CASE STUDIES IN THE CIRCULAR BUILT ENVIRONMENT

The 9R Strategies in Action

CIRCLE ECONOMY

CIRCLE ECONOMY

Circle Economy is driving the transition to a new economy. In this circular economy we help businesses, cities and nations leverage business opportunities, reduce costs, create jobs and inspire behavioural change.

As a global impact organisation, our international team equips business leaders and policymakers with the insights, strategies, and tools to turn circular ambition into action.

Circle Economy has been at the forefront of the circular economy since 2012. Our annual Circularity Gap Report sets the standard for measuring progress and we manage the world's largest circularity database, encompassing data from over 90 nations, 350 cities, and 1,000 businesses.

Realdania

Realdania is a fully self-endowed Danish philanthropic association dedicated to enhancing the quality of life for everyone through the built environment.

Our mission is to create positive impacts for all in Denmark by supporting projects and initiatives where thoughtful development of the built environment can improve people's daily lives, relationships, well-being, and health.

PREFACE

The construction sector is in the middle of a necessary transformation. As one of the most resource-intensive and climate-impacting sectors in Europe, construction not only has a responsibility but also a unique opportunity to lead the green transition. The future of construction is increasingly about rethinking how we do things today – building upon what we already have and reusing materials and resources repeatedly.

A circular approach to construction is crucial for achieving this. Circularity is not a niche approach or an experiment but a necessity if we are to ensure more sustainable construction and a resilient society in Europe. It represents a path forward, where we design buildings so materials can be reused, extend the lifespan of buildings, structures, and materials, and create new opportunities for value creation across the value chain.

This case collection demonstrates how circular strategies can be translated into practice. The case collection presents the cases through the lens of the so-called 9R framework and its nine guiding principles for achieving maximum circularity impact. Including using fewer new materials and keeping them in circulation for as long as possible – and by refusing new construction when unnecessary, and instead prioritising repairing, rethinking, and reusing buildings and materials. Through 18 cases from across Europe, we see how these guiding principles can be applied in everything from the transformation of historical buildings to new constructions designed as material banks. This provides valuable insights into how circularity can reduce the climate footprint while simultaneously creating new economic and social opportunities.

One might consider the 9R framework for circularity as a journey, and the projects in this collection are chosen because they represent one or several steps on the way. Each project offers key learnings and can inspire us to start or advance our own journey.

At the Danish philanthropic association Realdania, we are committed to scaling up circularity in construction. Over the past few years, we have supported research, innovation, pilot projects in construction and more, all of which have circularity as a common denominator. The necessary transformation requires collaboration across sectors, new ways of thinking about design, materials, and processes – and not least the courage to learn from both successes and challenges.

To compile this collection, we were glad to engage Circle Economy, a global Amsterdam-based impact organisation recognised for its expertise in circularity since 2012. Bringing their expertise to the table, this case collection is therefore not just documentation of what is possible – it is also an invitation to everyone working in construction to take part in the transformation. By sharing knowledge, experiences, and concrete examples, we hope to inspire even more people to see the opportunities in the circular agenda. After all, we all need to practice!

Vera Noldus

Head of Projects, Realdania

CONTENTS

Introduction

The circular economy is emerging as a core solution to the European construction industry's multifaceted challenges, offering pathways to lower resource consumption, reduce waste, and create long-term value. This is critical, as construction is one of the largest and most impactful sectors in Europe, currently accounting for about one-third of its total material consumption, over 40% of primary energy use, and more than 30% of the European carbon footprint. It is clear that the sector requires a holistic approach that enables the scaling of alternative sustainable solutions that prioritise resource sufficiency and efficiency while strengthening the sector's overall resilience and adaptability. By adopting circular principles, the industry can address its significant environmental impact while simultaneously tackling other pressing issues such as rising material prices, fragmented supply chains, regulatory barriers, skilled labour shortages in construction, and limited adoption of innovative technologies. This is further reinforced by EU policy and regulatory frameworks, including the Green Deal and the Circular Economy Action Plan (CEAP), which are driving Europe's transition to a more sustainable and circular economy. For example, the Waste Framework Directive and the Construction Product Regulation emphasise waste reduction, recycling, and resource efficiency, aligning with the broader shift towards circular construction practices. By fostering innovation through digital tools, enhancing collaboration across supply chains and supporting skilled labour, the circular economy can also contribute to the construction sector's resilience, reducing raw material vulnerability and ultimately making it more adapted for current and future economic, environmental and societal demands.

As circularity emerges as a crucial enabler of this transition, offering practical solutions to the industry's systemic challenges, this case study selection highlights circular practices in various building projects. Using the **9R circularity framework** as a set of guiding principles, the case studies explore how conventional construction practices can be transformed into more circular and sustainable approaches. By presenting existing circular projects and their critical learnings, challenges, and success stories, this collection provides the reader with actionable insights and practical strategies to advance circularity in construction. Through these examples, this report aims to inspire and equip stakeholders across the construction sector to adopt circularity and use these building blocks to drive the transition towards a more resource-efficient, future-ready industry.

THE CIRCULAR ECONOMY

The circular economy is an economic system where waste is designed out, everything is used at its highest possible value for as long as possible and natural systems are regenerated. The concept of circularity closely mimics nature, where there is no waste: all materials have value and are used to sustain life in a myriad of ways. If we effectively deploy these strategies, we will ultimately require fewer materials to provide for similar societal needs.

The 9R Framework

The 9R framework is a valuable tool for understanding and implementing circular economy principles, as it defines the key actions and strategies required for transitioning from linear to circular systems. The framework, originally suggested by the Netherlands' Environmental Assessment Agency (PBL) in 2017, provides a cascading hierarchy of strategies—Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, and Recycle and Recover (Figure one)—that prioritise resource sufficiency and efficiency while aiming to phase out waste.

Circular economy

Increasing circularity

Linear economy

R STRATEGIES	DESCRIPTION	R STRATEGIES IN CONSTRUCTION
R0 Refuse	Make a product redundant by abandoning its function with a radically different product	Avoid unnecessary construction by questioning the need for new buildings or expansions
R1 Rethink	Make product use more intensive (e.g. by sharing product)	Rethink how the intended purpose of a construction can fulfill different purposes or be fulfilled in an alternative, more sustainable way (e.g. design flexible and shared multi-functional spaces)
R2 Reduce	Increase efficiency in product manufacture or use by consuming fewer resources and materials	Optimise material use in the design and construction process
R3 Reuse	Reuse by another consumer of discarded product which is still in good condition and fulfills its original function	Use reclaimed building components and materials while maintaining their initial function
R4 Repair	Repair and maintenance of defective product so it can be used with its original function	Maintain and repair existing structures, façades, or building systems to extend their lifecycle
R5 Refurbish	Restore an old product and bring it up to date	Use updated materials that have been restored to a new like condition to fulfill original purpose
R6 Remanufacture	Use parts of discarded product in a new product with the same function	Disassembling used building elements and repair or replace worn parts, eventually reassembling them to meet original specifications
R7 Repurpose	Use discarded products or its parts in a new product with a different function	Adapt materials or structural components to serve entirely new purposes within the project
R8 Recyle	Process materials to obtain the same (high grade) or lower (low grade) quality	Process demolition waste into recycled materials or aggregates for use in new construction projects
R9 Recover	Incineration of materials with energy recovery	Incineration of materials with energy recovery. This strategy is therefore not applicable to the context of circular construction activities.

Figure one: Overview of the 9R Strategies and associated practices in construction and the built environment

At its core, the framework prioritises the strategies at the top of the hierarchy, such as Refuse, Rethink, and Reduce, which are the most effective at avoiding or minimising resource use and eliminating waste from the design phase. For instance, 'Refuse' questions the need for new construction at all, 'Rethink' encourages innovative design and usage strategies to achieve the same goals without building more, and 'Reduce' aims to optimise material efficiency. By addressing resource use early on, these circular strategies prevent unnecessary environmental impacts before they occur, making them the most effective for achieving circularity and sustainability in construction.

The middle levels—such as Reuse, Repair, Refurbish, Remanufacture and Repurpose—focus on extending the life of existing buildings, structures, materials or products, allowing them to continue fulfilling their original purpose or finding new functionalities for existing materials and components. By doing so, these strategies avoid using new materials and constructing new buildings where possible.

Finally, lower-tier strategies like Recycle and Recover deal with managing construction and demolition materials at their end-of-life. However, it must be noted that Recover is often considered non-circular since it consists of energy recovery from material waste incineration. It is, therefore, difficult to link to any circular construction practice, which is why it was left out of the scope of this case study collection.

Selecting the case studies

The set of case studies presented in this report showcases how circular principles have been practically applied across a variety of construction projects in Europe. They have been selected based on their capacity to demonstrate how circularity approaches can be integrated into various stages of construction, from the design of new buildings to major renovation and redevelopment projects. As such, the cases have been organised into three main categories— **Renovation Projects, New Builds,** and **Area Redevelopments**—which are reflected in the three main sections of this report.

To build the case studies, the 18 projects, which span different European countries, were analysed by conducting desk research and a comprehensive literature review of existing material and sources available for each project.

This review focused on identifying the circular strategies adopted and connecting them with the 9R principles presented above. Furthermore, the findings were used to feed into a review of the common approaches, innovative strategies, and the barriers encountered in circular construction projects. The case presentations and supporting data drawn from various sources, including written materials provided by the projects, third-party descriptions and analyses, and, when possible, interviews with experts and project participants, allowed us to validate the findings and ensure the practical relevance of the collected information to help refine the analysis. As a result, the information presented reflects the content emphasised in these materials and the insights shared by the project participants.

Overcoming barriers: Key learnings from 9R framework projects

The cases highlight how different strategies from the 9R framework have been successfully applied in the built environment sector, overcoming numerous challenges through innovative approaches and collaboration. The projects have demonstrated that circularity principles can be integrated into the built environment while achieving long-term value creation. The main learnings identified include the following:

Making the economic case for circular buildings: long-term benefits can outweigh initial costs.

A key takeaway from these projects is the importance of making the economic case for circular buildings. While the initial costs of circular construction may, in some cases, be higher due to the use of secondary materials and additional labour, the long-term benefits can outweigh these costs. For example, the K.118 project in Switzerland showed that savings from avoiding virgin materials balanced the extra costs of training workers and more frequent stakeholder collaboration. This approach can create economic value and support local industries, illustrating how circularity can generate new revenue streams and benefit regional economies. These trade-offs prove that circularity is not only feasible but can be advantageous when viewed from a long-term value creation perspective.

Emphasising flexible and iterative design processes

Circular construction often faces challenges related to the unpredictability of reused or secondary material availability and sourcing and the need for adaptive designs and cultural preservation. Secondary material quality, condition, and quantity may also vary, leading to logistical complications during the construction process. These factors, coupled with a lack of standardised logistic processes in circular construction models, can entail significant budget management and uncertainty risks. Successful projects overcome these hurdles by fostering **close collaboration among architects, designers, contractors, and suppliers** through flexible and iterative design processes. For example, in the Tscherning House, stakeholders assessed available materials, often salvaged from demolition sites, and adapted designs based on what is available, ensuring dynamic and adaptable solutions. This collaborative approach not only fosters sustainability but also creates a culture of ongoing learning and adaptation, which is key for the future standardisation of circular renovation practices.

Working with locally available resources

Some projects (The Rehafutur and Thoravej 29, for example) placed a particular emphasis on the value of leveraging resources that were already available, showcasing how circularity can be achieved without rigid adherence to predefined materials. This included cases where the ambition was to reuse as many materials and components as possible from the original building (in the case of renovations) or projects where new buildings sourced materials from regional demolition and deconstruction sites. A particularity of these projects was to often rely on the concept of material banks as storage spaces both for the construction phase and over the lifetime of the building in cases where materials and components were documented using material passports.

Leveraging tools for monitoring resource efficiency and environmental performance

Tools and assessment methods like Life Cycle Assessments, material passports, and carbon footprint analyses have played a vital role in addressing resource inefficiency and environmental impact. In the Saint-Vincent Hospital redevelopment project in Paris, these tools are guiding informed decisions and sustainable practices, providing a replicable model for overcoming barriers in urban redevelopment.

These projects reveal that overcoming the challenges of circular construction **requires a holistic approach**. By integrating regulatory, technical, economic, and organisational strategies, the transition to circularity is not only possible but practical. **Early stakeholder alignment, digital tools, and a focus on long-term value creation** are essential for making circularity a reality. Ultimately, embracing the 9R framework will help the construction sector pave the way for a sustainable, circular future that benefits the environment, local communities, and economies.

RENOVATION PROJECTS

K118: A blueprint for multi-layered R-strategies in construction and renovation

KEY FACTS AND MESSAGES

- The project achieved a **41% circular (non-virgin) material use rate** in volume, avoiding 494 tonnes of CO_2e during construction. This corresponds to a **59% reduction or avoidance in construction-phase emissions** compared to a building made with virgin materials.
- K.118 illustrates the complex trade-offs the construction industry faces, **balancing sustainable and circular construction**, maintaining cost-efficiency in material and design choices, and ensuring full regulatory compliance.
- The project **highlights emerging opportunities for architects** to expand their traditional role and scope within **circular construction** and **renovation projects**. In particular, K.118 highlights the new roles that architects played in project management and interdisciplinary collaboration, logistics optimisation during component sourcing, and oversight of component reuse processes.

The K.118 building transformed from a former carpentry factory into a mixed-use space using circular strategies. After various interim uses following its 1980 closure, Stiftung Abendrot (Swiss Pension Fund) began renovations in 2009. Instead of demolishing the existing structure and starting from zero, they approached the project as a case for circular renovation and expansion, adding three floors and using predominantly reclaimed materials from local building demolition projects. The new building has different spaces, hosting think tank studios and a tinsmith workshop.

Location	Winterthur, Switzerland
Project description	Renovation and expansion of a factory building into a mixed-use building with workshop and office spaces for a think tank.
Size	1,266 m²
Year of completion	2021
Partners	**Architect:** Baubüro in situ **Civil engineers:** Oberli Ingenieurbau AG **Construction companies:** Wetter AG (steel) and Josef Kolb AG (timber)
Prizes & recognition	K118 won the Gold Global Holcim Award in 2021
Website	Baubüro in situ website

R-Strategies

- Reuse
- Repair
- Refurbish
- Repurpose
- Recycle

Overview of the K.118 building exterior, showing the contrast between the original building and the additional floors following the renovation and expansion (Source: Martin Zeller).

R-Strategies in action

The K.118 building demonstrates a diverse application of R-strategies across the 9R framework, combining elements of Reuse, Repair, Refurbishment, Repurpose, and Recycle strategies to optimise material circularity at every stage.

At its core, the project aimed at prioritising the direct **reuse** of materials made available from other buildings in the region, such as windows, natural stone slabs, Expanded Polystyrene (EPS) insulation, wooden roof elements, profiled steel, and even a 22-metre high external staircase reclaimed from the Orion office building which had been demolished in Zurich. These elements were integrated into the building's supporting structure, shell, and interior fittings, achieving a 14% reuse rate by material weight and 41% by volume—the difference being attributed to the prevalence of lighter, more malleable reused materials compared to denser (and thus heavier) materials such as concrete reinforcements and foundations which could not be reused.

The entire process involved careful assessment of more than 2,700 components for potential reuse, with many requiring minor **repairs** and **refurbishment** efforts to adjust to their new use in the K.118 building and meet safety requirements. For example, the reused steel staircase had its bannisters retrofitted with infill panels for enhanced fall protection. Creative **repurposing** was also employed, with reclaimed components finding new functions throughout the building. This was the case with granite slabs for the kitchen and toilet floors, originally part of the Orion office building façade. Similarly, the layered brick walls incorporated into the building were also made of former roof tiles from another building. Lastly, **recycled** alternatives were prioritised for materials that could not be directly reused, refurbished or repurposed, particularly in concrete applications, further minimising the need for new carbon-intensive virgin materials. The final composition of non-reused building sections consisted of 23% recycled materials and 16% new materials.

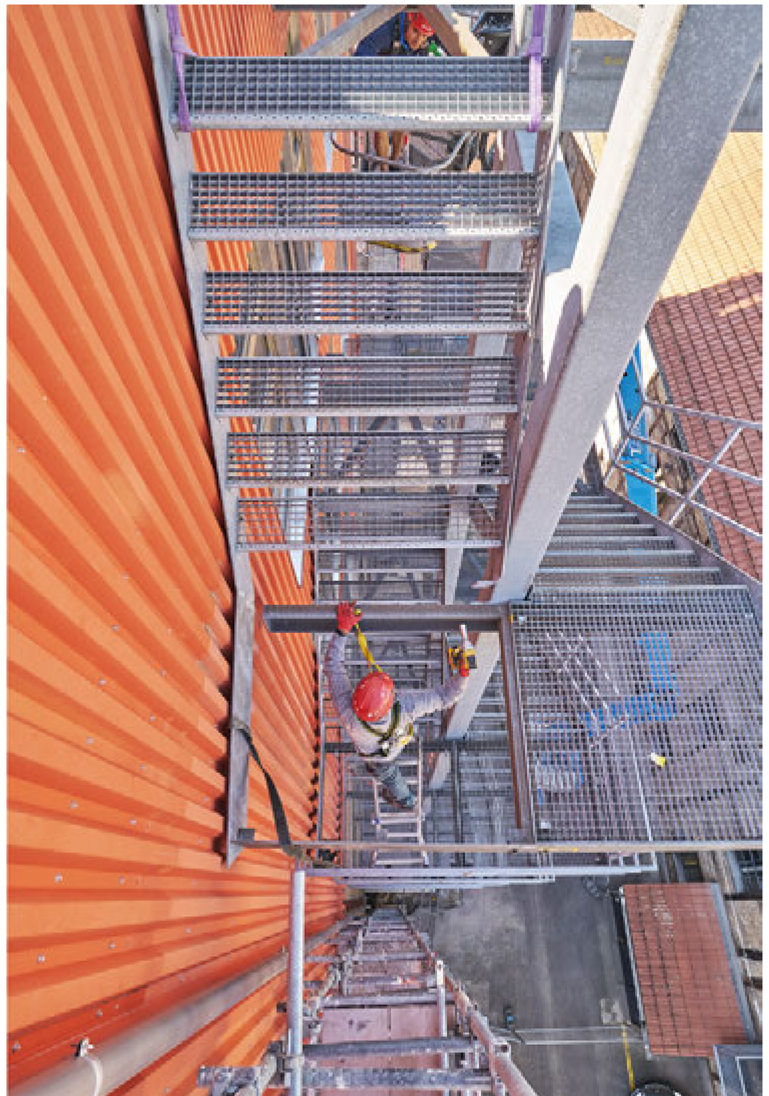
This approach illustrates the project's flexibility in circular construction, tailoring strategies to each of the building's needs and making the most of available materials based on the function they could fulfill.

What impacts were achieved?

The K.118 project achieved significant resource savings and avoided substantial environmental impacts by systematically prioritising reused materials. Notably, the choice of reused, refurbished and repurposed materials reduced construction-phase emissions by 59%, saving 494 tonnes of CO_2e compared to using identical but new materials (this is based on a model that covers all phases of the life cycle from raw material supply to disposal, including different transportation phases, manufacturing, installation, waste processing, et cetera). It's also worth mentioning that while materials were sourced within a 90-kilometre radius, transport emissions were a key contributor to remaining greenhouse gas (GHG) emissions. This underscores the value of local sourcing and highlights the broader impact reductions achieved across the entire value chains of different materials (for example, extraction, transportation and storage).

The project also provides interesting findings regarding the financial case of reusing building components through labour-intensive processes like dismantling and reassembly, which tend to increase costs, particularly in Switzerland. While complex reused

Reused and refurbished steel staircase with bannisters retrofitted with infill panels for enhanced fall protection (Source: Martin Zeller).



Interior image that shows the granite slabs from the Orion office façade repurposed as kitchen floors (Source: Martin Zeller).

items, like windows, offered cost savings due to their 'embodied craft', heavy components (such as steel structures and staircases) were less cost-effective due to the need for specialised equipment and labour. As a result, upfront costs were higher than in conventional construction (where normally such costs would typically be incurred later in the construction process), with 11% of the total cost incurred before construction began. Despite this unusual timeline, in the end, the total project was only 2.5% over budget (compared to the initial estimate), showing that with adequate cost control, careful planning, and flexibility, reuse can be financially competitive with conventional methods (using new materials).

In addition to environmental and financial benefits, the K.118 project serves as a proof of concept for the potential of circular construction to strengthen the local economy by creating new skilled jobs. Sourcing materials for reuse and the expertise needed for installation created opportunities for local workers, including engineers, consultants, and skilled craftsmen, further emphasising the growing role of circular construction. As such, costs avoided by not purchasing new materials were transferred into additional value creation and revenue streams for local workers and industries.

Balancing circularity, compliance and cost-efficiency

Beyond the renovation and expansion of the existing building itself, the K.118 project aimed to explore how extensively material reuse could be applied in the Swiss construction industry, both from a regulatory and cost-efficiency perspective. Some components are more likely to be reused cost-effectively than others. For example, certain materials like limestone and sandstone require a lot of cleaning and preparation, compromising time and cost-effectiveness. This led the project team to use new materials instead of reused ones. Additionally, the project points out the need to balance pragmatic solutions for increasing a building's circularity and sustainability with compliance with norms and standards. For example, certain materials could not come from reused sources because they didn't meet fire safety or noise protection requirements. While it is important to develop viable construction alternatives that meet necessary standards, it is also important that certain of these norms and standards are updated to align with ecological interests.

Revisiting the role of architects in circular construction projects

The project also provides many insights into the architectural process and the new roles that architects could play in circular construction. First, it offers an opportunity for architects willing to reinvent planning and design processes with circular thinking at its core. Instead of following the 'conventional' process of coming up with the building design before sourcing and procuring materials, the architects reversed the process. They began by inventorying available materials—both at the original building and from other projects around the region—before developing the design. Secondly, the K.118 project reveals significant opportunities for architects to take an even more prominent role in project management and interdisciplinary collaboration. By managing processes traditionally handled by contractors—such as logistics, component sourcing, and reuse coordination roles—the architects gained greater design flexibility and fostered innovation. This experience has led the architects to establish a specialised planning office as a spin-off of the architecture studio, offering circular expertise to firms without such capacities. This new approach showcases a promising path for architects to lead in circular practices, shaping a more sustainable construction industry.

Sources used

Arch Daily. (n.d.). K118 Kopfbau Halle 118 / baubüro in situ. Retrieved from: Arch Daily website

Baubüro in situ. (n.d.). K.118 – extension of building 118 Winterthur. Retrieved from: baubüro in situ website

Swiss Architects. (2022). K.118 – a pioneering achievement for circular construction. Retrieved from: Swiss Architects website

Immo Invest. (2020). K.118: a building made from construction waste. Retrieved from: Immo invest website

BauNetz Wissen. (n.d.). Extension of K.118 in Winterthur: Re-use par excellence. Retrieved from: BauNetz Wissen website

Stricker, E., Angst, M., Brandi, G., Buser, B., & Sonderegger, A. (2023). Case study K.118 – the reuse of building components in Winterthur, Switzerland. *Journal of Physics: Conference Series, 2600*(19), 192008. doi:10.1088/1742-6596/2600/19/192008

Rehafutur engineer's house: Renovation and conversion of a historic residential building

KEY FACTS AND MESSAGES

- By **prioritising circular strategies** like **reusing onsite materials**, the project not only achieved considerable energy efficiency gains, it also **reduced costs and waste generation**, demonstrating the economic and environmental benefits of a circular approach.
- Important challenges arose due to the building's **architectural complexity** and **cultural heritage preservation restrictions**. The **limited experience** and knowledge about the selected innovative sustainable materials was another issue the project team had to address.
- The project brought together a large interdisciplinary group of stakeholders and showed that **collaboration, willingness to learn**, and **good communication** are crucial factors in advancing circularity in current practices. Despite the challenges, the Rehafutur research project provided an effective **renovation process** for historical mining houses.

Location	Loos-en-Gohelle, France
Project description	A historical mining engineer's house was renovated to reach high energy efficiency and converted into office facilities.
Size	400 m²
Year of completion	2015
Partners	**Client:** Maison & Cité **Architect:** ARIETUR architecture group. Construction and Design: Consortium of 10 local SMEs led by cluster Eqution. **Partners:** French Building Association (FFB), Maison & Cité, City of Loos-en-Gohelle, French National Government, French Agency for the Ecological Transition (ADEME), and the Nord-Pas-de-Calais region.
Website	Biobased bouwen website

Located in a UNESCO World Heritage mining area and constructed in 1920, the building was formerly the home of a mining engineer. The project aimed to demonstrate the potential for such historic buildings to achieve passive house standards, build expertise among local stakeholders in handling similar renovation projects and support regional sustainability and rehabilitation goals. As part of the European Cycle Assessment Procedure for Eco-Impacts of Materials project (CAPEM), Rehafutur integrates and tests different types of renewable insulation materials as a passive energy measure to demonstrate the efficiency of eco-materials in reaching energy efficiency. Eco-materials, in this case, are mostly made from natural or recycled sources that can be easily reused or biodegraded at the end of their lifecycle.

R-Strategies

- Refuse
- Reuse
- Refurbish
- Repurpose

Front view of the Rehafutur building showcasing the preserved façade after insulation integration (Source: Biobased bouwen website)

R-Strategies in action

Rehafutur was a research-driven project focusing on circular strategies as a central aspect of the selected processes. It incorporated material reuse, refurbishment, and repurposing to preserve the building's cultural heritage.

The project's innovation lies in using diverse eco-materials for insulation, advancing environmentally friendly construction methods and **refusing** carbon-intensive materials for renovation works. To demonstrate their potential for achieving energy efficiency, the project used and tested eight different eco-materials, including wood fibre, flax fibre, hemp bricks, animal-sourced expanded cork, sheep wool, and three types of recycled materials: cellulose from various sources, locally produced textiles, and cellular glass. The project used Métisse, a regionally produced insulation material from recycled cotton textiles. In addition to its insulating properties, Métisse enhances noise reduction, further contributing to the building's environmental and functional goals. The insulation materials were applied strategically based on their specific characteristics and wall position to intensify their properties, thus optimising performance to meet passive house standards.

Reusing materials was a priority for the project to preserve the building's cultural heritage value. After the renovation, partial removals and interior demolitions were followed by carefully storing materials for reinstallation. Reused elements included 18 square metres of multicoloured cement tiles and 62 square metres of century-old spruce floorboards, carefully dismantled for high-performance (floor) insulation. Additionally, the façade reconstruction incorporated original materials and bricks to maintain the building's authentic appearance. Rubble from the building's interior was stored for reuse to meet the reconstruction's material demand. Once the material needs for the interior were met, the remaining rubble—around 350 cubic metres—was **repurposed** to level parking spaces and access paths in the outdoor area of Rehafutur.

Moreover, some **refurbishment** works were essential to preserve valuable architectural elements. For example, two existing marble fireplaces were refurbished to restore their original craftsmanship and then became ornamental features in the renovated building's public rooms.

What impacts were achieved?

The Rehafutur project reduced the environmental footprint of the old mining house. By integrating the selected insulation materials and a heat recovery system, the project significantly lowered the building's annual energy demand. Specifically, the current heating demand is 34 kilowatt hours per square metre per year under average usage conditions. This is comparable to the average energy consumption of a 100-square-metre apartment despite the building offering nearly 400 square metres of space. This efficiency level is quite high, given that the French 'BBC Effinergie' energy efficiency standard for low-energy renovations in Northern France is set at 104 kilowatt hours per square metre of primary energy per year.

The photo below features the use of recycled textile panels between rails, leveraging their cotton content to ensure thermal and acoustic insulation in the offices. The photo on the following page showcases hemp blocks arranged in beds and secured with sand and lime mortar, serving the same purpose. (Source: [Rehafutur website])

The project's total budget, including the research and development phase, outreach, administrative costs, renovation and monitoring, was €1,580,000. Nearly half (€720,000) was allocated to the actual physical implementation of the renovations, including securing materials, labour costs, and retrofit processes. Despite the costs of working with such innovative materials being higher compared to business-as-usual, there were also economic benefits coming from the selected circular strategies. Prioritising reuse and repurposing of onsite materials lowered overall project costs by reducing the need for new materials and minimising transport expenses. Notably, reusing materials like tiles led to significant cost savings, around €8,000, while preventing the need for 17 semi-trailers of debris to be transported to a landfill. The regional economy also benefited from the partnerships between local and regional enterprises, laboratories, educational institutions, and stakeholders throughout the process.

Establishing an effective renovation model for old mining houses to achieve energy efficiency is especially beneficial in this socioeconomically sensitive area, where many households struggle with fuel costs. In other words, reducing the building's operational costs contributes to a higher quality of life for the local community. Additionally, through involving local small businesses, the project enhanced local expertise. It fostered skills development that could be leveraged to create similar future projects, stimulating job opportunities for a region with high employment needs.

Balancing conservation and innovation

As a research project investigating innovative practices, the Rehafutur encountered numerous challenges. Due to the building's architectural complexity and the need to preserve its cultural heritage, the renovation process was particularly intricate. For example, restrictions such as the prohibition on altering the external façade and the mandatory installation of interior insulation were influenced by its status as a UNESCO World Heritage site.

Achieving energy efficiency in a building originally constructed to different standards was difficult. The use of innovative sustainable materials introduced further technical challenges, compounded by a lack of experience in their proper implementation. A key challenge was managing the interface between different insulation types and the building's airtightness system. After isolating the internal load-bearing walls from the external ones, various materials were applied to different walls to determine the optimal configuration. Each material's performance is being monitored to inform future projects.

Additionally, reusing floorboards and tiles presented challenges in disassembly. The unfamiliarity with non-standard materials also added complexity. On-site training sessions were held to address this, focusing on issues like airtightness, where all stakeholders collaborated to ensure proper implementation. Installing hemp blocks proved especially difficult, requiring additional training to upskill the teams involved. Ultimately, collaboration was critical to the success of the project.

Collaboration and ongoing learning were key to the project's success

With approximately 70,000 mining houses still in use across Northern France, the Rehafutur project serves as a valuable example with significant implications for future applications in post-industrial buildings. Mining houses and similar structures nationwide have unique environmental, economic, and social demands, presenting an opportunity to apply circular strategies. The project demonstrated that eco-materials and recycled materials can play a vital role in achieving energy efficiency and reducing environmental impact in such renovations. Additionally, circular principles like material reuse and repurposing are crucial for preserving a historically important building's cultural heritage while complying with legal restrictions.

The Rehafutur project adopted an interdisciplinary approach by engaging a diverse group of stakeholders. Collaboration among these varied participants was vital for addressing the challenges inherent in such an innovative research project. Effective communication was crucial and, in some cases, posed challenges in realising certain goals within the set timeline. Willingness to learn throughout the process was also pivotal to the project's success and stakeholders had to participate in training sessions that were deemed necessary for different parts of the renovation process. This underscored the importance of acquiring new skills and knowledge throughout the project.

The Rehafutur had a strong educational element as well. Interested individuals outside the project team and students were also allowed to visit the renovation site and participate in training sessions. Resources like a project blog enabled anyone to follow progress and gain insights, disseminating knowledge through different channels to raise awareness about sustainable construction practices. Investing in monitoring and evaluation of material performance will provide further insights in the future and contribute to the standardisation of the used processes and selected materials.

Sources used

Biobased bouwen. (2022). *Renovatie monument Rehafutur in Frankrijk*. Retrieved from: Biobased bouwen website

CE100. (2016). *Circularity in the built environment: case studies*. Retrieved from: Build360 website

CLIC Project. (2019). *Circular Economy Strategies in the Historic Built Environment: Cultural Heritage Adaptive Reuse*. Retrieved from: Clic project website

Mangialardo, A., & Micelli, E. (2018). Rethinking the construction industry under the circular economy: principles and case studies. In *Smart and Sustainable Planning for Cities and Regions: Results of SSPCR 2017 2* (pp. 333-344). Springer International Publishing. doi: 10.1007/978-3-319-75774-2_23

Rehafutur. (n.d.). *Ensemble, agissons pour un habitat responsable*. Retrieved from: Refafutur website

The Tscherning house: A circular renovation of a demolition company's warehouse

KEY FACTS AND MESSAGES

- The building's **circular transformation** used **89% reclaimed materials** (non-virgin) with various strategies, allowing a **58% reduction in GHG emissions** (318.6 tonnes of CO_2e) compared to a scenario in which new materials would have been used.
- The project revealed the **necessity and importance of active dialogue and collaboration** between the key stakeholders, which are critical to **achieving such a high rate of reuse and recycling** while dealing with material delays, changes of plan, and coordination of different engineers.
- The building's design aims to create an environment for employees by considering the interaction between people, the different spaces and the materials. It combines **behavioural design techniques** with circular **design principles** to enhance well-being and functionality.

Location	Hedehusene, Capital Region of Denmark, Denmark
Project description	Conversion of a demolition company's warehouse into modern company headquarters.
Size	1,300 m²
Year of completion	2024
Partners	**Architects:** GXN **Engineer:** Per Ermler **Engineering consultants:** SWECO (performed the LCA) **Client and main material supplier:** Tscherning **Local authorities:** Municipality of Høje-Taastrup
Prizes & recognition	The project won the Renoverprisen in 2024 for best renovation, and the Samarbejdsprisen collaboration award the same year
Website	Tscherning website

The Tscherninghuset building project involved refurbishing the construction and demolition company's warehouse in Hedehusene, Denmark, into an innovative, state-of-the-art office space that fully embraces sustainability and key circular economy principles. The project won the Renoverprisen in 2024 for best new transformation project in Denmark, an award organised by Grundejernes Investeringsfond and Realdania, highlighting the significance of renovation within the construction industry. It also won the Samarbejdsprisen in 2024, an award co-hosted by Building Green and WE BUILD DENMARK, recognising stakeholder collaboration between management and employees contributing to the sustainability of the construction sector.

R-Strategies

- Rethink
- Reduce
- Reuse
- Repurpose
- Recycle

'Before and after' of the interior of the warehouse building showing the different elements and materials that have been introduced to the new space (Source: My Lunsjö)

R-Strategies in action

The Tscherning house illustrates a comprehensive application of circular principles in construction, integrating various strategies to transform a former warehouse into a multi-functional office space. The objective of the renovation effort was to implement a circular transformation in which the highest possible rate of reuse and upcycling of materials and components was prioritised while providing the workers with a modern office that considers both material circularity and employee wellbeing. The first step was **rethinking** the layout of the building's interior spaces, with the new design combining meeting rooms, offices, and flexible spaces. The different spaces of the building effectively serve as a showroom for circular construction, where visitors experience firsthand the various circular techniques and materials used as they move through the different areas.

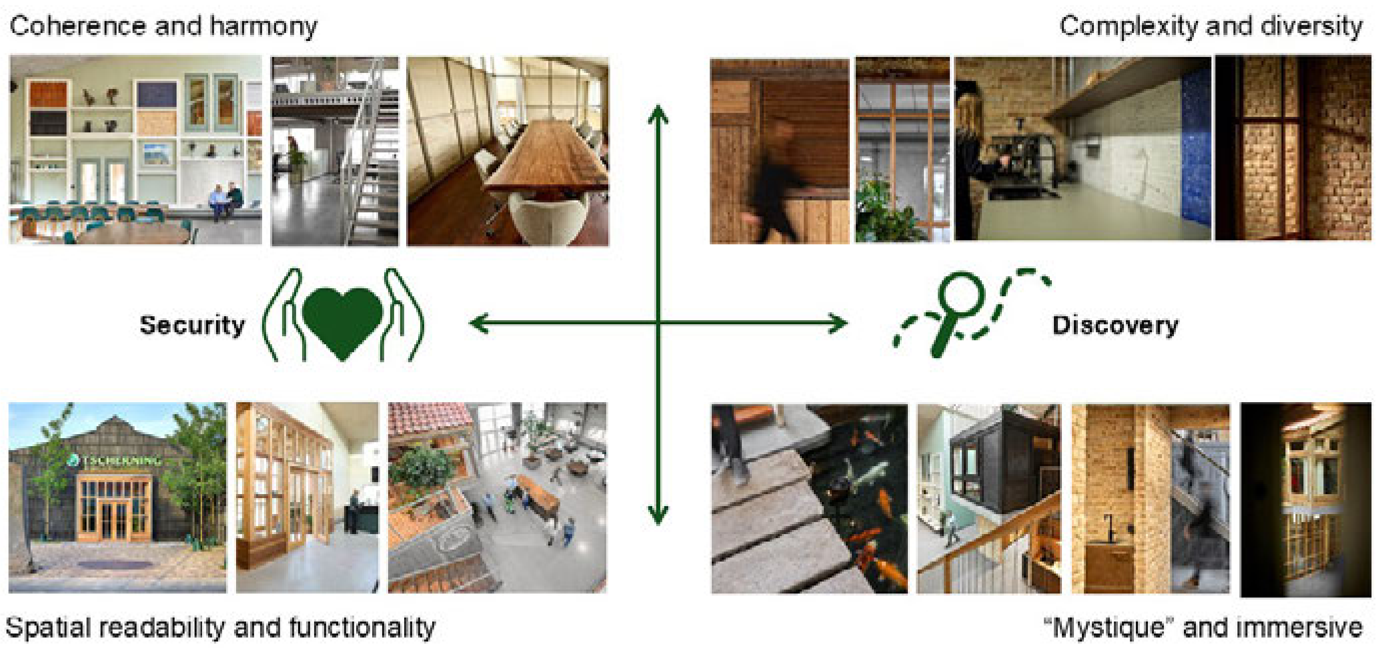
In terms of material sourcing, the project's primary focus was on direct **reuse**, incorporating whole elements (corrugated sheets, steel beams, doors, stairs, and different flooring materials) from Tscherning's demolition and deconstruction activities while simultaneously employing complementary circular approaches to the choice of materials. To a large extent, innovative **repurposing** solutions were implemented with the many reclaimed items for which no equivalent purpose could be found. Concrete decks, previously used as load-bearing materials, and reclaimed oak blocks were used as floor elements around the office spaces. Regarding soundproofing, an acoustic batt made from waste and residual textiles was placed behind wall panels in meeting rooms. Similarly, carpets were added in some areas made from upcycled wool scraps and residual fibres. A more unique example of repurposing was the use of red wing tiles from former roofs as wall cladding, enhancing both the office's acoustics and aesthetic appeal. Where reuse was not feasible, the project prioritised **recycled** elements, including glass doors and wooden frames made from recycled window glass and waste wood.

What impacts were achieved?

The project achieved a material recycling and reuse rate of 89% (referring to the share of non-virgin materials out of the total materials used). A Life-Cycle Assessment (LCA) conducted by environmental engineering firm Sweco revealed that these design and material choices reduced GHG emissions by 58% (318.6 tonnes of CO_2e) compared to conventional construction using new materials. Beyond the construction phase, the building was designed to optimise environmental performance during operation. It features a rainwater collection system that waters internal plant walls and supplies water for toilet flushing, significantly reducing reliance on the municipal water network. Additionally, integrating natural and mechanical ventilation, solar panels, and energy-efficient electrical systems will enhance energy efficiency in office spaces.

Completed at a cost of approximately 20,000 Danish kroner per square metre, the project aligns with the cost range of similar constructions in Denmark, such as detached houses or prefabricated buildings. While considered slightly costlier than expected, it demonstrates how value can be created by salvaging materials from demolition sites. The renovation process reimagines conventional demolition processes to one of deconstruction, becoming a source of reusable materials rather than waste. The project serves as a proof of concept, demonstrating to clients and industry partners the feasibility and value of turning potential waste into assets.

From its inception, the project integrated the principles of placemaking and circular design to ensure an optimal working environment for employees while at the same time showcasing the company's commitment to circular innovation. Placemaking, when combined with circular design, creates flexible and adaptable spaces that can evolve with changing functional needs over time. This tackles the challenge of short-lived spaces that often require demolition or major renovations.



Behavioural design matrix illustrating the balance between reassurance and discovery in the choice and layout of materials and shared spaces (Source: My Lunsjö)

Red tiles taken from demolition roofs repurposed as wall cladding for one of the office rooms (Source: My Lunsjö)

Balancing complex material supply and delays with a flexible and iterative approach

The construction of the Tscherning House relied on active dialogue and collaboration between the key stakeholders, as mentioned by the lead architect during an interview. The process involved the ongoing exchange of documentation between the client, who supplied salvaged materials from their own demolition sites, and architects, who then determined how each piece could be incorporated into the building. Relying so much on reused materials presented challenges: it caused delays in the supply of specific materials, which sometimes meant that construction works had to be interrupted, and required the client to shoulder the financial risk of delays and frequent re-designing. Another hurdle was ensuring these reused materials met stringent construction standards, including static calculations to verify structural integrity, health, and fire safety standards. Finding an engineer capable of certifying these materials was essential but complex.

Using circular design and placemaking to tell a story about reclaimed material

The client's goal was to transform an old warehouse without any particular appeal into a headquarters that showcases material reuse from demolition while providing a workspace centred on employees' needs. To create a welcoming and productive environment reflecting the organisation's values, the client and architects leveraged circular practices to integrate other innovative architectural designs, such as behavioural placemaking strategies based on reclaimed materials.

The project's circular design incorporates different reclaimed materials and elements, introducing diverse textures, patterns and natural elements that contribute to creating a sensory-rich environment. Placemaking strategies were used to ensure employee well-being while emphasising the circular nature of the project. For this, the architects used a preference matrix that balances the functionality and comfort of the resulting office spaces with the complexity and diversity of different materials and components laid out. This approach allowed the architects—and ultimately, the client—to design their new headquarters as an experiential journey, where people interact with different surfaces, colours, and textures throughout the office. This highlights the value of reused components not only as functional building materials but also as a way to create a narrative about their origin and material characteristics, making circularity visible and engaging for the occupants.

Like the rest of the processes, these approaches were achieved through a blend of stakeholder participation that balanced bottom-up and top-down processes. This ensured a design that resonates with employees and creates an inspiring workplace.

Sources used

GXN. (n.d.). Form follows Resources: From Imperfect to Authentic. Retrieved from: GXN website

My Lunsjö. (2024). GXN architect. Online interview

Tscherning. (n.d.). Project: Circularity. Retrieved from: Tscherning website

Tscherning. (n.d.). Project: Architecture. Retrieved from: Tscherning website

Tscherning. (n.d.). Project: LCA & Consumption. Retrieved from: Tscherning website

Tscherning. (2024). The Book of Tscherning House. Retrieved from: Tscherning website

Thoravej 29: Circular renovation through site-inspired adaptive reuse

KEY FACTS AND MESSAGES

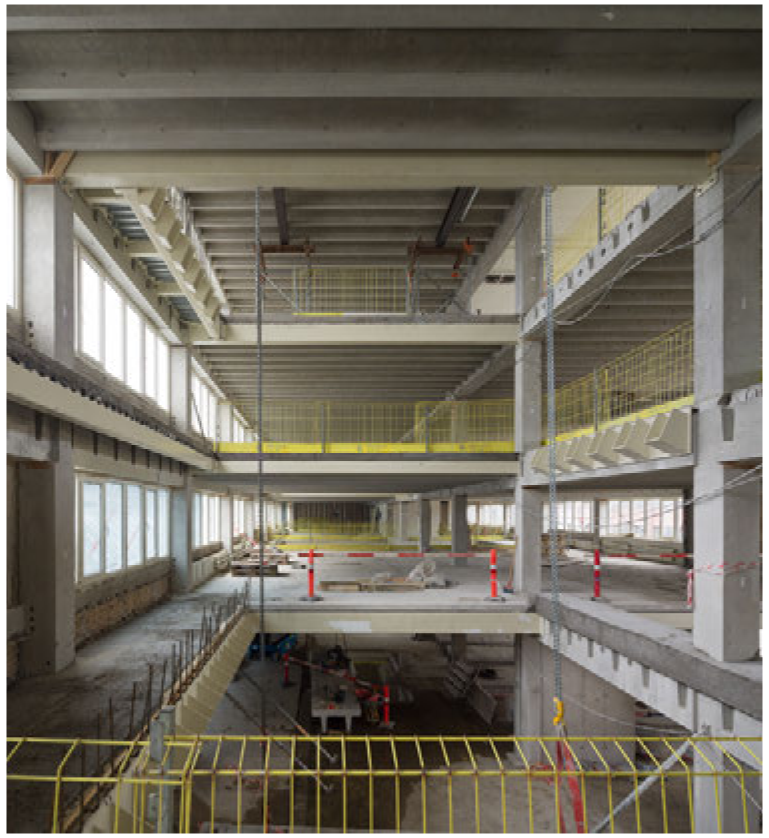
- The idea underpinning the entire renovation process is that **the building renovates itself**, emphasising the **reuse of existing structures, materials and components** based on on-site availability.
- The case study describes the architect's ambition to **recognise the current challenges and barriers of circular construction** and turn them into **sources of inspiration** and **opportunities**.
- Thoravej 29 emphasises the importance of **careful initial assessment** during exploratory and observation phases for **successful circular building design**. This adaptable approach allows for evolution, adjustment and optimisation where **design respects and utilises what is present** while ensuring flexibility for future use cases.

Thoravej 29 is a transformation project of a former industrial building from the late 1960s in Copenhagen's Nordvest district. Originally used for Danish fur auctions, the building has been converted several times since its initial use, serving as a laboratory for the Geological Survey of Denmark and Greenland and later as an administrative office. This time, it was adapted for the Bikuben Foundation, which supports young artists and aimed to adapt the building into a community centre with music studios, exhibition spaces and workshops for emerging talents in the arts and social sectors. To do so, instead of demolishing an unused building, the architect chose redevelopment, prioritising a key element of the circular economy: keeping as many existing resources as possible in use to meet the needs of the new community centre.

Location	Copenhagen, Denmark
Project description	Transformation project of a former industrial building into an open community hub.
Size	6,500 m²
Year of completion	2025
Partners	**Architects:** Pihlmann architects **Construction company:** Hoffmann A/S **Consulting engineers:** ABC **Client:** Bikuben Foundation
Prizes & recognition	Won the first prize in a competition organised by Bikuben Foundation in 2021 and was pre-certified with a DGNB Gold certificate at completion.
Website	[Pihlmann website]

R-Strategies

- Refuse
- Reuse
- Repair
- Refurbish
- Repurpose



Overview of the original structure, showing where concrete floors were opened up to change the interior spatial layout (Source: Hampus Berndtson)

R-Strategies in action

The main conceptual idea throughout the project has been that 'the supplier is the building itself', as stated by the main architect. This idea underpinned the entire process, emphasising the reuse of existing structures, materials and components based on their availability on-site. An extensive list of components was collected, inventoried and assessed to see how they could be re-integrated into the new design in order to avoid purchasing new materials.

As mentioned by the architect, the **refuse** principle was actively applied by strictly and deliberately retaining rather than replacing all functioning items, such as the existing plastic window frames, even if they were not the most modern or aesthetic fit for the new design. By doing so, the architects eliminated unnecessary replacements, an approach that prioritises sustainability over visual appeal. The primary approach was to **reuse** the building as much as possible, adapting interior spaces for flexible uses while avoiding major structural changes and demolitions (concrete and steel structures).

Other components that could be directly reused were claimed and inventoried, with some undergoing **repair** and **refurbishment** before being reincorporated into the new design to extend their useful lifetime and ensure they could continue serving their original function. When components could no longer serve their original purpose, they were adapted and **repurposed** into new uses. For example, concrete slabs previously used as flooring were tilted to form stairways in the new design, and surplus façade tiles were transformed into pavements. Additionally, some building elements were creatively converted into furniture, such as doors and replaced ventilation pipes that were fashioned into chairs and tables.

What impacts were achieved?

Although no quantification of environmental performance has been carried out or published to date, the radical approach of strictly using materials and parts already available on-site is a major advantage in avoiding environmental impacts across the entire value chain. By avoiding further raw material extraction, energy-intensive processing and manufacturing, transportation of materials, and waste generation during construction, the project minimises the ecological footprint of Thoravej 29. It should be noted, however, that this was not the sole objective of the architect, who, during an interview, stressed how this project attempted to go beyond resource and ecological awareness and advocate for a change in cultural barriers in the construction sector by showing how creativity and innovation can align with a more sustainable way of building.

Upon completion, the client (Bikuben Foundation) also hopes to use the building to create meaningful social impacts by opening a community hub. The centre will open its gates to young artists and creators from the visual and performing arts and social organisations (civil society, public sector, private companies). The plan is for the building to facilitate the exchange of knowledge, perspectives, and ideas between professional fields, allowing new thoughts and opportunities to emerge and new knowledge to be disseminated. By transforming the former industrial building into a completely new space, the architects wanted to highlight the project's pedagogic function and convey the message that what used to seem idle and perhaps even 'ugly' can be transformed into a highly functional and visually pleasing space. Furthermore, keeping reused and repurposed parts exposed in the new spaces allows users and visitors to appreciate the transformation and the diverse possibilities of circular construction.

Images showing the concrete slabs from the original floors being cut and tilted to fit new stairways (Source: Hampus Berndtson)

Navigating through regulatory hurdles and economic incentives

During an interview, the principal architect discussed some of the main challenges encountered in this transformation project. Besides the common economic and process-related barriers to circular construction, such as high upfront investments needed due to increased labour costs and less streamlined construction processes (highlighted in the introduction), a significant barrier in this project stemmed from the regulatory framework of buildings and construction activities. Danish building regulations differentiate quite clearly between new builds and renovations, with major building renovations requiring compliance with relatively rigid 'new-build' standards, sometimes discouraging projects and constraining creative and context-specific solutions, therefore presenting a trade-off with sustainable (and circular) renovation goals.

However, these challenges revealed new possibilities for innovative approaches to renovation. Thoravej 29 implied spending time with engineers making additional calculations or even searching for the company that delivered certain parts (such as concrete slabs) to provide original calculations and ensure repurposed materials could be used safely. Similarly, the project team turned the process's complexity and uncertainty into inspiration, opening the door to rediscovering 'forgotten' Danish construction methods, which historically focused on using locally available resources as much as possible, emphasising durability and resourcefulness. Reviving these techniques adds cultural value and supports adapting reuse practices in modern construction by providing proven low-impact alternatives.

Working with available resources as a foundation for design

Through this project, architecture emerges organically from the existing site, highlighting how construction can thrive by drawing directly from locally available resources. This means inverting the design process, which in a linear system goes from 'idea to concept', whereas here it went 'from observation to idea'. This approach begins with observing and investigating what is already present, making reuse a natural outcome rather than a strict mandate or substitute for new virgin materials.
All the strategies adopted throughout the building transformation stem from the initial concept of building from available resources rather than setting rigid parameters. With this approach, architects emphasise that particular circular construction practices should not be a prescriptive requirement nor a trend-driven feature. Instead, it should enhance the flexibility of the approach and create an enabling environment for creative solutions. While presenting obvious environmental benefits, reuse, in this case, is not inherently superior to new materials in terms of aesthetics or functionality, nor is it worse. It is simply a different way of approaching architecture, which, in a way, also reflects a nod to traditional construction methods, where builders made do with the resources available locally. Thoravej 29 draws inspiration from this adaptable mindset, where the design respects and utilises what is present but also allows for evolution, adjustment and optimisation as an integral part of the building's past, present and future life. This approach offers a modern yet timeless model for sustainable construction and design.

Sources used

Thoravej 29. (n.d.). The Building at Thoravej 29. Retrieved from: Thoravej 29 website

Pihlmann. (n.d.). Project: Thoravej 29. Retrieved from: Pihlmann website

Bikubenfonden. (n.d.). Thoravek 29. Retrieved from: Bikubenfonden website

Realdania. (2023). Circular Criteria. Retrieved from: Realdania website

Danish Architecture Centre. (2023). Podcast: How to transform buildings with no waste. Retrieved from: Danish Architecture Centre website

AEFoundation. (n.d.). Interview: Søren Pihlmann, by Callum Symmons. Retrieved from: AEFoundation website

Søren Pihlmann. (2024). Pihlmann architects. Online interview

La Grande Halle de Colombelles: Transformation of a post-industrial building into a circular innovation hub

KEY FACTS AND MESSAGES

- Through the **reuse of materials** and the **implementation of low-impact construction techniques**, the project prevented the generation of 18,901 kilograms of waste and reduced its GHG emissions by 25,095 kilograms of CO_2e.
- The Grande Halle project **addressed material reuse challenges** by testing and cataloguing reusable materials on an adjacent open construction site, **engaging the community** through cultural programs and input, and **demonstrating that a dedicated reuse strategy** is feasible and replicable for future projects.
- This project is unique because it **incorporated circular practices** into the building contract. **This is currently not a standard practice in the industry**. The contract included a workstream, 'Lot 01', that was dedicated to sourcing and assessing used materials.

Location	Colombelles, France
Project description	Post-industrial building transformed into a circular innovation hub
Size	3,500 m²
Year of completion	2025
Partners	**Client:** Normandie Aménagement **Architect:** ENCORE HEUREUX ARCHITECTS **Reuse specialists:** Le WIP
Website	Normandie Aménagement website

R-Strategies

- Reduce
- Reuse
- Repurpose

The Grande Halle de Colombelles project repurposed a former industrial building of the Normandy Metal Company, closed since 1993, into a 'third place'—a space beyond home or work designed to foster social connections, collaboration, and innovation. The restoration project aimed to create a hub for stakeholders in the sharing and circular economies. The project was completed with an investment of over €7.2 million, co-financed by the European Union.

Before and after image of the Grande Halle renovation (Source: Normandie Amenagement and Adrien Bossard)

R-Strategies in action

Renovating the Grande Halle benefited from significant public funding, making it possible to plan for the implementation of multiple circularity strategies during the renovation process.

The Grande Halle building was **repurposed** from an abandoned industrial site into a community-oriented hub featuring indoor and outdoor spaces suitable for events and co-working processes. The project preserved the historic structure rather than demolishing it, adapting the building spaces to promote the circular economy and support local culture. Maintaining the existing structure and relying on reclaimed materials effectively lowered the demand for new construction materials, reducing the project's carbon and material footprints. For example, preserving the original exterior structure of the building substantially **reduced** the need for new structural materials such as steel and concrete. Additionally, the design complied with E+C- and RE 2020 standards for energy efficiency, further minimising operational energy consumption and GHG emissions.

The project also placed a strong emphasis on material **reuse**, establishing a dedicated process to source reclaimed materials from local demolition sites that would be used for the building's new joineries, floorings, insulation, ventilation and plumbing systems. Numerous reclaimed items, including 21 guardrail posts, 18 doors, 14 sinks, five urinals, 12 toilets, 52 cast iron and steel radiators, and 200 square metres of rock wool insulation slabs, were integrated into the renovation.

What impacts were achieved?

La Grande Halle de Colombelles is an example of sustainable construction and local economic development. Driven by the commitment of a regional public institution, this seven-year project focused on the reuse of materials, demonstrating that reuse does not have to be a significant driver of costs in circular renovation projects.
By repurposing existing materials and adopting low-impact construction and design methods (the use of bio-based materials and passive building design), the project avoided 18,901 kilograms of waste and reduced its carbon footprint by 25,095 kilograms of CO_2e compared to construction with virgin materials. Additionally, innovative water management and biomass heating systems were integrated, reducing the building's reliance on non-renewable resources for the building's operational phase.

The renovation project reduced environmental impact and delivered social and economic benefits to the community. La Grande Halle integrates economic, cultural, and social activities, providing affordable spaces for local businesses, artisans, and cultural organisations. This hub has the potential to foster innovation and entrepreneurship, attract sustainability-focused enterprises, strengthen the local economy, and set a new benchmark for sustainable urban regeneration. Lastly, this renovation safeguards an industrial landmark while creating an inclusive environment that unites diverse social groups, fostering a sense of community identity and environmental awareness.
Through workshops, exhibitions, and shared workspaces, La Grande Halle aims to become a cornerstone of cultural enrichment and community cohesion in the region.

Renovated interior of the Grande Halle (Source: Normandie Amenagement)

Tackling material reuse standards through community-driven innovation

One of the main obstacles faced during the project was ensuring that reused materials met quality and reliability standards, a challenge for both technical controllers and insurers. To mitigate this, materials collected for reuse were tested at a smaller open construction site. Reusable materials were then identified and catalogued into a dedicated reuse batch, ready to be incorporated throughout construction. The open construction site engaged the community by showcasing expertise, fostering project acceptance, hosting cultural programmes, encouraging public input, and providing early exposure to the space as a pre-marketing strategy. This approach has now been validated, with the Grande Halle serving as a pilot project demonstrating that a workstream dedicated to the sourcing and preparing of reused materials is a valuable operational 'work package' that can be effectively implemented and replicated in other circular construction and renovation projects.

Integrating circular principles into the building contract

The Grande Halle project introduced innovations in building methodology, redefining how public construction projects can prioritise sustainability and material reuse. Two key innovations were aimed at prioritising sustainability and material reuse, marking a radical shift from traditional construction methods by eliminating suppliers and utilising existing materials with minimal transformation. The first innovation was incorporating construction Lot 01 into the building contract. A 'lot' typically refers to a contract section or a specific work package with a dedicated budget, responsibilities, and requirements. For the Grande Halle project, Lot 01 was uniquely created and dedicated to overseeing the reuse of materials, just as other lots would handle other specific tasks like electrical or structural work. Managed by the association 'Le WIP', Lot 01 was dedicated to sourcing and integrating reclaimed materials from regional demolition sites, which required close collaboration between the project owner, architects, control offices, and insurers. This was essential in keeping technical dossiers and specific testing for each reused material, and therefore, meeting quality and safety standards. The second included a flexible 'variant' technical specifications (CCTP) in the building contract, stipulating that contractors would aim to use reclaimed materials but could revert to virgin materials if reclaimed ones were unavailable. This clause allowed for the prioritisation of reuse without halting the building process due to material supply issues (unfortunately, no quantitative information is available regarding how many times the clause was leveraged). Demonstrating the feasibility of material reuse in public projects, the Grande Halle sets a replicable example for resource-efficient architecture, embracing innovative practices to address resource scarcity.

Sources used

Colombelles Great Hall | Ekopolis. (n.d.). Retrieved 6 November 2024, from Ekopolis website

Heureux, E. (2021). La Grande Halle. Retrieved 8 November 2024, from Encore Heureux website

La Grande Halle | Colombelles. (n.d.). Retrieved 8 November 2024, from Normandie Aménagement website

La Grande Halle de Colombelles. (n.d.). Retrieved 8 November 2024, from Construction21.org website

Boschgaard Collective Ecosystem: Bottom-up transformation of a community centre into a sustainable social housing complex

KEY FACTS AND MESSAGES

- The project achieved an impressive milestone, with **85%** of the used materials being reused.
- A key challenge for the project was **securing the necessary materials** to meet construction needs. Another key challenge was finding adequate **storage space**, which was more than the team initially anticipated.
- Boschgaard's **innovative ownership model** empowered residents to take a hands-on role, share responsibilities, and actively participate in all stages of the project. It also **contributed to shaping sustainable lifestyles** after the project's completion.

Location	Den Bosch, The Netherlands
Project description	A former community centre transformed into a residential complex comprised of 19 social housing units and a new community centre
Size	The housing units range from 39 m² to 44 m²
Year of completion	2024
Partners	**Client:** Zayaz Housing Corporation **Architect:** Superuse Studios **Construction:** Versteegden construction company **Partners:** Transfarmers, VanNimwegen
Website	Boschgaard website

The Collective Ecosystem Boschgaard is a residential project that combines circular construction, self-employment, and an innovative business model. The project transformed a former community centre into 19 collective living units, prioritising circular construction and utilising residual materials harvested from the project site and its surroundings. The project was initiated entirely by local residents, who took responsibility for its realisation from start to finish, with the financing of Zayaz, a local social housing corporation. They developed the concept, participated in the construction, and oversaw the project's execution. After construction completion, they took on the management of existing operations, establishing a collective self-management ecosystem.

R-Strategies

- Rethink
- Reuse

Site plan of the Boschgaard residential complex (Source: Superuse from Boschgaard website)

R-Strategies in action

Boschgaard is pioneering multiple fields through its innovative ownership model and an ambitious circular economy and sustainability approach. The houses within the residential complex were built according to standards that **rethink** the building's structure to prioritise sufficiency and sharing models over individual ownership. They are relatively small and emphasise functionality, efficiency and sustainability, resembling a 'tiny house' concept. They feature various shared spaces, allowing residents to access communal facilities like living rooms, a large kitchen, and a shared bathroom. The buildings are also designed for high energy sufficiency while providing space for urban agriculture and other similar activities that contribute to increasing the residential complex's sufficiency and sustainability.

Boschgaard is one of the Netherlands' first social housing projects prioritising **reuse**. Achieving a high reuse rate was a key objective of Boschgaard's design and construction processes. Priority was given to materials sourced from demolition and renovation projects in the surrounding area. Additionally, the structure, foundation, and certain elements of the previously existing community centre were reused in the new structure. When reused materials were unavailable, more sustainable alternatives were prioritised over traditional carbon-intensive options. For example, the foundation of the building features a wooden frame and plastering using clay. Despite facing challenges such as securing materials from other projects and limited storage space, which led to adjustments in design and planning, the project successfully achieved 84% material reuse, falling short of the original 90% goal.

What impacts were achieved?

The project's environmental goals included minimising impacts on natural ecosystems and reducing GHG emissions during the residential complex's construction and operation. Besides the lower embodied carbon associated with the selection of reused materials, the buildings are designed for minimal energy consumption. High energy efficiency is achieved through renewable energy production systems and passive energy measures. To this end, these measures lead to an estimated 70% reduction in CO_2 emissions compared to the current construction standard in the Netherlands. The building's green roofs and outdoor spaces (such as green façades) were also designed to positively influence local biodiversity by supporting plant growth and providing habitats for birds and insects.

In Boschgaard's case, circular economy measures resulted in substantial savings via reduced negative externalities. By using secondary materials instead of new products, Superuse estimated a savings of €700,000 in future environmental damage—around 20% of the total construction cost—through reductions in resource extraction, energy and transport costs. However, while the cost savings from material choices were substantial, the project's success was also attributable to the resident's active involvement in harvesting materials and participating in the building and supervision of the project. Their contribution made it possible to reduce overall costs and complete the project within the budget for social housing.

The Boschgaard is one of the first housing cooperatives in the Netherlands to operate through self-organisation and active resident participation in communal matters. Initially, the old community centre on the site was occupied by squatters. While the initial plan was to demolish the building, the project team adopted a socially conscious approach and decided on a different solution. The revised plan incorporated the foundation of the old structure into a new design, adding small studios and social spaces to be managed collaboratively by the residents. In Boschgaard, residents actively engage in decision-making, share responsibilities for the complex's development, and contribute to communal well-being.

This culture of sharing extends to the use of resources, including communal facilities and appliances like cars, tools, and washing machines. By fostering a sense of community and emphasising sufficiency, the cooperative aims to reduce costs and enhance its members' overall quality of life. The project's social impact extends beyond its residents and benefits the broader community. The entire outer shell of the building is dedicated to social activities, including workshops and events that foster community engagement. Additionally, lessons learned from the construction and management of the project are shared through different knowledge-sharing initiatives like tours. Hence, both the building and its residents' lifestyles help to inspire further efforts toward circular and sustainable living.

Boschgaard residents participating and taking on construction roles (Source: [Boschgaard website])

Managing the sourcing and storage of secondary materials

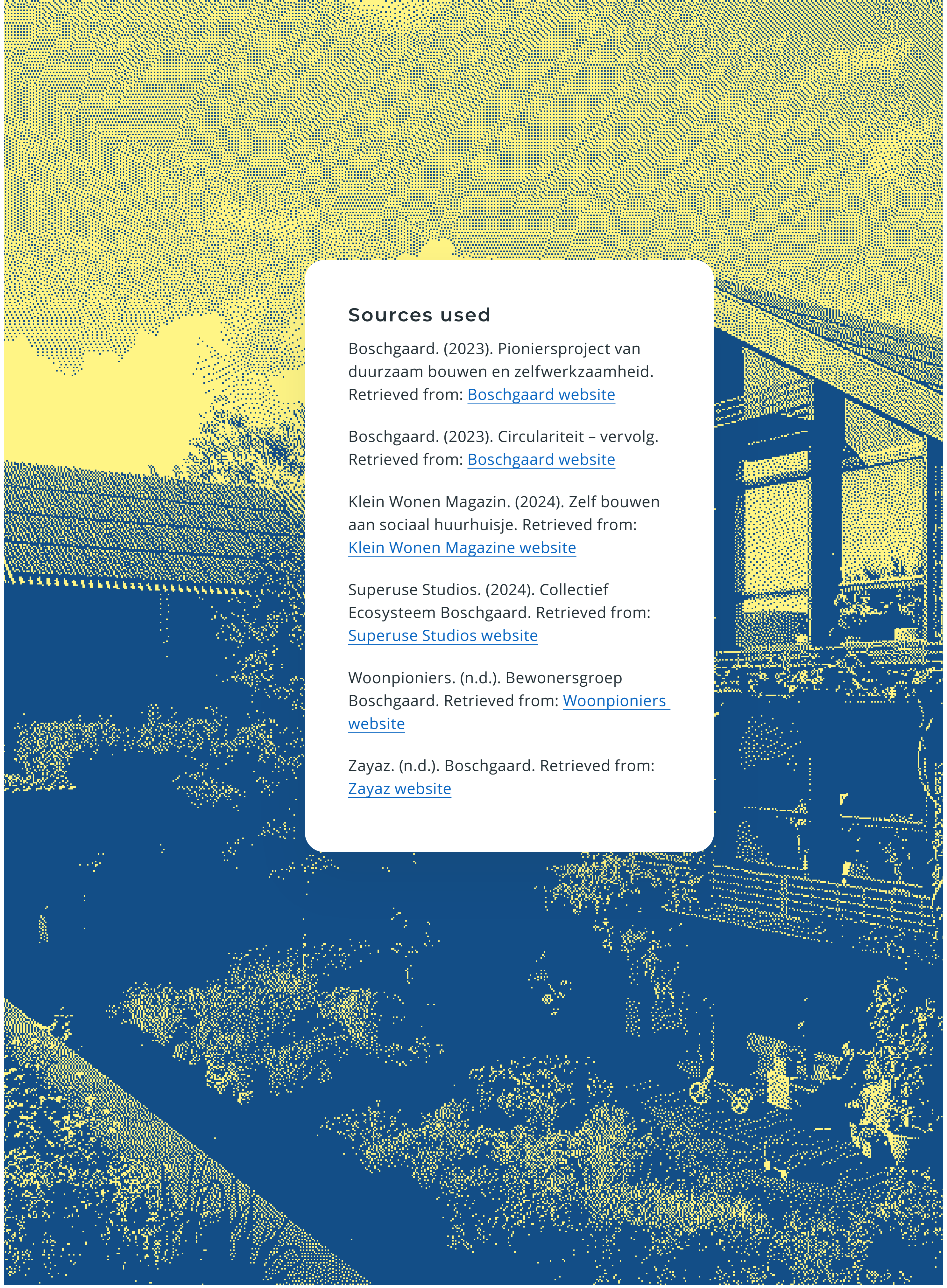
Building with and depending on secondary materials is challenging for construction projects. Ultimately, 84% of the materials used in the Boschgaard were reused, which is a significant achievement. However, the challenges faced during the project prevented it from reaching its initially set goal of 90%. In the case of the Boschgaard, a key challenge during the redevelopment process was securing the necessary materials to meet construction needs. This influenced the construction schedule since work often depended on the availability of resources from other projects, such as demolition works.

Another major obstacle was the need for storage. Secondary materials had to be stored at the construction site until needed since there are no dedicated public facilities for this purpose. Finding adequate space for on-site storage proved difficult, given both the costs and limited availability of space close to the construction site. The project team rented a warehouse to address this, but more was needed to meet all storage needs. This forced them to forgo some functional materials and alternate the design or planning multiple times due to space constraints.

An innovative ownership model fostering collaboration and sustainable lifestyles

Boschgaard's innovative ownership model empowered residents to take a hands-on role, sharing responsibilities and actively participating in all project stages, from planning and construction to ongoing management. Their involvement was pivotal to the project's success, yielding significant benefits like cost savings and fostering a collaborative spirit that strengthened shared ownership and commitment to common values. The residents' dedication to sustainability and circularity shaped key decisions, contributing to achieving a remarkable reuse rate and enhancing the project's environmental impact. Post-completion, these principles have been woven into everyday life through initiatives promoting sustainable and circular lifestyles, such as shared resources and services, establishing a long-term culture of environmental responsibility and community engagement.

Boschgaard's redevelopment of the old community centre into a residential complex and new community hub demonstrates the power of resident-driven projects to inspire broader change. This pioneering initiative sets an example in social housing, not only for its innovative use of sustainable construction and reuse but also for its model of tenant self-management, proving that such projects can achieve meaningful environmental and social impact.



Sources used

Boschgaard. (2023). Pioniersproject van duurzaam bouwen en zelfwerkzaamheid. Retrieved from: Boschgaard website

Boschgaard. (2023). Circulariteit – vervolg. Retrieved from: Boschgaard website

Klein Wonen Magazin. (2024). Zelf bouwen aan sociaal huurhuisje. Retrieved from: Klein Wonen Magazine website

Superuse Studios. (2024). Collectief Ecosysteem Boschgaard. Retrieved from: Superuse Studios website

Woonpioniers. (n.d.). Bewonersgroep Boschgaard. Retrieved from: Woonpioniers website

Zayaz. (n.d.). Boschgaard. Retrieved from: Zayaz website

BlueCity: Repurposing a water park into a circular model city

KEY FACTS AND MESSAGES

- The project **achieved a very high level of material reuse** (90%).
- **Maximising circularity in material use** posed challenges with certification. SUPERUSE addressed these by **leveraging its adaptive and creative construction process** to manage the unpredictable availability of materials.
- The construction followed the **unconventional process of SUPERUSE**, which does not follow a blueprint but rather **creates a concept of what they want to achieve**, scouts materials, verifies these for use, and finds ways to incorporate these into the build on an interactive loop.

Location	Rotterdam, Netherlands
Project description	A former tropical waterpark turned into a circular model business hub
Size	12,000 m²
Year of completion	Partially completed in 2020 (ongoing project)
Partners	**Architect:** Superuse studios **Advisory firm:** COUP **Client:** BlueCity
Prizes & recognition	Most Sustainable Real Estate Project (2020) and the Daan Dura Prize (2022)
Website	[Superuse studios website]

Formerly a tropical water park, BlueCity in Rotterdam has been reimagined and adapted as a pioneering circular business hub, housing innovative startups committed to building a sustainable future. This project aims for businesses to operate in closed loops, where the waste from one becomes a valuable resource for another, creating a self-sustaining ecosystem. The renovation project was recognised with the Most Sustainable Real Estate Project award in 2020 and the Daan Dura Prize in 2022.

R-Strategies

- Rethink
- Reuse
- Repurpose

Before and after image of the tropical swimming pool dome (Source: Denis Guzzo, Stadsarchief Rotterdam and SuperUse Studios)

R-Strategies in action

The BlueCity renovation project showcases the practical application of circular economy principles. Combining strategies focused on reusing materials, reducing reliance on virgin resources, and integrating renewable energy solutions provides a blueprint for sustainable and adaptive building reuse.

The project's core idea was to **repurpose** and transform the former Tropicana water park, preserving an iconic structure and preventing unnecessary demolition waste. A key part of this was to **rethink** how the different spaces and materials of the former water park could be given a new function. For example, the 'engine room' of the pool, where pumps and other machinery used to be installed, was renovated and opened up to host the different pieces of equipment of a local beer brewery. Concrete blocks that had been sawed and removed from the original building to create these openings were then repurposed in different parts of the building as new partition walls.

The project also minimised using virgin materials by prioritising locally sourced, **reused** interior building elements, such as salvaged windows, lamps, cable ducts, and repurposed balustrades from a decommissioned oil platform. For instance, an entire circular office wing was built where the old disco once stood, using 90% reclaimed materials. This approach also reduced demolition waste in other sites. Since the reclaimed materials did not always fit the new space's shape, they influenced the final design, as seen in the unique angles of office windows salvaged from a hospital in Maastricht, now part of the new office wing.

What impacts were achieved?

The Bluecity project successfully implemented circular economy strategies, delivering significant environmental, economic, and social benefits. By applying circular strategies to the renovation, the project achieved remarkable environmental gains: reducing CO_2 emissions by 68% (112,000 kilograms) compared to standard office renovations. The project team further reduced the building's environmental impact by leveraging its natural climatological properties, as it was originally designed to function as a tropical environment, reducing the need for new installations. Additionally, solar panels were incorporated to power the Lab within BlueCity. With 90% circularity in material use, the project sets a new benchmark for low-impact circular architecture through innovative reuse and sustainable practices.

Beyond the building itself, BlueCity aims to put the circular economy into practice by turning this building into a hub where businesses link their residual flows, turning waste into resources. Now home to over 30 circular startups, it serves as a living lab for testing circular solutions, inspiring collective efforts to minimise waste and prioritise environmental responsibility. BlueCity also fosters social engagement through workshops, events, and educational programmes in partnership with Hogeschool Rotterdam, empowering the community to adopt sustainable practices.

Reused interior windows and window frames, showing the different angles used to fit the elements in the office spaces (Source: SuperUse Studios)

Breaking barriers in circular construction

This project's commitment to rely primarily on reused materials presented different challenges, requiring SUPERUSE to adopt a flexible, adaptive construction process rather than following traditional blueprints. One major hurdle was finding experts and craftsmen willing to adapt to this unconventional approach and using secondary materials depending on their availability. Repurposing materials safely and practically requires a careful balance of expertise and the willingness to innovate. Unfortunately, this sometimes meant that certain materials that had been demolished from the original building structure could not be incorporated. For instance, obtaining fire safety approval for compound materials proved difficult; the cross-laminated timber (CLT) intended for fire-rated indoor walls couldn't meet the necessary standards. As a result, new virgin materials had to replace the CLT, which had to be sold. Storage constraints further complicated these processes, as storing materials on-site became impractical due to the limited space.

Adaptive and creative construction: Prioritising reuse in an iconic landmark

Working with this iconic Rotterdam landmark required the architects to embrace adaptability and creativity, breaking from conventional and standardised building methods. The process began with developing a vision for what the building would become, followed by meticulous research to identify materials already within the existing structure and nearby demolition sites.

After assessing the condition, usability, and quantity of reclaimed materials, the architects adjusted their design to accommodate these salvaged materials, often rethinking layouts, shapes and dimensions of structural elements as well as interior fittings. Once this analysis was completed, demolition became a carefully orchestrated process focused on preserving as many materials as possible for reuse. This unconventional method required flexibility and high-level craftsmanship to integrate diverse reclaimed elements into a cohesive and functional structure. The successful implementation of these different steps demonstrates the commitment to sustainable building practices and how iconic buildings can be transformed while preserving their heritage and minimising their environmental impact.

Sources used

Cao, Y. (2022). Urban resilience building for sea-level-rise adaptation and what is the relationship between resilience and sustainable development? Case studies of Rotterdam, the Netherlands and Yokohama, Japan. JUNCO | Journal of UNiversities and International Development Cooperation, V. 2 N. 2, Trento. doi.org/10.13135/2531-8772/6467

BlueCity. (n.d.). Construction file. Retrieved 5 November 2024, from BlueCity website

Rotterdam Make it Happen. (n.d.). First circular built biolab in the world opens in former tropical swimming pool. Retrieved 5 November 2024, from Rotterdam. Make it Happen. website

Deep circular renovation of a nineteenth-century Corte Palazzo

KEY FACTS AND MESSAGES

- The project **effectively applied multiple R-strategies** to increase the building's energy efficiency, leading to a **70% reduction in primary energy consumption** and **90% reduction in CO_2 emissions**, while saving on virgin material consumption and minimising demolition waste.
- The project demonstrates the possibility of renovating and modernising historic heritage buildings **using the EASY impact assessment framework**.
- The project **transformed an abandoned estate into inclusive housing for disabled individuals and disadvantaged families**, showcasing how **circular renovation practices** can drive social inclusion while preserving heritage and fostering community-driven renewal.

Location	Argelato, Italy
Project description	Villa converted into a multi-user residence for individuals with psychophysical disabilities
Size	563 m²
Year of completion	2023
Partners	**Architect:** Studio di Architettura ED Ingegneria Associato **Contractors and engineers:** ALIVA, Mirko Cioni, Habitat Plus **Client:** the private foundation Fondazione Carisbo **Collaborators:** Metropolitan City of Bologna, the Municipality of Argelato
Website	Borgo Digani website

The Corte Palazzo project, part of the Drive 0 initiative on developing deep circular renovations, involves the circular renovation of a historic villa within the 'Borgo Digani' complex in Argelato, Bologna. This project aims to restore the villa into a multi-user residence for individuals with psychophysical disabilities. Managed by a consortium of social cooperatives, Borgo Digani illustrates a case of circular renovation and stresses the potential of public-private partnerships in creating innovative, inclusive spaces that foster generative bonds and lasting community value. The renovation was completed with an investment of €4 million.

R-Strategies

- Reduce
- Reuse
- Repair

Before and after image of the renovation (Source: Drive0)

R-Strategies in action

The Corte Palazzo renovation integrated multiple R-strategies using the EASY framework, a decision-making tool designed to enhance circularity. The building's existing materials were evaluated based on three core parameters: Design for Disassembly (DfD), Materials' Origin (MO), and Reusability (RU). These parameters provided a comprehensive assessment of the building's circularity potential. The **rethink** strategy was applied through the use of prefabricated Plug&Play façade panels, which simplify installation and removal, enabling future **reuse** and minimising construction waste while fulfilling their improved insulation purpose. The project also embraced **refuse** by avoiding unnecessary material use and prioritising adaptable design solutions. **Reduce** was addressed by selecting **low-impact materials** with a lower environmental footprint, while reuse was maximised by retaining and repurposing existing building components. For instance, after the roof was rebuilt using a technique similar to the original, 90% of the original ceramic tiles were reinstalled to preserve the building's historical heritage.

The **repair** and **refurbish** strategies ensured that functional materials were restored and reintegrated instead of being discarded. Structural reinforcements were conducted on the building's load-bearing walls, foundations, and roof, ensuring improved safety and durability. Where direct reuse was not possible, the project applied **repurpose** by finding new functions for salvaged materials and **recycling** by reintegrating waste into new construction processes. Circularity improvements were quantified using the Building Circularity Indicator (BCI), demonstrating the measurable impact of these strategies.

What impacts were achieved?

The renovation of Corte Palazzo leveraged circular renovation techniques, showing how preserving historic integrity can align with modern objectives such as creating lasting value for the community, industry, and the environment.

The main objective of this renovation was to increase the building's poor energy performance by pursuing a circular approach. This was realised through a combination of high-performance modular insulation, advanced energy systems, and the integration of a photovoltaic system, which now supplies 70% of the villa's annual energy needs. Upon completion, the project achieved a 70% reduction in primary energy consumption (equivalent to 0.070 gigawatt-hour savings annually), which translates into a 90% decrease in CO_2 emissions from the building's use phase (compared to pre-renovation emissions), saving approximately 26 tonnes of CO_2e every year. This demonstrates how circular practices such as energy retrofitting and renewable energy integration can significantly lower a building's environmental footprint.

The renovation of Corte Palazzo also highlights the economic benefits of applying circular principles in construction. By using reused and refurbished materials, the project reduced renovation costs while ensuring the long-term durability of the building. Moreover, the use of existing materials and other locally sourced components minimised procurement costs and waste disposal expenses. This approach demonstrates how circularity can offer financial savings while ensuring the building remains sustainable for future generations.

The project's social impact was also significant, transforming an abandoned estate into a functional space for inclusive housing. The building was repurposed to provide housing for disabled individuals and disadvantaged families, showcasing how adaptive reuse can serve as a tool for social inclusion. The renovation also fostered collaboration among architects, conservationists, and sustainability experts, setting a precedent for future projects that aim to balance cultural heritage preservation with environmental and social sustainability. The integration of circularity in the design process not only preserved the historical essence of the villa but also gave it new life as a vital part of the community.

Balancing energy efficiency and cultural preservation

The project's challenges created several unique opportunities for innovation and sustainable design in a historical context. The regulatory constraints and the need to preserve authenticity led the project team to consider traditional materials and construction methods, blending historical preservation with environmental responsibility. Additionally, adapting prefabricated Plug&Play components to fit the historic structure's dimensions required precision, prompting the development of custom solutions that could serve as a model for integrating modular systems in other heritage buildings. Similarly, balancing circularity goals with budget limitations led to a strategic prioritisation of interventions, focusing on high-impact, cost-effective solutions that maximise social and environmental benefits.

This experience strengthened collaboration among designers, architects, and conservationists, creating a replicable model for future heritage renovations that aim to achieve both sustainability and cultural preservation. Additionally, some of the more technical challenges, like thermal insulation and building-integrated photovoltaics (BIPVs), provided valuable insights into integrating modern energy systems into older structures.

Simplifying circularity assessments in historic renovations: The EASY framework

The EASY framework proved effective in the Corte Palazzo renovation, working within both regulatory constraints and cultural preservation requirements. In the project, the EASY framework proved to be a valuable decision-making tool for assessing the material and design choices of the renovation project. The Design for Disassembly (DfD), Materials' Origin (MO), and Reusability (RU) parameters provided a comprehensive picture of the building's circularity potential, helping to prioritise interventions that would maximise environmental benefits. Calculating the Building Circularity Indicator (BCI) allowed stakeholders to measure the circularity of the building before and after renovation, emphasising the impact of renovation strategies and offering a tangible metric for success.

The straightforward approach simplifies circularity assessments by focusing on key indicators (such as material durability, reusability, and embodied carbon), making it accessible to all stakeholders, without requiring technical expertise or complex data collection. By establishing achievable goals and practical insights, the framework serves as a model for integrating sustainability into historic building renovations.

Sources used

Borgo Digani. (n.d.). Borgo Digani, Chi siamo. Retrieved 20 November 2024, from Borgo Digani website

Drive 0. (n.d.). Case 4: Villa within the new "Borgo Digani" building complex, Argelato, Bologna. Retrieved 22 November 2024, from Drive 0 website

Knubben, C. (2023, December 12). Inaugural ceremony of Borgo Digani, the Drive 0 Italian pilot building. Retrieved 22 November 2024, from Drive 0 website

Mazzoli, C., Corticelli, R., Dragonetti, L., Ferrante, A., Van Oorschot, J., & Ritzen, M. (2022). Assessing and Developing Circular Deep Renovation Interventions towards Decarbonisation: The Italian Pilot Case of "Corte Palazzo" in Argelato. *Sustainability, 14*(20), 13150. doi.org/10.3390/su142013150

Mazzoli, C., Benedetti, A. C., Costantino, C., & Ferrante, A. (2024). Life cycle impact analysis of different intervention scenarios for regenerating the existing building heritage. The case study of the new "borgo digani" in Argelato, Bologna. *Lecture Notes in Civil Engineering*, 537–555. doi:10.1007/978-3-031-71867-0_36

NEW BUILDS

Cradle-to-cradle construction of Venlo's new city hall

KEY FACTS AND MESSAGES

- C2C implemented principles guarantee that **the new City Hall materials will be reused or recycled**.
- The building's design and implemented strategies **led to important environmental benefits** for the wider area, **reduced costs during the use phase** and a positive return flow from year one.
- The development of **material passports** to record all used building components and ensure future reuse was emphasised. This allowed the building to function as a **material bank**.

With the new city hall, the city council wanted to lead by example and inspire more C2C and circular construction within the city. However, the project's goals went beyond circularity to also contribute to the regeneration of the surrounding area while enhancing the well-being of the people using the building and achieving long-term cost savings. The city hall met these targets and is now a state-of-the-art, energy-neutral, waste-free building equipped with rainwater and wastewater management systems and a 'green lung' façade that filters air pollution coming from the adjacent motorway.

Location	Venlo, Netherlands
Project description	New City Hall for the city of Venlo
Size	27,700 m²
Year of completion	2016
Partners	**Client:** Municipality of Venlo **Architect:** Kraaijvanger **Construction:** Laudy Construction and Development **Partners:** Veldhoen & Company, WSM Constructeurs, Heythuysen, the Royal Haskoning in Nijmegen, BBN and Houten
Prizes & recognition	As a result of the project's innovative approach and the cradle-to-cradle (C2C) integration, the new City Hall is an Architzer A+ Award-winning design and has won several other architectural awards.
Website	[Kraaijvanger website]

R-Strategies

- Refuse
- Rethink
- Reuse
- Recycle

Front view of the city hall showcasing its green façade and interior gardens. The constructed wetland filters and recycles water, including rainwater and sink water, for use in the green façade and flushing toilets (Source: Ronald Tilleman from The Plan website)

R-Strategies in action

The design of the new city hall is based on the Cradle-to-Cradle (C2C) principle, therefore focusing on creating an adaptable, dismantlable building using materials that can either be recovered and reused or safely returned to nature.

At the core of the construction project was the idea of **refusing** non-renewable and non-recyclable materials. Materials that lacked transparency or could hinder the future **reuse** and **recycling** of other resources were also avoided from the outset (for example, certain types of glues, paints, and sealants). Because of this selective approach, stakeholders were constantly challenged during the design phase to identify the best material choices and achieve high circularity. In some cases, the project team was able to come up with innovative products that were better than those described in the project's material specifications. Multiple suppliers were also contacted early on during this phase so that they could get their C2C certification in time. In cases when cradle-to-cradle materials were not available, low-impact materials alternatives were selected. For example, C2C-certified concrete was not yet available during the building's design phase. Instead, a mix containing 60–70% **recycled** concrete aggregate was chosen, as concrete remained the only viable option for a structure of this scale.

Venlo's City Hall showcases how C2C design can extend the lifetime of materials. Going beyond this, the new city hall design is **rethinking** the building's use and role itself. Principles like flexibility and adaptability were incorporated, allowing the spaces to serve multiple purposes and enabling the structure to adjust to evolving needs over time. In addition to serving as the city's council hall, the design choices enhance the overall environmental quality of the building and the surrounding area. For example, a 200 square metre interior green façade helps purify the air in workspaces, and the exterior green façade provides environmental benefits for the wider area.

During construction, materials were treated in a way that does not compromise their ability to be reused or recycled in the future. Natural assembly and treatment methods were prioritised to allow materials like wooden structures to be safely **reused** in the future by avoiding contamination from chemicals or residues. For example, wooden walls are not glued or screwed together but rather secured with wooden pegs to avoid leaving metal parts or glue residue in the wood after dismantling. The wooden ceiling has been treated with vinegar, making it fully reusable, unlike impregnated hardwood, which can retain toxic substances. Additionally, emphasis was placed on using processes and constructing structures to enable materials to be recycled or upcycled rather than downcycled. For instance, the concrete walls were left bare without plaster or cement coatings, simplifying future **recycling** efforts.

What impacts were achieved?

C2C implemented principles guarantee that the materials used in the new city hall will be either reused or recycled, avoiding future waste generation and raw material consumption. Additionally, the city hall is energy-neutral and designed to be connected to natural systems. For example, a rainwater capture system minimises its draw on water resources while enhancing ecosystem services in an area that is in need of regeneration. The building's green façade is the largest in the world and supports biodiversity comprising over 100 plant species while providing habitats for several birds and insects. It also plays an important role in reducing pollution from traffic and purifies outdoor air in a radius of 500 metres surrounding the building by absorbing 30% of sulphur and nitrogen oxides while offsetting the emissions of particulate matter from local traffic.

The entire project was carried out with the underlying goal of improving the well-being of both city hall users and the wider community. The open house concept allows both employees and the public to work in the building, benefiting from a design approach that prioritises well-being and high environmental quality. It has been designed to offer a variety of spaces, including 630 flexible workspaces and meeting rooms. The air quality inside the building is purer than outside. Urban services like public space, including a cafe, a theatre and a large garden, further increase the building's added social value. Additionally, during the design and construction phases, Kraaijvanger devoted considerable resources to knowledge sharing among partners and getting more stakeholders involved in the process to increase their expertise and inspire more C2C construction.

All this was achieved while proving that circular construction has economic value. The initial allocated project investment was €53 million, but through the implemented strategies—reusable material choices and design for disassembly—a part of the original investment will be recouped in the future. The building's material residual value of 5% translates to an annual savings of approximately €175,000. However, it is estimated that the actual value could be even higher. Arrangements like 'product-as-a-service' or 'buy and buy-back' for furniture further increase economic returns. Overall, the financial impact of the circular strategies and sustainability measures integrated into the project is estimated at an 11.5% rate of return on investment in the first 40 years, which adds up to €16.8 million. The return is significant considering that the original cost of the selected measures equals approximately €3.4 million.

Leveraging material passports: The city hall as a material bank

The project catalysed advancements in C2C practices, with several suppliers achieving C2C certifications for their products. During the design and construction of the city hall, significant emphasis was placed on developing material passports to record what goes into the building and ensure future reuse and recyclability. Each building element is documented in a digital record, detailing its material composition, properties, and disassembly instructions for recycling or return to the manufacturer. This approach maximises the lifecycle value of materials, extending their lifetime and reducing waste while allowing the recoupment of a proportion of the initial investment. By logging the residual material value of each material, the city hall functions as a 'material bank'. In other words, the city hall serves as a temporary repository of materials, with various components retaining measurable financial and material worth for future reuse. This approach supports a viable circular economy model for the construction sector and incentivises contractors and manufacturers to innovate and adopt a life cycle-oriented material design approach.

Sources used

ARQA. (2018). City Hall Venlo. Retrieved from: Arqa website

Circular X. (2021). Case Study: City Hall Venlo. Retrieved from: Circular X website

C2C Expolab. (n.d.). Stadskantoor Venlo. Retrieved from: C2C Expolab website

Ellen Macarthur Foundation. (2021). City Hall from Cradle to Cradle: Venlo. Retrieved from: Ellen Macarthur Foundation website

Kraaijvanger. (n.d.). Municipal Office Venlo. Retrieved from: Kraaijvanger website

The Plan. (2017). City Hall Venlo: Kraaijvanger Architects. Retrieved from: The Plan website

Recyclinghaus am Kronsberg: Exploring the potential of comprehensive circular design

KEY FACTS AND MESSAGES

- The project result is a fully **decomposable** and **recyclable** residential building consisting mostly of **reused** and **recycled** materials.
- **Finding** suitable secondary materials, **testing** their compatibility, and **planning** their installation proved more time-consuming and costly than traditional practices. The **lack of documentation** regarding secondary materials contributed to these issues.
- Standard processes, such as the **design phase**, had to be modified based on material availability and other factors, such as storage space or regulatory compliance.

The Recycling House is an innovative pilot residential building, recognised as a first-of-its-kind approach in Germany at the time. This research project aimed to construct a house entirely using 100% secondary materials. This aspirational target explores the possibilities of maximising the use of various circular methods, investigating their potential to minimise CO_2 emissions and resource consumption in the high-impact construction sector. Completed in 2019, the building revealed many successful applications of circular methods and achieved substantial environmental benefits (all highlighted in the following sections). While initially conceived as an experimental project, it is now being used for residential purposes by a family.

Location	Hanover, Germany
Project description	Residential building from recycled materials
Size	274 m² in total and 150 m² of living space
Year of completion	2019
Partners	**Client:** Gundlach GmbH & Co **Architect:** Cityförster Architekten **Construction:** Gundlach GmbH & Co
Prizes & recognition	The project has gained significant recognition. It won the Special Prize for Sustainability at the German Façade Prize in 2020, the Innovation Prize 2021 in the 'Sustainability' category from the real estate association BFW, and has been nominated for several other awards.
Website	Gundlach website

R-Strategies

- Refuse
- Rethink
- Reuse
- Recycle

Exterior view of the Recycling House featuring the striking greenish-blue glass façade on the lower floors that was previously part of a paint shop and the jet-black fibre cement panels, previously decorating a recreation centre (Source: Gundlach website)

R-Strategies in action

The Recycling House project is a prototype designed to research and test various circular strategies for reducing environmental impacts during construction. A key first step was **rethinking** the entire material selection process and use, designing elements for disassembly, and incorporating different types of secondary materials that could be reused at their end-of-life.

The building also incorporates reused or recycled materials to the greatest extent possible. Gundlach played a crucial role in sourcing **reused** materials from their own building stock, as well as from local demolition and renovation projects. These included corrugated iron sheets, window elements, and several wooden and steel components. Bricks and concrete salvaged from old buildings were collected, **refurbished** by giving them a new coating, and incorporated back into the new building. A standout example is the building's façade, 90% of which is cladding made with four different reused materials, all sourced locally from Gundlach's demolition and conversion projects, which then were reformatted and coated in jet black before being added in the façade panels.

Different **recycling** methods were also tested during the project, reducing the share of raw materials in the construction process. Specifically, the building's foundation was made of 42% recycled concrete, considerably higher than average recycled concrete aggregates used for structural purposes (20–30%). Other recycled materials included wall insulation material crafted from jute cocoa bean bags. Overall, more than half of the materials used in the building's interior came from recycled sources.

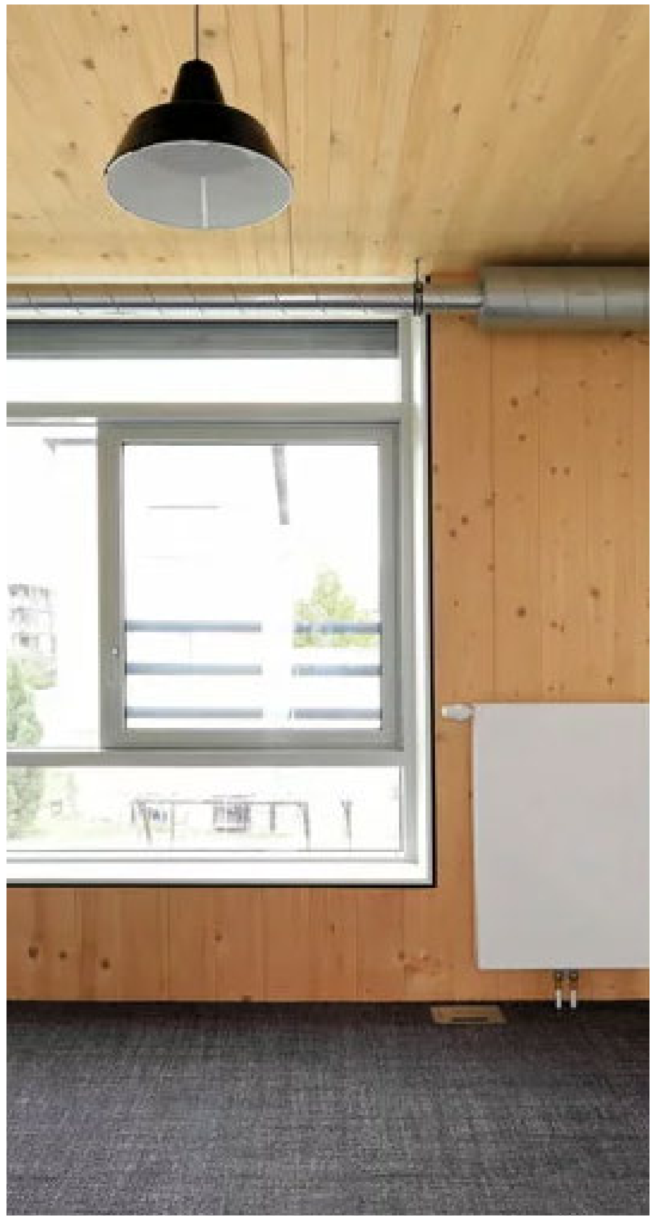
Beyond incorporating as many secondary materials as possible through the strategies mentioned above, the Recycling House also ensures material choices and construction methods allow for future **reusability** and **recyclability**, considering criteria like ease of disassembly and the retention of material value. For instance, copper heating pipes were integrated, exposed and mounted on the walls to facilitate easy future removal and reuse. Additionally, certain materials like glue were intentionally avoided to ensure that chemical substances would not compromise the value retention of materials and structures like the solid wood elements.

What impacts were achieved?

Different choices in the selection and assembly of materials in the Recycling House significantly reduced the demand for raw materials while lowering the building's embodied carbon emissions. For example, the choice of renewable materials, such as the wooden elements, in the structure sequestered approximately 100 tonnes of CO_2e during their lifetime. Similarly, other design strategies, including avoiding polluting substances and adhesives, ensure the future reuse of different building components (including wooden structures). Additionally, sourcing materials from local demolition and renovation sites reduced large volumes of construction and demolition waste while minimising the emissions generated during production, transport, and storage of components by keeping the supply chain local. The design of the building also took into account its operational phase: the house meets low-energy standards and requires less energy for daily use compared to similar-sized buildings.

Due to the project's experimental nature, the Recycling House incurred higher costs than conventional projects in the region, reaching approximately €6,000 per square metre of living space (compared to €3,646 for apartments and €4,913 for houses). This elevated cost can be attributed to different factors. For example, the research and planning before the start of construction works was extensive, demanding a comprehensive and, therefore, resource- and time-intensive preparation phase. Additional factors include sourcing reused materials and the manual labour embedded into repair and installation, which added to the project's costs. However, the project proved to be a successful pilot and is now in use, showcasing a potential commercial approach to sustainable circular construction from reused and recycled materials.

Interior spaces of the Recycling House built using reused materials, including bricks salvaged from an old farmhouse and walls used in exhibition constructions (Soure: Gundlach website)



Addressing material scarcity and documentation gaps

The building served as a research project and a prototype, partly explaining the challenges faced during its design and construction. Finding and testing suitable materials while planning their installation proved time-consuming and expensive. Overall, the project's planning and research spanned two and a half years. Because standardised parts were scarce and the team committed to using local materials from the Hanover region, they had to secure materials early and adapt their plans accordingly. Uncertainty about material availability also forced modifications to standard processes. For example, since Kronsberg regulations require triple-glazed windows and suitable second-hand options were unavailable, Gundlach had to adapt the reused window frames they collected to meet these requirements. Additionally, the process of removing materials for reuse in the Recycling House was significantly more expensive than simply demolishing a building, further contributing to the project's high costs.

Another key challenge the team faced was that many recycled materials lacked proper documentation, requiring extra work to gather information about each component, with one exception. They found a convenient solution for the building's façades: hiring the same contractor who had installed them at their original site in 2007 to handle both the dismantling and reassembly. This contractor still had the original work plans and component information, making it much easier to incorporate these materials into the new design. This example also illustrates the importance of properly documenting the choice of building parts and the particular relevance this holds in the context of circular construction.

The importance of optimising material procurement and storage for circular construction projects

While not achieving the aspirational (and perhaps impossible) objective of reaching 100% circularity, the project successfully delivered a dismantlable and recyclable residential building predominantly made of reused and recycled materials. As a prototype, it proved that this approach can be effectively integrated into building design, both from a technical and aesthetic perspective, providing useful insights and learning about circular techniques.

The project showed that securing secondary materials at early stages is essential to control costs and avoid complications. Designing based on the resources available in the region differs from the conventional practice of procuring materials based on the building's design. The Cityförster team conducted pioneering methods for sourcing secondary materials, adapting their design to the available resources and finding alternatives to unavailable parts. This approach delivered significant environmental benefits and increased the circularity of the building without compromising its attractiveness or functionality, proving that multiple avenues exist for obtaining secondary resources that meet standards for new constructions.

The project also highlighted the critical need for adequate storage space to preserve materials until use. Because securing enough space is challenging for construction projects, public authorities can play a crucial role in supporting circular practices by establishing facilities for secondary material storage and handling (such as material banks). This type of infrastructure will become increasingly important as circular construction projects become more common and sustainability and circularity criteria become more standardised.

Sources used

Deutsches Architektenblatt. (2020). *Recycling house in Hanover by Cityförster.* Retrieved from: Dab website

Gundlach. (n.d.). *Germany's first recycling house at Kronsberg*. Retrieved from: Gundlach website

CityForster. (n.d.). *Recyclinghaus, Hannover*. Retrieved from: Cityforster website

Circular Buildings Toolkit. (n.d.). *Recyclinghaus am Kronsberg: Hanover, Germany*. Retrieved from: CE-toolkit website

Cradle Magazin. (n.d.). *Recyclinghaus: ein preisgekröntes Wohnprojekt*. Retrieved from: Cradle-mag website

Properstar. (2024). *Hanover: housing price and price/m²*. Retrieved from: Properstar website

The World Business Council for Sustainable Development (WBCSDI. (2009). *The Cement Sustainability Initiative: Recycling Concrete*. Retrieved from: WBSCD website

Triodos Bank Head Office: Timber-based headquarters built as a material bank

KEY FACTS AND MESSAGES

- The headquarters was **one of the first large-scale buildings made predominantly with wood and timber** and **designed for disassembly**, featuring a comprehensive **material passport system**. This allows the building to be energy-positive (storing 1,633 tonnes of CO_2 during the lifetime of the building) but also fully demountable for future uses.
- The project **overcame challenges in obtaining and managing Industry Foundation Classes (IFC)** files through a systematic, trial-and-error approach, creating a 'material passport' via the **Madaster platform**.
- The **reversible design** of the Triodos Bank office enables it to function as a **material bank**, ensuring **building materials remain a valuable asset over time**, a key feature to **increase material resilience** in the construction industry in the face of resource scarcity.

Location	Driebergen-Rijsenburg, The Netherlands
Project description	Timber-based Bank Head Office
Size	12,500 m²
Year of completion	2019
Partners	**Client:** Triodos Bank Architect: RAU Architecten **Construction:** Aronsohn and J.P. van Eesteren **Interior design:** Ex Interiors Consultants: Deerns, DGMR, BBN **Landscape architects:** Arcadis
Prizes & recognition	The building achieved the BREEAM Outstanding certification, earning a score of 94%.
Website	Rau Architecten website

Triodos Bank's new office is located on the De Reehorst Estate in Zeist, a protected natural area in the Netherlands. Beyond reducing the building's environmental impact, this structure was designed to foster a regenerative relationship with its surrounding environment. The architects incorporated natural design elements inspired by biomimicry and circularity principles. Designed as a material bank, the structure can be fully disassembled and repurposed at the end of its lifecycle.

R-Strategies

- Refuse
- Rethink
- Reuse
- Recycle

The building is located over a previously built-up surface in a natural protected area (Source: Ossip van Duivenbode)

R-Strategies in action

The guiding principle for this building was to minimise environmental impact and ensure it is built for disassembly. It was designed as a 'temporary material bank', where every material used is meticulously documented on a digital tracking platform for construction materials. This comprehensive system creates a 'material passport' that records specifications, like, in this case, the dimensions of wooden beams or the origin of the silica used in the 1,280 glass façade panels, enabling their future **reuse or recycling** at the building's end of life. The platform also monitors the value of materials over time, recognising that some components may become more valuable over time.

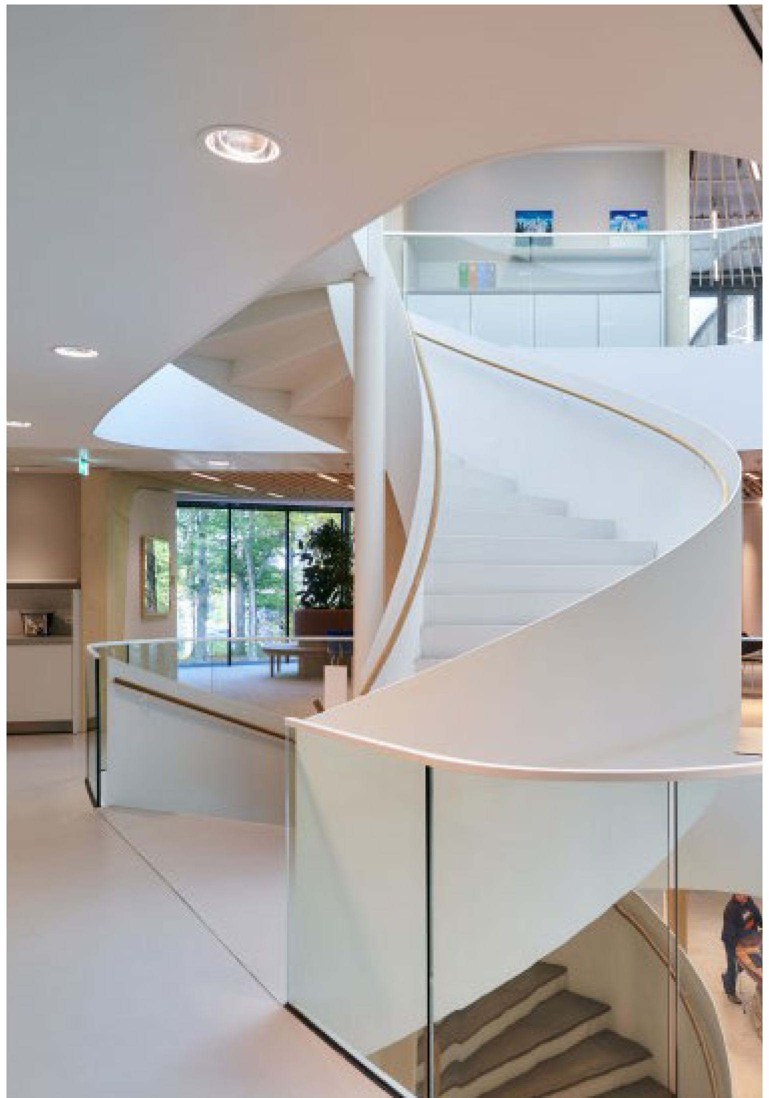
The building's structure and layout are designed in a way that **rethinks** the material and energy intensity based on principles like multifunctionality and modularity of shared spaces (such as through the use of modular desks and workspaces). This approach helps reduce the total quantity of materials used. These principles are also used to optimise access to daylight, placing office spaces on the top floors while essential facilities like toilets, printers, and stairways are positioned in the core. Other areas that are not necessary on each floor and don't require natural light, such as storage rooms, technical spaces, and bicycle parking, are situated in the basement.

The choice of wood as the primary construction material further **reduced** the use of resource-intensive materials like concrete and its embodied carbon emissions. Over 82% of the primary structural framework is made of wood, including 1,615 cubic metres of laminated wood, 1,008 cubic metres of cross-laminated timber (CLT), and five original tree trunks, mostly sourced from the estate. Concrete usage was limited to the basement, where it was necessary for water management purposes. The extensive use of wood, combined with natural interior fabrics, enables the building to store 1,633,052 kilograms of CO_2e. The building's environmental performance extends to its operational phase as well, thanks to a low-tech yet highly effective system of geothermal islands that manage indoor climate.

The building also focussed on the possibility of future **reuse**. The demountable structure serves as a material bank, where, at the end of the building's life cycle, all materials can be reclaimed. This process is further aided by the material passports that were assigned to the components of the structure. For example, material passports ensure that the 165,312 screws used in the project, along with other materials, are accurately inventoried and continuously monitored for their value.

Finally, though not part of the construction itself, the new offices combined **reusing** and **refurbishing** strategies for the interior furnishings (including 400 existing workstations, refurbished laptops, reconditioned furniture, *et cetera*).

Image showing how layout of facilities like stairs, kitchens or printers are placed in the core of the building to maximise daylight in spaces like offices and shared rooms (Source: [Ossip van Duivenbode])



What impacts were achieved?

This building combines circular design principles with environmental stewardship to create a fully demountable structure that prioritises material reuse while capturing its long-term value. The predominantly wood-based design of the building structure contributes to storing the equivalent of 1,633 tonnes of CO_2e and avoids the extraction of finite resources like sand and gravel. The building's material passports and demountable structures ensure that the raw materials of the building can be reused at the end of the building's life cycle. The building is also equipped with additional features like solar panels installed over the parking lot to power electric vehicles and the use of bidirectional charging, which allows cars to return electricity to the building when needed. Additionally, a green roof collects rainwater for toilet flushing, and the building employs geothermal systems for heating and cooling.

In addition to the building's specific features, to limit the conversion of natural land for construction, the building was placed on a previously developed plot within the forest reserve. With this construction, the project team aimed to revitalise the area and promote the recreational use of the natural environment while keeping public access to parts of the building. It was also designed to avoid disrupting bat flight paths and to minimise light pollution at night. It also includes a pond that provides a water source for local wildlife.

An impact assessment of different materials and site planning choices was conducted, focusing on this building as a case study. The assessment demonstrated that design and material choices were made in a way to minimise the shadow cost of the building, that is, the 'non-market' monetary value associated with the environmental benefits obtained from the sustainable material and design choices.

Overcoming data management challenges

The Triodos Bank building project was an ambitious undertaking that required learning and adaptability at every stage. One significant challenge was gathering the necessary information and Industry Foundation Classes (IFC) files from subcontractors. These files facilitate the exchange of information about building components and structures across various platforms, allowing architects, engineers, contractors, and other stakeholders to collaborate more effectively on projects. Obtaining these proved to be a complex task in a project of this scale. Without established processes in place, the team had to develop a systematic approach to ensure seamless data flow. Through trial and error, they refined a step-by-step procedure, allowing for the accurate collection and input of materials data into a digital platform. The platform enabled management, documentation, and storing of information about materials and products used in buildings, serving as a 'material passport' for the project. This effort not only streamlined the process but also set a blueprint for efficient and transparent material management in sustainable construction projects.

Material bank for long-term value creation

The reversible building design principle enabled the office to be a material bank, where materials could be reused, recycled, or repurposed at the end of the building's lifecycle. With this concept, the building serves as a repository of valuable resources, reducing construction and demolition waste (CDW). Every component, from structural elements to finishes, can be dismantled and repurposed in future projects. Therefore, if the company ever needs to relocate or close, all of the components can be easily disassembled, and its materials will remain valuable assets, ready to be reused rather than discarded. This approach is becoming increasingly relevant as the industry faces growing resource scarcity. With the rise of the circular economy and a growing number of 'harvesters', specialists who carefully dismantle buildings for material reuse, this practice will mark a pivotal shift towards circular construction.

Sources used

ARUP. (n.d.). Circular Buildings Toolkit. Retrieved from: ARUP website

Future-proof head office for Triodos Bank. (n.d.). Retrieved 18 November 2024, from Deerns website

Peters, A. (2019). This office was built with 165,312 screws so it can be disassembled and reused. Retrieved from: Fast Company website

RAU Architects. (n.d.). Triodos Bank Nederland. Retrieved from: RAU Architects website

RAG Administration Building: Leveraging C2C design and material passports

KEY FACTS AND MESSAGES

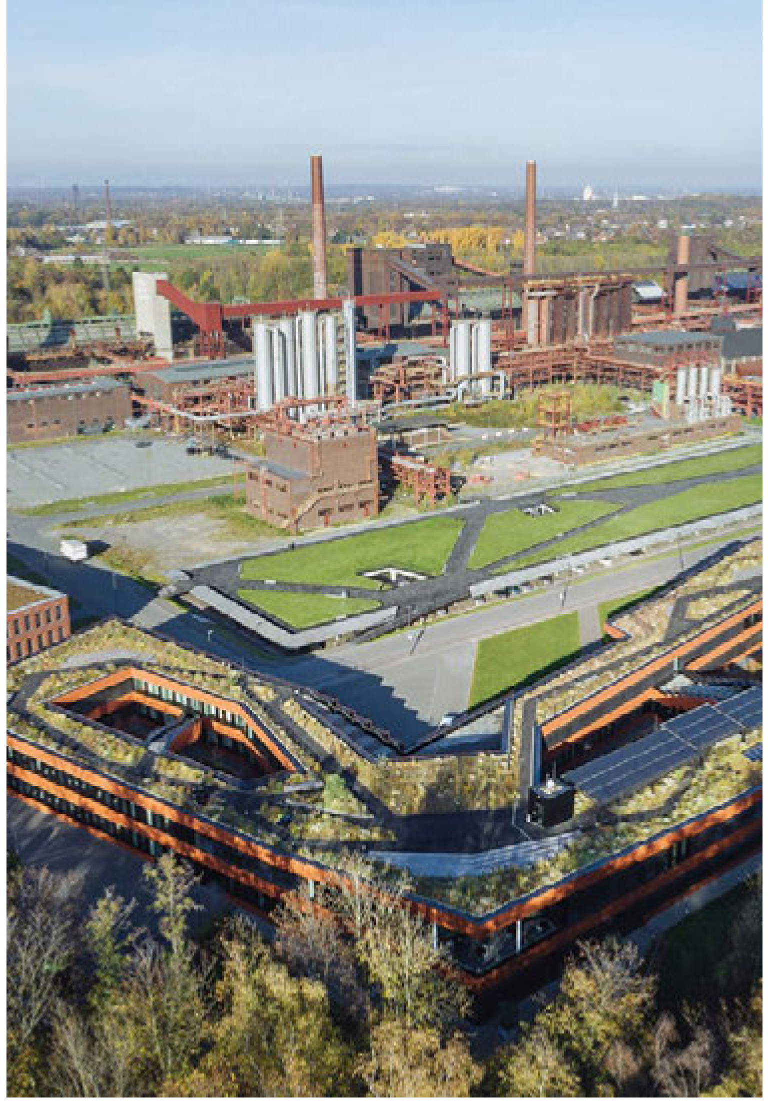
- RAG's new building has **established its own identity** at the intersection of industrial heritage and the natural landscape, using circularity to achieve these goals. **The design prioritised reuse and flexibility**, incorporating modular partitions for **easy reconfiguration, disassembly, and material regeneration**.
- **Material passports** were created for all building components, transforming the building into a repository of valuable raw materials.
- An **advanced quality assurance process** was established, exceeding legal requirements and showcasing how circularity **can drive innovation and meet current legal standards**.

The RAG Foundation's new administrative building, situated in the Zollverein coal mine, a UNESCO World Cultural Heritage site, was constructed with a focus on circularity to meet high environmental and social standards. It is among the first buildings in Germany constructed according to C2C principles, meaning both the building's design and materials are chosen so that at the end of its lifecycle, they retain their value and can be reused, recycled, or safely reintegrated into nature. In addition to adhering to the C2C principles, the project aimed to generate economic, social, and environmental benefits. These goals translated to creating positive impacts for both people and nature, shaping a flexible and healthy working environment, and transforming the building into a raw material depot.

Location	Essen, Germany
Project description	RAG Foundation's new office building
Size	Approximately 9,400 m²
Year of completion	2017
Partners	**Client:** RAG-Stiftung **Architect:** Kadawittfeldarchitektur **Partners:** KÖLBL KRUSE, Essen + RAG Montan Immobilien, Greenbox Landschaftsarchitekten, Drees & Sommer Advanced Building Technologies GmbH.
Prizes & recognition	The building was awarded the German Sustainable Building award (*Bundespreis Umwelt und Bauen*) and meets the standards for Platinum certification by the German Sustainable Building Council (DGNB).
Website	[Kadawittfeldarchitektur website]

R-Strategies

- Refuse
- Rethink
- Reuse



The new administrative headquarters of RAG, located west of the iconic mining tower and opposite the impressive former coking plant within the UNESCO World Heritage Site Zollverein (Source: Nikolai Benner from Kadawittfeldarchitektur website)

R-Strategies in action

The new RAG administration building was constructed to meet high sustainability standards, making it fundamentally different from the highly industrialised structures existing in the Zollverein area. Following C2C principles, commonly used traditional materials that are non-recyclable were **refused** and replaced by more circular alternatives. The design process focused on **rethinking** and **reusing** the building's features and spaces, integrating flexible spaces and modular partition walls that allow it to be adapted to changing needs and ensure easy disassembly and material regeneration. For example, lightweight walls were installed instead of load-bearing interior walls, allowing for simpler reconfiguration and dismantling. In addition, adhesive bonding was largely replaced by mechanical connections, facilitating easier dismantling of structures in the future.

In line with the C2C design principles, materials were selected for their ability to retain value, ensuring that, at the end of the building's life cycle, most of them can be directly **recycled**. One example being the ribbon windows featuring a frame structure composed of C2C certified aluminium profiles and glass. In addition, regional materials were prioritised throughout the construction phase to minimise transportation needs and achieve further environmental benefits for waste reduction.

The same principles were applied to the building's interior, including the use of furniture and other components, such as a carpet made from reusable fibres. Take-back schemes were exploited for several building components and furniture already from the construction phase. For example, the C2C-certified parquet flooring used as floor covering will be returned to the manufacturer for **reuse**.

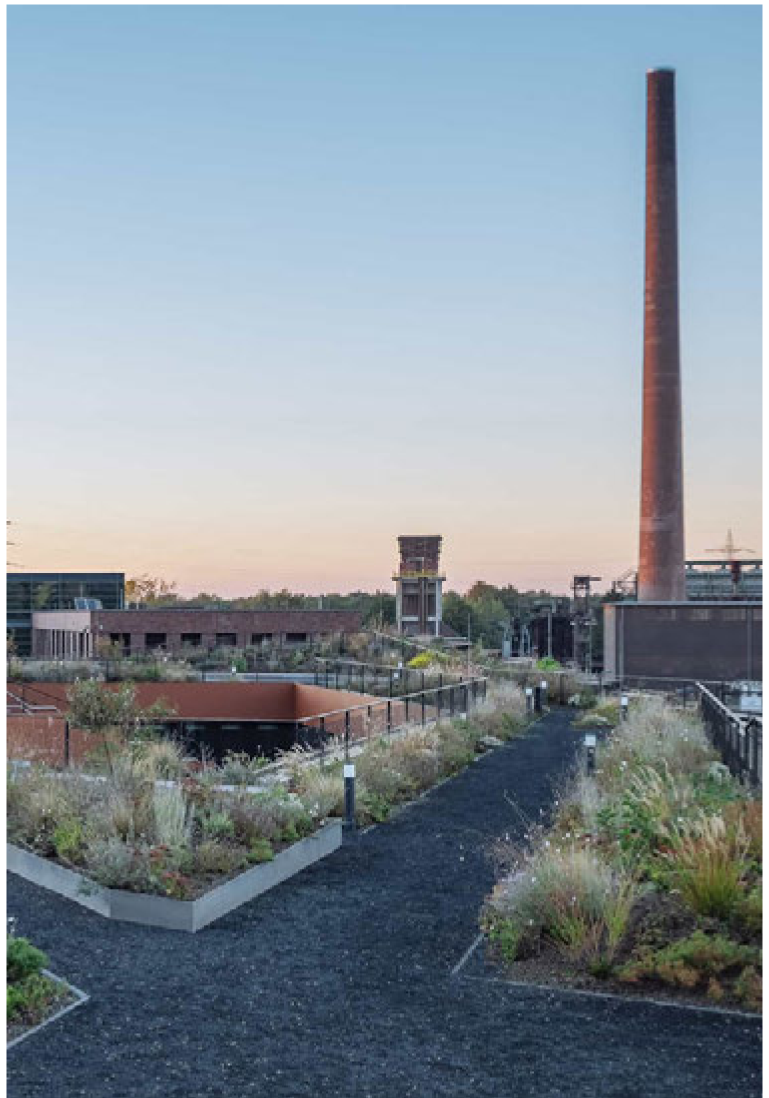
What impacts were achieved?

The new administrative building plays an important role in regenerating the formerly highly industrialised Zollverein area. By choosing this location, priority was given to the revitalisation of the culturally important brownfield site and to creating positive impacts for nature, in addition to creating the Foundation's new building. Along with using circularity to reduce material footprint, several other sustainable measures were adopted. An extensive green roof was added to the new building with a multifunctional role ranging from compensating for the soil area sealed by the building to serving as a retention area for rainwater. A roof-mounted photovoltaic pergola generates renewable energy, which, combined with the use of geothermal energy, increases the building's energy efficiency. Additionally, the roof has an important role in increasing biodiversity with the existing plants, urban gardening activities and bat boxes that create small biospheres.

The new RAG administrative building provides a healthy and appealing environment for employees and visitors within the heritage site. An important focus point of the building's design was to create a good indoor climate, aiming to enhance people's daily lives. Advanced insulation measures, careful selection of materials directly in contact with the interior, green walls and a dust-binding carpet help to maintain a comfortable indoor climate while minimising energy demand. Public spaces like the foyer, conference rooms and canteen are easily accessible and provide social services to everyone in the building. The extensive green roof allows people to enjoy the scenery and the view of the Zollverein site and take long walks.

The implemented measures were intended to restore the overbuilt area to both nature and the community. Overall, the new building promotes the cultural importance of the area and actively contributes to its transformation into a prime site for the art, culture and creative sectors. The success of its design and underlying principles attract more than two million visitors per year.

The images on this spread represent the building's green roof, captured from both the ground and above, showcasing the multi-purpose roof landscape that compensates for the occupied ground area (Source: Nikolai Benner from Kadawittfeldarchitektur website)



A temporary material bank in the intersection between an industrial, cultural and natural landscape

RAG's new building has established its own identity at the intersection of industrial heritage and the natural landscape. Located in a world heritage site, the new building revitalises an underused area, bridging its industrial heritage with nature and people. Circular strategies played an important role as guiding principles during all phases of the project. As one of the first buildings in Germany designed according to C2C principles, the new building showcased how such circular principles can bring benefits to both the surrounding area and the people using the building.

Material passports were created for all building components, transforming them into a repository of valuable raw materials. These passports document every component, detailing its composition, origin, and instructions for future dismantling, separation and reuse. This process not only enhances transparency and traceability but also ensures that materials retain their value over time, encouraging their reintegration into new projects instead of being discarded. This innovative approach marks a shift from the traditional linear model of 'take, make, dispose' to a regenerative model where materials are seen as assets.

Moreover, the rigorous quality assurance process established during the project exceeded legal requirements, showcasing how circularity can drive innovation and meet current legal standards. It also strengthened the commitment of architects, contractors, and manufacturers to circular practices by ensuring their contributions are recognised and aligned.

Sources used

Drees & Sommer. (2020). *German Sustainable Building Award: RAG Foundation new build awarded special prize for sustainability and innovation*. Retrieved from: Drees & Sommer website

Kadawittfeldarchitektur. (n.d.). RAG-Stiftung and RAG AG Zollverein: Closed-loop building - Every square metre of cultural heritage is precious. Retrieved from: Kadawittfeldarchitektur website

Circle Economy Knowledge Hub. (2021). Essen's RAG administration building comes with a Material Passport. Retrieved from: Knowledge Hub website

Maars Living Walls. (2021). *Office space within industrial monument: Zollverein*. Retrieved from: Maars Living Walls website

Now Near Next. (2020). *RAG Headquarters, Essen, Germany*. Retrieved from: Now-Near-Next website

Rathaus Korbach: An urban mining concept based on selective demolition

KEY FACTS AND MESSAGES

- The project **managed to use 62% of the demolition material** from the original building, corresponding to approximately **6,000 tonnes of material saved from demolition waste**.
- The project **demonstrated the feasibility and replicability of local recycling in circular construction**, even though challenges like limited recycled material quality and outdated recycling technologies made selective demolition and material reuse more difficult.
- The Korbach Town Hall project **was recognised as a blueprint for circular construction** by the regional authorities, and **offers practical guidelines for resource-saving building practices** that align with the standards for sustainable urban development in the region of Hesse.

The Rathaus Korbach project involved the careful deconstruction of the 1970s Town Hall extension, which was deemed unsuitable for renovation, to make way for a new, sustainably designed municipal building that was built for disassembly on the same site. This project not only incorporated selective demolition but also prioritised local recycling of mineral materials from the original structure, setting a benchmark for circular construction.

Location	Hessen, Germany
Project description	Municipality building renewed based on urban mining concept and selective demolition
Size	6,996 m²
Year of completion	2022
Partners	**Architect:** AGN Niederberghaus & Partner GmbH **Material partner:** Rheinzink
Prizes & recognition	Top four finalist for the German Sustainability Award for Architecture 2023
Website	Korbach website

R-Strategies

- Rethink
- Reduce
- Reuse
- Recycle

The building extension from the 70s was replaced (Source: Anja Rosen, AGN)

R-Strategies in action

The Rathaus Korbach project integrates diverse strategies to achieve a circular, sustainable and adaptable structure for the municipality building. The **Rethink** strategy played a central role in the approach to construction and material use, treating the original and new buildings as 'material banks'. With this idea in mind, the original Town Hall structure was deconstructed and then used as a source of **recycled** materials to build the new facility. In turn, the new building was also designed to serve as a future material bank, with features that facilitate easy disassembly and recycling. For example, the new roof features a standing seam zinc covering paired with detachable insulation and is made predominantly from secondary raw materials, including glass wool and foam glass. This approach ensures that the materials from different components of the roof can be recycled at the end of the building's life cycle.

The design of the building not only focused on incorporating reused components, recycled and recyclable materials but also ensured that as little was extracted from nature as possible. For this reason, high-quality, fair-faced concrete was used, eliminating the need for additional plastering and minimising composite waterproofing in components touching the ground. This **reduced** the overall complexity of the building, enhancing future recyclability and minimising waste during the initial construction.

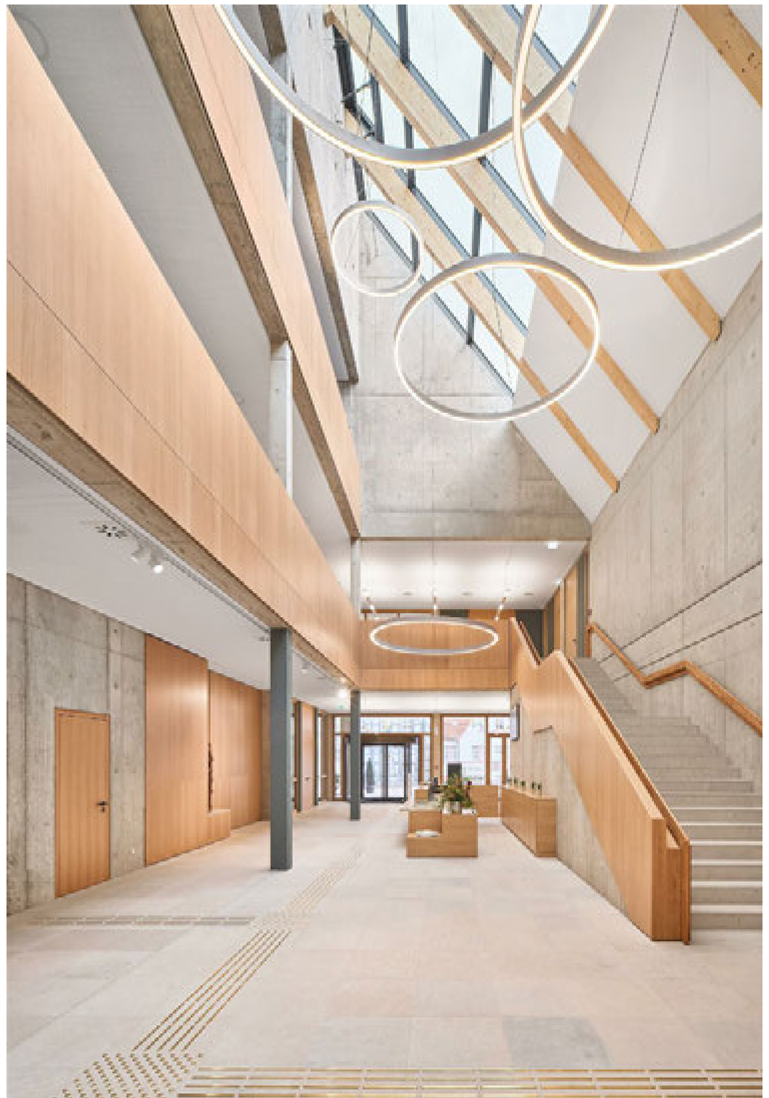
The Rathaus Korbach project incorporated significant materials from the original building into the new structure. Approximately 5,400 tonnes of concrete from the ceilings, beams, and columns of the existing 1970s building were **recycled**, with up to 50% of this material processed as recycled Type 1 stone aggregates to reinforce the supporting structure of the new building. Additionally, around 23 tonnes of brick fragments were integrated into the façade, while finer particles from the demolition were used to fill the construction pit on-site. This method reduced the need for new materials and retained the value of existing resources.

What impacts were achieved?

This project, initiated by the city of Korbach, prioritised local recycling facilities, which played a key role in reducing transportation and disposal costs while supporting the regional economy. By selecting local recycling companies for material processing, the project promoted high-quality recycling services in Hesse and strengthened the collaboration between public projects and local industries. This demonstrated the economic viability of using recycled materials in new construction within the region.

In the long term, the project's emphasis on closed-loop construction, which achieved a 42% circularity rate on the Urban Mining Index, is expected to deliver economic advantages. By designing the building as a 'material bank' with easily deconstructable and reusable components, the Rathaus Korbach aims to minimise future renovation or demolition costs. The study underscored these benefits, presenting the Rathaus Korbach as a resource-efficient construction model that delivers immediate and lasting economic value. This success sets a benchmark for public projects in Hesse, showcasing how resource conservation can drive sustainable and economically viable construction practices.

The images on this spread show the renovated interior (Source: Anja Rosen, AGN)



Hurdles in selective demolition and material reuse

Despite its overall success, the project encountered significant challenges, particularly in selective demolition and material reuse. Before issuing the tender, project planners conducted thorough research on local recycling companies to ensure they could process materials into high-quality aggregates suitable for concrete. Discussions with these companies addressed processing methods, transport distances, and associated costs, enabling the team to clarify logistical and financial aspects early on. The tender specified a selective demolition process to ensure that mineral materials were processed locally for collection and recycled, aligning with the project's circular economy goals.

Despite this meticulous planning, issues arose during the implementation phase, particularly with the bonding materials in the original structure. As a result, the quality of the recycled materials that could be recovered was limited, which reduced the availability of high-quality aggregates for the new building's concrete. Regardless of this setback, the project successfully established a framework for local recycling and reuse, proving that building with recycled materials and reusable components is feasible and replicable. These experiences highlighted the need for improved material processing technologies to address bonding issues in future projects, shedding light on both the complexities and the potential of circular construction.

Creating a blueprint to guide circular construction in the Hesse region

Examining the construction project, the Hessian Ministry for the Environment, Climate Protection, Agriculture, and Consumer Protection issued a report titled 'Resource-saving Construction Using the Example of Korbach Town Hall' (Hesse Ressourcenschonendes Bauen am Beispiel Rathaus Korbach). The report details the entire construction process of the Rathaus Korbach, including challenges, methodologies, and the benefits of employing circular construction practices. The Ministry's primary goal was to showcase the feasibility of circular construction practices, specifically in the context of selective demolition and local recycling of building materials.

The report aimed to establish foundational insights and practical methods for creating closed material cycles that minimise reliance on primary raw materials. The report's purpose extends beyond documentation; it serves as a guideline and a model for sustainable building practices throughout Hesse. The project and its findings are supported by public funds intended to inspire and inform future construction projects, encouraging a shift toward resource-saving strategies in urban development. By promoting these practices, the Hessian Ministry aims to foster long-term conservation of primary resources and demonstrate that circular construction is a viable and impactful approach. The Korbach Town Hall project now stands as an example for municipalities and developers, illustrating how circular principles can be applied effectively and systematically in future projects.

Sources used

AGN. (n.d.). Finalist Nachhaltigkeitspreis: Rathaus Korbach beispielhaft für kreislaufgerechtes Bauen. Retrieved from: AGN website

AGN. (n.d.-b). Recycling beim Best-Practice Beispiel Rathaus Korbach. Retrieved from: AGN website

Rheinzink. (n.d.). Project of the month: City Hall of Korbach [Rheinzink.com]. Retrieved from: Rheinzink website

Rathaus Korbach KREISLAUF GERECHTES BAUEN. (n.d.). Retrieved 17 December 2024, from Grohe Objekte website

Villa Welpeloo: A residential house made from locally sourced reused materials

KEY FACTS AND MESSAGES

- Relying on **locally sourced repurposed materials** resulted in the building **using 60% reclaimed materials** and decreasing the construction's CO_2 emissions by 90%.
- **An innovative harvest platform** for the material sourcing process, making it easier to **find suitable materials, avoid delays**, and **manage consultations** with multiple stakeholders.
- The project **adopted a 'dynamic final design' approach**, allowing flexibility to incorporate reclaimed materials as they became available, **enabling high levels of reuse**.

Villa Welpeloo is a residential home with storage for the residents' art collection, an exhibition space, a studio, and a guest house. This project aimed to create a circular house with a 90% CO_2e reduction in the construction and façade as opposed to a building using 100% new materials.

Location	Enschede, The Netherlands
Project description	Building a residential house based on materials salvaged from the area
Size	250 m²
Year of completion	2009
Partners	**Client:** Private **Architect:** Superuse **Interior design elements:** En-Fer
Website	Superuse Studios website

R-Strategies

- Reduce
- Reuse
- Repurpose

The façade of the building was constructed using cable reel slats (Source: Superuse Studios)

R-Strategies in action

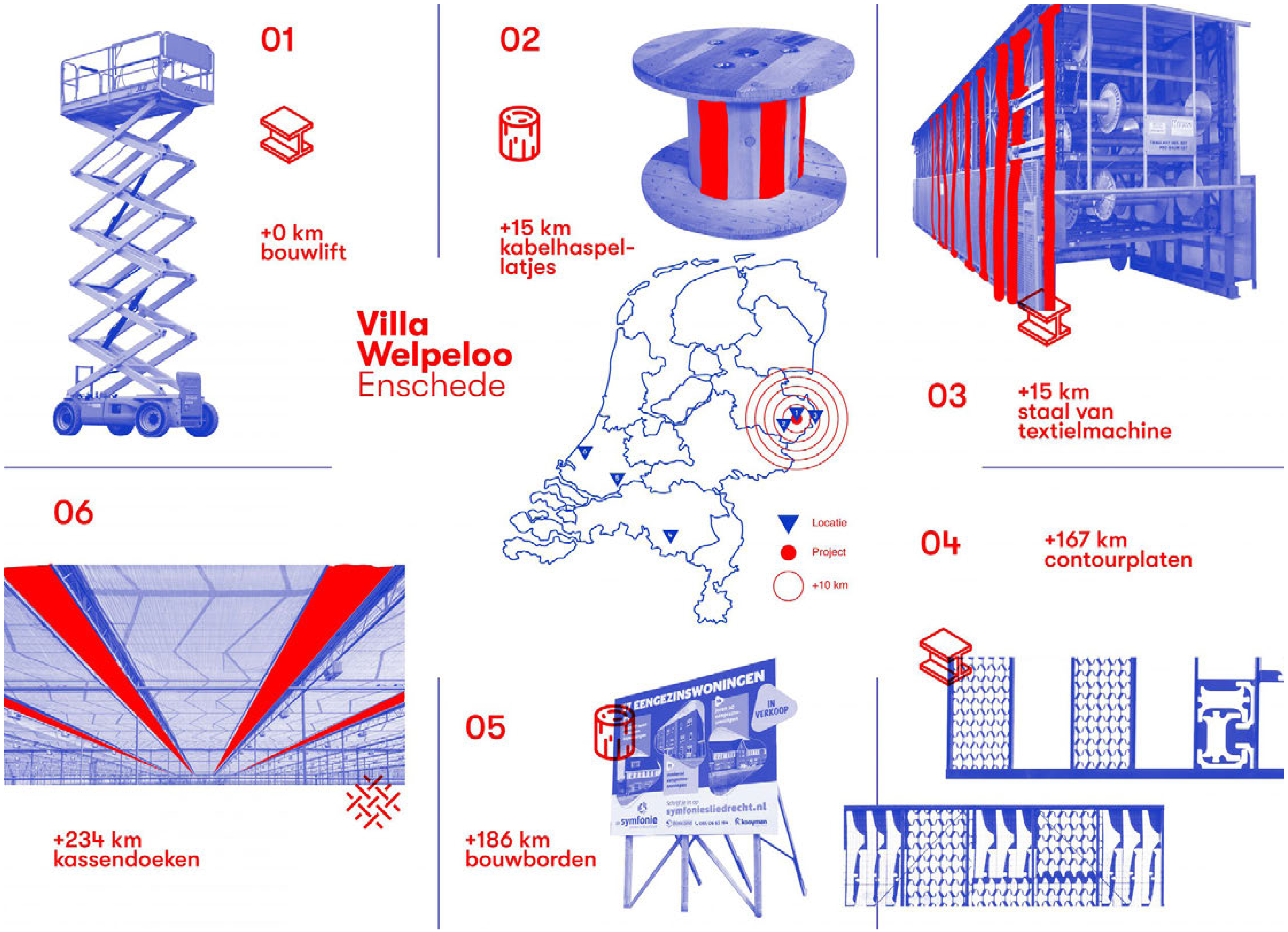
The building was designed based on strict circularity principles with the goal of reducing the required virgin materials during construction. By choosing to build as much of the building out of locally sourced secondary materials as possible, the project **reduced** the raw material demand and emissions from transportation.

Approximately 60% of the materials used are **repurposed**: the floors, the steel structure (90%), the secondary structure, wooden stability walls, insulation, façade cladding and parts of the custom cabinets, which incorporate old construction boards on the inside. Even in the light fixtures, umbrella spokes were used, and plastic coffee cups were compressed into panels for the sanitary spaces' wall cladding. Most materials in the construction process were creatively repurposed from everyday objects. One construction element, however, was and is continuously **reused** in the Villa: the crane used during the construction of the façade is now used in the gallery space to move art.

What impacts were achieved?

This building was part of an experiment to assess the cost and environmental impact of building out of repurposed materials instead of raw materials. It is estimated that this building methodology uses 60% less raw materials and decreases the CO_2 emissions of construction by 90%. Villa Welpeloo's reliance on repurposed materials instead of virgin ones eliminated the need for additional natural resource extraction, processing, and waste generation.

By doing so, the project reduced its impact on major factors contributing to biodiversity loss, including climate change and the overuse of natural resources.



Infographic showing the origin of different materials and components incorporated in the Villa Welpeloo sourced from different distances. 01. Construction Lift: +0 km construction lift, 02. Cable Reel Slats: +15 km cable reel slats, 03. Steel from Textile Machine: +15 km steel from textile machine, 04. Contour Plates: +167 km contour plates, 05. Construction Boards: +186 km construction boards, 06. Greenhouse Screens: +234 km greenhouse screens. (Source: Superuse Studios)

Dynamic final design to overcome the complexities of sourcing and integrating reused materials

The initial phase of the design process for Villa Welpeloo required an extended timeline as architects faced the challenge of sourcing suitable secondary materials. This process included conducting extensive research, performing rigorous material tests to ensure quality and safety, and engaging in consultations with engineers to navigate the complexities of material reuse. Although the design of Villa Welpeloo was finalised, it wasn't entirely 'construction-ready' in the traditional sense. For the architects and contractors to be able to integrate this much-existing material into the final building and to navigate the complexities of sourcing these materials, they had to work with a 'dynamic final design'—a flexible design approach that accommodates changes during the construction process without compromising the core sustainable principles of the project.

This flexible approach allowed the team to adapt the design as reclaimed materials became available, accommodating their changing availability and unique characteristics rather than adhering to a rigid, predefined construction plan. Challenges, such as the toxicity of railway slabs (initially intended for the building's structure) and the lack of standardised processing methods, required design adjustments and on-site modifications. By remaining adaptable, the team maximised material reuse while ensuring the building aligned with its sustainability goals, even if the final design and material choices evolved during construction.

Proof of concept for online harvest map

This project served as a proof of concept for Superuse's material harvesting strategy and laid the foundation for future circular building projects, including the creation of Oogstkaart. Using the innovative harvest map tool, the team dedicated significant effort to identifying and locating potential material sources, ensuring they aligned with the project's sustainability goals. This online platform tracks and tags waste and scrap materials, providing geographical information on their availability. While the initial phase of the design process for Villa Welpeloo was prolonged due to the time needed to identify material sources, conduct research, perform material tests, and hold consultations, developing the harvest map tool represented a significant step forward.

As this tool expands and evolves, it is expected to streamline the process of sourcing reused materials, making constructing future buildings easier and more efficient using circular principles. By addressing challenges such as the unpredictability of material properties and the absence of standardised methods, this project highlights how tools like the harvest map can simplify the integration of reclaimed materials and pave the way for smoother circular construction workflows.

Sources used

Costa Duran, S., Fajardo Herrero, J., & Duran, S. C. (Eds.). (2010). *The sourcebook of contemporary green architecture* (1. ed). New York, NY: Collins Design.

Ellen MacArthur Foundation. (2021). Finding and utilising 'waste' materials for construction purposes. Retrieved from: Ellen MacArthur Foundation website

lwadmin. (n.d.). Homepage. Retrieved from: Oogstkaart website

Jacqueline Knudsen. (2010, January 20). Villa Welpeloo Enschede. Retrieved from: Architectuur.nl website

Yalçinkaya, Ş., & KaradeniZ, İ. (2022). Sürdürülebilir Mimari Tasarımda Atık Malzemenin Yeri. Mimarlık Bilimleri ve Uygulamaları Dergisi (MBUD), 7(2), 750–762. doi.org/10.30785/mbud.1168291

De Warren: A communal housing project based on flexible spaces and material reuse

KEY FACTS AND MESSAGES

- The client's **commitment to circularity** combined the use of repurposed and predominantly biobased materials, while also **prioritising a design that would allow the building to be energy negative**.
- The De Warren project showcases how parametric modelling **optimised the use of repurposed materials** by integrating material supply with design, reducing waste, cutting costs, and **advancing circular construction practices**.
- The housing corporation partnered with ToekomstGroep, a contractor experienced in **sustainable construction**, to **overcome challenges in circular construction**, aiming to demonstrate its feasibility and inspire broader adoption of environmentally and economically beneficial building practices.

Location	Amsterdam, The Netherlands
Project description	Communal housing built with material repurposing
Size	3,070 m²
Year of completion	2023
Partners	**Client:** KONIJN (housing cooperative) **Architect:** Natrufied Architecture **Construction:** The Future Building and ToekomstGroep **Engineering:** Summum Engineering
Prizes & recognition	Winner of the 2023 Amsterdam Architecture Prize
Website	[Natrufied Architecture website]

De Warren is a residential building and living lab. The ambition was to create communal housing, reduce the impact of the building, and use as many bio-based building materials as possible. In 2023, it won the Amsterdam Architecture Prize. The jury commended De Warren for addressing significant urban challenges like affordability, climate, and community in a comprehensive manner. The building provides communal housing, with 30% of the interior space reserved for communal spaces, leaving enough room to realise 16 social and 20 mid-rent homes.

R-Strategies

- Rethink
- Repurpose

Overview of the housing cooperative building, showing the predominantly wood-based structure and façade (Source: Jeroen Musch)

R-Strategies in action

De Warren was envisioned not just as a communal living space but as a tribute to sustainable living. To bring this vision to life, the housing cooperative collaborated closely with the design team to incorporate as many sustainability-focused elements as possible. The building features a supporting structure made of wooden columns and beams, and its light interior walls can be removed if a different layout is desired in the future. In this way, **rethinking** what a building should offer and adding flexibility to its design.

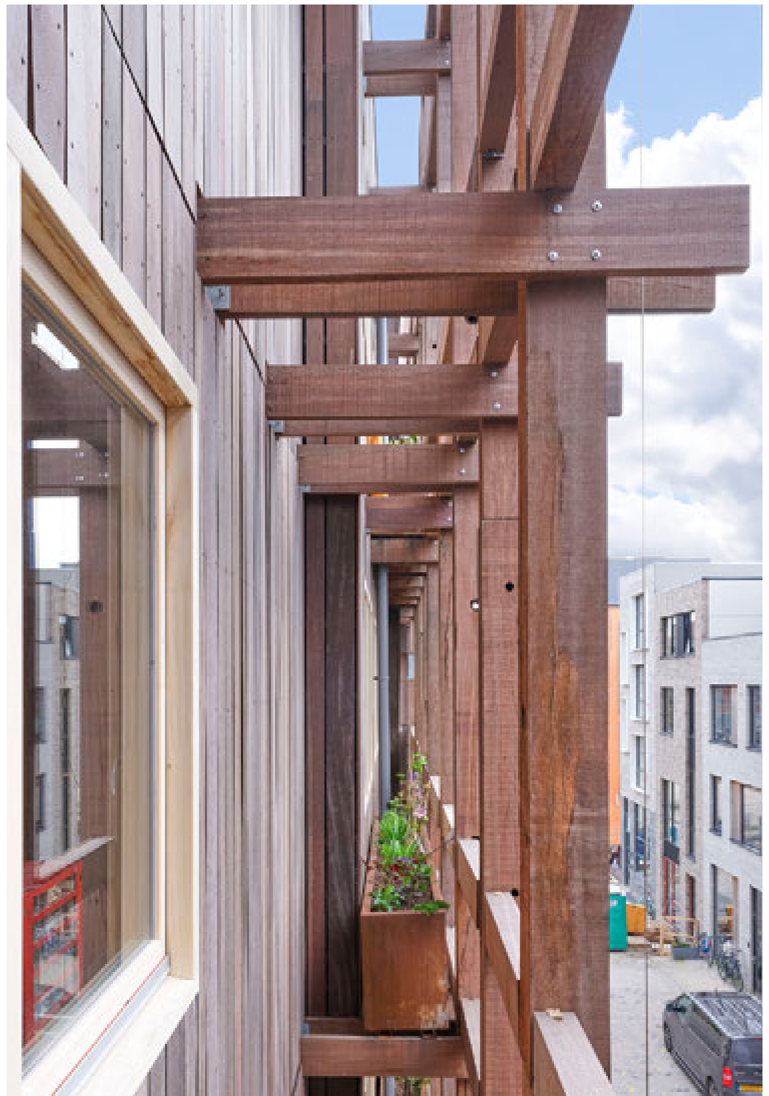
This commitment to sustainability extends beyond the building's structure to the innovative use of **repurposed** materials in its exterior design. The building's exterior cladding is made from repurposed fender systems, and retaining walls were made out of Azobe wood previously used in marinas. By building with repurposed materials, such as timber from fender systems, instead of opting for a steel and concrete structure, De Warren **reduced** the demand for virgin materials while minimising waste. These untreated planks are maintenance-free, contributing to the building's longevity and reducing upkeep costs. To achieve the necessary thickness for the façade, the harvested planks were doubled, ensuring structural integrity and aesthetic appeal. The 'Mikado' façade, which adorns the balconies, is constructed from repurposed mooring posts made of Basralocus wood. This design not only provides a unique visual element but also incorporates planters that utilise rainwater from the polder roof, promoting a nature-inclusive approach. The selection of Azobe and Basralocus woods is strategic due to their durability and resistance to environmental factors, making them ideal for exterior applications.

What impacts were achieved?

De Warren exemplifies a holistic approach to sustainability, delivering economic, social, and environmental benefits through circular design, community collaboration, and resource-efficient systems. To minimise environmental impact, De Warren incorporates multiple circular strategies. The project utilised reclaimed timber from fender systems, as well as new wood, reaching approximately 330 cubic metres of wood in total, which is estimated to store over 300 tonnes of CO_2—equivalent to the emissions produced by an average car in the Netherlands over 200 years. The building's nature-inclusive design further enhances sustainability by integrating features to support biodiversity. Gaps in the façade provide habitats for bats, wooden cladding supports bird nests, and a wadi system encourages local wildlife such as frogs. Vegetation on the rooftop terrace and surrounding gardens attracts insects and birds, while the removal of paving to create a sidewalk garden reduces impervious surfaces, improves stormwater management, and supports plant growth. These combined elements reduce the building's ecological footprint, foster urban biodiversity, and create a microclimate that promotes a healthier, more resilient environment.

Central to the philosophy of the housing cooperative is a sharing economy that emphasises collective living and shared facilities accessible to both residents and the surrounding neighbourhood. Each floor features shared kitchens, bathrooms, and living rooms, fostering a strong sense of community while reducing the duplication of household items. Key features of this approach include shared cars, semi-public spaces, and communal tools, which provide a richer and more expansive living experience compared to individual apartments. This lifestyle reflects the ethos of 'access over ownership', a principle of circular economy models, and demonstrates how communal living can reduce environmental impacts while strengthening community bonds.

Wooden fender systems were repurposed to create the façade of the building (Source: Jeroen Musch)



Wooden fender poles were specifically identified and measured so that the linear programming model could optimise their shape and layout on the final structure (Source: Boris Zeisser)

Finding the right project partners

The housing corporation faced challenges in finding a contractor willing to take on such an ambitious project. The risks associated with reusing materials in construction are inherently high, including uncertainties about the structural integrity of repurposed materials, difficulties in obtaining fire safety certification, the additional effort required for sourcing and processing these materials, and the potential for unforeseen costs. These challenges were compounded by the intense demand in the housing market, which has driven up prices and made many contractors wary of taking on projects perceived as risky or experimental.

To tackle these, the housing corporation eventually found a specialised construction company with experience dealing with these issues and managed to deliver a functional building that matched their sustainability ambitions. By doing so, they hope to demonstrate that circular construction is not only feasible but also economically and environmentally beneficial. They intend for this project to act as a proof of concept, encouraging other contractors and developers to adopt similar methods, leveraging the ideas, processes, and blueprints developed here. In doing so, they aspire to shift industry norms and pave the way for a future where circular building practices become mainstream.

Optimising construction with parametric modelling

The De Warren project on Centrumeiland stands as an example of how parametric modelling can drive innovation in the construction sector. At the core of this pilot project is the use of advanced parametric modelling developed by Summum Engineering to optimise the use of reclaimed materials, such as large bollards, in the construction of the building's façade. The model integrates material supply information with architectural design, calculating the most efficient way to cut each bollard into precise façade elements. It reduces material waste, optimises cutting processes, and maximises material usage—ultimately minimising costs and material consumption.

By applying linear programming algorithms, the model generates a detailed sawing list, accompanied by visual aids, which makes the complex task of fitting irregular materials into the design both efficient and cost-effective. Through the use of parametric modelling, De Warren demonstrates how advanced digital tools can optimise material use and enhance the efficiency of construction processes while contributing to a more circular and resource-efficient approach to building.

Sources used

Architect, R. de. (2024). ARC24: Wooncoöperatie De Warren, Amsterdam - Natrufied architecture. Retrieved 15 October 2024, from Dearchitect website

Bertrand. (2024). De Warren—Architectuurwijzer. Retrieved 15 October 2024, from Architectuurwijzer website

De Warren. (2021). Retrieved 15 October 2024, from Openresearch.amsterdam website: openresearch amsterdam website

De Warren. (n.d.). Retrieved 15 October 2024, from Summum Engineering website: Summum engineering website

De Warren – uniek duurzaam woonproject. (n.d.). Retrieved 15 October 2024, from AT Osborne website

Over De Warren. (2019, March 2). Retrieved 15 October 2024, from De Warren website

AREA (RE)DEVELOPMENT

De HER: A circularity centre using dismantled building materials

KEY FACTS AND MESSAGES

- A key challenge for projects prioritising reuse is the **unpredictability of material availability** and its quality, condition, and quantity, which influences the project's logistics and design processes.
- In De HER's case, most materials were harvested from **a single source**, significantly reducing typical challenges associated with sourcing and securing materials.
- A major advantage of the project was that all components of the donor building were documented in **a material passport**, significantly reducing the uncertainty regarding material quality and quantity.

Location	Rotterdam, The Netherlands
Project description	Construction of a circularity centre within Rotterdam's environmental park
Size	2,400 m²
Year of completion	2025
Partners	**Client:** Municipality of Rotterdam **Architecture and design:** N3O Architects and architects from the Municipality of Rotterdam **Construction:** BAM Construction and Technology **Partners:** IMd Consulting Engineers, BAM Advice & Engineering, Vic Obdam Steel Construction, DGMR, and BOOT, among others.
Website	Rotterdam Circulair website

De HER is located in Rotterdam's first circularly built environmental park, allowing residents to explore, learn about, and engage with the concept of circularity. Visitors can dispose of waste at the recycling centre or donate items to the circular centre, where their belongings will be given a second life. The so-called 'Upcycling Mall' is designed to raise awareness of circular practices and foster education, creativity and entrepreneurship in the circular field. A key feature of both the environmental park and the Upcycling Mall is that most of the construction uses materials from a laboratory in Delft, initially built in 1999. This laboratory was dismantled, preserving its materials' value, which were then transported to Rotterdam and stored for reuse in the new circular centre.

R-Strategies

Rethink

Reuse

The building of De HER, constructed using materials from a former laboratory in Delft (Source: N3O Architecten from Rotterdam Circulair website)

R-Strategies in action

The project was primarily built using secondary materials sourced from the same original building. The potential uses of materials and space were **rethought** to identify the most efficient way to realise the design and optimise resource use. Advanced technological tools were used to streamline this process and optimise the structural design of the new building, enabling the **reuse** of available materials with minimal modifications and **reducing** the need for additional virgin resources. The building was designed with a focus on modularity, intensifying the use of space and therefore contributing to the goal of efficient resource use. Moreover, all components were installed using detachable methods, allowing the building to be easily dismantled in the future and supporting future circular reuse or reconstruction efforts, thus further extending the life cycle of its materials.

As stated above, most of the materials for the circular centre came from a former laboratory in Delft after it had been dismantled. The laboratory was built with future disassembly in mind, which allowed even heavy structures like its existing steel structure to be reused for the new building. Using 3D models and other tests, the project team assessed the dismantled components' capacity and strength, and the new building's structural design accounted for only the minimum necessary adjustments. Parts of the façade, such as the container components, were also reused materials. Each component underwent a detailed assessment for its retained durability and any signs of damage or corrosion, ensuring they could meet the new building's functional needs.

What impacts were achieved?

By prioritising material reuse and efficient resource management, the project contributed to preserving natural resources by avoiding new material extraction and energy use, as well as the associated GHG emissions throughout the process. Materials from the original laboratory building in Delft were reused, including more than 100 tonnes of steel from structural elements, avoiding the creation of construction waste and additional environmental pollution.

Besides the construction project itself, the building's future use also intends to fulfil an important purpose as a hub for fostering circular practices, educating the public, and promoting circular lifestyles. The municipality of Rotterdam aims to leverage this facility to increase both individual and corporate capacity for circularity. It offers a blend of practical, hands-on activities and educational opportunities, making it a dynamic environment for learning and development. De HER is a resource for students and school groups, offering tours, working sessions, and educational activities to inspire future generations. It provides opportunities for internships and research positions, allowing students to gain direct experience in circular practices as well.

Circular enterprises are also encouraged to establish themselves at De HER, where they are provided with spaces to meet, collaborate, and hold workshops. This network of circular businesses and professionals strengthens the local circular economy. Including a cafeteria and restaurant, the facility is designed to be a social, welcoming space that encourages interaction between various stakeholders, from entrepreneurs and visitors to students and residents. This strong social focus ensures that De HER is not just a recycling centre but also a catalyst for broader community engagement with circular principles.

The project reuses different items in the façade elements of the building, for example, washing machines as shown in this picture (Source: Jan van der Meijde)

Overcoming unpredictability in material reuse

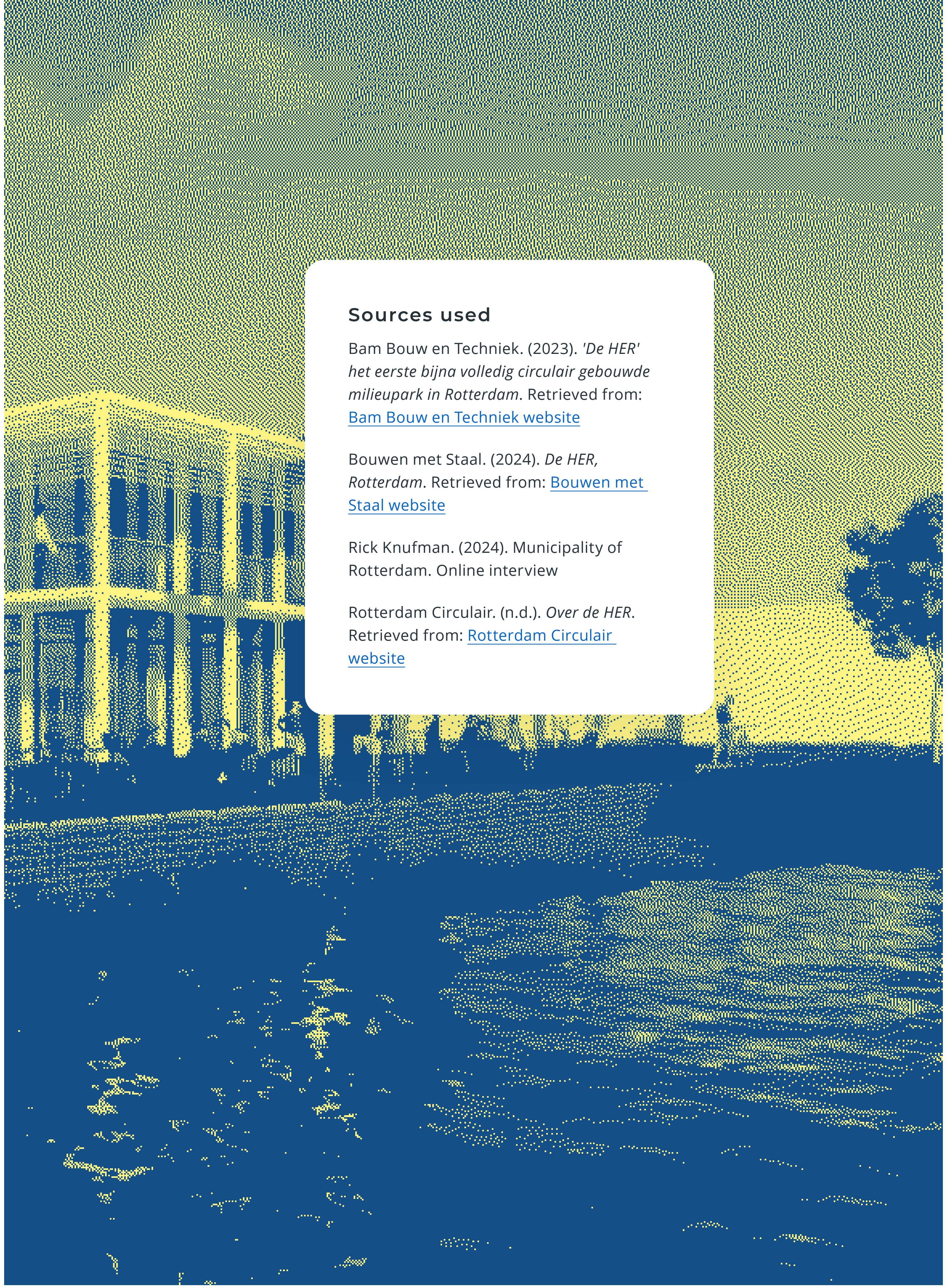
Reusing materials in construction poses challenges such as unpredictable availability, quality and quantity of secondary materials, logistical complications, and the associated risks in terms of budget management and uncertainty. As most of the materials for the De HER project were harvested from a single source, the challenges relating to sourcing and securing reused materials were significantly reduced. By focusing on a single location, the project team could streamline the process of gathering the necessary components and other building materials and ensure their availability at the right time for construction. The uncertainty regarding material quality and quantity was also reduced because all materials were already documented in a materials passport, which provided a great source of information for the project team before the building's demolition.

Another major challenge for De HER was acquiring the necessary permits to ensure that the new building's aesthetics would match the standards of the urban guidelines. Using reused materials and an adaptive design process based on available resources makes this approach more demanding than traditional construction methods.

Pioneering entire building reuse

De HER pioneers the reuse of entire buildings, which is still an uncommon practice in the Netherlands and most other European countries. This pilot project is especially significant in light of Rotterdam's ambitious goal to halve the use of primary raw materials by 2030. The project's success in reusing an entire building, along with valuable lessons and knowledge gathered during its implementation, will likely inspire and inform future construction projects prioritising reuse.

The use of a well-documented donor building, combined with tools like 3D modelling, minimised material modifications, optimised reuse and reduced energy demand. The updated materials passport ensures future traceability, reinforcing circular principles. The success of De HER serves as a valuable precedent, highlighting the feasibility of circular construction. De HER illustrates how public projects can lead by example in promoting reuse and sustainable building practices and how municipalities can encourage residents and companies to adopt circular practices in their lifestyles and operations by providing spaces for circular activities or circular hubs. Overall, through its construction and future intended use, De HER aims to play an important role in shaping a future in which waste is used as a raw material.



Sources used

Bam Bouw en Techniek. (2023). *'De HER' het eerste bijna volledig circulair gebouwde milieupark in Rotterdam*. Retrieved from: Bam Bouw en Techniek website

Bouwen met Staal. (2024). *De HER, Rotterdam*. Retrieved from: Bouwen met Staal website

Rick Knufman. (2024). Municipality of Rotterdam. Online interview

Rotterdam Circulair. (n.d.). *Over de HER*. Retrieved from: Rotterdam Circulair website

Transformation and redevelopment of the former Saint-Vincent-de-Paul Hospital

KEY FACTS AND MESSAGES

- The **redevelopment of the Saint-Vincent-de-Paul Hospital** serves as a pilot district for Paris' sustainable urban development plans, **using circularity as a main means to achieve this goal**. Overall, 60% of existing buildings are being conserved and renovated, **saving thousands of tonnes of material**.
- The scale and complexity of this redevelopment project require establishing a **multi-tool approach**, combining life cycle assessments, material passports, and footprint analyses to evaluate all processes and **ensure alignment** with the overarching environmental and **circular objectives**.
- This approach promotes the adoption of **lifecycle and urban metabolism perspectives** in urban planning and aims to serve as a replicable model for other redevelopment projects, advancing standardisation in the field.

Location	Paris, France
Project description	Transforming a former hospital complex into a mixed-use eco-neighbourhood
Size	3.4 hectares
Year of completion	2025
Partners	**Client:** Paris Batignolles Aménagement **Architect:** Anyoji Beltrando Agency, EVP Ingenier **Partners:** Alphaville, Empreinte, Artelia, Le Sens de la Ville, Alto Step, ATM, Climat Mundi, and Medieco, Codra, Chronos, Bérénice, Mobius, Lab Ingénierie, Neo Eco, BTP Consultant, and Atelier Na, À vrai dire la ville and Palabréo.
Website	City of Paris website

A historic hospital complex in central Paris is being redeveloped into a mixed-use eco-neighbourhood. Initially established in 1650 as a novitiate for Catholic priests, the Saint-Vincent-de-Paul complex later operated as a children's hospital until its closure in 2012. A decade later, the City of Paris acquired the site to transform it into its first zero-carbon, zero-waste district, setting a benchmark for sustainable and resilient urban design.
The project aims to honour the site's historical significance while promoting social diversity and environmental leadership. This large-scale project, led by Paris Batignolles Aménagement, brings together numerous stakeholders with a development budget of approximately €182 million, of which €94.3 million is directly tied to the land purchase.

R-Strategies

- Rethink
- Reduce
- Reuse
- Repurpose
- Recycle

Overhead view of the Robin and Oratory buildings, showcasing the preserved historical façade (Source: Sergio Grazia from Ville de Paris website)

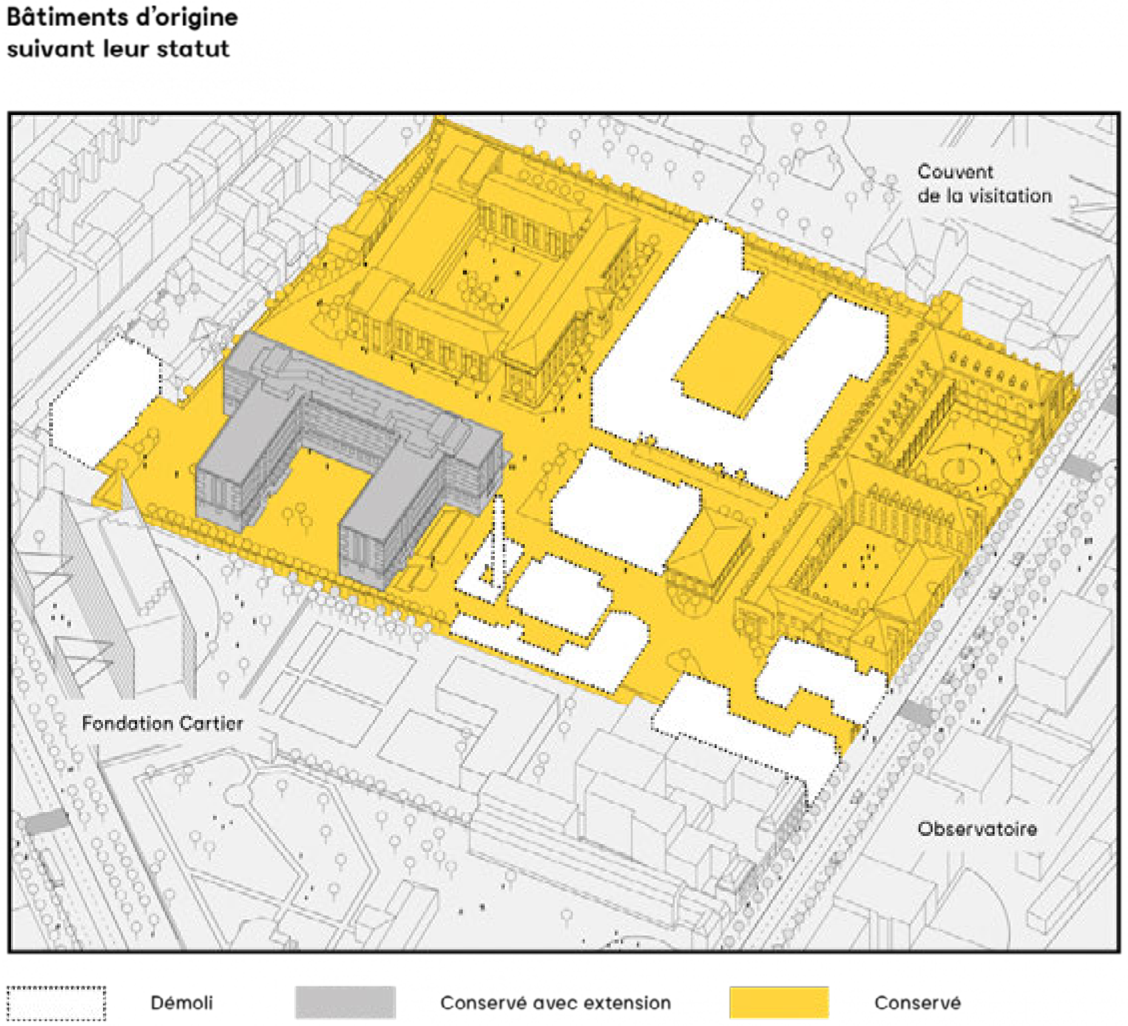
R-Strategies in action

The redevelopment of the Saint-Vincent-de-Paul Hospital is pioneering sustainable urban development in Paris, aligning with the city's environmental, governance, and urban growth goals. Circularity is a guiding principle for the project, incorporated through several strategies ranging from **rethinking** the use of space to integrating bio-based and reclaimed materials specifications in new construction projects.

The redevelopment project innovates across different fields. For example, temporary use of buildings began as early as 2011, when idle buildings were first granted to a housing association. This strategy expanded during the planning phase through the Les Grands Voisins project, allowing the project team to find a social purpose and use entire complex immediately rather than waiting for development and construction plans to be elaborated. Additionally, the redevelopment emphasises preserving built heritage and **rethinking** the use of space and resources, retaining 60% of existing buildings to reduce demolition and new construction. Redevelopment works aim to create adaptable and multi-functional spaces that respond to changing needs, emphasising models like sharing facilities and modularity. These measures contribute to intensifying the use of existing and new materials, eliminating inefficiencies, and narrowing overall material consumption, beginning with the design phase.

To preserve historically significant buildings, the redevelopment project creatively **rethinks** the use of existing infrastructures, **repurposing** components and entire buildings. For instance, the historic English courtyards, a characteristic architectural feature of the former hospital, will be preserved and adapted to support modern functions. Specifically, they will be transformed into house shops, business spaces, and other services, integrating new uses into the original architectural framework. Salvaged secondary materials collected during the redevelopment process that cannot be directly reused are also given new purposes within the eco-neighborhood. For example, reclaimed limestone slabs or brick panels from building façades will have a second life on the floors of public spaces.

The **reuse** of materials and building components is a key priority during renovation. To achieve this goal, Paris Métropole Aménagement has developed a strategy to salvage as many elements as possible from the demolition process for reuse both on- and off-site. This process begins with a systematic recovery and inventory of dismantled components suitable for reuse. This catalogue of secondary materials and components, such as doors, windows, bricks, stairs, and many more, will streamline reuse and facilitate distribution to the project and other projects in the region that may benefit from them. Materials and components that cannot be reclaimed completely, namely concrete and brick wastes, will be recycled and used as aggregates mainly for the embankment of new buildings or recycled into new concrete where possible rather than discarded.



Drawing of the Saint-Vincent-de-Paul hospital redevelopment project (Source: Diane Berg from Ville de Paris website)

What impacts are expected to be achieved?

Circular construction strategies are mainstreamed during the redevelopment project to yield important environmental benefits, including avoided emissions, minimal waste production and reduced virgin resource consumption. For example, the ambition to reuse 60% of the existing buildings and their material reuse targets for new buildings are expected to yield up to 30% in GHG emission reductions (compared to buildings with new materials). Additionally, the buildings are being designed to leverage Paris's non-drinkable water network to create a local heat exchange system complemented by the urban heat network to support the goal of achieving 100% renewable energy use by 2050. The design also features a comprehensive green infrastructure strategy, centred around a 4,000 square metre green public space aimed at achieving high environmental quality in the eco-district, which will be complemented with green façades, roofs and other similar open spaces which to foster urban biodiversity and enhance the district's aesthetics.

The project also fosters social diversity, combining housing with public and private facilities, businesses, and other economic activities. The City plans to allocate two-thirds of the area to a balanced mix of housing options, including 50% social housing, 30% open-access housing, and 20% intermediate housing with below-market rents. A standout feature of the project is the commitment to 'urban co-production' through participatory planning, which began in 2019 and will continue until 2026. This approach actively involves future residents, users, and professionals in shaping the district's design, construction, and management of communal spaces, aiming to create a neighbourhood that reflects its future inhabitants' collective needs and aspirations.

Leveraging data and information technology to achieve circularity in large-scale transformation projects

The City of Paris set a clear roadmap for the Saint-Vincent-de-Paul project, aiming to renew urban planning models and practices and increase circularity in the construction sector. The project introduced the concept of an urban metabolism, focusing on material and energy flows within the territory. This approach proposed new methods to account for non-monetary flows in urban production, challenging conventional frameworks. Additionally, the project pursued high environmental ambition in all aspects of its design, with reducing carbon footprint becoming a central focus for measuring environmental performance. Hence, the approach to metabolism went beyond a simple material flow analysis, adopting a broader strategy focused on resource management, materials and energy cycles.

Because of the project's complexity and scale, this strategy established a multi-tool approach leveraging different data types and advanced methods to evaluate potential processes and ensure alignment with overarching objectives. This approach integrates Life Cycle Assessments (LCAs), material passports, and carbon footprint analyses, among other tools. This approach was applied at every stage of redevelopment, including deconstruction, renovation, and new construction projects. Additionally, the Urban Print software, developed by CSTB and Efficacy, was used for the first time during this project to assess the environmental impacts from a lifecycle perspective. As a result of this process, critical insights into resource requirements and carbon impacts enable informed decision-making on processes, materials, and other key factors. The strategy will continue to guide the district's ongoing development, promoting the adoption of a life cycle and urban metabolism perspective in urban planning. Ultimately, this project aims to establish a replicable model for other urban redevelopment initiatives, standardising these tools and approaches in the field.

Sources used

City of Paris. (2024). *Saint-Vincent-de-Paul, un écoquartier au cœur de Paris*. Retrieved from: City of Paris website

Appendino, F., Roux, C., Saadé, M., & Peuportier, B. (2021). The circular economy in urban projects: a case study analysis of current practices and tools. *Transactions of AESOP*.

Guiding Architects. (2020). *Saint Vincent de Paul in Paris: Sustainable and participatory Urban planning*. Retrieved from: Guiding Architects website

Paris and Metropole Amenagement. (2023). *Saint Vincent de Paul: Another kind of Paris*. Retrieved from: Paris Metropole Amenagement website

Project Saint Vincent de Paul. (n.d.). *Projet Saint-Vincent-de-Paul*. Retrieved from: Blog Saint Vincent de Paul website

Urbanités. (2024). *La reconversion de l'hôpital Saint-Vincent-de-Paul à Paris: Comment faire compter ce qui compte dans une opération de recyclage urbain*. Retrieved from: Urbanites website

Kera district: Transformation of a traditional industrial area into a low-carbon, 20-minute neighbourhood

KEY FACTS AND MESSAGES

- The Kera district redevelopment plan **combines circular and low-carbon measures** serving as a testbed for Espoo's sustainability goals for 2030.
- The redevelopment is projected to ***transform the area into a vibrant hub***, introducing 14,000 new homes and creating 10,000 employment opportunities **centred around sustainable urban development services**.
- The 'Kera Area Development Commitment', established through the **land-use agreement**, sets clear objectives and **circular principles** to guide all projects spanning from the 2020s to the 2040s. The document will **ensure flexibility** to **address evolving needs and technologies** while maintaining consistent progress toward sustainability goals.

The Kera district redevelopment will transform the former industrial area into a sustainable, circular, mixed-use neighbourhood housing 14,000 residents and 10,000 workplaces by 2040. While integrating the 20-minute neighbourhood concept, the ambition is to transform Kera into a testbed for sustainable practices, an international model of circular urban development that achieves climate neutrality (contributing to Espoo's carbon neutrality target by 2030) and circular use of materials and resources. The project will feature low-carbon construction, sustainable mobility options, renewable energy systems, and digital solutions designed to create a more efficient and sustainable urban environment.

Location	Espoo, Finland
Project description	Redevelopment of a highly industrialised area into a mixed-use circular neighbourhood
Size	Approximately 22 hectares
Year of completion	Ongoing
Partners	**Client:** City of Espoo **Architect and constructor:** Kera Co-Op **Partners:** Land-owners, WSP, Forum Virium Helsinki, Neste, Fortum, SOK Corporation among others
Website	City of Espoo website

R-Strategies

- Rethink
- Reduce
- Reuse
- Repurpose
- Recycle

Site plan of Kera's redevelopment project (Source: Arkkitehtitoimisto B&M Oy from City of Espoo website)

R-Strategies in action

With a focus on co-creation and community involvement, Kera combines a range of circular solutions, integrated green spaces, and shared economy initiatives to become a pioneering circular neighbourhood that enhances sustainability and quality of life.

At the project's core, the ‘Kera Design Manual’ sets the framework for all constructions, renovations and redevelopments to be high-quality, sustainable, and carbon-neutral, ensuring all projects align with circular economy principles. **Rethinking** traditional space design practices, Kera’s constructions will adapt original spaces to integrate more flexible and modular design, intensifying their operational use by adapting to current needs. Buildings will also be easily dismantlable to facilitate future **reuse** and recyclability of materials. Moreover, temporary uses of vacant spaces will support community activities, urban agriculture and cultural events, blending practicality with creativity. For example, the former logistics centre has become a vibrant hub for street art, exercise, and urban farming.

The main redevelopment work in Kera will take place in the former headquarters and logistics hub of one of Finland’s largest retailing cooperatives. The design will focus on minimising the need for new construction by utilising the previously underused industrial estate, **reducing** the demand for new materials and the need for new structures to be built. Similarly, materials and components (such as steel beams, concrete slabs and columns) claimed from the old buildings will be reused or **repurposed** in new projects within the district. Most materials that cannot be directly reused for similar end-use will be recycled on-site to meet the demands of new constructions within Kera. For example, concrete aggregates from the demolition of various parts of the industrial site will be **recycled** into asphalt mixtures, while earthworks will prioritise recycled soils from existing excavations. Demolition waste will be sorted by material type based on a pre-demolition survey to ensure materials can be recycled according to their highest-value application.

The ground floor of the logistics centre will serve as a temporary storage area for secondary materials to facilitate material reuse and repurposing. Upon completion, the new district will have a dedicated reuse centre to promote long-term support for material reuse within Kera.

What impacts are expected to be achieved?

Kera’s redevelopment is entirely designed to ensure a holistic, sustainable urban environment. From a built environment perspective, the different circular and low-carbon solutions chosen also contribute to achieving carbon neutrality, in particular through the use of carbon-binding materials, but also with the integration of energy-saving and renewable energy-producing technologies. In terms of land use and regeneration, the former brownfield site will be rehabilitated through soil treatment and, where possible, soil reuse within new developments around the district. This measure will complement the 85,000 square metre network of green spaces featuring a central park and various adjacent areas aiming to support biodiversity and ecosystem services.

The redevelopment of Kera will also be leveraged to foster socio-economic well-being in Espoo, by creating spaces that combine economic and employment opportunities while providing a safe, healthy and inclusive living environment. Kera aims to develop a business ecosystem to attract small businesses and research institutions, creating an estimated 10,000 new jobs focused on the provision of urban services, circular economy activities and pilot project experimentation. Additionally, the project will establish collaborative management systems that enable residents to participate in local decision-making while building a sharing economy and community culture. The district has already launched knowledge-sharing programmes, including Kerat Talks, an annual event centred around sustainable urban development that covers topics like well-being in cities.

Establishing a redevelopment strategy: Long-term goals as a key to success

Setting clear and long-term objectives (mostly qualitative) was part of Espoo's urban development process and has been crucial to the project's success so far. By maintaining a consistent course of action over time, Kera reconciles the long-term vision with the shorter-term construction and development milestones needed to achieve its goals. At the core of this approach, the 'Kera Area Development Commitment' was collaboratively established during the planning phase as a document setting explicit objectives for all land-use and built environment projects within Kera. This commitment emphasises the principles of circularity but also caters to adaptable strategies that can accommodate changing needs (that is, changes in governance or ownership) and technologies over the different phases of implementation. This shows that commitment documents can align stakeholders (local companies, municipalities, research institutes, and citizens) towards common sustainability goals.

While the focus and importance of this case study is the circular transformation of an underused district, the scale of this redevelopment enables the integration of circular measures across many other sectors and levels. It provides an opportunity to assess current practices, address uncertainties and inefficiencies, and close knowledge gaps. The area will act as a platform for circular economy services, particularly in construction, with potential benefits for other European cities. Insights and successful practices from Kera can then be shared to promote wider adoption in Finland and beyond.

Sources used

Appendino, F., Roux, C., Saadé, M., & Peuportier, B. (2021). The circular economy in urban projects: a case study analysis of current practices and tools. Transactions of AESOP. doi: 10.24306/TrAESOP.2021.01.006

Circular City Funding Guide. (2021). *Espoo: one of the most sustainable cities in Europe*. Retrieved from: Circular City Funding Guide website

City of Espo. (n.d.). *Kera*. Retrieved from: City of Espoo website

City of Espo. (n.d.). *Kera development commitment*. Retrieved from: City of Espoo website

Enter Espoo. (2021). *Espoo's Kera district is the new standard in smart city piloting environments*. Retrieved from: Enter Espoo website

Helsinki Smart Region. (2016). *An industrial area turns into a liveable circular neighbourhood*. Retrieved from: Helsinki Smart Region website

Nordic Innovation. (2016). Kera Co-Op City: *New Nordic Neighborhood*. Retrieved from: Nording Innovation website

ACKNOWLEDGEMENTS

PARTNERS
This publication was supported by the Danish philanthropic association Realdania

AUTHORS
Pau Ruiz (Circle Economy), Danai Louzioti (Circle Economy), Zoé Héjja (Circle Economy)

CONTRIBUTORS
My Lunsjö (3XN / GXN), Rick Knufman (Gemeente Rotterdam), Jos de Krieger (Superuse Studios), Boris Zeisser (Natrufied Architecture), Søren Pihlmann (pihlmann architects)

EDITORIAL
Megan Murdie (Circle Economy)

DESIGN & LAYOUT
Alexandru Grigoras (Circle Economy),
Nicolas Raspail (Circle Economy)

How to cite this report
How to cite this report: Circle Economy, Realdania. (2025). Case Studies in the Circular Built Environment: The 9R Strategies in Action. Amsterdam: Circle Economy.

Photo credits
Cover photo: natrufied.nl
Photo pages 6-7: AdobeStock_510666849
Photo page 11: AdobeStock_1003939216
Photo pages 14-15: AdobeStock_564656832
Photo pages 64-65: AdobeStock_434399594
Photo pages 108-109: AdobeStock_209220097

Version 1.0 (March 2025)

circle-economy.com