defined as the potential savings achieved in a second iteration of a building compared to a BAU approach. The 'net income' is potential savings compared to BAU of cost, carbon or materials over multiple iterations.

However, the net income can be adjusted to represent any kind of business model that needs to be studied. This can include the resale value of reused materials, the increased rent capture by providing adaptable buildings with higher tenancy, or the simple savings from not having to replace all building elements during refurbishment.

This means the ROI of a DfD or DfA project can be calculated as:

$$\frac{\text{Potential savings over time compared to BAU}}{\text{Upfront investment}}$$

Two types of upfront investment can be identified to calculate the ROI, depending on the business case that needs to be portrayed. This is illustrated in Equations A and B.

In **Equation A**, the upfront investment is the total investment for the DfA or DfD project, which provides a ROI of the project compared to BAU.

$$ROI = \frac{(BAU^{UC1} + BAU^{UC2}) - (DfD/DfA^{UC1} + DfD/DfA^{UC2})}{DfD/DfA^{UC1} + DfD/DfA^{UC2}} \times 100$$

In **Equation B**, the ROI is calculated on the additional upfront investment required to deliver a DfD or DfA project compared to BAU, and the potential saving this additional investment can bring. Equation B is only applicable on the cases where the upfront cost of a DfD or DfA project is higher than the BAU.

$$ROI = \frac{(BAU^{UC1} + BAU^{UC2}) - (DfD/DfA^{UC1} + DfD/DfA^{UC2})}{DfD/DfA^{UC1} + BAU^{UC1}} \times 100$$

In the equations:

- BAU^{UC1} denotes built as usual upfront investment in the first iteration
- BAU^{UC2} denotes built as usual upfront investment in the second iteration
- DfD/DfA^{UC1} denotes DfD or DfA project upfront investment in the first iteration
- DfD/DfA^{UC2} denotes DfD or DfA project upfront investment in the second iteration

To illustrate the difference between the two calculations, the costs involved in the adaptable housing demonstrator project in Copenhagen are used in the two equations.

EQUATION A:

$$ROI = \frac{(5{,}437 + 5{,}437) - (6{,}757 + 1{,}081)}{6{,}757 + 1{,}081} \times 100 = 38.83\%$$

EQUATION B:

$$ROI = \frac{(5{,}437 + 5{,}437) - (6{,}757 + 1{,}081)}{6{,}757 + 5{,}347} \times 100 = 230\%$$

In the calculations:

- BAU^{UC1} built as usual upfront investment in the first iteration = 5,437 DKK (approximately €729)
- BAU^{UC2} built as usual upfront investment in the second iteration = 5,437 DKK (approximately €729)
- DfD/DfA^{UC1} DfD and DfA project upfront investment in the first iteration = 6,757 DKK (approximately €906)
- DfD/DfA^{UC2} DfD/DfA project upfront investment in the second iteration = 1,081 DKK (approximately €145)

The Equation A calculation illustrates the monetary ROI for the adaptable housing concept in Copenhagen is 38.83% over two life cycles, i.e. the potential money saved over two lifecycles compared to BAU.

The Equation B calculation illustrates the ROI on additional investment to deliver the adaptable housing concept instead of BAU is 230%, i.e. the extra 1320 DKK (approximately €729) a developer spends will potentially result in a 230% ROI over two iterations.

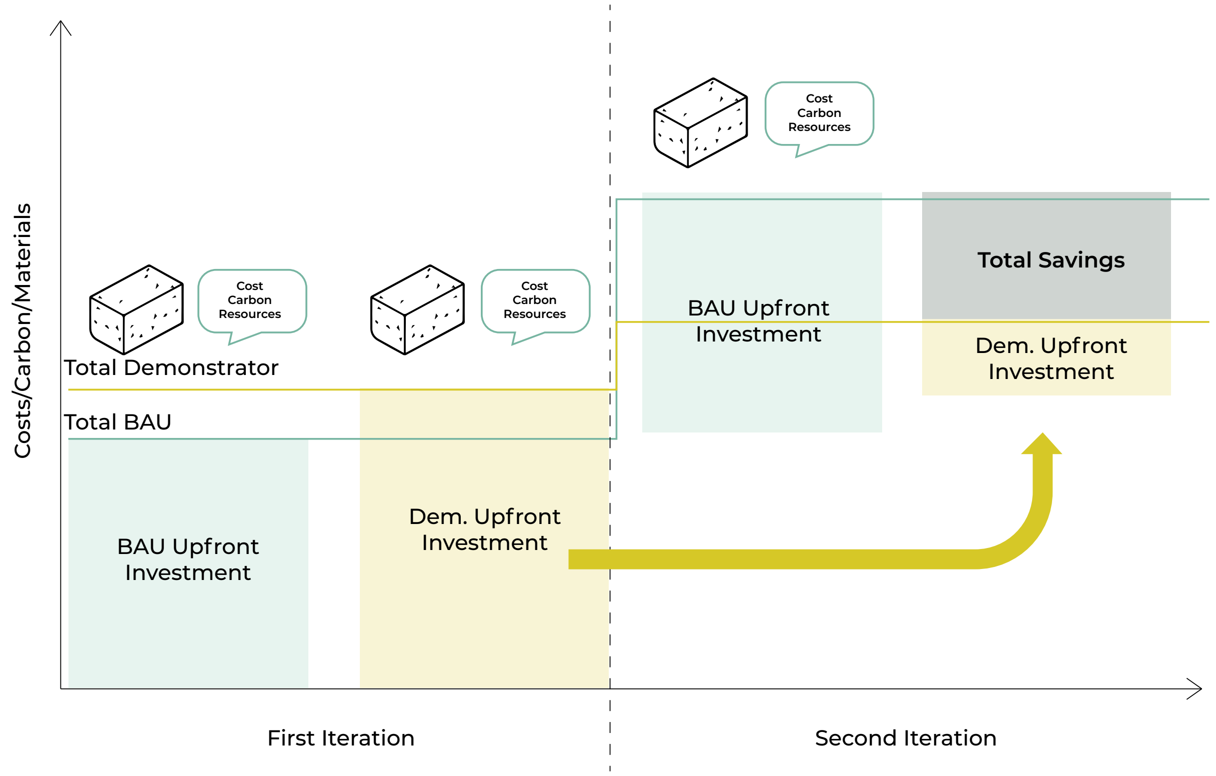


Figure 3.3: Visual illustration of savings after second iteration of Dfd building

Methodology to assess the scaling potential of DfD and DfA concepts

Once a DfD or DfA concept has been established, the scaling methodology can be used to create a 'probability' score. This score determines the likelihood of whether a DfD or DfA concept will be built and then scaled at a city level.

Step 1: Identify an existing source of lost value because of a linear economy in the city
The first step is to analyse current market trends and identify a current loss of value related to a linear construction approach such as premature demolition, vacant land or depreciated building materials. Rate this value loss as significant, less significant or insignificant.

For example, Denmark is prematurely demolishing around 32,000 public housing units. At the same time, 60,000 new dwellings are being built in Copenhagen. Using average data for construction cost and carbon, it's possible to estimate the potential value loss if circular construction practices are not applied to the new dwellings and they are prematurely demolished.

Step 2: Identify a DfD or DfA solution to the value loss identified in step 1
Next, rate how well you think your DfD or DfA solution responds to the identified value loss in step 1. This could be low, medium or high.

For example, adaptable housing (see page 3-6) could prevent Copenhagen from prematurely demolishing buildings in the future.

Step 3: Potential profit score
Use the ROI methodology for DfD and/or DfA (see page 3-18) to estimate the potential profit of adopting a DfD or DfA solution. This could be a cost, carbon or materials profit. Apply this to the scale of the problem the solution will solve to get a full grasp of the potential profit from adopting the DfD and/or DfA concept.

For example, in Copenhagen the monetary ROI for using the adaptable housing concept instead of BAU is 38.83% over two iterations. Applying this percentage to the cost of building 60,000 new dwellings (60,000 x 5,437 DKK) means the city of Copenhagen would save nearly 127 million DKK (170 million Euro) over two lifecycles/iterations.

Step 4: Market readiness score
Analyse the degree to which the DfD or DfA solution is market ready. For example, identify the percentage of market ready components, use of standard dimensions, impact on construction line, etc. Rate the DfD or DfA solution not market ready, somewhat market ready or market ready.

Step 5: Implementation scalability score
Analyse the degree to which relationships between stakeholders and requirements (policy, legislation, etc) are in place to implement the DfD or DfA concept instead of BAU.

For example, if there is a need for legislative changes to building codes, implementation might be very complex. If all that is required is an incentive through planning, it might be less complex. Rate your solution high complexity, medium or low complexity.

Step 6: Conclusion
Based on the preceding five steps, make a conclusion about how probable and scalable your DfD or DfA project is.

Making the case for design for disassembly and design for adaptability

A 'business case' is understood as making a case for changing something. It is directed at a specific audience who can enact the proposed change. It describes actions to be taken outside of a business as usual (BAU) scenario and the outcomes that are expected. Four of the business cases that were developed by drawing on the carbon and cost analysis of the CIRCuIT design for disassembly and adaptability demonstrator projects are shared below.

Each business case includes five perspectives on making the change that are presented under the headings strategic, financial, feasibility, risk and scalability. Together these commentaries and the demonstrator templates provide evidence on the benefit of investment in the proposed changes for decision makers and local communities.

> **The full list of all business cases developed from demonstrator results can be found in Appendix A1.2**

I. Local authorities can help to create circular supply chains by driving demand for novel DfD construction by adopting its use in public projects

Strategic: If local authorities take a leading role in briefing design teams to specify DfD, they can reduce embodied carbon emissions in line with their own carbon reduction objectives and help to break down barriers to the wider adoption of novel circular construction.

Financial: Compared to BAU, upfront costs were found to be 25% lower for Demonstrator 25 and 1% higher for Demonstrator 26. Lifecycle cost savings of 37% Demonstrator 25 and 61% Demonstrator 26 were achieved once the components were used for a second time.

Feasibility: Adopting novel construction techniques requires strong impetus from those commissioning construction to set a direction of travel. Officers in development and regeneration roles will need to understand the reasons for the policy and act as custodians as the policy is enacted in project briefs and challenged through the course of a project's development.

Appointed design teams will be asked to design and specify product systems in a way that differs somewhat from their normal practice. Clarity of rationale and awareness of carbon and circularity will be key to resisting pressure to revert to BAU.

Risk: Association with innovative, circular businesses can enhance the reputation of a local authority amongst staff, residents and industry. The opportunity cost of achieving carbon savings or other environmental benefits should be weighed against other options for achieving the same benefits. The starting point is to understand the scale of benefits. In the demonstrator cases, DfD was found to achieve 75% and 85% reductions in embodied carbon emissions once components were used for a second time.

Scalability: The emergence of building futures contracts and a market mechanism for their exchange will lend credence to the long-term residual value of DfD construction, and justify additional upfront investment.

Nevertheless, the ability to scale this business case depends on the availability of DfD products that are ready to apply to major projects. Greater demand for DfD from across the market, driven by progressive purchasing and tighter regulation of whole life carbon, will create more opportunities for businesses to develop such products.

Related demonstrators: Demonstrator 25 – Hamburger Klassenhäuser – Slab construction, Demonstrator 26 – Hamburger Klassenhäuser – Façade comparison.

W. Manufacturers can generate new revenue streams by developing demountable product-as-a-service business models

Strategic: Manufacturers can retain ownership of assets and generate revenue from leasing building products and systems, including partition systems, façade components, warehouse buildings and raised access flooring.

Financial: In the demonstrator projects on which this case is based, upfront costs were found to be higher where systems were designed for future disassembly (by 11–25%). However, lifecycle cost savings were achieved once the components were used for a second time (13–25% saving), and with each additional use cycle this return on investment improved further.

Whilst future returns are inherently uncertain, the Neustadt case showed real savings achieved for the recipient project through the reuse of 200m2 of a partition wall system in collaboration with the original manufacturer. These savings represent a competitive advantage for a manufacturer that is able to disassemble, reassemble and re-warranty their products.

Feasibility: Disassembly and reassembly techniques exist but leasing models remain largely unfamiliar to developers, specifiers and contractors. A shift in mindset is required for these models to become commonplace. Pricing and ownership models need to be considered to suit different component types and market segments.

Risk: There is financial risk in increasing manufacturers' upfront costs with returns coming over a long period. There is organisational risk for existing manufacturers in developing and integrating new business models where traditional upfront sales models are felt to be effective. However, retaining ownership of materials is a hedge against future resource price rises and price volatility.

Scalability: Leasing models are most applicable to shorter lived building components, temporary buildings and typologies that could be expected to be deployed on different sites before the end of the components' lifespans. If they become commonplace, it will raise questions over universality/compatibility versus manufacturer-specific technology (e.g. connection types) and subsequently collaboration versus competition amongst manufacturers.

Alignment over technology (e.g. connection types) and robust information retention (e.g. through material passports) will help to ensure that components are disassembled and reused as intended, even if their original manufacturer ceases trading.

Related demonstrators: Demonstrator 27 – Neustadt – Partition walls, Demonstrator 29 – DfD modular façade – Taastrupgård, Demonstrator 32 – DfD warehouse, Demonstrator 36 – Green Street affordable workspace.

E. Public and private developers can create more valuable homes, improve resident satisfaction and reduce lifecycle cost by developing adaptable housing

Strategic: Public and private developers can create more valuable homes, improve resident satisfaction, reduce lifecycle cost and simplify maintenance and upgrades by developing adaptable housing that facilitates multigenerational living and flexibility of living and working.

Financial: In the demonstrator projects on which this case is based, upfront costs were found to be higher where systems were designed for adaptability (by 21–24%). Savings are achieved when dwellings are transformed to suit changing needs, especially where the alternative is demolition and new construction.

In one case, the redevelopment of an adaptable home compared to demolishing and rebuilding after one use cycle resulted in a 28% lifecycle cost saving. Economic benefits for the building owner may also be generated by shortened periods of vacant flats, due to the capability to adapt flats to meet changing demands.

Feasibility: Adaptability can be achieved through simple design changes such as optimising positions of load-bearing elements and building services layouts and accessibility. The demonstrators apply construction methods and technologies that are readily available.

Risk: The resident survey conducted in Helsinki found that there is demand for flat adaptability amongst both owner-occupiers and tenants, as it reduces the likelihood of having to move house, allows changing use of space as family life and work life change, and makes it possible to rent or sell a part of the flat to yield income.

There is a willingness to pay a premium for adaptability, generally 2–10% on top of the purchase price, if its potential benefits are clearly communicated. For building owners, investment in adaptability reduces the risk of buildings being demolished before the end of their technical lifespan.

Scalability: In owner-occupied housing, the investor and the beneficiaries are different. The potential savings must be communicated and recognised as additional value at the point of sale, otherwise the split incentives will reduce motivation to invest in adaptability. For public developers and housing associations that retain ownership of buildings, adopting lifecycle costing is essential to assess the merit of designing for adaptability.

Related demonstrators: Demonstrator 28 – Copenhagen adaptable housing, Demonstrator 33 – Helsinki adaptable flats, Demonstrator 35 – RightSizer

F. Public and private landowners and asset owners can achieve increased rental income by facilitating 'meanwhile use' of underused land and assets

Strategic: The term 'meanwhile use' represents a range of strategies that can be put into place to make under-utilised spaces and places become productive, both in an economic and social sense.

Landowners can achieve increased rental income by identifying opportunities for 'meanwhile use' and maximising use of land and assets prior to longer term redevelopment.

Financial: Land and assets earmarked for redevelopment are often protected with hoarding and security services in the period before construction starts. These periods of under-utilisation of assets are often significantly longer than is first anticipated, potentially leading to years of outgoings.

Meanwhile use' achieves rental income and avoids the need to pay for securing disused sites, but it requires investment in a temporary building (by the landowner or others) that may need to be deployed multiple times to achieve a return. The demonstrator on which this case is based was a disused brownfield site. Upfront construction costs of a relocatable building to suit a 10-year lease period on the site were found to be 6% higher than an equivalent building not designed to be relocatable. However, lifecycle costs for three 10-year uses of the building were 23% lower.

Feasibility: Information about a site's previous use allows assessment of the capacity of any existing foundations. In the demonstrator case, the 'meanwhile building' was designed to be lighter than the previous building so that no new foundations were required. The demonstrator used standard construction materials and techniques, with some modifications to improve design life and demountability.

Construction supply chains are not fully prepared to scale these techniques to maximise their potential impact, but the supply capacity and skills required are within reach. Deconstruction and relocation expertise exists, but it will also need to be scaled to meet the needs of a larger market in relocatable buildings.

Risk: Maximising return on investment will require 'meanwhile buildings' to be deployed multiple times. Under current regulations, a building will be defined as new at the point that it is relocated to another site. It will require full planning permission and will need to meet the relevant building regulations of the day. This may add complexity and cost to future relocation.

Scalability: All buildings become non-compliant over time, but existing buildings that remain on the same site do not need to be recertified every 10 years. This raises the question – Should relocatable buildings become a new special category and regulations relaxed to simplify their widespread adoption?

Taking London as an example, there are 466 disused plots of land of a size that would be suitable for 'meanwhile use' similar to that adopted by Demonstrator 34. The total area of this land is nearly 500,000m^2. In the UK as a whole, there are 36,000 disused brownfield sites. This represents a significant opportunity to roll out 'meanwhile use' prior to redevelopment.

Related demonstrators: Demonstrator 34 – Albion Street / The Hithe

Further reading

For further information about the outputs featured in this report and the work behind them, please read the following reports, which were published by members of CIRCuIT partner organisations during the lifetime of the project.

- D6.2 Circular building concepts for concrete, hybrid concrete-wood, and volume construction
- D6.3 Set up of demonstrators and scenarios for four partner cities
- D6.4 Part 1 Threefold ROI assessment of building concepts and threefold ROI of urban plan – preliminary report
- D6.5 Four city case roadmaps for implementation

All these reports can be downloaded at circuit-project.eu/post/latest-circuit-reports-and-publications

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CIRCUIT

4

Data and indicators for a circular built environment

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821201.

Data and indicators for a circular built environment – why they matter

Cities need to take action in many areas to enable a transition to circularity within the built environment. This includes introducing new policies, supporting the development of novel business cases, and advancing material exchange infrastructure. However, if these actions are to be successful, they must be underpinned with robust, quality and accessible data.

Successfully building using circular eocnomy principles requires access to additional information about the local building stock and building industry that is not required in BAU take-make-use-dispose models. The specific characteristics of a building or material need to be defined, recorded, and shared freely, and at the right time during the construction process. This need for additional data was clearly highlighted by key findings from the CIRCuIT project:

Limited data leads to limited results – It is not possible for decision makers at any level to identify key challenges and opportunities relating to the circular economy without robust, quality data.

Accurate, reliable and complete data is needed – Modifying the circularity of a city requires the availability of as much detailed data on as many relevant systems as possible.

Data enables circularity of material flows – The flow of resources is influenced by decision makers who could use data to create circular material flows.

Standardisation is key to the exchange of data – The standardisation of units and formats of datasets is key to facilitating and promoting the exchange of quality data amongst different built environment stakeholders.

To successfully analyse large amounts of data at the city-level, cities need high-quality circular indicators. A circularity indicator is a piece of information that can be used to measure performance within the built environment to guide decision making and enable stakeholders to communicate their circular economy actions in a consistent way. Indicators can help cities benchmark their current activities, set clear goals, communicate about benefits, and assess their performance against targets.

Measuring circularity in the built environment is still a relatively unexplored area. Even though there is often a large volume of data captured, the CIRCuIT project found there are still many gaps in data and other data challenges for circularity to be successfully adopted in cities. These challenges include limited accessibility to existing data, as well as the data often having poor accuracy, granularity and interoperability.

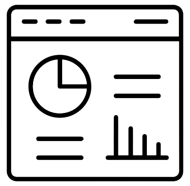
In addition, cities do not fully understand what data they need to measure to get a better picture of circularity in their city. The infrastructure to capture, analyse and store the data that's needed is also not always set up to a necessary standard.

This chapter showcases the tools, methodologies and recommendations developed by CIRCuIT to standardise and improve the capture of circular data relating to the built environment. This includes templates that standardise data capture, as well as 37 key indicators that built environment stakeholders can use to guide decision making and measure circularity performance so they can drive forward circularity in their city.

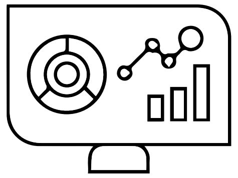
Figure 4.1: Icon illustrating material passport use

Data to measure circularity – the current state of play

To explore what data cities typically have access to, as well as identify what data is needed to measure circularity within the built environment, the four cities involved in the CIRCuIT project carried out two key activities:



Activity 1 – Mapping data in a city – This was a data mapping exercise that aimed to identify the data accessible to each CIRCuIT city in relation to historical, current and future building material stocks and flows.



Activity 2 – Assessing the usefulness of available data – This exercise assessed whether the data identified as 'accessible' during activity 1 can deliver the insights needed to help cities transition to circularity in the built environment.

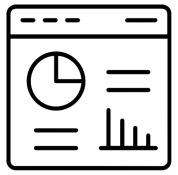
Undergoing these activities are key steps in the transition towards a circular built environment, as they can highlight data gaps and other challenges relating to data.

When the four cities involved in the CIRCuIT project carried out these two activities, they identified the following key findings:

- **Accessibility of data** – Large volumes of data were often present but held privately and not open for access. This significantly hindered material flow related work that requires an overview of all construction in the city.
- **Spatial and temporal granularity** – Datasets did not align in terms of the geographical area they covered or the frequency of their updates. This meant the conclusions that could be drawn were very general or out of date.
- **Inaccuracy and unreliability** – Datasets were not always accurate, due to human error, double counting, extrapolations, etc.
- **Standardisation and interoperability** – Datasets were not standardised, which meant they could not be aggregated and used together.

The steps the CIRCuIT cities followed to undertake these activities are outlined in this chapter, as are key learnings that can help to inform similar initiatives in other cities.

Following Activities 1 and 2, CIRCuIT's project partners also developed a set of data templates and recommendations that can be used to help capture the data needed to integrate circularity, build consistency across the industry and address gaps and weaknesses typically found in the data.



Activity 1: Mapping data in a city

Members of the CIRCuIT project and their built environment stakeholders worked together to map the building material stocks and flows ecosystem in each CIRCuIT city with the aim of building understanding and enabling circularity. To do this, the following data types were investigated:

- **Inflows** of materials or products to the building and infrastructure stock, such as data on installations or material sales
- **Building and infrastructure stock figures** such as number of buildings, total floorspace, kilometres of track, split of building and infrastructure types
- **Current material stocks** in use across existing building and infrastructure
- **Circular flows** of materials or products at end-of-service life to a new-use cycle, i.e. reuse, remanufacture and recycling of building components, products and materials
- **Outflows/waste flows** of materials or products at end-of-service life in buildings and infrastructure stock to landfill, incineration, energy recovery or fly-tipping
- **Past, current and future demand** for buildings and infrastructure, and for the materials and products they contain
- **Future arisings of materials or products** at end-of-use within a city
- **Externalities** – the environmental, social and economic impacts arising from the extraction, operation, transport and disposal of products and materials
- **Contextual data** including data on factors that influence or are related to material stocks and flows, such as demand for new housing
- **Geographical and land-use data** that could provide a basis for mapping and visualisation

Undergoing these activities are key steps in the transition towards a circular built environment, as they can highlight data gaps and other challenges relating to data.

Assessment of mapped data

Variable accessibility of data

Open data is data that can be freely used, modified and shared by anyone for any purpose. This data is usually collated into centralised datasets and shared by local authorities or government bodies. The mapping exercise revealed that a significant amount of open data about a city's building material stocks and flows is typically available. However, most open data is top-down data, which tends to be broad and lacking granularity.

Public non-open data is data that is usually available to all but has a set of requirements to satisfy prior to access, such as registration fees or a licence. The mapping exercise identified that this is the most common type of data available about a city's building material stocks and flows.

CIRCuIT partners concluded that making non-open data more freely available would significantly help built environment stakeholders capture a fuller picture of the material stocks and flows in a city, and especially upstream (material supply) and downstream (demolition/waste management) material flows.

Private data is collected by a private entity for their own purpose and is not viewable to the public. The mapping exercise identified that there is a large amount of data held privately about materials stocks and flows. If this was centralised and released as open data (aggregated and anonymised, as appropriate), this data would support and enhance commercial and political decision making relating to the circularity in the built environment.

Data quality issues

Granularity of data – The mapping exercise identified a wide range of granularity across datasets, from single statistics on recycling rates at a national level to real-time data uploaded to centralised planning systems. Overall, the granularity of the surveyed data tended to be low, with many datasets only being updated annually and covering a broad subject area.

Accuracy and reliability of data – The accuracy and reliability of data tends to be difficult to ascertain, largely owing to poor transparency in terms of the data collection methodology, analysis and verification. Often, there is only one dataset relevant to a particular subject available within a city, which means there are often no benchmarks for comparison.

Standardisation of data – There are a large number of datasets from varying sources which use different units and formats. In some cases, even different datasets dealing with the same subject do not use standardised units and formats. Another challenge is the discontinuity of some material and product classifications.

Updating of data – Large variability was observed in terms of how up-to-date datasets are and whether they are actively monitored. In many cases, there was a gap between the data's timeframe and the date of its publication, which could stretch to a number of years. Additionally, many datasets were identified that were relevant in terms of subject but no longer updated.

Data differences at different points of the construction pipeline

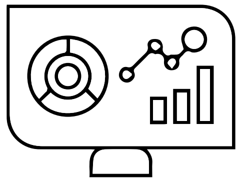
Supply chain – There was little data openly available related to the supply of construction materials. However, there is likely to be substantial data collected privately by supply chain organisations on the volumes of materials being handled and exchanged with upstream or downstream actors in the supply chain. If this data was centralised, aggregated, made openly accessible and, where necessary, anonymised, it could help to plug significant gaps in understandings of material flows. See chapter 6 for more information on our work on material flows.

Building typology – Data on residential building stock was found to be widely available. Building-level datasets were also accessible within the four cities. Both provide a good degree of granularity and a more precise indication of the characteristics of a building, which may be aggregated.

In some cases, however, there was found to be less systematic data collection on non-residential building stock, such as commercial, industrial and retail buildings, despite these being estimated to represent large proportions of stock.

Material stock data refers to materials that are currently in use within buildings and infrastructure. Data that focused on material stock quantities per building or per infrastructure was not available within the CIRCuIT cities. However, there is data available in all cities that could enable a material flow analysis to calculate material stocks.

Waste management and circular material flow data is typically more complete and extensive than other segments of material flow chains. In all the CIRCuIT cities, data was readily available on the tonnage/volume and origin of construction and demolition waste. This data is generally split by material/waste class, partly due to reporting requirements under the European Commission's Waste Framework Directive. In some cases, data on the destination of waste is also captured.



Activity 2: Assessing the usefulness of available data

After identifying what building material stock and flow data is accessible across each CIRCuIT city, project partners then created 29 potential use cases for how this data could be used to provide insights relevant to the circular economy.

These use cases cover the entire materials stocks and flows ecosystem and include a range of built environment stakeholders, including product manufacturers, contractors, waste management organisations, policymakers, planning authorities and researchers.

To develop these cases, partners first assessed what specific data was needed for each use case, and then looked to determine:

- whether the required data existed in each CIRCuIT city and was available to the relevant stakeholders
- whether there was any indication of the quality and reliability of data sources that did exist

All 29 use cases can be found in the CIRCuIT report D3.2 Recommendations for improving the capture of material flow data in the built environment. This is available to download at circuit-project.eu/post/latest-circuit-reports-and-publications

Two examples of how data could potentially be used to provide circular economy insights

Use case 1 – Using building typology data to calculate a city's material stock

If it's not possible to calculate the amount of materials in individual buildings, it may be possible to follow a building typology-based approach. This involves obtaining or calculating the typical quantities of materials in a range of common building types, which are distinguished from each other according to factors such as age, use class, construction type, and so on.

Using this information, the material totals for the area under study may be calculated based on the number of instances of each building type within it, multiplied by their respective typical material quantities.

Use case 2 – Using historical data to predict demolition rates in a city

One way to estimate the future rate of demolitions in a city is to carry out a survival analysis of building stock.

Historical demolitions data can be used to ascertain patterns related to the typical age that different building types are demolished and the circumstances preceding demolition.

By evaluating information related to a building's attributes (such as age and use class) and the contextual factors influencing their survival or demolition, it's possible to identify patterns in mortality and survival of certain building types.

In turn, this may be applied to a city's current building stock to predict future rates of demolition. See the report Extending the lives of buildings through transformation and refurbishment for more information about identifying buildings at risk of demolition.

Improving data capture across the built environment

In Copenhagen, Hamburg, Vantaa/Helsinki Region and London, CIRCuIT partners identified that data issues are preventing decision makers and built environment stakeholders from increasing circularity in the built environment.

To help address these data gaps and weaknesses, a set of templates were created to improve and standardise the capture of data across the building ecosystem.

Additionally, 17 overarching recommendations were developed for stakeholders across the value chain, from planning officers and policy makers to industry practitioners. These aim to help address gaps and weaknesses in circular data.

Circular economy data templates

Templates help to define the data required at all levels of a city's built environment ecosystem. These levels relate to the following dimensins: A) components, B) spaces, C) buildings, and D) areas

The templates developed during CIRCuIT are organised as 'data dictionaries', where information about an object is listed as 'properties'. For each property, a description and the recommended unit of measurement are provided, as well as predefined response options, where relevant. Wherever possible, these have been standardised across all levels.

The data templates serve as a complete framework for the consistent capture of data and cohesive sharing of data between professionals. Ultimately, this will improve the collection process of data and help stakeholders to take actions promoting circular use and the management of built environment resources.

Recommendations for addressing gaps or weakness in data

Based on the availability and quality of data found in the mapping exercise outlined in Activity 1, CIRCuIT partners and built environment stakeholders developed a list of recommendations for how data could be improved or applied more effectively to increase circularity in a city's built environment.

Recommendations on data creation through primary research

Develop a methodology for calculating the reuse potential of a building component or element based on available data

It's not easy for stakeholders such as building owners or prospective reused material procurers to understand the reuse potential of a building once demolished or disassembled. Research is required to create an approach to fill this gap.

Relevant stakeholder(s)

Researchers

Develop a methodology for automatically calculating building and spatial transformation capacity based on available data

Stakeholders cannot easily quantify how transformable a building is. More information is needed to support decision making about whether to attempt to transform a building, replace it, or leave it as it is. Research is required to create an approach to fill this gap.

Relevant stakeholder(s)

Researchers

Develop lifecycle assessment (LCA), lifecycle costing (LCC) and social impact factors

Developing these factors at product and building level can incorporate the whole lifecycle impacts related to the transformation, reuse and recycling of materials from existing buildings (urban mining), and design for disassembly and adaptability.

This could be used to model and compare the lifecycle impacts of different approaches or specifications, or to inform decisions on whether to refurbish a building, demolish it or leave it as it is. This could also help to inform retrofit strategies at a city-scale, based on costs and benefits variable by building type and context.

Relevant stakeholder(s)

Researchers

Develop methodologies for quantifying the reuse potential/ transformation capacity of materials, components, elements and buildings

Once recommendations 1 to 4 have been achieved, and given appropriate data on the building stock, it could be possible to quantify the reuse potentials/residual values of materials, components and elements currently embedded in the building stock, and the transformation capacity of buildings.

Combined with LCA/LCC/social value modelling, this could assist with decision making over how to manage different segments of the building stock to achieve optimal environmental, social and economic outcomes.

Relevant stakeholder(s)

Researchers

Recommendations on capture of data by practitioners

Capture data relevant to circular economy according to circularity data templates

As identified by research carried out by CIRCuIT partners, there are issues with the granularity, accuracy and reliability of building materials stocks and flows data, which is preventing cities and built environment stakeholders from increasing circularity in buildings and infrastructure.

Getting cities and stakeholders to capture the data outlined in the data templates developed by CIRCuIT partners could help overcome this issue. See page 4-10 for more information about the templates.

Relevant stakeholder(s)

Construction industry

Recommendations on data standardisation and interoperability

Develop and mainstream the use of circularity indicators

Strong circularity indicators will enable cities and stakeholders to consistently measure circular economy approaches. This will help with the setting of targets and improve the sharing of information between stakeholders.

Please go to page 4-19 to see the set of key circularity indicators developed and recommended by CIRCuIT partners for cities. You can also see how CIRCuIT cities used circularity indicators in practice by visiting the Circularity Dashboard at circuit-project.eu/circularity-dashboard

Relevant stakeholder(s)

Researchers | Policy makers | Construction industry

Develop and mainstream the use of circularity data templates at multiple levels

Data templates that identify what data is necessary to support circular action in the built environment should be developed. Standardisation is absolutely essential, as is the ability to integrate the data captured by the templates.

This supports the better exchange of data between stakeholders at different levels of organisations and at different points in material lifecycles.

Relevant stakeholder(s)

Researchers | Policy makers | Construction industry

Develop and mainstream data exchange methodologies for integration of material and product data with building data

Currently, there is little ability to carry through material/product data to building information models (BIM) upon installation, and from BIM models to subsequent data management systems upon the material or product's deinstallation from the building.

Without this 'golden thread' of data from cradle-to-cradle or cradle-to-grave of a material, it is less easy for subsequent material/product handlers to understand the origin and circular economy-related attributes, and to make decisions that promote circularity.

Relevant stakeholder(s)

Standards organisations | Researchers

Recommendations on exchange of data between stakeholder groups

Capture data on each unit of material, component or element throughout its lifecycle, and store it in a transferable digital record

This would enable accurate and transparent measurement and modelling of circularity and lifecycle impacts at any point across the value chain. As a result, a procurement manager, for example, could calculate exactly how the use of a particular product may impact the footprint of their project. Relevant data may include material passport data, as well as composition, circularity indicators, and any other circular economy-related information.

Relevant stakeholder(s)

Construction industry

Create, update and handover building information models (BIM) to relevant stakeholders, depending on building lifecycle stage

BIM models will be essential in circular economy since they allow the storage and sharing of data useful for circular decision making between relevant stakeholders. Additionally, given appropriate data on the impacts of a product, design or logistical method, they may be used to model the whole life impacts different project approaches through integration of LCC/LCA and social impact assessment approaches.

Relevant stakeholder(s)

Construction industry

Recommendations on integration of data into databases

Create a database of services and facilities assisting with circular economy of the built environment

This could follow the example of the London Waste Map and its underlying database, expanded to include all services and facilities of use to the circular economy, with live or regularly updated data that is readily integrated into the management systems of stakeholder groups.

Relevant stakeholder(s)

Policy makers

Create a live database of material stocks and flows

A city level database that records where materials are stocked and how they flow throughout the city system, including data of relevance to circular economy such as whether materials are reused or what their typical sale prices are.

If aggregated and analysed, this would be a valuable resource for planning and policymaking to enable city-level material flow management (including waste management), as well as for other applications, for example, prospective material sellers being able to understand the likely market value of their assets post-demolition.

Relevant stakeholder(s)

Construction industry Policy makers

Create a live building stock database

This database could include data on existing building stock, as well as predictive or modelling capabilities regarding the future of building stock. This could inform decision making and strategy by planning officers and policymakers as to how to modify patterns of construction, refurbishment and demolition to achieve the best social, economic and environmental outcomes.

Relevant stakeholder(s)

Construction industry

Recommendations on analysis of databases

Quantify and predict rates of circular economy-related building stock dynamics

Understanding the existing rates of building stock dynamics (e.g. new construction on greenfield sites, demolition and replacement, transformation, design for disassembly and adaptability in new construction, the reuse and recycling of materials, etc), as well as more detailed information such as the typical efficiencies, financials and impacts associated with different approaches, is useful for developing strategies, benchmarks and policies that decision makers in cities' construction and buildings sectors can use to guide their actions.

Relevant stakeholder(s)

Researchers

Quantify and predict stocks and flows of (reusable / recyclable) materials, components and elements from building stock

Understanding the profile and quantities of different building materials, components and elements within building stock, and those that are projected to emerge from the stock, can inform strategies and policies around recycling, reuse and building stock management.

Relevant stakeholder(s)

Researchers

Quantify and predict demand for reused and recycled products

Understanding the demand for reused and recycled products can allow prioritisation of which building stock segments may be demolished and those for which demolition should be avoided, based on both the proportions of recyclable and reusable parts within them, as well as the level of demand for those parts.

Relevant stakeholder(s)

Researchers

Indicators for measuring circularity

For the CIRCuIT project, a 'circularity indicator' is a piece of information that any stakeholder in the built environment sector can use to measure performance and guide their decision making to enable a circular economy.

Numerous circular indicators have already been developed around the world. However, these indicators vary significantly, with most using different methodologies, structures, terminologies and measures.

This lack of standardisation is currently a significant barrier to built environment stakeholders who wish to accelerate circularity in their city and beyond. To address this issue, CIRCuIT partners used the findings from their city data mapping exercises and a comprehensive research programme to identify a list of key circularity indicators for cities.

The indicators provide an overview of circularity at city, building and materials levels and use a mix of impact metrics (such as recycled content, material use), productivity metrics (e.g. per value, area) and enabler metrics (the number of projects with circularity economy requirements).

Each of the 37 indicators is listed with supporting information, including which built environment stakeholder it is relevant to.

Built environment stakeholders can look through the indicators to understand what they should measure to support circularity in their city. The indicators can also be used to measure the environmental, economic and social impact of circular economy decisions and set circular targets for stakeholders, from product designers to local authorities.

At a city-level, the indicators can help to support evidence-based policy and planning development, as well as decision making to support the circularity of material flows within buildings and throughout material lifecycles.

How local government can use policies to drive circularity in their city is explored further in the report titled Using policy to power circular construction.

Using indicators in the real world

CIRCuIT partners identified five key circularity indicators for their cities. These are presented visually on a Circularity Dashboard at circuit-project.eu/circularity-dashboard

Read more about the Circularity Dashboard and other online tools developed as part of the CIRCuIT project in Chapter 6.

Recommended city level indicators

Indicator name	Description	Unit	Stakeholder benefits
Material inputs to building stock			
Total material inputs to building stock (UM)	Indicates the quantity of material inputs (virgin and secondary) to the city's built environment. Calculated as an absolute quantity of materials used.	Tonnes of materials	Urban planners will be able to set targets on how much materials is needed and what type.
Secondary inputs to building stock – recycled materials (UM)	Indicates the proportion of raw material inputs to the city's built environment that are recycled (excluding downcycling) following a previous use cycle.	% by mass of recycled materials versus virgin materials	Planning officers will be able to set targets for amount of recycled materials to be used in future buildings.
Secondary inputs to building stock – reused materials (UM)	Indicates the proportion of raw material inputs to the city's built environment that are reused) following a previous use cycle.	% by mass of reused materials versus virgin materials	Planning officers will be able to set targets for amount of reused materials to be used in future buildings.
Lifespan and in-use performance			
Transformation market penetration (L)	This indicator is intended to demonstrate the extent to which transformation activities is being pursued within the city relative to new construction. If the ratio increases over time this would suggest that space is being utilised more efficiently/ intensively (where the ratio is increased through an increase in transformations) or that transformation is displacing new construction demand (where the ratio is increased due to a drop in new construction accompanied by a stable or increasing number of transformations).	% by value (transformation as a proportion of all works including new construction)	Urban planners will be able to assess how much demolition they are avoiding and more easily set benchmarks, targets and requirements for transformation.
Average transformation capacity of building stock (L)	A transformation capacity score given to each existing building within the building stock, which is then aggregated and averaged for the whole city.	Monofunctional (score 3-6) Transfunctional (score 6-8) Fully transformable (score >8)	Policymakers and planners can set benchmarks and targets for the amount of transformation activity in the city based on the building stock's propensity to be transformed.
Intensiveness of use (L)	The average intensiveness of use of the building stock relative to the average potential intensiveness of use. This indicator is only suitable for buildings such as schools, offices or community centres.	% hours actually occupied versus potential	Planning officers will be able to validate the need for new buildings to be added or if they could more efficiently use existing ones.
Circular potential of existing building stock			
Reuse/recycling potential of existing building stock (UM)	The amount of materials which are available for reuse/recycling in the building stock.	Tonnes of materials that has the potential for reuse/recycling	Policy makers will be able to set targets for recycling and reuse.

Indicator name	Description	Unit	Stakeholder benefits
Material outflows and recirculation – based on actual current activities			
Total materials/ wastes arising from construction and buildings sector and end of life reporting (UM)	The total amount of materials and wastes emerging from the construction and buildings sector.	Tonnes of wastes generated	Policy makers will be able to understand quantities of wastes generated.
Recirculated materials (UM)	The proportion of total materials arisings at end-of-use in buildings within the city/ region (see above), that enter new use cycles within the city/region (reuse/recycle).	% per tonnes of the city's construction and demolition waste that is recycled or reused % per tonne of the city's solid waste that is recycled or reused	Policy makers will be able to validate their targets for recycling and reuse against those numbers.
Quantity of materials that is reused/recycled through dedicated centres (UM)	Quantity of materials that is reused/recycled through as a material outflow.	Tonnes of materials reused/recycled	Policy makers will be able to understand the efficiency of reuse/ recycling ability at city level.
New buildings			
New buildings designed to circular policies and principles/ standards (CD)	This indicator measures the extent to which new projects are being designed according to circular policies and principles, demonstrating whether practitioners are considering how they can ensure that the buildings they create support circular economy throughout their life cycle.	% of new building stock by floor area % of new building stock by value	This would help policymakers and planners to understand the extent to which new buildings are being designed and built using circular principles, providing an evidence base for policy development.
Average transformation capacity (new buildings) (CD)	Measures how adaptable are the new buildings constructed within the city. Higher average transformation capacity in new build means that there is a possibility for a higher rate of transformation versus building replacement in future.	Monofunctional (score 3-6) Transfunctional (score 6-8) Fully transformable (score >8)	As above.
Average reuse potential of materials and components at end of life (of new construction) (CD)	The average portion of new buildings which can be reused at the end of the life of the building.	% by mass of materials within new building stock that can be reused or recycled at their end-of-use	As above.

Recommended building level indicators

Indicator name	Description	Unit	Stakeholder benefits
Building design			
Dematerialisation (linked to total material inputs to building stock) (CD)	Building has been designed so that the minimum material inputs are required to achieve the same whole life functionality, without compromising on durability, resilience, other technical performance requirements or health and safety.	% by mass of material not used	Designers demonstrate that they have designed the asset with material optimisation. This will support building level assessments, such as BREEAM. This information will also inform LCA and LCC studies.
Design for disassembly (CD)	Proportion of building components that are reversible from the wider building without significant damage to either the removed component or its wider assembly. This indicator should be linked to BIM and guidelines to ensure stakeholder down the supply chain can optimise the building end of life. This indicator is measured using ISO20887.	% by mass of the building that can be disassembled at the end of life	Designers can demonstrate to urban planners that the building can be disassembled at the end of its life. This will support building level assessments, such as DGNB. This information will also inform LCA and LCC studies.
Design for adaptability (transformation capacity) (CD)	The spatial and technical aspects of building design allow for adaptation to another function (as designed). This indicator is measured using ISO20887.	% by mass of the building that can be adapted at end of life	Designers can demonstrate to urban planners that the building can be disassembled at the end of its life. This will support building level assessments, such as DGNB. This information will also inform LCA and LCC studies.
Material inputs to building			
Reused content (UM)	Proportion of the building that is formed of reused products and product components.	% by mass reused content	These will enable contractors to demonstrate compliance with local requirements, such as the GLA circular economy statement. This indicator will also inform policy makers to set future targets. This information will also inform LCA studies.
Recycled content (UM)	Proportion of the building that is formed of recycled/upcycled products and product components (exclude downcycling).	% by mass recycled content	
Circular potential (as built)			
Transformation capacity (L)	The spatial and technical aspects of building design allow for adaptation to another function (for existing buildings).	Monofunctional (score 3-6) Transfunctional (score 6-8) Fully transformable (score >8)	This enables building owners/ managers or developers to understand the potential to transform their building to deliver greater value and function with lower resource inputs.
Reuse potential (UM)	The percentage (by mass) of products which can be reused at the end of the life of the building.	% by mass of products that can be reused	These will enable contractors to demonstrate compliance with local requirements, such as the GLA circular economy statement.
Recycling potential (UM)	The percentage (by mass) of products which can be recycled at the end of the life of the building.	% by mass of products that can be recycled	Core.

Indicator name	Description	Unit	Stakeholder benefits
Lifespan & in-use performance			
Intensiveness of use (L)	The average intensiveness of use of the building stock relative to the average potential intensiveness of use. This indicator is only suitable for buildings such as schools, offices or community centres. Number of hours the building is occupied versus the number of hours it has the capacity to be occupied in average.	% hours actually occupied versus potential	Clients will be able to understand whether the use of their asset is optimised. Planning officers will also be able to validate the need for new buildings to be added or if they could more efficiently use existing ones.
Material outflows and recirculation			
Residual value (all materials in building) (UM)	The forecasted total value obtained from material recirculation of materials within the building.	£ or € that can be extracted from the reuse of components in the building	Demolition companies and contractors will be able to quantify the benefits of maximising reuse and recycling. Investors will understand the value of their portfolio.
Total material arisings (whole life) (UM)	The amount of waste materials from the building across its lifetime, including during future refurbishment, repair phases.	Tonnes of waste arising	Policy makers will be able to understand quantities of wastes generated. This information will also inform LCA and LCC studies.
% reused, remanufactured, recycled (UM)	The percentage of materials which were reused, remanufactured or recycled at the end of the life of the building.	% by mass reused, remanufactured, recycled	Policy makers will be able to validate their targets for recycling and reuse against those numbers. This information will also inform LCA studies.
End of Life reference scenario (UM)	Mapping of material history and recycling potential, before it reaches a material bank/storing site.	Typical % by mass recycled or reused at end of life	Policy makers will be able to validate their targets for recycling and reuse against those numbers. This information will also inform LCA studies.

Recommended materials, products, and component level indicators

Indicator name	Description	Unit	Stakeholder benefits
Product design			
Dematerialisation (linked to total material inputs to building stock) (CD)	Product has been designed so that the minimum material inputs are required to achieve the same whole life functionality, without compromising on durability, resilience, other technical performance requirements or health and safety. The percentage of material that has not been used as a result of redesigning the product and as a function of the total amount of material used.	% by mass of material not used	Product manufacturers demonstrate that they have designed the product with material optimisation. This will support scheme such as the cradle to cradle certification scheme. This information will also inform LCA and LCC studies.
Design for repairability (CD)	Product has been designed to enable future repair of key components of the product. This is not applicable to all products.	% by mass of components of the product that can be easily removed and repaired or replaced.	Product manufacturers demonstrate that they have designed the product for future repairability. This will support scheme such as the cradle to cradle certification scheme. This information will also inform LCA and LCC studies.
Material inputs (as manufactured)			
Reused content (UM)	Proportion of the product/ component that is formed of reused materials/products.	% by mass reused content	These will enable products manufacturers to demonstrate to contractors' compliance with local requirements, such as the GLA circular economy statement. This indicator will also inform policy makers to set future targets. This will also support product certification schemes like EPD or cradle to cradle. This will support schemes such as the cradle to cradle certification scheme. This information will also inform LCA and LCC studies.
Recycled content (UM)	Proportion of the product/ component that is formed of recycled materials/products (exclude downcycling).	% by mass recycled content	

Indicator name	Description	Unit	Stakeholder benefits
Material inputs (as installed in building)			
Product is reused after it has been used in a building (CD)	The product has previously been used for the same function in another building. The percentage of similar products/ components that are reused at the end of their life based on actual waste analysis.	% by mass reuse	This informs the product manufacturers on the end of life potential of their product/ component.
Product is recycled after it has been used in a building (CD)	The product has previously been used for the same value function in another building and has been through some processing. The percentage of similar products/ components that are recycled at the end of their life based on actual waste analysis. Excludes downcycling.	% by mass recycled	This can also inform policy makers on whether there is a further need for recycling facilities. This will support scheme such as the cradle to cradle certification scheme. This information will also inform LCA and LCC studies.
Circular potential (as installed)			
Reuse potential (UM)	Product is designed and installed so that it can be easily demounted from the wider assembly with no loss of value to itself or the assembly. The percentage of the product/ component that has the potential to be reused.	% by mass potential reuse	This will support scheme such as the cradle to cradle certification scheme. This information will also inform LCA and LCC studies.
Part of an extended producer responsibility scheme (CD)	The product is covered by an Extended Producer Responsibility scheme by the manufacturer (e.g. a take-back scheme). This is a yes/no answer	Yes/no	This will enable policy makers to identify where more EPR schemes may need to be implemented. This will affect product manufacturers & suppliers.
Repairability potential (L)	The amount of components of the product that can be easily removed and replaced (once installed).	% by mass of the essential components of the product that can be repaired	This will enable the replacement of core components of units without the need to replace whole units. This will enable facility managers to manage better the buildings.
Lifespan and in-use performance			
Service life (L)	The number of years the material or product has been used for its intended function.	Number of years	This will enable the demolition industry to understand whether the product/component can be reused. It will also inform contractors on when the product needs to be considered for further testing to ensure it is fit for purpose.
Material outflows and recirculation			
Residual value (L)	Financial value obtained by actor with duty of care of product at building end of life.	£ or € that can be made from the reuse of a product	Demolition companies and contractors will be able to quantify the benefits of maximising reuse and recycling. Investors will understand the value of their portfolio.

Further reading

More information on the tools, methodologies and recommendations developed by CIRCuIT to standardise and improve the capture of circular data for the built environment is available in the reports listed below.

- D3.1 State of the art on material flow data in the built environment
- D3.2 Recommendations for improving the capture of material flow data in the built environment
- D3.3 Recommendations on circularity indicators for WP8
- D3.4 Report on the creation of CIRCuIT circular economy data templates
- D3.5 Business case for database and marketing strategy
- D3.6 Finalised framework of data attributes and analytics for pilots
- D3.7 How to exploit the framework and data at city level

All these reports can be downloaded at circuit-project.eu/post/latest-circuit-reports-and-publications

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CIRCUIT

5 Using policy to power circular construction

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Why policymakers must take action

Global construction is centred in cities. By 2050, an additional 2.5 billion people are projected to live in cities, and as urban populations grows, the need for new buildings and infrastructure will intensify. Cities have a growing responsibility to mitigate construction's role in the climate crisis.

Cities are uniquely positioned to promote and support the transition from a linear to circular economy, particularly in construction and urban development. While some cities have already taken up the challenge to start working with circular economy principles to minimise their impacts, an understanding of how to holistically implement circular solutions often remains blurry.

The CIRCuIT project developed specific lessons related to circular construction in cities – such as Transformation (Chapter 1), Urban mining (Chapter 2) and Design for Dissasembly and Adaptability (Chapter 3) approaches. Now these learnings need to be translated into clear recommendations for action.

Two significant areas of influence for cities are through their planning and procurement policies. For example, by leveraging procurement power, cities can set the level of ambition for the entire city providing a strong signal of confidence for the sector or specific solutions. Cities can also use procurement requirements to bolster their own climate priorities, targets and strategies through clauses that address embodied carbon or city regeneration, among others.

Embedding circular strategies into planning policies helps to scale up action and introduces a much larger portion of the supply chain to circular solutions. However, all policy changes need to be supported by open dialogue, a factor that CIRCuIT explored through developing a dialogue tool.

This chapter outlines a range of different policy mechanisms to drive circular construction, a dialogue tool to guide productive conversations between developers and cities and illustrates the roadmaps CIRCuIT cities developed to put these into actions.

While some cities have already taken up the challenge to start working with circular economy principles to minimise their impacts, an understanding of how to holistically implement circular solutions often remains blurry.

Barriers to circular action in cities

The CIRCuIT project identified specific barriers to circular action in cities that city decision makers must consider when outlining their change making mechanisms. Addressing these barriers can help policy makers design effective interventions.

Regulatory barriers: Failure of a policy to be clearly defined, aligned and/or enforced across national, municipal and local hierarchies. When these various layers do not enforce each other (or contradict each other) this can lead to confusion. Regulatory barriers can also include overreach of regulations, like energy efficiency, that inadvertently make circular solutions more difficult.

Market barriers: Failure of the market based on communication and access. This can happen when there isn't a common language to define needs (for example missing standards and data). Businesses can have trouble accessing the market due to missing or unaligned standards as well as lack of communal infrastructure needed to support the market – for example material storage and exchange depots.

Economic barriers: The current financial system values new materials and conventional construction far above circular approaches. In some regions, such as the UK, retrofits are taxed at a higher rate than new construction. This means it is often financially impractical to pursue circular construction as incentives are not currently provided for circular economy approaches. Where incentives are available, they are not divided equitably along the supply chain to further drive circular construction. Upskilling built environment professionals to enable uptake of new approaches can also be prohibitively expensive.

Process barriers: The conventional construction process can sometimes be a barrier. Barriers can include the large multidisciplinary teams on projects and comparatively low margins on budget. Circular activities that prolong the construction period are unlikely to be successful – they cost the investor more both in terms of running the construction site and 'missed' rent while the building isn't operational.

Social barriers: Uptake of circular construction practices requires behavioural change. Lack of knowledge, interest or awareness of construction techniques can stall progress, as can the perception that any change is inevitably more expensive. In addition, construction does not have a collaborative culture people can harness to easily break through these cultural barriers .

Circular activities that prolong the construction period are unlikely to be successful – they cost the investor more both in terms of running the construction site and 'missed' rent while the building isn't operational.

Embedding urban development policies

City administrations can harness a range of policy interventions to further circular action and overcome barriers to circularity. Adopting new circularity-related regulations can require significant changes both in terms of process and cultural expectations. Transitioning towards a circular approach to construction means changing what and where cities build, how spaces are developed and how materials are made, recycled and used.

Policies can be adjusted to align with local stakeholders' capabilities and the varying levels of support from national governments. For example, they can be supported by integrating non-regulatory practices, such as developer dialogue tools (page 5-12), which help develop open circularity conversations between cities and industry.

> **For the full list of policy interventions, and the specific recommendations for interventions in each of the four CIRCuIT cities, please see 7.1 Circular economy in urban planning at circuit-project.eu/post/latest-circuit-reports-and-publications**

Policy recommendations are presented in three key areas of circularity action: transformation and life cycle extension, urban mining and material reuse and design for disassembly and adaptability. They cover five types of policy instruments:

Legislative and regulatory: Policy interventions relating to requirements for planning or demolition, licences and permitting, data reporting and design requirements.

Economic and fiscal: Relating to taxes or levies on certain behaviours, as well as subsidies or investments from the city.

Agreement and incentive-based: Interventions related to collaborative actions and agreements between parties. Can also include pledges, commitments and voluntary certification schemes.

Strategy, roadmap and information-based: Interventions that support direction and knowledge, written roadmaps and guidelines or eco-labelling, widespread use of best practice case studies.

Knowledge and innovation: These tackle more systematic knowledge gaps through upskilling and training, curriculum changes and stakeholder engagement.

Policy interventions to embed circularity in cities

Transition to circular construction requires system change. This means it can be beneficial to implement a range of policy interventions that reinforce each other. For example, if there's a legal requirement to increase the use of reused and recycled materials (legislative/regulatory instruments) this could be supported by a primary materials tax (economic instrument) and pilots to determine best practice (knowledge/innovation instruments).

Life cycle extension and transformation drivers

Encourage planning authorities to prioritise reuse of assets in strategy and culture – Changing perceptions of the value of existing buildings from strictly cultural to environmental due to the sunk carbon costs in all planning authority operations.

Strategy and roadmaps

Ensure zoning and planning regulations do not restrict refurbishment – Reviewing requirements and removing certain elements (e.g. stringent energy efficiency requirements, densification blockers) that make it harder to maintain existing buildings.

Legislative/ regulatory

Require demolition and rebuild vs. retrofit carbon assessment of site before issuing demolition or new development permit – Assessments can reveal which intervention is more effective from a carbon perspective. Ensure the scope is considered too – emissions saved in the next 10 years are more impactful than those saved in 60 years.

Legislative/ regulatory

Urban mining drivers

Require a minimum time between demolition permitting and demolition activity – Time is a very valuable resource in construction. Requiring a minimum amount of time between permitting and demolition means reusable and recyclable materials are more likely to find a useful second life. Time delays can also be enforced for projects that choose to demolish rather than deconstruct and reuse materials so there is no time benefit to conventional, non-circular demolition practices.

Legislative/ regulatory

Require a pre-demolition audit before issuing a demolition permit or approving a new development permit including how waste will be minimised – Pre-demolition audits ensure the material on site is catalogued and assessed for reuse or recyclability. Requiring this step means all projects must consider what to do with the buildings on their existing site.

Legislative/ regulatory

Set requirements (%) for amount of material (waste) reused/recycled in demolition permit – Ensures a baseline level of reusable materials in the city market.

Legislative/ regulatory

Require waste hauler to be licenced and identified in the demolition or new development permit – Ensures material reuse and recycling is traceable and second uses can be verified.

Legislative/ regulatory

Require buildings meeting specific criteria to be deconstructed, not mechanically demolished – Certain building types that include specific desirable building materials (e.g. single family homes built with old growth timber) should be required to be deconstructed carefully to allow for maximum material reuse of high value materials.

Legislative/ regulatory

Make pre-demolition audit information public – Pre-demolition audits are a great source of city-level data on material flows. Making the granular data publicly accessible means better predictions and smoother secondary reuse markets are possible.

Knowledge and innovation

Set requirements (%) for number of reclaimed/recycled materials incorporated in new development permit – Ensures a baseline of secondary material demand to drive the secondary reuse markets.

Legislative/ regulatory

Ban use of certain (non-circular) materials – Helps ensure effective urban mining is possible in the future.

Legislative/ regulatory

Design for disassembly and adaptability drivers

Set requirements that short life span buildings should be modular or prefabricated – If use cases for the building are limited to the short term require modular and demountable structures be considered.

Legislative/ regulatory

Set disassembly targets for shorter lifespan or higher reuse potential buildings or elements.

Legislative/ regulatory

Multiple circularity solution drivers

Articulate clear planning strategy that centres circular and regenerative solutions – Establishing public goals and priorities can help the local supply chain adapt and better meet the near-future needs of the city.

Strategy and roadmaps

Allow larger development areas where certain circularity approaches are applied (e.g. % reused materials, % existing building maintained) – Provide an indirect financial incentive by allowing more square metres of development as reward for exemplary circular practices.

Agreements/ incentive

Provide a 'fast-lane' permitting process where certain circularity approaches are applied (e.g. % reused materials, % existing building maintained) – Provide an indirect financial incentive by allowing construction to proceed more quickly as reward for exemplary circular practices.

Agreements/ incentive

Reduce permitting fees where certain environmental criteria are met (e.g. retention of existing building, reuse %, carbon footprint, green building rating scheme) – Provide a direct financial incentive by allowing construction to proceed more quickly as reward for exemplary circular practices.

Economic/fiscal

Support innovative pilot projects – The city can support exciting new projects in the area, blazing a trail for other circular work.

Economic/fiscal

Train city staff and supply chains – Policy implementation will happen much more smoothly if the people on both sides of the table understand circular construction. The city can support training initiatives, especially for smaller businesses who may not have the resources to develop this knowledge on their own.

Agreements/ incentive

Supporting circular economy policies: In dialogue with developers

Relevant and well-developed policies cannot be created, or enforced appropriately, without the support of the local construction sector. Working to establish an open and supportive communication channel between city officials and developers is key to achieving sustainability and circularity goals. This seven-part check list can support this dialogue.

1. Give developers a vision

Developers say they often feel confused about a city's direction on the circular economy. This can lead to business-as-usual practices.

To tackle this, cities need to prioritise their circular goals and communicate them clearly to urban planners and developers. They also need to ensure that these goals relate to existing agendas, such as an overarching objective of becoming carbon neutral.

Developing and sharing a circular economy strategy and roadmap for a city's built environment will also help create a clear vision for developers.

2. Provide a clear overview of the planning process

A city's planning process can appear complicated. Developers may not know when and how to introduce circular economy initiatives.

A good way a city can help overcome this problem is by visualising all the stages of their planning process. At each stage there should be easy-to-understand information about what is expected from a developer and which city officials will work with them.

It's important each stage should also clearly explain what a developer can do to help embed circular economy principles in their project.

3. Talk about circularity as early as possible

To increase the probability of circular approaches being adopted, it's critical city officials speak as early as possible to developers about them.

These conversations must start before demolition of existing structures and a developer submits their planning application.

This can be done by organising sustainability kick-off meetings with developers, consultants and all relevant city officials.

4. Identify common circular interests and goals

A developer may have a different objective or perspective than a city on the circular economy, or they may believe circular objectives and requirements are out of reach.

To increase the chance of circular activities being adopted, cities should work with developers to identify common sustainable interests and goals, such as reusing components from demolished buildings.

City officials should continue to work with and support the developer to ensure that any common objectives are achieved.

5. Discuss incentives for developers to adopt circular practices

Circular construction is not yet a top priority for most developers. To change this, municipalities and developers should agree incentives, which could include:

- Developers being exempt from certain regulations if they adopt circular approaches. For example on energy demands, material longevity or documentation requirements.
- Developers being allowed to increase the floor area offered by a building if it is constructed in a way that meets specific circular targets.

6. Establish channels for communicating policy change and circular economy knowledge

For a developer to be in a strong position to implement circular economy approaches, it's important they have a good knowledge of a city's planning process and circular construction practices.

To do this, a city should establish an official channel, such as an online forum, they can use to communicate planning process changes and knowledge about building sustainably and the circular economy.

A city should also set up an internal network for urban planners and other city officials engaged with the circular economy agenda. The officials could use this network to ensure their planning practices are aligned in a way that increases adoption of circular practices.

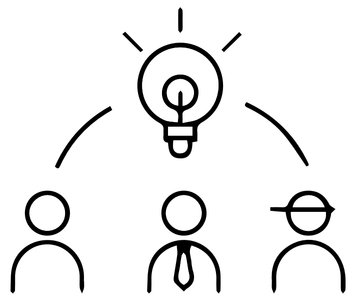
7. Use circular economy data and best practice to drive action

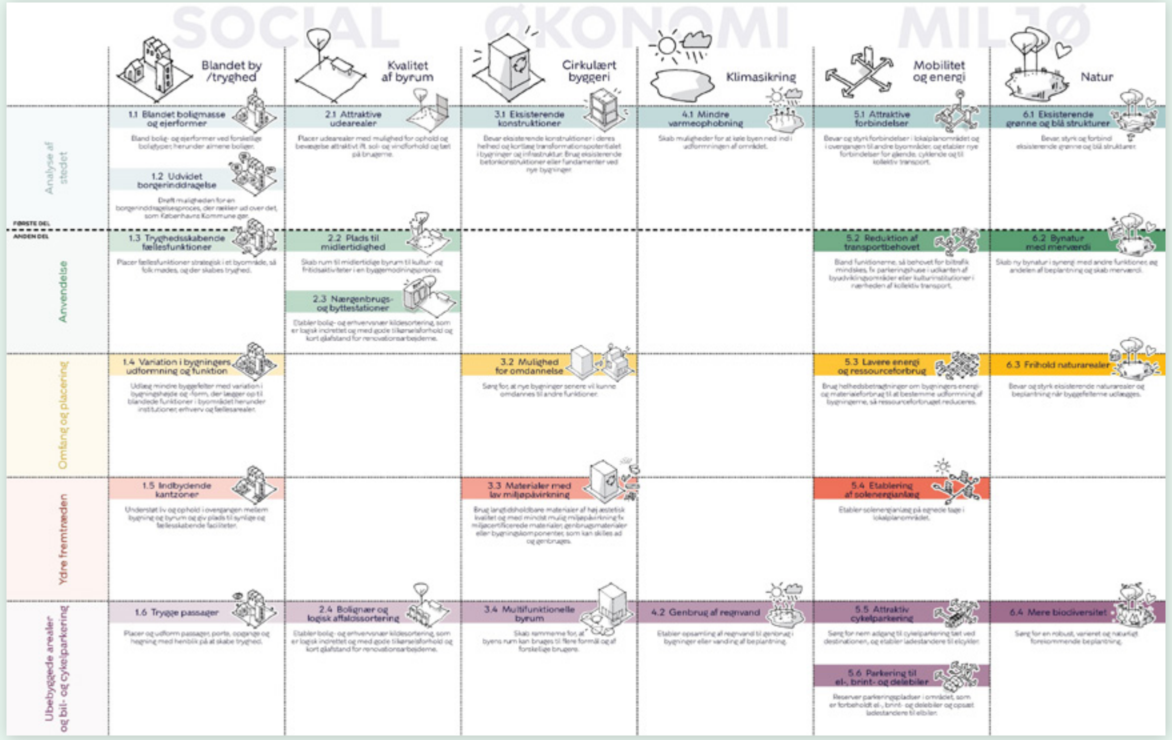
Hard evidence and best practice often play a key role in changing behaviour.

Cities should collect data on circular construction initiatives and the environmental, economic and social benefits they deliver. Also, they should create a catalogue of best practice building projects that have used circular economy principles.

Share data and case studies with developers, urban planners and other built environment stakeholders to increase their knowledge and encourage similar action.

If a city is unsure how best to do this, or generally lacks knowledge about the circular economy, it should consider hiring a circular construction expert to support city officials and local developers.





The Copenhagen Sustainability Tool (CST) in action

A Copenhagen Sustainability Tool (CST) was developed to improve dialogue on sustainability between the planner and developer. The CST is a discussion tool that helps the city planner effectively communicate the city's strategies on environmental, social and economic sustainability and options for the developer to support these priorities. The planner, developer and consultants use the tool to choose 3-5 of the most relevant initiatives and assess how to integrate them into the final development plan. This plan is then submitted to the city council including outcomes of the dialogue. The tool will be updated to focus on CO_2 reduction and material reuse and recycling as key initiatives for dialogue.

Embedding circularity: Using public procurement

Incorporating circular economy principles into public procurement has potential for large-scale positive impact. In Europe, public procurement accounts for approximately 14% of GDP. This means the demolition, renovation and construction of a city's own buildings are a great opportunity to lead by example, promote, trial and normalise circular construction.

Current procurement practices are generally optimised to minimise short-term financial cost. This doesn't capture the long-term financial and environmental benefits circular practices can deliver. Circular economy solutions are innovative – and municipalities must adapt and incorporate new developments into procurement practices. Even in cases when sustainability and circularity goals are named priorities, there can be issues seeing requirements carried through to the final product.

This is for a few reasons:

- When circular economy criteria are outlined in public sector tenders, they tend to feature 'soft' wording (like 'striving for' sustainability) rather than hard targets. There are no consequences for missing these targets.
- Without defined circularity targets to hit, there can be different interpretations of what a circular approach looks like. This makes it difficult for a city to assess proposals and identify the best one for a project.
- Existing sustainability construction standards, such as DGNB or BREEAM, are sometimes used in public procurement tenders to encourage sustainable and circular economy practices. However, not all the criteria in these standards are prioritised and enforced to the same extent. Circularity criteria is often less prominent, leading to mixed circular outcomes for a project.

To help city governments overcome these issues, CIRCuIT partners developed a set of circular economy criteria that any city can include in their tenders for public demolition, renovation and construction projects. When applying this criteria cities should consider these points:

- Procurement criteria is most effective when formulated as minimum requirements in the tender document, rather than as award criteria, to ensure implementation in a project. This way circular economy strategies will be incorporated in all bidders' proposals while price, quality and additional sustainability factors will remain the competitive elements of the bid.
- The highest priorities should be maintenance, repair, refurbishment, renovation and transformation of buildings to achieve circular economy. This means procurement criteria should place more emphasis on them.
- Municipalities should select criteria relevant to the stage of the project. Some criteria will be useful in tenders for a concept development, while others will be useful for execution of a demolition project.

For the full list of criteria and a complete discussion of the procurement work please see D7.4 Recommendations: Criteria for public tenders on construction at circuit-project.eu/post/latest-circuit-reports-and-publications

Recommended circular economy criteria for public sector tenders

Renovation

Avoiding demolition through investigating transformation opportunities can extend the life of the building, and promote life cycle value creation. It also reduces resource use and the developers' carbon footprint while potentially safe guarding the cultural value of existing buildings.

Require a screening of potential new use in the transformation –-This requires study of each building in terms of condition, location, local plan and spatial structure. Design of different transformation scenarios and recommendations for project to select should be provided.

Project development stage

Require a feasibility study of vertical extension potential in renovation projects –- The vertical extensions can be used to meet carbon footprint targets. This requires a study of each building for condition, location, local plan and spatial structure.

Design stage

Require LCA and LCC calculations for comparison of different renovation and transformation scenarios Decisions on which renovation or transformation strategy should be chosen should always consider the potential savings on carbon footprint. Some CO_2 -limits may be set by legislation or by the city. LCA and LCC calculations and their comparison should be required for different scenarios to make an informed decision for project execution. A light version of LCA and LCC can be required in the design stage of the project. The in-depth LCA and LCC can be required before the execution stage.

Execution (construction) stage

Demolition

Requiring circular economy criteria for the demolition stage can help reduce demolition waste by extending the life cycle of existing materials. This can inturn reduce natural resource use and energy consumption, due to no virgin material excavation and processing.

Require a pre-demolition audit – Require the timeframe of the audit and a list of stakeholders participating. Ensure you provide a template to allow for comparable and detailed reporting.

Execution (demolition) stage

Require training certification from demolition personnel – Require reference to specific training for demolition personnel.

Execution (demolition) stage

Require a plan for storage of recovered elements –- Require a plan on-site or off-site for recovered material before demolition starts. Preferably on-site storage to prevent transportation.

Execution (demolition) stage

Require a plan for material reuse –-Require assessment of potential reuse of material after recovery. Ideally, this should happen before demolition to prevent long-term storage and transportation.

Execution (demolition) stage

Construction

Requiring circular economy criteria for the construction phase can help future proof buildings requiring considerations for future reusability and adaptability. In the next iterations of the building this can reduce on site waste creation and reduces the need for new materials by supporting reuse.

Require a plan for potential future uses of the project
Ask project teams to outline potential future uses for the project – this can be a change of use for the building, future retrofit or building relocation.

Project development stage | Design stage

Require an outline of estimated life span for each building layer
Ask project teams to estimate the life span of different building layers (structure, façade, building services, space and stuff).

Design stage

Require a DfA and DfD approach for each building layer based on potential future uses and lifespan
Ask project teams to outline what DfA and DfD can be applied to each building layer based on potential future use and the expected life span.

Design stage

Require a LCA of DfD and DfA strategies and their potential impact on cost and carbon
Ask the project team to conduct a LCA on at least three DfD and DfA strategies applied and realised to different building layers and compare against not applying it.

Design stage

How to embed best practice in policy: City Policy Roadmaps

Despite cities embracing the task of incorporating circular economy principles, the sequence of implementation and integration into existing workflows can remain tricky. The four CIRCuIT cities each reviewed the wide range of circular recommendations developed by the project and considered these alongside their city's needs, environmental priorities and ambition. The result is four circularity strategy roadmaps all developed from a different and unique perspective. The sequence of actions and pace of change can support similar action in other cities where the context may be similar.

> **For the full roadmap descriptions see D7.6 Implementation of Circular approaches into city planning at circuit-project.eu/post/latest-circuit-reports-and-publications**

Copenhagen City Policy Roadmap

In Copenhagen the aim of the roadmap was to influence action at the municipal level taking findings from different areas of CIRCuIT and compiling them into the new Copenhagen Climate Plan 2035 as well as into the municipality's own building stock.

TARGET	WHO					WHEN						IMPACT
Target: Implementation of an improved dialogue tool for sustainability in local planning process	Urban Plans section in the City of Copenhagen	Climate and City Development Department	Council for Sustainable Construction	National stakeholder	External Consultant	Now	6 months	1 year	2 years	3 years	Future	Expected impact/value added
Theme 1: Select a relevant approach												
1.1 Review the processes and standard procedures in local planning to understand potential for sustainability improvements	●					●						Identification of how CST can contribute to local planning work and the opportunities to integrate CO_2-saving measures. In turn, the purpose and use of a sustainability tool will be sharpened.
1.2 Identify the needs in local planning processes and define the use of sustainability dialogue tool	●						●					Ensure that the selected tool will be relevant, operational and usable in local planning work.
1.3 Specify the focus areas of the dialogue tool	●						●					The focus and aim of the tool will be specified (e.g. by prioritising indicators) making it more intuitive, simple and user-friendly.
1.5 Secure financing and the mandate and responsibility for implementing the dialogue tool	●						●	●				Governance around the tool is defined and expectations are aligned, ensuring more effective implementation in the municipality.
Theme 2: Improve the current CST												
2.1 Revise the local planning procedure to ensure CST can be implemented as early in the process as possible	●					●						The tool is implemented early in the local planning process, before critical decisions are made. This gives better results in implementing sustainability and circular economy in local plans.
2.2 Reduce the number of initiatives featured in CST	●					●						The tool is easier to understand and use and so is more effective.
2.3 Align CST with the new local planning regulation	●					●						The tool reflects the updates in local planning regulation, strengthening the argument for its widespread implementation.
2.4 Connect CST with supporting tools, such as CO_2 calculation tool, transformations tool or biofactor tool	●				●		●					The tool is supplemented with quantitative data on the sustainability of different alternatives. This allows more evidence-based decision making leading to more sustainable choices.
2.5 Conduct necessary communication and education activities internally in Copenhagen Municipality	●							●	●			The tool is supplemented with quantitative data on the sustainability of different alternatives. This allows more evidence-based decision making leading to more sustainable choices.
Theme 3: Implement a nationwide CST tool												
3.1 Establish relations with relevant partners to contribute to a nationwide sustainability tool	●		●	●	●		●					Cooperation with relevant actors is established.
3.2 Transfer the lessons learned (e.g. the needs of municipalities) identified from local planning into the nationwide tool	●						●					The knowledge and experience of the City of Copenhagen, as well as municipal needs, are reflected in the national tool. This increases the feeling of ownership and makes it locally relevant. It also ensures compliance with local legislation.
3.3 Ensure alignment of the tool with national and local regulations	●		●	●	●			●				The tool is aligned with other legislation and processes in urban planning work at national level. This helps develop the area in a circular direction by identifying relevant indicators, tendencies and ways to enter into dialogue about circular economy in local planning work.
3.4 Conduct necessary communication and education activities internally in Copenhagen Municipality about the nationwide sustainability dialogue tool	●								●			Awareness and feeling of ownership of the tool is secured in the municipality.

Hamburg City Policy Roadmap

Roadmap development in Hamburg focused on development of the physical infrastructure needed for urban mining drawing from CIRCuIT learnings on urban mining and PDAs.

TARGET	WHO										WHEN							IMPACT
	Demolition company	Recycling companies	City cleaning	Manufacturers	FHH (BSW and BUKEA)	ORPUD / LIG	(Construction) planner	Facilities operators	External operator	Legal advisor	Now	1 year	2 years	3 years	4 years	5 years	Future	Expected impact/value added
Theme I: Intermediate storage for the reuse of building products and parts																		Establishment of a material hub in Hamburg with public sector participation to create a local market for re-using building products
1.1 Clarify the function					●			●			●							Better marketing than non-waste, more throughput
1.2 Legal clarification on the handling of re-use components and materials, on the term product/waste and landfilling					●			●		●	●							Temporary, flexibly rentable warehouses prevent vacancies and running costs. These will probably only work if re-use components are not traded as waste (no permits required)
1.3 Prioritise particularly suitable/in demand components/ materials for reuse	●	●		●	●			●					●					Increases the throughput of the warehouse, reduces disposal costs in the event of non-switching
1.4 Determine the useful life of the area			●		●			●			●	●	●	●		●	●	
1.5 Analyse requirements and needs for the area depending on materials	●	●			●		●	●			●							
1.6 Determine structural requirements for storage		●	●		●			●			●							
1.7 Logistical requirements for storage space		●						●	●		●							
1.8 Perform market analysis	●	●			●			●			●	●	●	●		●	●	Inclusion of further components, gradual expansion/adaptation of the offer
1.9 Location scouting					●	●					●							
1.10 Perform inventory analysis of selected properties					●	●	●					●						As little reconstruction as possible
1.11 Optional: tender for planning competition					●													
1.12 Invitation to tender for necessary structural measures, refurbishment or upgrading of technical equipment							●					●						
1.13 Find an operator					●							●						
1.14 Optional: Tender for the operation of a component exchange								●										
1.15 Determine the type and operation of a platform and data collection of incoming and outgoing products and materials								●	●			●						Digital warehouse logistics, online shop with connection to existing platforms
1.16 Material acquisition								●					●	●				
1.17 Marketing of components to planners / architects / dealers								●						●				Increases the throughput of mediated components

TARGET	WHO										WHEN							IMPACT
	Demolition company	Recycling companies	City cleaning	Manufacturers	FHH (BSW and BUKEA)	ORPUD / LIG	(Construction) planner	Facilities operators	External operator	Legal advisor	Now	1 year	2 years	3 years	4 years	5 years	Future	Expected impact/value added
Theme II: Intermediate raw material storage for recycling																		Establishment of an interim storage facility for recycled building materials to collect raw materials and prepare them for return to the industry. If necessary, integration into existing recycling yards or separate collection point for product-specific raw material collection
2.1 Legal clarification on handling the term product/ waste and on landfilling			●		●					●	●							
2.2 Determine useful life			●		●			●			●	●	●	●		●	●	
2.3 Identify required permits and authorizations			●	●	●		●	●		●	●							
2.4 Obtain necessary permits and authorizations			●				●					●						
2.5 Analyze requirements and needs for the area depending on materials			●		●		●				●	●		●				
2.6 Define structural requirements for storage facilities			●				●	●			●							
2.7 Define logistical requirements for storage space, handling, equipment			●					●			●							
2.8 Receipt of products: formulate acceptance and quality and quantity check. Create product data sheets (component catalogue)				●				●				●						Acceptance prices should be at least 25% below those of the material recycling of the local recycling companies (extra expenditure in removal, loading and transport)
Compensation is only necessary for components that would otherwise be recycled in scrap																		
2.9 Market analysis (ongoing)	●	●		●	●			●			●	●	●	●	●	●	●	
2.10 Scout for location			●		●	●					●							
2.11 Perform inventory analysis of selected properties					●						●							
2.12 Invitation to tender for necessary structural measures, new construction, refurbishment or equipment upgrade							●					●						
2.13 Optional: tender for planning competition					●							●						
2.14 Plan structural measures							●	●				●						
2.15 Find an operator					●						●							
2.16 Optional: tender for the operation of a component exchange					●						●							
2.17 Marketing, communication, involvement of associations					●			●				●						

TARGET	WHO										WHEN							IMPACT
	Demolition company	Recycling companies	City cleaning	Manufacturers	FHH (BSW and BUKEA)	ORPUD / LIG	(Construction) planner	Facilities operators	External operator	Legal advisor	Now	1 year	2 years	3 years	4 years	5 years	Future	Expected impact/value added
Theme III: Bulk material, Soil handling, Urban processing																		Bulk materials are handled close to the construction site, shortening transport routes. Flexible infrastructure exists for the reuse and recycling of bulk materials
3.1 Understand process, identify competences and contact process participants	●	●	●		●						●							
3.2 Analyze material flows and perform quantity analysis		●	●	●							●							
3.3 Market analysis and product development		●	●	●							●							
3.4 Decide which type of facility should be considered		●	●								●							
3.5 Identify project management or project sponsor			●		●		●				●							
3.6 Analyze area requirements and needs		●	●				●				●							
3.7 Define logistical requirements for storage space		●	●				●				●							
3.8 Identify required permits and authorizations		●	●		●		●				●							
3.9 Find suitable areas in terms of identified requirements, considering the ownership situation		●	●		●	●			●		●							
3.10 Determine a suitable operator		●	●		●		●		●		●							
3.11 Engineer a concrete implementation concept		●	●						●			●						
3.12 Obtain necessary approvals and permits		●	●		●		●		●	●		●						
3.13 Implement in the usual construction process	●	●	●	●								●						

London City Policy Roadmap

The London roadmap focused on incorporating CIRCuIT findings on streamlining data, pre-demolition audits and establishing the data frameworks of material passports into the existing circular economy statement policy that exists in the city.

TARGET	WHO		WHEN								IMPACT
	City Government	ReLondon		Policy Guidance 1		London Plan Policy Cycle 1		Policy Guidance 2		London Plan Policy Cycle 2	Expected impact/value added
Theme 1: Leveraging CE Statement data for city-level material flow											Improves city-level data capturing infrastructure and indicator monitoring
Connect CE Statement data flow to existing data infrastructure	●		●								
Assess suitability of planned PLD for CE Statement data sharing	●			●							
Update CE Statement template to streamline CE Statement data sharing	●						●				
Integrate CE Statement template data into PLD	●						●				
Assess city-level indicators that can be measured with CE Statement template data		●	●								
Identify city-level indicators that can influence policy priorities		●			●						
Theme 2: Leveraging Pre-Demolition Audits to drive retention and reuse											Improves data capture on availability of secondary materials to inform material pipeline
Collect input and establish consensus from industry and relevant stakeholders on change to CE Statement template to include retention and PDA standardisation.	●		●								
Update CE Statement template to include retention and PDA standardisation	●			●							
Support development of city-wide material exchange portal	●		●		●						
Update policy to require submission of PDA and CE targets at pre-application stage	●					●					
Link CE Statement template PDA data to city-wide material exchange portal	●						●		●		
Update policy to require CE Statement template PDA data to be uploaded onto the city-wide material exchange portal	●									●	
Collect input and establish consensus from industry and relevant stakeholders on the inclusion of required reuse and recycled % of materials into new build to drive secondary reuse market	●								●		
Creation of best practice guide to CE Statement – how to incorporate PDA findings into CE targets		●	●								
Support development of city-wide material exchange portal		●	●		●						

TARGET	WHO		WHEN								IMPACT
	City Government	ReLondon		Policy Guidance 1		London Plan Policy Cycle 1		Policy Guidance 2		London Plan Policy Cycle 2	Expected impact/value added
Theme 3: Establishing demand signal with the Bill of Materials											Improves data capture on demand of materials to inform material flow pipeline
Collect input and establish consensus from industry and relevant stakeholders on the level of detail and input needed to make BoM useful as demand signal on material exchange platform	●		●								
Update CE statement template BoM section according to stakeholder engagement findings	●			●							
Support development of city-wide material exchange portal	●		●		●						
Establish connection between the CE Statement template BoM data and the city-wide material exchange portal	●										
Link CE Statement template BoM data to city-wide material exchange portal	●										
Update policy to require CE Statement template BoM data to be uploaded onto the city-wide material exchange portal	●										
Support development of city-wide material exchange portal		●	●		●		●				
Theme 4: Embedding materials passports											Futureproof is incoming material data for improved secondary material recovery
Collect input and establish consensus from industry and relevant stakeholders on use of material passports – settling on agreed framework for London/UK	●		●		●						
Update policy to require Material passports provided on completion for 20% of FFE	●					●				●	
Update policy to require Material passports provided on completion for 80% of FFE	●										
Support upskilling of LAs and SMEs on new topics such as material passports		●	●		●						
Theme 5: Broadening the scope of applicable developments.											Establishes broad base of understanding and application of CE Statement policy to gather more comprehensive city-wide dataset and improved compliance
Support further training and upskilling staff to take on the additional assessment of the new CE Statements	●		●		●						
Include language that outlines the CE Statement requirements used by LAs for non-referrable major application	●					●				●	
Convene LA working group to achieve consensus on the requirements for CE Statements non-referrable major applications		●	●		●						
Commitment from all interested LAs to apply CE Statement requirements to all major works in their boroughs		●			●						
Support further training and upskilling of staff and built environment stakeholders to take on the additional assessment of the new CE Statements						●					
Convene LA working group to achieve consensus on the evolution of requirements for CE Statement's non-referrable major applications		●									

Vantaa City Policy Roadmap

In Vantaa the roadmap focused on integrating best practice findings from CIRCuIT into the existing 'Resource Wisdom' strategy document.

TARGET	WHO		WHEN							IMPACT
Target: Circular economy aspects are implemented in planning.	City zoning	Building inspection	Now	1 year	2 years	3 years	4 years	5 years	Future	Expected impact/value added
Theme 1: Incorporate circular economy aspects into the plans. Encourage renovation and adaptive reuse through urban planning and zoning measures										
1.1 Investigate the legislative prerequisites for increasing the flexibility of zoning plans	●			●						
1.2 Add circular economy themes to the planning report template	●		●							
1.3 Create a guideline and an assessment model to encourage additional construction in connection with renovation. Compare the impacts of demolition to preservation in zoning processes	●	●	●	●	●					
Theme 2: Enhance collaboration between the city and private sector to support circular economy pilots in Vantaa.										
2.1 Choose the first pilot(s)			●							
2.2 Carry out the pilot(s)				●	●					
2.3 Set up the operating model						●	●			
Theme 3: Enhance collaboration between urban planning and building inspection to promote circular economy. Allocate resources for coordinating circular economy in planning and building inspection.										
3.1 Add circularity to kick off-meetings' agenda	●	●	●							
3.2 Circularity in planning and building inspection is business as usual	●	●		●						

Further reading

For further information about these outputs and the work behind them, please read the following reports, which were published by members of CIRCuIT partner organisations during the lifetime of the project.

- D7.1 Circular economy in urban planning and building permits – possibilities and limitations
- D7.3 Recommendations: Instruments for the dialogues with developers
- D7.4 Recommendations: Criteria for public tenders on construction
- D7.5 How to implement the EU guideline for pre-demolition audits
- D7.6 Implementation of Circular approaches into city planning

> **All these reports can be downloaded at circuit-project.eu/post/latest-circuit-reports-and-publications**

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CIRCUIT

6

Supporting circular construction with digital tools

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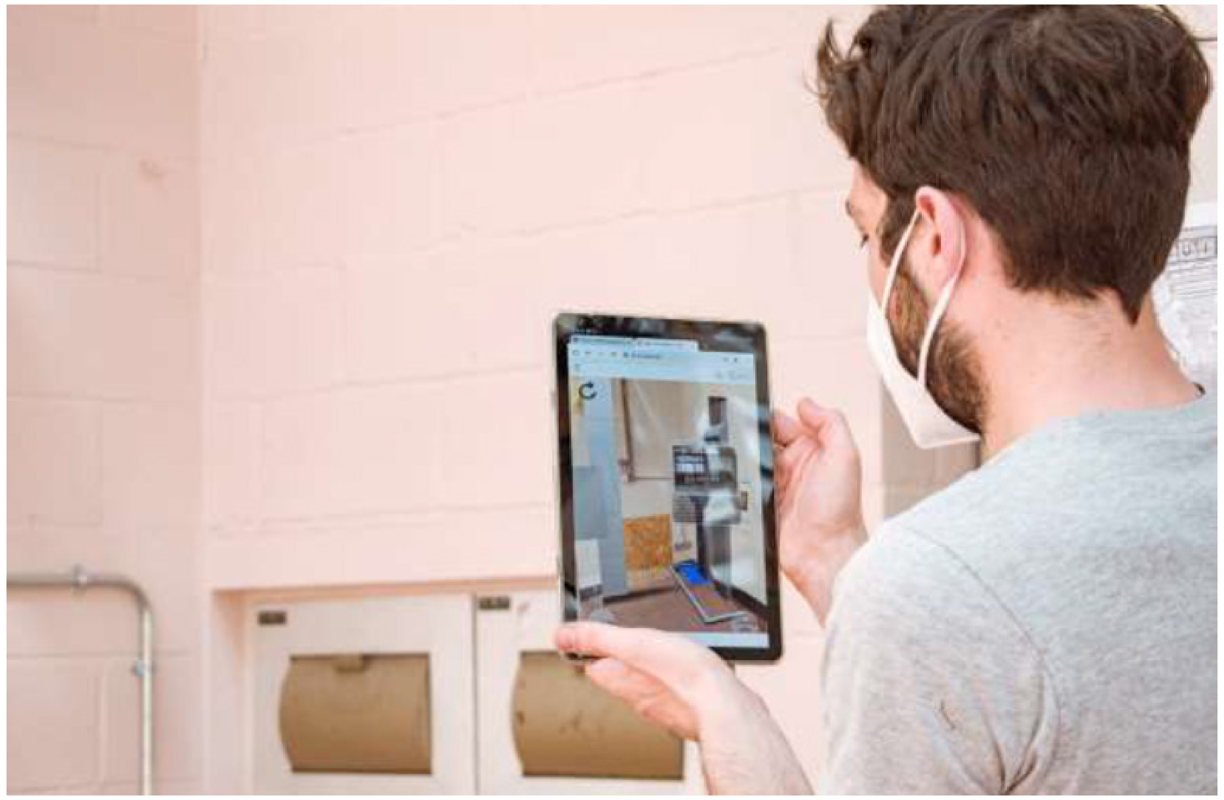
Establishing digital tools to support circular construction

To support the transition to circular construction, decision makers and built environment stakeholders need to have access to tools that can help turn theory into practice. This includes tools that provide real time data on material availability, illustrate city level planning impacts, or detail project case studies. High quality and user-friendly digital tools can support professional knowledge and expedite acceptance and adoption of circular construction.

To help meet this need, CIRCuIT's project partners developed five online tools, hosted on their Circularity Hub, to support the mainstreaming and adoption of circular construction practices. These tools are the Material Reuse Portal, Circularity Dashboard, Circularity Atlas, Citizen Engagement Portal and Circular Economy Wiki.

The five tools enable stakeholders across the value chain to extract knowledge and insights at the city-level. These insights support dialogues, collaboration and market mechanisms across the supply chain in the city. Tools can also be a novel way for cities to increase engagement on circular construction issues with a wider audience, introducing the benefits of circular construction to city residents.



Overview of the tools on the Circularity Hub

Material Reuse Portal

The Material Reuse Portal brings together listings of surplus construction materials from a range of online material marketplaces onto one platform – making them simpler to source.

Circularity Dashboard

Using circularity indicators, the Dashboard introduces a framework to capture a city's, region's or country's circular economy capability and performance so professionals can compare and contrast.

Circularity Atlas

The Atlas is an interactive map that allows policy makers and urban planners to easily view and analyse circular economy data and other relevant data for a whole city.

Citizen Engagement Portal

This website and augmented reality app showcases circular construction in existing buildings and makes circular construction approaches more accessible to the public. This can support dialogues in the city around the benefits of adopting circular economy principles.

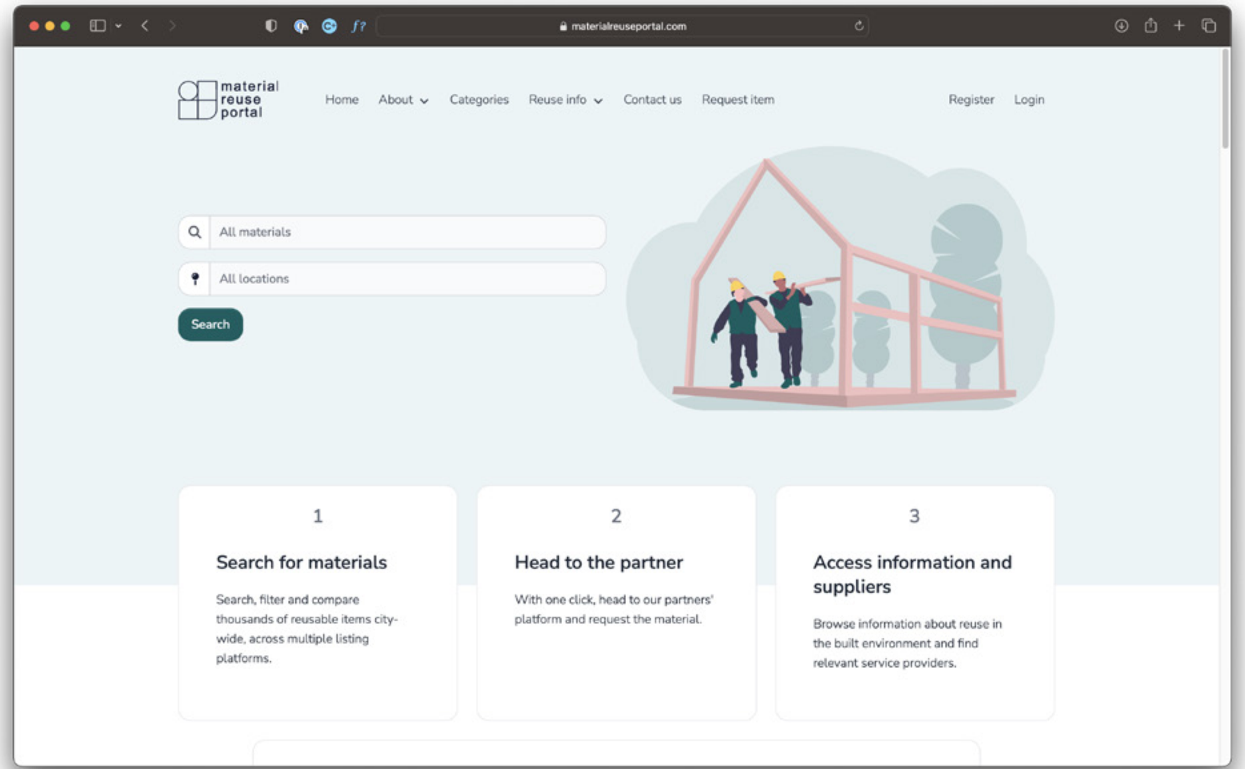
Circular Economy Wiki

This website for built environment stakeholders features articles, guidance and definitions for circular construction, with the aim of building a common understanding and spreading awareness of circular economy practices in the construction industry.

A close look at the digital tools

Material Reuse Portal

materialreuseportal.com



The current construction process is wasteful. Construction projects usually require large amounts of new materials that are downcycled or landfilled long before the end of their technical life span when the building is retrofitted or demolished. Removing materials from buildings in such a way that they can be reused is possible and there is growing interest in applying reused construction materials to new buildings. However, due to the long timelines of construction projects to reuse materials effectively and at scale there must be a way to see the future demand for reused construction materials alongside the future supply of reusable construction materials.

In most cities, material marketplaces do exist . These marketplaces show the materials that are currently readily available for use, and they do not usually operate at the scale necessary to mainstream secondary material use. Cities can help tackle this problem by establishing a platform that makes it easier for built environment stakeholders to view, buy and sell reusable or recycled building materials from across many different platforms, aggregating data from across the region.

About the tool

The Material Reuse Portal (MRP) is an online tool that features listings of surplus or reusable construction materials from multiple marketplaces to create a single place where reusable materials can be found. It's free to use and brings together useful information from different sources in one site.

The prototype was designed and built for London and select surrounding regions. But it can be easily adjusted to incorporate data from material exchange platforms in any city.

The MRP collects data about the types of items that are being searched for and listed on exchange platforms. It also provides useful advice and information on the circular economy and the reuse of construction materials.

How the tool supports circular construction

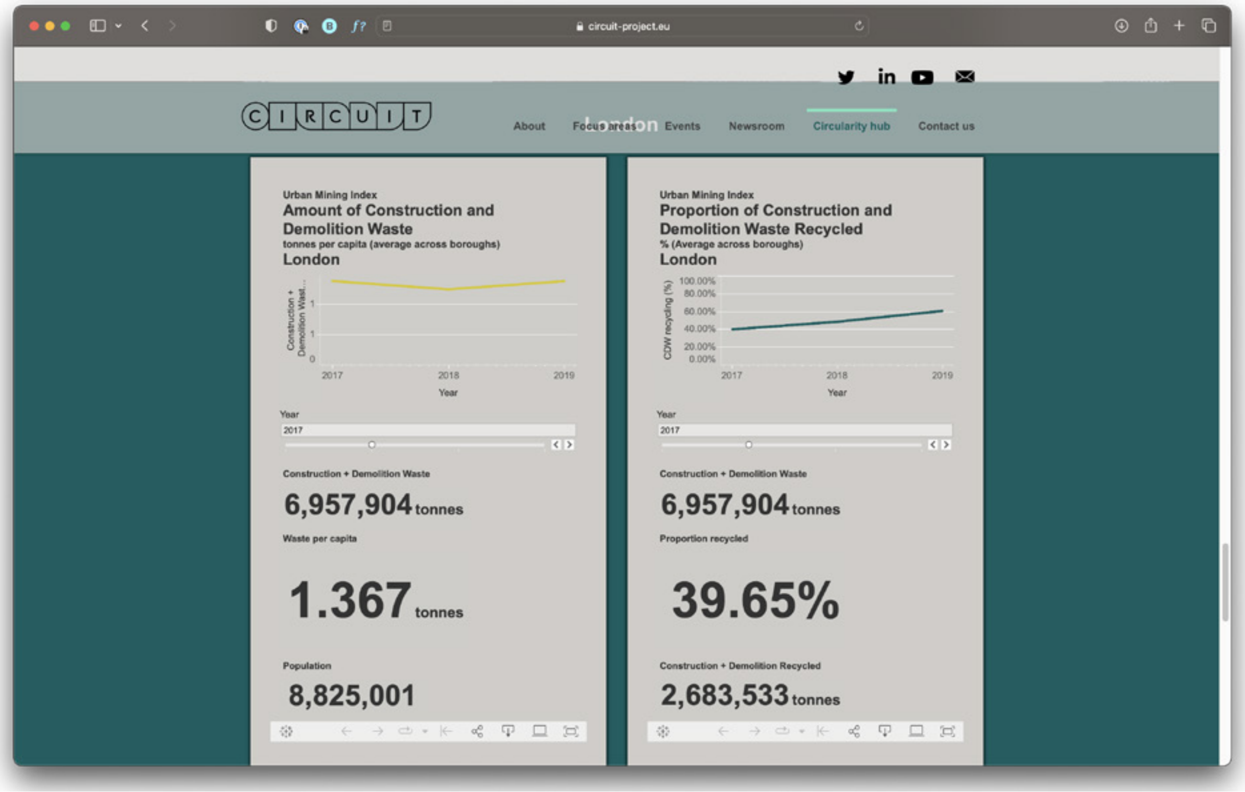
- Provides users of the MRP with comprehensive information about the reusable materials currently available in their city.
- Gives users who wish to sell or donate reusable materials the opportunity to reach a wider audience.
- Increases awareness and use of existing construction material marketplaces available in a city.
- Increases understanding of the availability and demand for reusable materials by collecting data on the types of items being searched for and listed on material exchange platforms.

Lessons learned during development

- The platform aggregation model, where multiple platforms are combined, is of great interest to the built environment industry.
- There is interest in further integrating real-time demand signals to the platform to build the material supply pipeline into the future to reduce the time spent searching for a buyer or storage.
- Not all material portals are easy to connect to an aggregator model because of technical reasons. Some smaller platforms also have few staff members. Additional support is needed to ensure all types of platforms can be linked up with an aggregator reuse portal such as the Material Reuse Portal.

Circularity Dashboard

circuit-project.eu/circularity-dashboard



Currently, there is no standardised tool for visualising data that allows cities to easily showcase how they are performing in key areas relating to circularity within the built environment.

As a result, decision makers and built environment stakeholders such as urban planners lack accessible information that could help them make decisions and set targets that would accelerate circular activities.

In addition, a lack of accessible, visual data may be hampering circular construction because the supply chain and the public are unable to easily understand the environmental and economic benefits this approach delivers.

A lack of accessible, visual data may be hampering circular construction because the supply chain and the public are unable to easily understand the environmental and economic benefits this approach delivers.

About the tool

The Circularity Dashboard is an online tool that visualises city-level indicators. A circularity indicator is a piece of information that can be used to measure performance within the built environment to guide decision making and enable the industry to communicate their circular economy actions in a consistent way. The indicators developed for this tool relate specifically to the circular economy within the built environment.

After carrying out comprehensive research on existing indicators and the needs of the stakeholders that will use them, five indicators were selected to feature on the Circularity Dashboard:

- The amount of construction and demolition waste being generated within a city
- The recycling rate of construction and demolition waste
- The amount of refurbishment and transformation taking place relative to new construction
- The overall demolition rate
- The average age of demolished buildings

Another consideration that was central to selecting these indicators was the availability of data in a city, as this often determined whether it would be feasible to create an indicator.

This issue highlights the strong need to improve and standardise the collection and classification of data relating to circularity within the built environment. You can read more about this issue and potential solutions in the report titled Data and indicators for a circular built environment.

How the tool supports circular construction

- Provides urban planners and policymakers with a quick overview of circular construction indicators in a city.
- Offers a standardised method for benchmarking the circular economy performance of a city.
- Helps urban planners and policy makers to highlight the benefits of circular construction.
- Helps a city to set targets to reduce construction and demolition waste and increase the refurbishment or transformation of buildings.
- Circularity indicators that feature on the Circularity Dashboard could be integrated into governance and development processes, helping to increase transparency and accountability.

Lessons learned during development

- It can be difficult to illustrate the same indicator across different cities because of differences in data collection.
- Dashboards need to be located in a place where decision makers already go to collect data to help ensure they see and use the overview provided.
- Use circularity indicators in the monitoring of policies so city officials understand their application. This will also ensure dashboards remain helpful, active tools.

Circularity Atlas

circuit-project.eu/circularity-atlas

To combat the climate crisis, it is vital to include environmental factors in urban planning and decision making. Analysing and synthesising information like waste and demolition data can be an effective way to achieve this, as it can help built environment professionals understand a wider context and inform where actions will have the greatest impact.

About the tool

The Circularity Atlas is an interactive map of a city that combines circular economy data with satellite imagery provided by Copernicus, the Earth observation component of the EU's space programme.

The Atlas allows users to click on buildings and locations on the map to instantly access circular economy information. For example, a Circularity Atlas was created for Copenhagen that provides information on demolition taking place across the city at a building-by-building level.

The Circularity Atlas may also combine geographical data, such as land use or land surface temperature, with other information such as social or health data. This can help professionals find potential connections between datasets that may help with evaluating materials' usefulness or potential.

The Circularity Atlas is intended to supplement the data and information visualised on the Circularity Dashboard (see page 6-6).

How the tool supports circular construction

- A Circularity Atlas allows stakeholders such as policy makers and urban planners to easily view and analyse circular economy data and other relevant data for a whole city.
- With increased uptake of Circularity Atlases, it will be possible to easily compare circularity data across different cities.

Lessons learned during development

- Similar to the C ircularity Dashboard, it can be difficult to illustrate the same data across different cities because of differences in data collection.
- Circularity Atlas maps need to be located in a place where decision makers already go to collect data to help ensure they see and use the overview provided.
- How useful a Circularity Atlas is to a user is directly linked to the quality of the data that's inputted into it. To collect better data inputs, communicate the value of spatially displaying data.

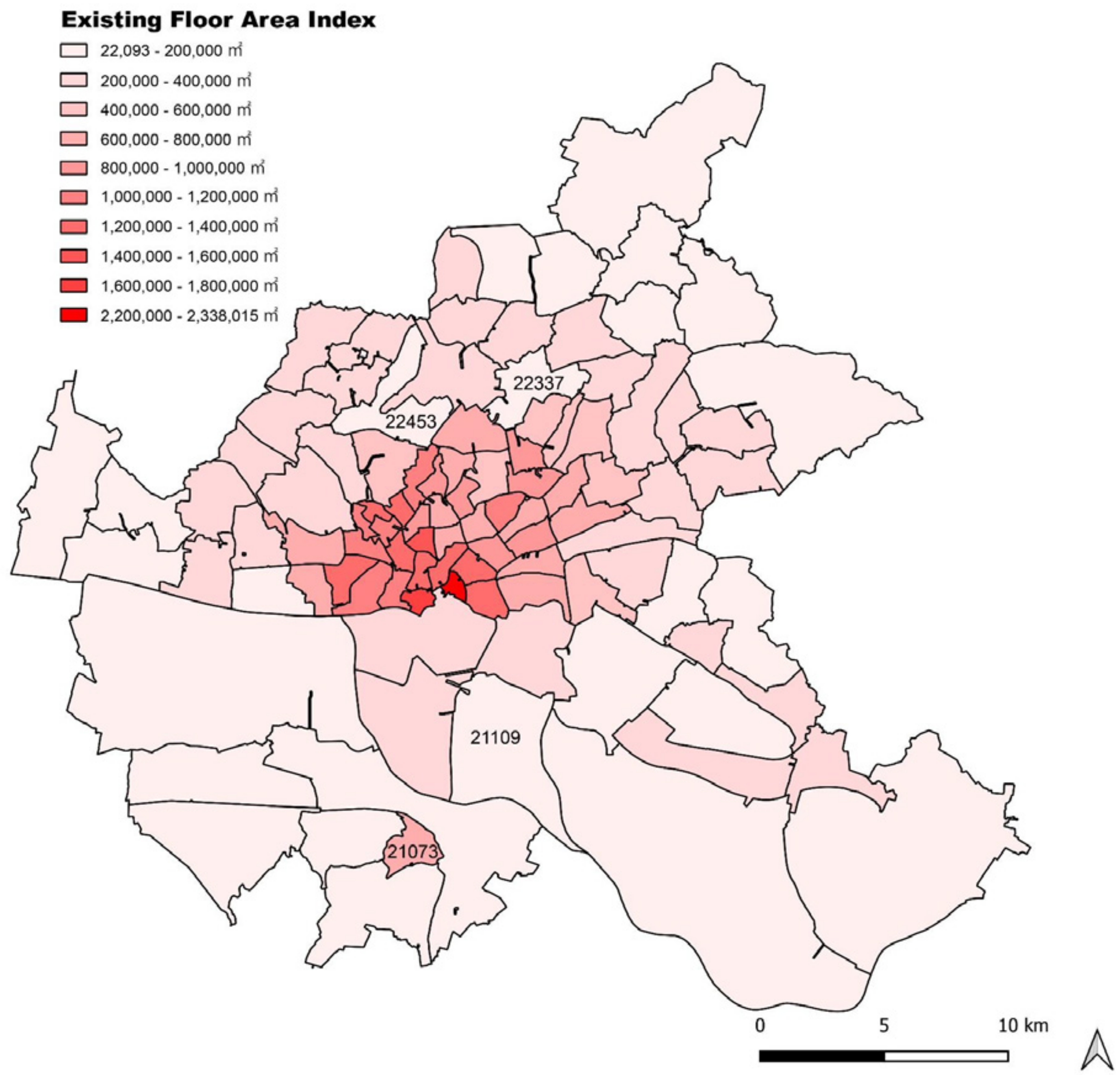
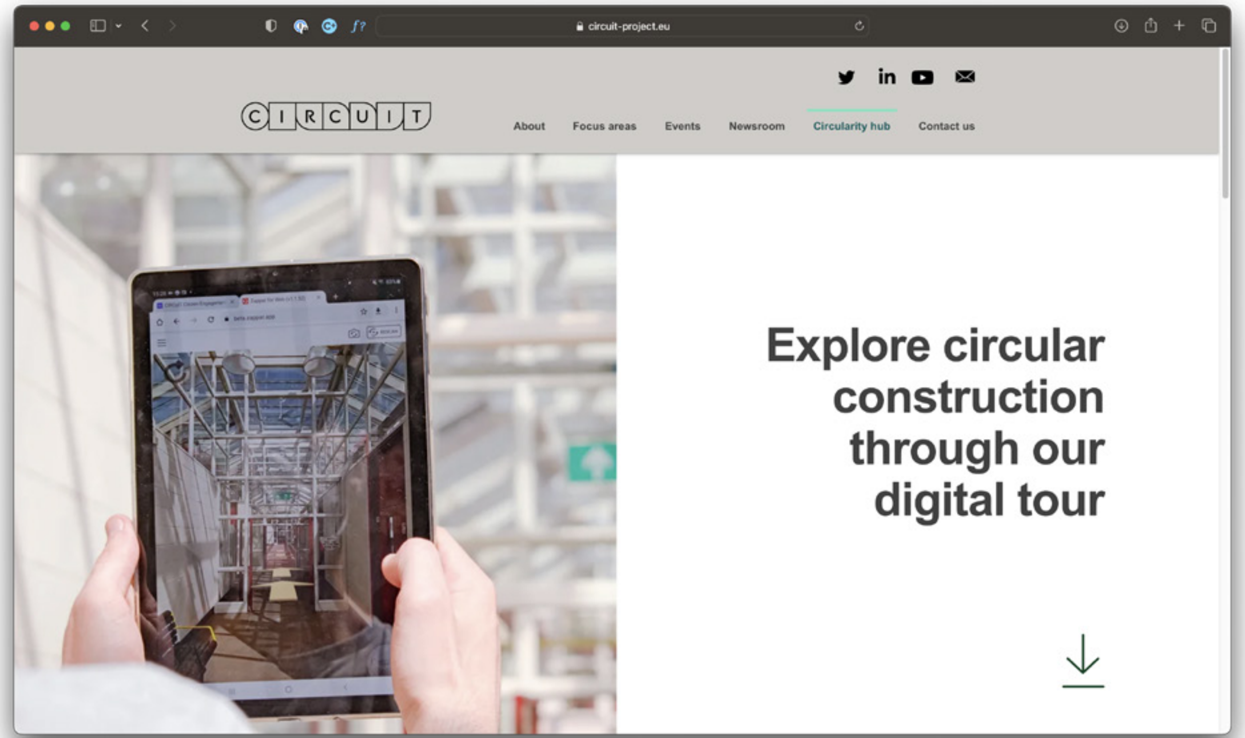


Figure 6.1: 2020 floor area index per postcode in Hamburg

Citizen Engagement Portal

circuit-project.eu/citizen-engagement-portal



Residents typically have limited access to easy-to-understand examples of what circular construction looks like in practice, which can prevent understanding and buy-in.

As a result, it's important that best practices which showcase local circular construction projects are collected and shared to increase residents' knowledge of circular construction.

Subsequently, this could lead to people becoming more involved with decisions about their local built environment and starting to champion circular construction by sharing their knowledge and best practice examples.

It's important that best practices which showcase local circular construction projects are collected and shared to increase residents' knowledge of circular construction.

About the tool

Augmented reality (AR) is an interactive experience that combines the real-world and computer-generated content. Virtual reality (VR) is solely a computer-generated 3D environment with scenes and objects that appear to be real.

CIRCuIT partners identified that 3D technologies such as AR and VR offer cities a novel way to engage people, introduce circular construction best practices and increase their knowledge of this approach.

After considering the needs of potential users and available 3D technologies, a Citizen Engagement Portal was developed featuring two key elements:

- A website portal that takes users on an online tour of buildings that have used circular construction approaches.
- An augmented reality app that enables interactive experiences for users within buildings that have used circular construction approaches. This involves embedding QR codes at particular locations within a building and encouraging people to scan them on their phone or other mobile device.

Taking this action connects a user with building-specific circular construction information that' s displayed over their real-world environment. This allows the user to see and interact with this information on their phone or mobile device.

For the CIRCuIT project, online tours and augmented reality experiences were created for the following buildings:

Konstabelskolen, Copenhagen
Konstabelskolen is a former school building that has been transformed into youth housing. It showcases how a clear design strategy can preserve the cultural importance and materials of a listed building while transforming it for different uses and modern specifications.

CRCLR House, Berlin
The CRCLR House is a former brewery that has been turned into a co-working and living space. The ambition for CRCLR House was to create a zero-waste building through the reuse and refurbishment of existing building materials.

Sortti Mini Station, Vantaa
The Helsinki Region Environmental Services authority (HSY) built a new information centre (Sortti Mini Station) in Koivukylä, Vantaa. The new centre showcases two aspects of circular construction: how to reuse existing building materials and how to design a building that is fully transferable and can easily be moved to another location in the future.

Hackney Depot, London
Hackney Depot is former derelict building that was transformed into a light industrial space for London's creative community. It's a stunning example of how a building can be refurbished in a way that meets the needs of a local population and preserves the rich history of the original building.

How the tool supports circular construction

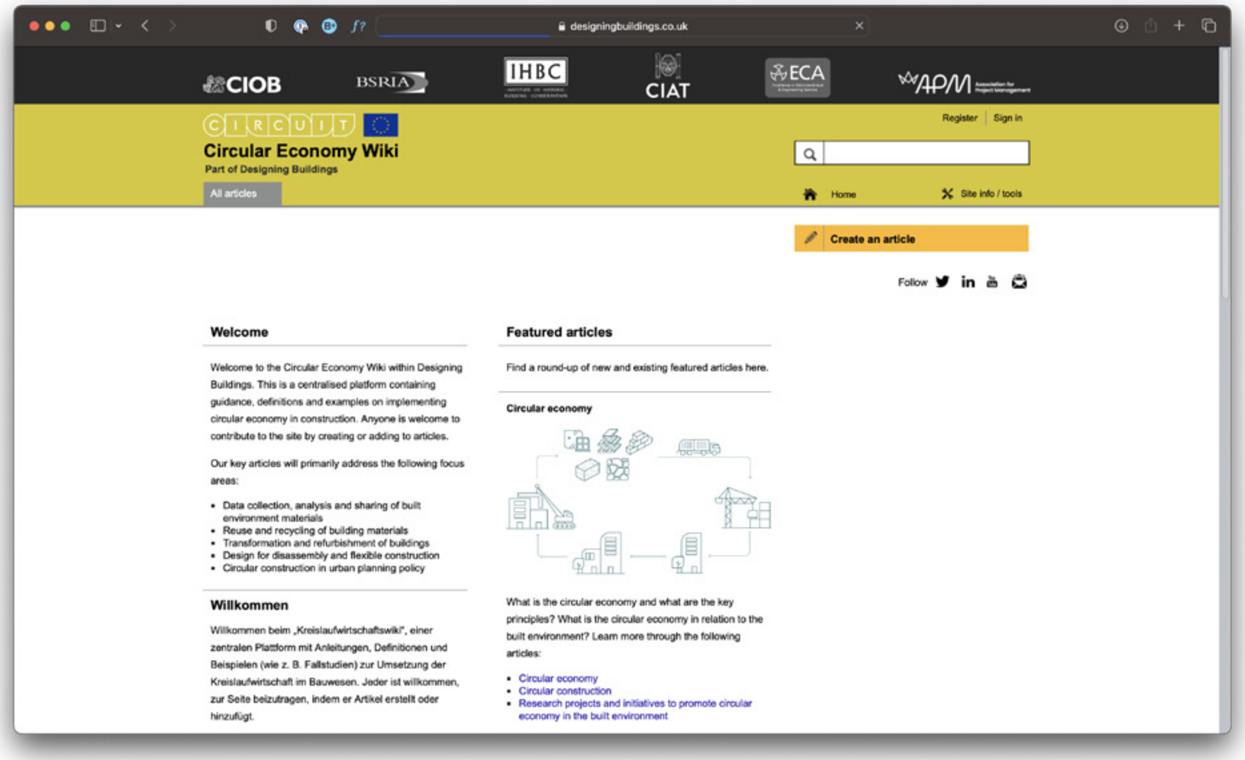
- Showcases circular construction best practice in existing or soon to be constructed buildings.
- Creates a unique circular construction learning experience for users.
- Helps to make circular construction approaches more accessible to a wide range of people.
- Helps to increase demand for reusable materials by allaying concerns about the aesthetics of these materials.
- Helps to bring to life projects that have transformed existing buildings by providing before and after 3D visualisations.

Lessons learned during development

- Augmented (AR) and virtual reality (VR) apps are great ways to engage with the general public about circular construction. They draw interest and curiosity about a topic some people may not have previously known about or been interested in.
- While AR and VR are exciting ways to bring circular construction to life, CIRCuIT partners found they worked best as a supplement to an in-person event, for example they could serve as a visual aid to an engaging talk. Partners also felt people were unlikely to try out AR or VR systems as a standalone experience .
- There is great potential for AR and VR use in the professional sphere to illustrate circular concepts of upcoming building works.

Circular Economy Wiki

designingbuildings.co.uk/Circular_economy_wiki



Built environment stakeholders, such as architects and urban planners, are becoming increasingly interested in circular construction and the environmental and economic benefits it can deliver.

However, professionals need a common understanding of circular economy concepts to be able collaborate effectively and adapt at pace across the value chain.

As a result, cities need to provide their local built environment stakeholders with easy access to reliable information about all areas of circular construction and case studies that can help to bring this approach to life.

Cities need to provide their local built environment stakeholders with easy access to reliable information about all areas of circular construction and case studies that can help to bring this approach to life.

About the tool

The Circular Economy Wiki is a website that aims to inform and inspire stakeholders from the whole construction value chain.

The platform features guidance on implementing circular economy in construction, outlines definitions and lists of materials and products, and shares case studies that feature exciting examples of circular construction in practice.

Information on the site primarily focuses on:

- data collection, analysis and sharing of built environment materials
- reuse and recycling of building materials
- transformation and refurbishment of buildings
- design for disassembly and adaptability construction
- circular construction in urban planning policy

The Circular Economy Wiki also provides the opportunity for users to create their own articles so they can share their circular construction experiences and best practice.

How the tool supports circular construction

- Centralised platform where built environment stakeholders can easily find information about circular construction.
- Excellent opportunity for parties involved in circular construction to share their knowledge and experiences with other stakeholders.
- Search capability of the site allows users to quickly find the circular construction information they're interested in.
- Promotes circular construction best practice and what not to do when starting a circular construction project.

Lessons learnt during development

- A Circular Economy Wiki is a great way to introduce the basics of circular construction to people who have little or no knowledge about the practice.
- Regional wikis with specific entries about local policies and practices are necessary to transition built environment professionals from beginners to competent practitioners in circular construction. A general wiki approach will not capture the nuances necessary for achieving this transition in all cities.

Further reading

For further information about these outputs and the work behind them, please read the following reports, which were published by members of CIRCuIT partner organisations during the lifetime of the project.

- D8.1 Report on the set up of Circularity Hub
- D8.3 Report on using 3D for citizen engagement
- D8.4 Report on the establishment of the Circularity Dashboard
- D8.5 Materials Exchange Portal
- D8.6 Public report on business model for the Circularity Hub

All these reports can be downloaded at
circuit-project.eu/post/latest-circuit-reports-and-publications

Please note that the Circularity Hub referenced in the title of some of these reports is the platform on which all the tools were housed when the CIRCuIT project was live.

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Paris Nikitidis, Grimshaw Architects

CIRCUIT

A Appendices

A1.1: CIRCuIT demonstrators

	Theme	City	Demonstrator name
1	Urban Mining	Hamburg	Luruper Hauptstraße
2	Urban Mining	Hamburg	Offakamp
3	Urban Mining	Hamburg	Musterbude
4	Urban Mining	Copenhagen	Circulation of materials from Gladsaxe school / The Swan
5	Urban Mining	Copenhagen	Stablen / The Stack
6	Urban Mining	Copenhagen	Hyltebjerg school
7	Urban Mining	Vantaa/Helsinki Region	Hevoshaka school
8	Urban Mining	Vantaa/Helsinki Region	Vantaankoski school
9	Urban Mining	Vantaa/Helsinki Region	Tikkurila school warehouse
10	Urban Mining	London	Component reuse of retail unit
11	Urban Mining	London	Demolition of One Leadenhall Street
12	Urban Mining	London	Glulam from secondary timber
13	Transformation	Hamburg	Godewind Park
14	Transformation	Hamburg	Horner Geest
15	Transformation	Hamburg	Gröninger Hof Parkhaus
16	Transformation	Copenhagen	1900s housing urban densification
17	Transformation	Copenhagen	1970s housing estate – Taastrupgård
18	Transformation	Copenhagen	1930s commercial plot
19	Transformation	Vantaa/Helsinki Region	Korso school
20	Transformation	Vantaa/Helsinki Region	Transforming 1970s public rental housing
21	Transformation	Vantaa/Helsinki Region	Adaptive reuse of office buildings for housing in Vantaa
22	Transformation	London	Extending the life of a large 1980s commercial shopping outlet
23	Transformation	London	Transformation of Meridian Water Block F
24	Transformation	London	Transformation of 31-34 North Row
25	Dfd and Dfa	Hamburg	Hamburger Klassenhäuser – Slab construction
26	Dfd and Dfa	Hamburg	Hamburger Klassenhäuser – Façade comparison
27	Dfd and Dfa	Hamburg	Neustadt – Partition walls
28	Dfd and Dfa	Copenhagen	Copenhagen Adaptable housing
29	Dfd and Dfa	Copenhagen	DfD modular façade – Taastrupgård
30	Dfd and Dfa	Copenhagen	Living places Copenhagen
31	Dfd and Dfa	Vantaa/Helsinki Region	Vantaa Hybrid school
32	Dfd and Dfa	Vantaa/Helsinki Region	DfD Warehouse
33	Dfd and Dfa	Vantaa/Helsinki Region	Helsinki Adaptable flats
34	Dfd and Dfa	London	Albion Street / The Hithe
35	Dfd and Dfa	London	Meridian Water: RightSizer
36	Dfd and Dfa	London	Green Street Workspace, Newham

A1.2: Business cases emerging from the CIRCuIT demonstrators

A 'business case template' was prepared based on data attributes and analytics developed during the CIRCuIT project to support, monitor, measure and assess CIRCuIT demonstrator projects.

This template has been used as the framework to gather data and present findings from demonstrators across the three core themes of the project: urban mining and material reuse, building transformation and life cycle extension, design for disassembly and adaptability. The completed templates for all demonstrators can be found at circuit-project.eu/post/latest-circuit-reports-and-publications.

In this section, cases emerging from all demonstrators are aggregated to provide a selection of concise, evidenced, and actionable business cases. A 'business case' is understood as making a case for changing something. It is directed at a specific audience who can enact the proposed change. It describes actions to be taken outside of BAU and the outcomes that are expected. These commentaries and the demonstrator templates provide evidence on the benefit of investment in the proposed changes for both the decision maker and the community.

Public and private asset owners, investors, and developers

A. Public and private asset owners can assess cost and carbon saving opportunities from reuse across projects and asset portfolio by commissioning and acting upon pre-demolition audits

Related demonstrators: 2 – Offakamp, 4 – Circulation of materials from Gladsaxe School / The Swan, 6 – Hyltebjerg School, 7 – Hevoshaka School, 8 – Vantaankoski school, 10 – Component reuse of retail unit, 11 – Demolition of One Leadenhall Street

Public and private asset owners can reduce costs and carbon emissions by implementing PDAs proactively or in early project stages. By understanding the materials available for reuse and establishing a potential material reuse pipeline, materials more likely to be exchange within the asset portfolio. Financially, conducting PDAs early can offer a cost- material solution. One demonstrator found a 12% construction cost reduction by implementing onsite use of recycled aggregates. While PDAs are gaining industry familiarity, some secondary material supply chains do not have the financial capacity yet to widely and strategically implement them. Policy recommendations suggest mandating PDAs for all projects, upscaling PDAs and in turn reducing the costs of deconstruction, processing and testing.

B. Public and private asset owners can identify the optimum cost and carbon approach to projects by commissioning assessments of different degrees of retaining and transforming existing assets

Related demonstrators: 19 – Korso School, 24 – Transformation of 31-34 North Row

Owners of public and private assets can identify optimum cost and carbon approaches to projects by commissioning early-stage assessments of the different ways to use buildings (I.e transformation and retention). The demonstrator projects have shown that optimal retention approaches (achieved through early assessments) can save 7% - 41% of total project costs, amounting to €1 million - €5.5 million saved making a strong case for investing in these assessments. The skills and knowledge do exist to implement assessments to retain buildings and in turn reduce costs and associated carbon. It is vital to consider the cost and carbon saving benefits with evidence at the beginning of projects and appoint experienced consultants. For less economically viable projects, financial incentives such as (in a UK context) charging VAT equally on new build and refurbishment might be necessary.

C. Public and private asset owners can assess existing housing roof and loft spaces and other opportunities for densification

Related demonstrators: 16 – 1900s housing urban densification, 20 – Transforming 1970s public rental housing

Public and private asset owners can assess existing housing roof and loft spaces and other opportunities for densification to cope with increasing housing demand. This essentially means accessing the benefits of transforming roof spaces into residential space. For example, demonstrator project 16 assessed several roof transformation projects in Copenhagen to conclude that roof transformations for residential space can enhance environmental performance, in turn supporting the case for transformation. Roof conversions for housing is technically straightforward but they have legislative and financial obstacles which limits the upscaling potentially, however more assessments of the benefits could help to build a case for more lenient roof conversion regulations.

D. Public and private asset owners can activate a neighbourhood and support new businesses by retaining existing assets for meanwhile use during long-term, phased regeneration projects.

Related demonstrators: 23 – Transformation of Meridian Water Block F

Public and private asset owners can activate a neighbourhood and support new businesses and job creation by assessing masterplans to identify existing assets to retain for temporary use during long-term, phased regeneration projects. In the demonstrator project, construction costs for adapting an existing building were 6% less than providing an equivalent new building. The projected return on investment over a fifteen-year temporary use period was enhanced by 8% compared to the new build alternative. Building retention option creates significantly higher net revenue, more jobs and a greater net total Gross Value Added when compared to when an existing building is demolished, not replaced, and the land is rented out. Building retention for temporary use is technologically feasible, but the challenge lies in recognising opportunities early and prioritising benefits in planning. With long redevelopment timeframes, there is good scope to treat existing buildings as assets that can provide income and social benefits through temporary use.

E. Public and private developers can create more valuable homes, improve resident satisfaction and reduce life cycle cost by developing adaptable housing

Related demonstrators: 28 – Copenhagen adaptable housing, 30 – Living places Copenhagen 33 – Helsinki adaptable flats, 35 – Meridian Water: Rightsizer

Public and private developers can create more valuable homes, improve resident satisfaction, and reduce lifecycle cost by creating adaptable housing. In the CIRCuIT demonstrators the upfront costs for adaptable housing were 21% - 24% higher. However, in one case life cycle cost savings of 28% were achieved if the spaces was adapted compared to demolishing and rebuilding after one use cycle. Adaptability of the spaces was made possible through simple design changes using available construction methods. Resident surveys show demand for adaptable flats, with a willingness to pay a premium (2–10%) for the communicated benefits. In homes owned by residents, a noted challenge was making owners aware of potential savings to motivate them to invest in adaptability. For public developers and housing associations, it's crucial to use life cycle costing over multiple life cycles to evaluate the benefits of designing for adaptability when they retain ownership.

F. Public and private landowners and asset owners can achieve increased rental income by facilitating meanwhile use of underused land and assets.
Related demonstrators: 34 – Albion Street / The Hithe

The term 'meanwhile use' represents a range of strategies that can be put into place to make under-utilised spaces and places become productive, both in an economic and social sense. Sites set for redevelopment often remain unused for a long time before construction begins, leading to unnecessary expenses for security and hoarding. Some businesses have evolved to offer meanwhile use construction for these underused plots, but finding a willing site can sometimes be difficult. Landowners can achieve increased rental income by identifying opportunities for 'meanwhile use' prior to longer-term redevelopment and actively working with the organisations offering meanwhile use construction. In London, there are 466 suitable plots, totalling nearly 500,000 sqm, showcasing the significant opportunity for meanwhile use, and thus increased rental income for public and private landowners in the UK.

G. Local authorities can help to create circular supply chains by driving demand for novel remanufactured secondary materials by adopting their use in public projects.
Related demonstrators: 12 – Glulam from secondary timber

Local authorities can support circular supply chains by instructing procurement teams to specify secondary materials in public projects. This will help local authorities to meet their carbon reduction objectives, while increasing the market for novel remanufactured secondary materials. The demonstrator project showed that deconstructing timber framing was estimated to add 15% to the demolition contractors' costs, however there is a holistic economic benefit to the area if more construction spend is retained in the local economy. This spend also helps new businesses to expand and reduces their costs, increasing the competitiveness of circular supply chains in the longer term. In the demonstrator, using secondary timber in glulam manufacture can achieve a 40% reduction in embodied carbon compared to conventional production. Understanding and communicating these environmental benefits of using novel secondary materials in projects will be key to resisting the pressure to revert to business as usual. The success of this business model relies on having enough secondary materials for big projects to enable consistent demand.

H. Public asset owners and housing associations should include assessments of whole life carbon, resource consumption and waste generation in strategic decision-making over retention and retrofit versus demolition and redevelopment
Related demonstrators: 17 – 1970s housing estate – Taastrupgard, 14 – Horner Geest

Public asset owners and housing associations should include assessments of whole life carbon, resource consumption and waste generation in strategic decision-making over retention and retrofit versus demolition and redevelopment. Assessments have shown that the transformation of socially challenged developments can be considered a win-win, aligning with both social and climate concerns, particularly when coupled with ambitious climate impact reduction initiatives and sustainable practices like repurposing and reuse. Through such assessments, demonstrator 14 showed that by updating and modernising apartment buildings, we can reduce carbon emissions by 4.5 kg per square meter of living space. Economic analysis shows a 20.9% cost reduction per square meter for demolition and construction/modernisation, building a case for retention and retrofit versus demolition and redevelopment.

I. Local authorities can help to create circular supply chains by driving demand for novel DfD construction by adopting its use in public projects.
Related demonstrators: 25 – Hamburger Klassenhäuser – Slab construction, 26 – Hamburger Klassenhäuser – Façade comparison

Local authorities can play a pivotal role in reducing future embodied carbon emissions and promoting circular construction by leading procurement teams to specify DfD in public projects. While resource savings are a large driver for implementing DfD techniques, the CIRCuIT demonstrators also found financial benefits. Demonstrator 26 found that in comparison to the basecase, the circular construction intervention adopting DfD facades resulted in an overall cost reduction of 61 % over the building's life cycle. Implementing novel construction techniques requires commitment and understanding from development and regeneration officers who must champion the policy through project briefs and challenges. Collaborating with innovative, circular businesses can enhance a local authority's reputation. The scalability of this business case depends on the availability of ready-to-use products and increased market demand driven by progressive purchasing and tighter regulations.

J. Local authorities can achieve faster, cheaper school construction and the ability to adapt sites to rising and falling school-age populations by procuring DfD construction
Related demonstrators: 25 – Hamburger Klassenhäuser – Slab construction, 31 – Vantaa Hybrid school

Local authorities can achieve faster, cheaper school construction and the ability to adapt sites to rising and falling school-age populations by procuring DfD constructions for schools. Demonstrator 31 showed that enabling larger degrees of flexibility in school design would allow the buildings to adapt to changing future needs without requiring major construction works, bringing carbon, material and cost savings. This business case could potentially be replicated to all future school projects in which could potentially result in significant environmental savings and increased efficiency of school space for the city at large.

K. Private asset owners, investors and developers can gain recognition and market differentiation by adopting novel, remanufactured secondary materials
Related demonstrators: 5 – Stablen / The Stack, 10 – Component reuse of retail unit, 12 – Glulam from secondary timber

Embedding circular strategies into construction can allow private asset owners, investors and developers to gain recognition and market differentiation. Effective use of remanufactured materials can highlight the private asset owner, investor, or developer as a sustainable lead in the industry. Strong carbon benefits can be found by embedding this approach as well. Demonstrator 5 showed that by using 58% reused and 42% new glulam beams, there was a 47% reduction in overall carbon impact of the project. This approach was also shown to reduce costs 12% compared to using only new beams. This specific approach could be applied in other types of buildings that have a beam structures.

L. Private asset owners, investors and developers can develop expertise in identifying and transforming underused assets
Related demonstrators: 15 – Gröninger Hof Parkhaus, 24 – Transformation of 31-34 North Row

Private asset owners, investors and developers can develop expertise in identifying and transforming underused assets to reduce construction costs and increase social value. For example, demonstrator 15 highlighted that there is a large market for the transformation of unused car parks, especially in cities like Hamburg that are transitioning away from cars to more sustainable travel. This transformation of underused spaces can contribute to the creation of valuable living and social and commercial spaces in inner cities. The total construction costs were also found to be 5% lower in the transformation model.

M. Private asset owners, investors and developers can relocate entire structural steel frames by connecting to others' project needs

Related demonstrators: 22 – Extending the life of a large 1980s commercial shopping outlet

Certain assets such as steel frame builds are technically simple to take apart and relocate. Private asset owners, investors and developers have the opportunity to capitalise on this by facilitating the relocation and transformation or selling their assets for the purpose of relocation. Demonstrator 22 illustrated that whole life carbon was improved 47% by applying the relocation and transformation approach as opposed to demolishing and building new. This approach was also more cost effective with a 15% saving in the capital construction cost, and reduced the Whole Life costs by 2%. This points to the value in pursuing the sale of a steel frame asset as a relocatable building.

N. Private asset owners, investors and developers can gain recognition and achieve market differentiation by assessing whole life carbon when deciding between retrofit and demolition

Related demonstrators: 13 – Godewind Park, 18 – 1930s commercial plot, 21 – Adaptive reuse of office buildings for housing in Vantaa

Private asset owners, investors, and developers can gain recognition and should consider whole-life carbon assessments when deciding between retaining and retrofitting versus demolishing and building new on new developments. This approach has strong financial benefits, with the CIRCuIT demonstrator projects illustrating that retrofit scenarios can result in total costs up to 37% lower than new builds over a 50-year period. There were also strong carbon benefits with retrofit scenarios illustrating an up to 23% lower whole-life carbon than new builds. This approach can be scaled with increasing software access, consultants can efficiently conduct whole-life carbon assessments of retention or demolition and rebuild scenarios. To integrate assessments into strategic decisions, developers should go beyond the legal requirements and set ambitious policies. Consistently taking on this approach will also allow the companies to benefit from beneficial market differentiation. Specialising in this approach also enhances resilience against policy/tax shifts that incentivise retrofit over demolition. Scaling retrofit solutions requires familiarity with existing buildings and innovative surveying methods for better data as to existing structures.

O. Private investors and developers can rent out affordable workspace by deploying a portfolio of reusable assets on meanwhile use sites

Related demonstrators: 34 – Albion Street / The Hithe, 36 – Green Street Workspace, Newham

Private investors and developers can increase their return on renting affordable workspace by acquiring demountable and reusable buildings and deploying their portfolio on meanwhile use sites. Land and assets earmarked for redevelopment are often underutilised before starting construction. These periods of under-utilisation of assets are often significantly longer than is first anticipated, due to delays in projects coming forward for allocated sites and delays in implementing existing planning permissions, leading to years of outgoings for landowners. Developers should invest in a portfolio of relocatable assets and market them to owners of underused land. The demonstrator The Hithe found that over thirty years and in comparison to a conventional basecase, the circular construction intervention resulted in a 6% increase in construction cost, but an overall reduced operational cost by 5%, reduced maintenance cost by 13%, reduced renewal costs by 60% and reduced the Whole Life costs by 23%.

Municipality as policymaker

P. Local authorities can help to create supply chains for secondary materials by establishing circular economy construction hubs closer to city centres.

Related demonstrators: 1 – Luruper Hauptstraße, 3 – Musterbude, 5 – Stablen / The Stack, 12 – Glulam from secondary timber

Local authorities can help create circular supply chains for secondary materials by allocating sites for circular economy construction hubs and facilitate partnerships to manage them. These hubs enhance material value retention in the local economy, reducing supply chain length, and creating local jobs. Issues such as limited storage space and high transportation costs for materials can impact reuse opportunities. However, as reuse becomes more visible, costs are expected to decrease. Partnering with organisations experienced in site management is crucial. Temporarily using disused brownfield sites for these hubs can revitalise unused spaces and benefit the urban environment. Such initiatives contribute to evolving urban waste management into a circular economy infrastructure, with demonstrator projects illustrating carbon emissions reductions ranging from 2% to 47%. Policy objectives aimed at achieving waste self-sufficiency should support the development of these sites.

Construction industry – deconstruction and secondary materials management

Q. Demolition contractors can maximise revenue from existing materials by assessing cost/benefit of different deconstruction techniques

Related demonstrators: 9 – Tikkurila School Warehouse

In a circular economy, existing materials are valued and there are market systems in place to sell and exchange materials. Demolition contractors are in a great position to leverage this newfound value by establishing a process of valuing existing materials and costing the necessary deconstruction techniques to extract these materials. Demolition contractors usually view buildings up for demolition through the lens of waste, however when materials are seen as resources the contractors detailed knowledge of deconstruction techniques can be applied to create a new income stream. Knowledge of deconstruction techniques are not yet widely known though there have been success stories of demolition companies refashioning themselves into deconstruction companies specialising in value retention. In the demonstrators various techniques for deconstructing bricks - e.g using hand held power tools, using an excavator – were compared for their efficacy and cost. Handheld power tools were more effective in harvesting undamaged bricks but took significantly longer to deconstruct the building and cost more due to increased labour needs – 17% more than other reclaimed bricks and 69% more than virgin bricks. Using the excavator resulted in reclaimed bricks that were 48 % cheaper than other reclaimed bricks and 24% cheaper than virgin bricks. Understanding the most effective way to reclaim materials can keep costs down and secondary materials of interest to consumers. x

R. Demolition contractors can improve cost estimates by comparing PDA predictions to actual materials arising from demolitions

Related demonstrators: 1 – Luruper Hauptstraße, 2 – Offakamp

Seeing demolition materials as resources as opposed to waste can increase the profitability of deconstruction or demolition work. However, as this is a new sector the practice of deconstruction or selective demolition to retain the value of materials still requires a level of data collection and analysis to determine optimal approaches. Demolition contractors looking to shift from waste management to reselling material resources should approach each project as an information collection exercise and compare PDA results to eventual material arisings from demolition. This comparison will help hone the most effective deconstruction techniques. These demonstrators showed that current method to estimate recyclable content are flawed and onsite demolition and reusing of mixed mineral waste results in lower environmental impacts compared to demolition and being processed in a recycling facility.

S. Demolition contractors can maximise higher quality recycling by streamlining mineral wastes

Related demonstrators: 3 – Musterbude

Demolition contractors can maximise high quality recycling by being more effective in the collection and separation of mineral wastes. Clear separation reduces the likelihood of downcycling of aggregates by allowing more control in terms of performance and aesthetics. The Musterbude demonstrator tested seven different concrete mixes with various levels of recycled aggregate. Aggregate with the highest value recycled material was 55% cheaper than virgin aggregate.

T. New and existing businesses can achieve new revenue streams by launching products based on novel recycling and remanufacturing processes

Related demonstrators: 12 – Glulam from secondary timber

There is growing interest across the industry to reduce the carbon impacts of projects by increasing the proportion of material that is reused or recycled. This poses an opportunity for new and existing businesses to achieve new revenue streams by launching products based on novel recycling and remanufacturing processes. For example, the Glulam from secondary timber demonstrator showed that reclaimed timber can easily be worked and transformed, allowing it to serve various functions like structural columns and beams. Challenges include obtaining reliable material sources within a useful timescale, characterisation of the material in terms of material grade, and identifying metallic fasteners in the material as removal is crucial to avoid damaging the tooling used in the formation of the glulam. A significant amount of construction waste is downcycled, so there is significant scope for upscaling this solution.

U. Demolition contractors can achieve new revenue streams by becoming retailers of recovered materials

Related demonstrators: 5 – Stablen / The Stack, 8 – Vantaankoski school, 9 – Tikkurila School Warehouse, 10 – Component reuse of retail unit

Demolition contractors can find new ways to make money by becoming experts in urban mining and reclaiming materials for reuse, remanufacturing, or high-quality recycling. In terms of reselling components demolition contractors traditionally focus on high-value goods for heritage projects, however there is a growing demand for other secondary materials like structural steel. In one demonstrator project, deconstructing a steel frame added £50/tonne to costs, but the resale value is approximately £80/tonne, making it financially viable for demolition contractors to sell. Simplifying deconstruction through improved skills and technology, along with a better understanding of secondary material markets, can reduce costs and enhance feasibility even further. Greater demand for secondary materials, driven by progressive purchasing and carbon regulations, can increase profit margins and expand the range of recoverable materials.

Construction industry – designers and supply chain

V. Designers can become building transformation specialists, capable of rigorously assessing a range of approaches to building retention and adaptation

Related demonstrators: 19 – Korso School, 24 – Transformation of 31-34 North Row

Thriving in the circular economy will require rethinking the entire construction process from design through to demolition. On the design side this means designers must become specialists in transformation – being able to assess a range of approaches to building retention and adaptation. Initially this can support the design organisation differentiating themselves as a leader in the sustainable construction field. As policy requirements for circular approaches and low embodied carbon construction grow, specialising in transformation will futureproof design agencies against future requests and requirements.

W. Manufacturers can generate new revenue streams by developing demountable product-as-a-service business models.

Related demonstrators: 27 – Neustadt – Partition walls, 29 – DfD modular façade – Taastrupgård, 32 – DfD warehouse, 36 – Green Street Workspace, Newham

Manufacturers can make money by leasing building products, like partition systems, and keeping ownership for future savings. In the demonstrator projects, systems designed for disassembly had 11–25% higher upfront costs but saved 13–25% when used a second time. Real savings were seen in the Neustadt example, benefiting manufacturers who can disassemble and re-warrant their products. To make leasing common, there needs to be a mindset shift and considerations for pricing and ownership. While there are financial and organisational risks, keeping ownership of materials protects against future price changes. Leasing works best for shorter-lived components and temporary buildings, raising questions about compatibility among manufacturers. Technology alignment and information retention, like material passports, ensure proper disassembly and reuse, even if the original manufacturer stops trading.

X. Manufacturers can invest in offsite manufacture of slabs and façade elements to enable faster construction

Related demonstrators: 25 – Hamburger Klassenhäuser – Slab construction

Manufacturers can invest in offsite manufacture of slabs and façade elements to enable faster construction and thus make themselves the preferred supplier. Shorter construction times means lower costs for the client, so providing a product that makes this possible while also offering environmental benefits can be a key business strategy. Demonstrator 25 illustrated that byincorporating flexible designs for slabs, a 75% reduction incarbon footprint can be achieved. The economic analysis found that a cost reduction of 37% is possible, when considering two buildings constructed with a 90% reuse potential of the slabs compared to demolition and building new.

Citizens

Y. Citizens can form cooperatives and create new affordable homes and workspace by identifying and transforming underused assets.

Related demonstrators: 15 – Gröninger Hof Parkhaus

Citizens can form cooperatives to collaborate with municipalities to identify and repurpose underused assets around the city transforming them into valuable buildings. In one CIRCuIT demonstrator a citizen cooperative led the transformation of an underused multi-story car park in Hamburg into a mixed use residential development. This approach found a 15% saving in demolition costs and a 5% reduction in total construction costs compared to demolition and new build. Citizen-led cooperatives can enhance feasibility of such projects by building relationships with city planners and investing in alternative residential-led mixed-use developments. Early investigation of existing structures is crucial to understanding and mitigating risks associated with hazardous materials or contamination. Scaling this approach is feasible, particularly in cities aiming to reduce car use, with Hamburg alone expecting nearly 10,000 parking spaces in multi-storey car parks to be suitable for transformation in the next twenty years. Municipalities can support cooperatives by systematically identifying assets at risk of demolition, maximising the potential for their transformation and social, environmental, and economic benefits.

Z. Housing cooperatives and resident associations can assess roof and loft spaces of existing housing for building- or estate-wide densification potential.

Related demonstrators: 16 – 1900s housing urban densification

As cities struggle with housing availability and affordability, expanding existing buildings vertically is a compelling option as it increases density without changing the character of the city area. Assessing this transformation potential for housing cooperatives and resident associations would allow these organisations to create significant additional value for a fraction of the financial and environmental cost of an entirely new development.

CIRCuIT's housing densification demonstrator illustrated that creating new housing via roof conversions is technically uncomplicated but runs into legislative and financial barriers. For this approach to be taken forward successfully, certain apartment requirements such as additional parking spots would need to be lightened or removed. These legislative changes should be possible with close collaboration with the city. A full transformation of the attic space is also too expensive for individual housing owners to consider, even with the rent income from future apartment residents, as construction costs remain high due to the customized nature of building on top of existing structure. Different financial arrangements, such as selling the entire floor to a developer could circumvent this challenge. The environmental benefits of this approach are clear, with the embodied carbon of a rooftop conversion being 48% lower than a comparative new build.

CIRCUIT

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