CircBoost

D6.1 Pilots value chain analysis

WP6 MARKETIZE: BOOST THE MARKET READINESS OF CIRC-BOOST ICS

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List of abbreviations

EC – European Commission

GA – Grant Agreement

WP – Working Package

VCA – Value Chain Analysis

CDW – Construction and Demolition Waste

LCA – Life Cycle Assessment

EPD – Environmental Product Declaration

RAC – Recycled Aggregate Concrete

1 Executive summary

This report provides an in-depth and holistic synthesis of the activities, strategies, and advancements of the five Circ-Boost pilots executed in Spain (Pilot 1), France (Pilot 2), Serbia (Pilot 3), Norway (Pilot 4), and Czechia (Pilot 5). The Circ-Boost project constitutes each of these pilots as a living laboratory for investigating the practical application of the principles of the circular economy to the construction industry. Through the intersection of technical innovation, cross-industry cooperation, and contextual experimentation, the pilots are spearheading a fundamental transition from the linear to the circular model of construction in Europe.

The European construction industry is one of the largest consumers of raw materials in the region and a source of notable waste generation and carbon output. Construction and demolition waste (CDW) alone contributes more than a third of all waste in the EU, as estimated by the European Environment Agency. Against this, the EU laid out a strategic vision to reshape the sector in the European Green Deal, the Circular Economy Action Plan, as well as in supporting frameworks such as the EU Taxonomy. The Circ-Boost pilots do so directly, providing place-based proof of how the circular approach can be integrated within the construction value chain, from the sourcing of materials and demolition to new building, logistics, design, and stakeholder engagement.

The following report uses Porter's Value Chain as an analytical tool, allowing for consistent and comparative analysis of the application of circularity throughout all of the pilots. Every value chain area – Inbound Logistics, Operations, Outbound Logistics, Marketing & Sales, After-Sales Services, Infrastructure, Human Resources, Technology Development, and Procurement – is examined to reveal the application of circularity in practice.

- Pilot 1 (Spain) is located in the region of Catalonia, in the municipality of Sant Andreu, a district of Barcelona, where the pilot is incorporated into the circular urban development agenda. Its main objective is to improve the reuse of building elements with better reverse logistics and traceability. Specifically, it transforms a former industrial production site into an eco-district, introducing innovative decontamination approaches and applying circular strategies to manage materials from demolition. The overall ambition of the pilot is to prove the possibility of using reused materials in new constructions at the urban/territorial level, while providing replicable governance and value-chain integration models. In turn, the pilot takes advantage of intense public-private alliance and aims to affect local policy environments, aligning urban development with material reuse.
- Pilot 2 (France) targets the Île-de-France region, the most densely populated metropolitan zone in Europe and one of the most active construction sites of the continent. The environment both offers opportunities and proves challenging: high construction turnover generates huge amounts of CDW, but complexity of logistics and regulatory fragmentation discourage material reuse. The pilot overcomes the challenges by constructing interoperable physical and digital infrastructures, in particular by connecting demolition sites, recycling platforms, and reuse markets through novel paradigms of coordination and traceability. Backed by strong institutions such as Métropole du Grand Paris and technical partners such as CSTB and Université Gustave Eiffel, the pilot integrates robust scientific inquiry with practical implementation to forge a more circular, data-driven built environment.
- Pilot 3 (Serbia) is a pioneering intervention in a region that continues to be in a nascent stage of development in the area of circular construction. Headquartered in Belgrade, the pilot is spearheaded by the Faculty of Civil Engineering and provides a real-life demonstration of demountable and reusable structure systems, as well as innovative solutions to concrete recycling. While Serbia now hosts one industrial-scale CDW treatment facility near Belgrade, standardized recycled materials remain limited and broader infrastructure is still developing. The pilot, therefore, serves both as a technical model and a catalyst for cultural shifts in the Western Balkans,

demonstrating the feasibility of circular construction even in evolving regulatory and infrastructural environments.

- Pilot 4 (Norway) is located in the Arctic municipality of Sortland and offers a compelling case study in localized circularity under extreme conditions. The pilot repurposes CDW from a former slaughterhouse (Nortura building) and channels it into the construction of a new public building – the GAIA Vesterålen Museum. Notably, this is one of the first Norwegian projects to directly implement the updated national standards allowing for the use of Recycled Concrete Aggregates (RCA) in structural concrete. Through innovative on-site crushing, dust mitigation strategies, and selective demolition, the pilot showcases a highly localized and low-carbon construction loop, minimizing the need for imported materials in a remote setting. The project's alignment with cultural and sustainability goals also contributes to broader Arctic resilience narratives.
- Pilot 5 (Czechia) takes place in Prague, in a massive residential development called "Modřanský cukrovar", developed by Skanska with technical partners such as ČVUT. The pilot is differentiated by its industrial-level maturity and commercial scalability. Certified low-carbon concrete (Rebetong) with high RCA content is incorporated in several phases of the construction process, from structural elements to façades, and even 3D-printed architectural elements. The pilot marries technical sophistication (e.g., high-tech concrete mixture designs, monitoring in-site with Concrete sensors) with unambiguous market orientation, taking advantage of Czechia's increasing regulatory receptiveness to the use of circular materials as well as pressure from the public to achieve more sustainable urban development. The pilot is one of the limited numbers of EU pilots that can show how to achieve circularity in an industrial-scale setting, highlighting the potential for widespread adoption.

Each pilot presents unique strengths and challenges, offering valuable insights into the practical application of circular construction principles. Across all of the pilots, the report outlines common challenges and systemic bottlenecks:

- Regulatory ambiguity or fragmentation concerning material reuse and recycled aggregates.
- The absence of harmonized certification schemes and raw materials passports for secondary raw materials.
- Limited digital infrastructure to link supply, demand, and quality data across the material lifecycle.
- Cultural resistance to change among clients, designers, and contractors.
- Logistical limitations and costly transport, especially in distant or urban-concentrated areas.

In spite of these challenges, the pilots as a whole offer robust proof that systemic circular change is both possible and transferable, most notably when driven by consistent policy frameworks, industry engagement, and stakeholder co-creation.

The report ends by setting out strategic recommendations for replicability and scaling up of the piloted solutions, to be further elaborated in subsequent project stages. These are:

- The design of models that are aligned to reuse platforms, recycled concrete, and digital tracing.
- Development of training programs and capacity-building initiatives to facilitate sector-wide culture change.
- Development of recommendations for standardization and integration of circularity requirements into public procurement.

Essentially, the Circ-Boost pilots are setting the groundwork for a truly circular built environment in Europe, facilitated by innovation, institutional coordination, and a common vision of sustainability.

This report serves not only as a documentation of progress but also as a roadmap for how regional circular construction pilots can scale into national and EU-wide transformation.

2 Introduction

2.1 Value chain analysis overview

The deliverable 6.1 (D6.1) includes an analysis of construction value chains at the five pilot locations of the Circ-Boost project with special attention to opportunities and challenges for promoting circular economy in the built environment. Each of the pilots is based in a different geographic, regulatory, and market context, providing various insights on how circularity may be implemented at various levels of the construction value chain, from material sourcing and design to construction, reuse, and end-of-life strategies.

The primary objective of this work is to facilitate the shift towards more circular, resource-conserving construction systems through an analysis that outlines principal actors, gaps, synergies, as well as sources of innovation in the local ecosystem of each of the pilots. By so doing, the deliverable contributes to an improved comprehension of how circular construction practice can be replicated in various European regions.

To ensure a coherent and comparable analysis across pilots, a common methodological approach has been adopted. It involves use of a structured value chain analysis framework, stakeholder engagement, and use of qualitative and quantitative data collected from surveys, interviews, and documents of pilots.

In line with the public nature of this deliverable, care has been exercised in order to prevent disclosure of sensitive or confidential information. The analysis is geared to raise systemic insights and actionable recommendations relevant to larger groups of stakeholders in order to avoid compromising proprietary knowledge. Additionally, the deliverable places every pilot project in regional construction environments in order to remind us of that circular construction solution viability and scalability are irretrievably intertwined with then-existing business-as-usual (BAU) norms, supply chain sophistication, regulatory frameworks, and local market readiness.

2.1.1 Scope and objectives

The construction industry is among the largest consumers of natural resources and one of the main producers of greenhouse gases and wastes. In light of these facts, moving towards circular economy concepts is not only preferable but also imperative to minimize environmental footprints, enhance material utilization, and promote climate aims. Within this general framework, Deliverable 6.1 (D6.1) of the Circ-Boost project deals with examining the construction value chains of all pilots with the aim to identify tangible opportunities, necessities, and obstacles to applying circular solutions at regional as well as operational levels.

The scope of this deliverable covers the five Circ-Boost pilots, which are all placed in various European countries with distinctive circumstances and challenges. They are:

- **Pilot 1**: The redevelopment of the former Mercedes-Benz factory in Spain
- **Pilot 2**: A physical and digital platform for circular construction in France
- **Pilot 3**: A modular, demountable housing prototype in Serbia
- **Pilot 4**: The adaptive reuse and refurbishment of Museum Nord in Norway
- **Pilot 5**: Industrial upscale of recycled aggregate concrete in Czechia

The analysis focuses on how each pilot engages with the key stages of the construction value chain, including inbound logistics, operations, outbound logistics, marketing and sales, after-sales services, firm infrastructure, technology development, procurement, and human resource management. The objectives are to:

- Identify how circular economy principles are currently integrated.
- Detect bottlenecks, systemic gaps, or missing links that may hinder circular practices.
- Highlight strengths and opportunities to scale or replicate successful approaches.
- Understand stakeholder needs, roles, and interdependencies.

- Provide actionable, tailored recommendations to strengthen circularity.

The overall goal of this deliverable is to present an in-depth, structured analysis of existing circularity in the pilot value chains. It is intended to facilitate project partners, as well as other stakeholders, in decision-making processes that will help mainstream circular construction.

In addition, the deliverable aims to connect technical innovation with market integration by determining leverage points where investment, capacity development, and policy can maximize implementation and replication of circular construction. Eventually, the work will contribute to the overall objectives of the Circ-Boost project by adding to systemic change in the European construction sector and paving the way for more circular and sustainable value chains in the built environment.

The deliverable also aims to evaluate how circular construction solutions implemented in every pilot reinforce or counter the existing regional BAU approaches. Through comparison of pilot innovations with traditional norms in local sourcing, construction, demolition, and reuse in every context, analysis will seek to identify enabling or obstructive factors to wider replication.

2.1.2 Methodology

The methodology used in this deliverable is based on Michael Porter's Value Chain Analysis (VCA) framework, which is used as a strategic technique for examining the internal processes of an organization or project in order to locate opportunities for value creation, efficiency, and competitiveness.

For the purposes of Circ-Boost, this methodology has been tailored to evaluate circularity potential and change opportunities in the construction ecosystems of the five pilots. The original structure of Porter's framework – making a differentiation between primary activities and supporting activities – is maintained but is interpreted anew from a circular construction perspective.

Each of the pilots is evaluated based on nine value chain activities (five core and four supporting), both technical and systemic in nature. The following are presented in brief below and described in detail in Section 3.2:

- **Primary activities**: inbound logistics, operations, outbound logistics, marketing & sales, after-sales services.
- **Support activities**: firm infrastructure, technology development, procurement, human resource management.

Regional context analysis involved an integrated use of local construction industry reports, partner pilot insights, as well as secondary research about general practice on material sourcing, handling of demolition, and reuse in every pilot region. This guaranteed that recommendations are based not just in the pilot but in the regional ecosystem as a whole in which they exist.

The value chain analysis was developed using a combination of primary and secondary data sources that was collected through:

- Structured interviews with pilot leaders and key partners
- Technical presentations and updates from pilot teams
- Surveys, feedback forms, and Pilot deliverables (notably D3.1 and D3.2)
- Regional construction industry reports and academic research

Each pilot was examined through all nine value chain activities through a three-layered evaluation framework:

1. **Current status**: what is currently being done in each value chain activity, with respect to circularity.
2. **Issues identified**: main challenges, gaps, inefficiencies, or missed opportunities in the existing value chain configuration.
3. **What should be done**: tailored recommendations and interventions to overcome the issues and enhance the pilot's circularity potential.

This approach allowed for a comparative but context-aware analysis to acknowledge differences in scale, ambition, maturation, and local environments among the five pilots. It also facilitated the ability to identify both specific pilots' needs as well as cross-cutting suggestions for scaling circularity in construction.

Ultimately, this methodology underlines systemic comprehension of how value comes to be created, lost, or changed throughout the construction process – from material sourcing to handling at the end of life. It makes it possible to identify major leverage points where technical, managerial, policy, or financing interventions can unlock substantial advancement towards circular practice.

By concentrating not just on the technical nature of circular construction, but also on stakeholder relationships, workflows, governance models, and information flows, this value chain analysis bridges the gap between innovation and implementation by ensuring circular solutions are technically feasible, as well as economically and institutionally adoptable.

2.1.3 Team organization

The preparation and delivery of D6.1 has been led by Lorenzo Strocco, WP6 Leader, and Paolo Luperto, WP6 team member, both from Officine Innovazione (OFI). Their work included coordinating inputs from pilot partners, conducting research, synthesizing findings, and drafting the report.

The analysis has depended significantly upon active engagement by all the pilot teams, who contributed important documentation, took part in interviews, and provided fresh information and comment. The multi-actor, collaborative method guarantees that the deliverable is based upon actual project circumstances and permits an adequately informed, context-appropriate analysis.

Person	Role
Lorenzo Strocco (OFI)	WP6 Leader
Paolo Luperto (OFI)	WP6 Team member

Table 1: Circ-Boost team roles

3 Pilot-level value chain analyses

3.1 Overview and methodological approach

This section provides a detailed description of how value chain analysis was used in every Circ-Boost pilot in order to understand circular construction practice at both project and regional levels. The methodology is an attempt to bridge theoretical circular economy concepts with actual challenges and possibilities faced by Europe's various construction ecosystems.

In this deliverable, the value chain analysis (VCA) methodology employed is a context-specific extension to Michael Porter's strategic value chain framework, which conventionally charts all processes associated with developing and distributing a product or service. In the framework of Circ-Boost, this framework has been interpreted anew to align with the specific features of the construction industry as well as to capture the nature of circular economy implementation.

Each pilot is analyzed both in their project-specific innovations, as well as in their place in the larger regional context of construction. It is necessary to have this double focus in order to distinguish which elements of circularity stem from the internal organization of the pilot, versus those that are affected or are constrained by systems such as supply chains, regulation, infrastructure, and market culture.

In order to execute the analysis in an organized and comparable fashion, a nine-activity framework was used, including both primary activities and supporting activities. The categories permit an organized examination of how value is created, maintained, or lost along construction project lifecycles and how circular strategies are realized.

The methodology also incorporates a three-layered analytical lens:

1. **Current practices**: what is currently being done within each activity.
2. **Challenges and gaps**: where inefficiencies, inconsistencies, or barriers exist.
3. **Recommendations**: what can be improved or leveraged to increase circularity.

This approach allows for each pilot's individual set of stakeholders, materials, technologies, and goals to be assessed in detail, all in keeping with overall goals of the Circ-Boost project.

Key to this is that pilots are not evaluated in silos. Rather, every pilot is examined as part of a larger system that is interacting with supply chains, policy settings, and end-use markets. By doing so, analysis not only enables learning in individual pilots but also enables identification of cross-cutting opportunities, synergies, and avenues for systemic change.

Lastly, this methodological framework allows for insights to be translated into actionable, context-specific recommendations that are not only technically sound but also economically viable as well as institutionally appropriate. The outputs are integrated with the strategic objectives of WP6 of Circ-Boost and are conceptualized to facilitate replication as well as upscale in/around the pilot zones.

3.2 Value chain framework for circular construction

The analytical framework is founded upon a reinterpretation of Porter's Value Chain Model from a circular construction perspective. The original model offers an initial premise through which value is created by various business operations; in turn, the circular adaptation takes this thinking through to value retention, material circularity, and closing resource loops in the built environment.

In traditional linear construction paradigms, value is created by transferring material from extraction to production to installation to ultimate use to disposal. A circular value chain, in contrast, aims to maximize material/component utility over time, decrease virgin resource dependency, and reduce waste by prolonging lifecycles through reuse, recyclability, and versatility.

To clearly present the structure used for the analysis in this deliverable, Figure 1 below illustrates the original Porter's Value Chain Model, which serves as the foundational framework for the regional and pilot-level evaluations. The value chain is split along two divisions: primary activities, which are directly associated with producing and distributing products or services, and secondary or supporting activities, which facilitate and improve the smooth running of core processes.

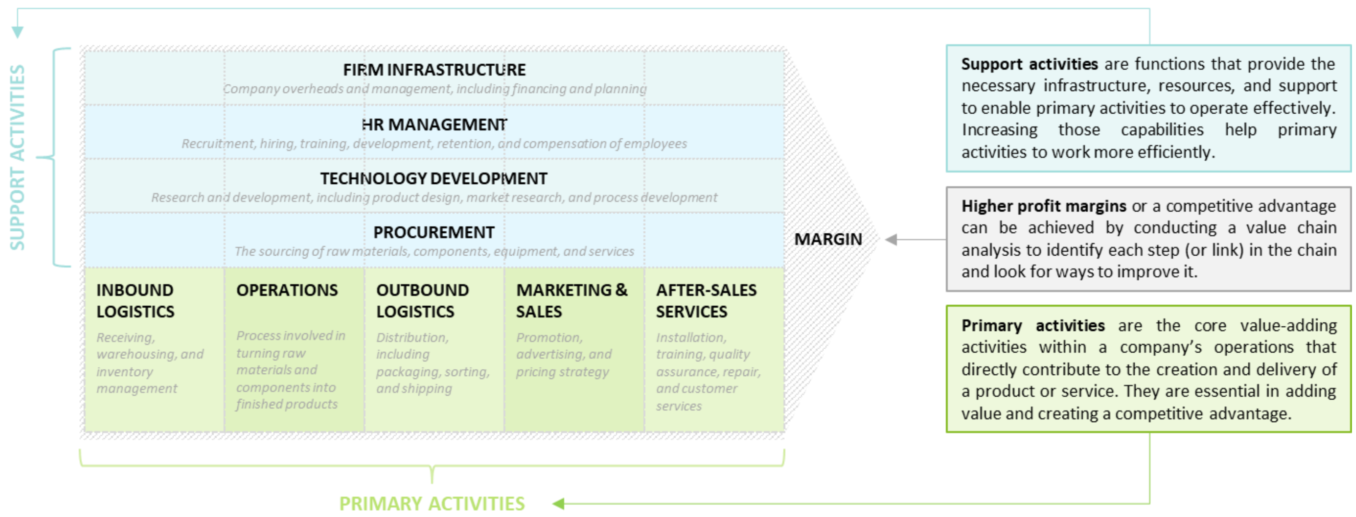

Figure 1: Porter's Value Chain Model

This conceptual framework allows for an organized analysis of all elements of a pilot construction value chain to pinpoint strengths, inefficiencies, and opportunities for circularity. It also reveals likely leverage points where circular strategies – i.e., the use of recycled products, local procurement, or digital traceability – can add value and minimize ecological impact.

In this adapted framework, nine core activities are assessed for each pilot:

Primary activities:

1. **Inbound Logistics**: reviews how material is acquired, with focus placed on using recycled, reused, or locally sourced materials; transportation influences; and traceability features such as material passports or QR tagging.
2. **Operations**: emphasizes construction processes, prefabrication, and demolition processes, with modular system utilization, disassembly design, resource efficiency in situ, and embedding of circular material and processes.
3. **Outbound Logistics**: examines how products or components in their finished state (such as prefabricated panels or dismantled material) are delivered or reintegrated to the built environment, including reverse logistics and material redistribution techniques.
4. **Marketing & Sales**: assesses how circularity is being conveyed to stakeholders and customers, such as participation in green procurement platforms, ESG integration, as well as branding for sustainability.
5. **After-Sales Services**: looks to how circularity is carried forward after construction through operations such as servicing, customization, modular upgrade, assistance for reuse or for second-life use.

Support activities:

6. **Firm Infrastructure**: examines governance frameworks, certification schemes, administrative arrangements, legal frameworks, and public-private partnerships that facilitate circular construction implementation.
7. **Human Resource Management**: oversees training and retention of staff with circular skills, working conditions, as well as knowledge transfer mechanisms in institutions.

8. **Technology Development**: encompasses developing and applying innovative technologies, including Building Information Modelling (BIM), digital twinning, smart sensors (e.g., RFID traceability), and novel material technologies to facilitate circularity.
9. **Procurement**: evaluates the means of acquiring goods and services, particularly those which emphasize circular performance (such as choosing low-carbon materials, collaboration with recycling plants, tender inclusion of circularity).

This framework allows for an overall evaluation of how every pilot contributes to circular construction, not only technical innovations but organizational and systemic enablers or blockers. By assessing pilots in all nine dimensions, analysis takes account of the multifaceted nature of circular value creation in construction – from material flows to governance models, technological capacity, and market behavior.

Moreover, it allows for identification of leverage points – targeted activities where action would unlock broader systemic gains. For example, innovation in procurement would trigger upstream material innovation, and optimizing after-sales services might promote long-term flexibility and minimize lifecycle emissions.

4 Pilot value chain assessments

4.1 Pilot 1 – La Mercedes (Spain)

4.1.1 Regional construction context

Spain's construction sector is witnessing a deep seismic change driven by the ambitious European agendas of the European Green Deal, the EU Taxonomy, and the Renovation Wave initiative. These policies have inspired governments at the national and regional levels to prioritize the themes of circularity, energy efficiency, and carbon neutrality in the built environment. The Renovation Wave, in turn, focuses, by 2030, on renovating 35 million buildings, thereby at least doubling the EU's annual pace of building renovations. Concurrently, recovery funding from EU recovery instruments such as NextGenerationEU has spurred the roll-out of pilot projects and action measures in urban renewal, including in the case of Catalonia, the setting for the Pilot 1.

Catalonia offers a thriving environment for the development of the circular construction approach. The region is supported by a robust research community, including the Institute for Advanced Architecture of Catalonia (IAAC), that works to establish architecture that can be used to tackle global issues in the fields of construction and inhabitation. Progressive city councils, such as the city of Barcelona, are also leaders in green urban development. Mainstream construction, however, persists in a primarily linear approach. Limited demolition is still the norm, reuse of materials is piecemeal, and recycled aggregates are seldom employed in structural use. Circularity in procurement is beginning to be supported by regulations, yet still in an emerging, non-systematic way.

Barcelona, in turn, is witnessing extensive urban transformation, attempting to recover post-industrial terrain and achieve dense, sustainable city development. Projects such as the "Superblocks" (Superilles) strive to develop people-centered urban space that minimizes traffic, noise, and pollution levels, reflecting the city's dedication to sustainable urban planning. Nonetheless, in spite of the progress, systemic constraints exist. There is no standardized system of tracing materials, few incentives for the reuse of components, and decentralized coordination of public and private stakeholders. This leads to a disparity between showcase innovation pilots and their scaling into broader construction practices.

In this regard, Pilot 1 – La Mercedes is a timely and strategic project. Located in one of Barcelona's most celebrated industrial brownfield redevelopments, it proposes to trial scalable solutions in digital traceability, modular construction, and clean-up of the soil – three levers of the circular construction paradigm. The outcome of the pilot can potentially impact not just upcoming projects in the city, but also the overall regional policy and market architectures influencing Catalonia's construction value chain.

Furthermore, the Catalan Circular Economy Projects Programme seeks to promote the transition of companies into a circular economy model, supporting initiatives that align with the objectives of Pilot 1. Collaborative research projects like the ARV project, which received €20 million in funding from the EU's Green Deal call, aim to develop climate-positive circular communities in Europe, providing guidelines and policy frameworks that could benefit similar initiatives in Catalonia.

With these regional strengths in mind and the resolution of the current challenges, Pilot 1 – La Mercedes can be a blueprint for embedding the principles of the circular economy into everyday building practices, advancing the overall aims of carbon neutrality and sustainability in the built environment.

4.1.2 Description of the Pilot

Pilot 1 – La Mercedes is part of the reuse of the old Mercedes-Benz car plant in the Sant Andreu borough of Barcelona. The 9-hectare area, once a mainstay of the city's industrial economy, is in the process of becoming one of the city's flagship eco-districts, with residential housing, schools, offices, and public squares.

As part of this wider city change, the Circ-Boost pilot is targeting three main lines of innovation:

1. **Soil decontamination using advanced, low-impact techniques**: leveraging innovative bioremediation and stabilization methods, the goal is to reduce the toxicity and transport needs of excavated soil. By lowering its hazard classification, the soil can either remain on-site or be disposed of under more favorable terms, thereby minimizing the environmental and economic footprint of land preparation.
2. **A modular, deconstructable concrete prototype**: constructed off-site in Madrid, the building utilizes prefabricated concrete panels pre-equipped for easy dismantling and reuse. The system is based on design-for-disassembly principles to demonstrate the potential ability of future buildings to be designed with reusability and adaptability in mind from the very beginning.
3. **A digital traceability system based on RFID sensors**: Smart Engineering, a spin-off from the UPC, has engineered embedded radio-frequency identification (RFID) chips that hold lifecycle data in the concrete elements themselves. The technology enables material passporting and has the potential to be integrated into digital building models in the case of long-term circular asset management.

The pilot is led by the **Universitat Politècnica de Catalunya (UPC)** and takes advantage of a multidisciplinary consortium comprising:

- **Acciona**, which provides the off-site demonstration location in Madrid.
- **Smart Engineering**, leading RFID integration.
- **Control Demeter**, responsible for soil remediation.
- **Tesis**, contributing design methodologies and circularity strategies.

4.1.3 Value chain analysis (VCA)

The value chain analysis of Pilot 1 – La Mercedes shows a multifaceted, pioneering application of principles of circularity in a number of connected activities. It both identifies the technological capabilities of the pilot as well as operational and systemic limitations to the uptake in the mainstream. The analysis adheres to the nine-activity structure outlined in Section 3.2, both for the primary and supporting activities.

Inbound Logistics:

The pilot's supply logistics are informed by the need to align specialized material and technology inputs for soil purification, precast concrete elements, and digital sensors. Although the initial plan to reuse demolition materials from the Mercedes project proved unachievable because of the early beginning of the demolitions, raw materials for the demonstrator are now supplied externally. In an effort to minimize emissions, the team ranked local suppliers along the Madrid area, where the test piece is to be constructed. Although recycled materials in the elements still are in limited share, the strategy focuses on logistically efficient and proximal sourcing, consistent with the principles of the circular economy.

Operations:

There are three parallel streams of operations. On-site treatment of excavated soil using a new combination of chemical and microbial methods will treat about 200,000 cubic meters of soil. Whilst new in a global sense, the process is unprecedented in the scale of application in Catalonia and is designed to decrease hazardous classification by more than 90%. The second operation is the off-site construction of a modular concrete proof of concept, applying principles of DfD to facilitate component reuse. Last, the RFID system of traceability is under development and test in controlled environments, with microchip integration into the concrete to record origin, materials, and lifecycle information. These activities are high-potential developments, but still in demonstrative phases.

Outbound Logistics:

Transportation and installation of prefabricated panels for the demonstrator structure are the main focus of outbound logistics. Further, the reuse of the panels in subsequent structures through disassembly is also a practical evaluation of the application of reverse logistics in modular construction. While internal to the pilot, the in-built RFID sensors represent a look-forward mechanism to facilitate increased data-driven flows of materials in the aggregate among sites, enabling the building of next-generation digital markets and networks of reuse.

Marketing & Sales:

While the pilot is non-commercial in scale, it does involve significant dissemination and raising of awareness. The demonstrator will be promoted via visits to sites, academic conferences, and promotion materials. Additionally, the system of tracing – if successfully tested – may find its way into the core of a commercially available Smart Engineering service. The pilot offers a platform to showcase the value proposition of the circular economy to developers, municipalities, and manufacturers, although the latter will need further investment in business case development and stakeholder engagement.

After-Sales Services:

A key component of after-sales services is the traceability system, which allows lifecycle data to be updated throughout the use phase of structural components. This digital infrastructure lays the groundwork for long-term component tracking and reuse, offering a scalable model for material passports. However, institutional integration (e.g., via public procurement or BIM regulations) is still lacking, and the system's long-term support model – e.g., who updates the data or guarantees data security – remains to be defined.

Firm Infrastructure:

The initiative has a minimalist but strong organizational structure facilitated by UPC, supported by intense industry-academy partnerships. Acciona and other partner members offer administrative and logistics coordination. Although the structure enables innovation, it is thin in relation to deep integration into public administration structures and urban planning authorities. Deepening these institutional associations will be vital to advancing from autonomous innovation to systemic change.

Human Resource Management:

The pilot mobilizes a diverse and skilled team of researchers, engineers, and industry professionals. Training and learning-by-doing are embedded in the development of the prototype and sensor systems. However, broader capacity-building efforts, such as industry-wide training or stakeholder workshops, have not yet been implemented. As such, knowledge transfer beyond the project team remains limited, potentially hindering large-scale adoption.

Technology Development:

Technology development is a mainstay. The pilot combines three complementary innovations: a context-specific remediation method, a design-for-deconstruction structural system, and an RFID-based platform for traceability. All three play their part in helping to address different paths to circularity – environmental performance, reuse of materials, and management of data. None of them, as yet, are codified in Spain's norms for construction, so may be held back from market integration even though they are ready technologically.

Procurement:

Procurement practices changed throughout the project in light of logistical limitations. Initially oriented toward reuse from in-place demolition, the project team moved toward regional procurement of new precast elements. Procurement continues to be largely conventional and price-driven, lacking official circularity specifications. However, the use of digital elements and tracing technology marks the beginning of the move toward intelligent and value-driven procurement, particularly if supported by public sector lead demand or ESG frameworks.

4.1.4 Strengths, challenges & recommendations

Pilot 1 – La Mercedes presents a strong example of the potential of circular construction to be unlocked through multi-layered innovation, a combination of remediation of the soil, modular construction, and digital tracing. Its strongest point is the linking of scholarly research, technological advancement, and industrial demonstration in the framework of a high-visibility urban renewal project. The technical validity that comes from the partnership of UPC, Smart Engineering, Acciona, and other partners, as well as the feasibility of operation, is ensured.

The application of design-for-deconstruction methods and RFID-based material monitoring makes the pilot a national leader in digital circular building. The method of remediation of the soil, based as it is on established principles, is being implemented at scale and in a new context in Spain, with important lessons for the treatment of residual industrial pollution in new developments to be learned.

Nonetheless, a number of challenges reduce the pilot's systemic effect. Initial intentions to incorporate reuse of on-site demolition had to be dropped in the face of timing mismatches, and urban planning approval has slowed down the process of soil decontamination. The deferment to off-site demonstration – although expedient – limits the project's visibility and minimizes direct integration into the Mercedes redevelopment process.

Furthermore, although the traceability system is encouraging, it continues to be wanting in a commercialization plan, institution-wide backing, or alignment with regulatory mechanisms including the mandate of material passports. Also, the public sector's non-participation, industry stakeholders' training, and the low adoption of official circular procurement practices can hinder the scaling of the innovations from the pilot to the broader industry.

In an endeavor to fill such gaps, the following are suggested:

- Enhance stakeholder engagement, most notably with urban developers, public procurement agencies, and local authorities, to align the pilot with policy levers and regulatory priorities.
- Foster the commercialization plan for the RFID traceability system, including standardization and possible partnerships with public clients or certifiers.
- Document and share the method of soil remediation, including scientific data, a cost-benefit analysis, and guidelines for application to facilitate reproduction in other sites in Spain and Europe.
- Improve training and outreach, staging workshops, site visits, and online materials to disseminate lessons learned to contractors, architects, and construction managers.
- Establish a business case for the modular concrete system with estimates of environmental savings, life cycle advantages, and cost savings over traditional building methods.

Thanks to its multidisciplinary approach and strategic urban location, Pilot 1 is in a strong position to be a reference project for the transition of Spain toward circular construction. Yet in order to achieve sustained change, work must translate from demonstration to systemic integration in public policy, procurement, and industrial practice.

4.2 Pilot 2 – Digital and physical platform (France)

4.2.1 Regional construction context

The construction sector in France is undergoing a significant transformation, influenced by ambitious national and European Union policy objectives focused on sustainability, decarbonization, and the transition to a circular economy. This shift is particularly pronounced in the Île-de-France region – the country's most densely populated and urbanized area – where Pilot 2 is situated. The region faces intense construction pressure due to urban renewal projects, infrastructure expansion, and the growing demand for sustainable housing and public buildings.

At the national level, France has enacted a set of ambitious regulatory measures to drive circularity in the construction sector. Indicatively, the 2020 Loi Anti-Gaspillage pour une Économie Circulaire (AGEC) sets compulsory measures to minimize waste and maximize the reuse of materials in all sectors, including construction. It obliges, for instance, public building works contracts to specify minimum reuse and recycled proportions and makes developers submit waste diagnostic reports before demolition.

The RE2020 (Réglementation Environnementale 2020), implemented in January 2022, also strengthens environmental performance in new buildings, with an emphasis on minimizing embodied carbon and encouraging life cycle assessments. These regulations are in full alignment with other EU-wide measures such as the Green Deal and the Circular Economy Action Plan, equally putting pressure on the industry to change.

In spite of these regulatory developments, the Île-de-France construction industry continues to be dominated by mainly linear production patterns. Construction and demolition (C&D) waste produces more than 227 million tons of waste annually in France, accounting for almost 70% of the country's overall waste production, although national recovery rates are increasing, reuse of the materials remains less than 1%, a long way from the EU target.

In Île-de-France in particular, high-density urbanization and a shortage of space available for sorting or temporary storage cause demolition waste to be sent long distances for treatment or disposal. The loop of treatment and disposal off the construction site both increases the environmental footprint of activities and separates waste streams from reuse within the local area. Logistical bottlenecks and a shortage of infrastructure for tracing waste streams hinder the systematic reuse of bypassed materials in new projects.

Furthermore, current reuse practices are very project-specific, normally driven by single actors or showcase developments and not integrated in a systemic regional strategy. Digital reuse and recycling platforms (e.g., Cycle Up, Backacia) now link supply and demand, but they are still disconnected from physical depots, logistics services, and from certification schemes.

Nevertheless, the region benefits from the presence of several key institutional and industrial drivers. The Métropole du Grand Paris (MGP), a strategic planning body overseeing the metropolitan area, has placed circular construction at the heart of its sustainable urban development agenda. Initiatives such as the Métropole du Grand Paris circular economy roadmap include pilot projects, land-use planning incentives, and public-private partnerships aimed at reducing the carbon footprint of construction and valorizing local material flows.

Significant players such as Eiffage, Bouygues, and Vinci are more and more investing in circular material banks, reuse sites within the building, and closed-loop construction schemes. These corporate efforts, nevertheless, are not yet fully interoperable with public policy mechanisms as well as local reuse centers, so coordination is difficult.

France also has a strong research environment that underlies circular construction innovation. Organizations like the Centre Scientifique et Technique du Bâtiment (CSTB) and Université Gustave Eiffel are working to advance the development of selective deconstruction methodologies, the characterization of materials, life cycle assessments, and digital traceability instruments. As an example, CSTB's research into the development of a material passport and BIM integration for a circular approach to construction is leading the way to standardization and scaling reuse in the built environment. These research capabilities underpin France’s role as a potential global leader in the application of data-driven strategies to the reuse of materials, most particularly in the most intensely resources and environmental-pressure contexts of urban environments.

Within this complex landscape, Pilot 2 is designed to act as a systemic intervention in the construction material value chain. By bridging digital and physical infrastructures for reuse and recycling – and by involving partners such as CSTB and Eiffage – the pilot aims to overcome fragmentation and create interoperable systems for traceability, logistics, and certification. It is uniquely positioned to scale up from isolated experiments to territorial-level integration of circular practices. In the end, Pilot 2 also reacts to technical as well as environmental imperatives, alongside the imperatives of institutional coordination, market maturity, and data transparency that are necessary to mainstream the circular construction in Île-de-France and elsewhere.

4.2.2 Description of the Pilot

Pilot 2 – Digital and Physical Platform, led by Cap Digital and deployed across the Greater Paris area, aims to create an integrated ecosystem for circular construction through two interconnected platforms:

1. A digital platform (BTP Match) that centralizes information on available reused and recycled materials and enables automatic matchmaking between supply and demand in the construction sector.
2. A physical platform network of multi-site facilities that aims to enhance the sorting, storage, treatment, and sale of reusable and recoverable construction materials.

The digital platform is based upon an earlier proof of concept launched by Plaine Commune in partnership with the startup SKOP. Circ-Boost is scaling up the platform and adding new innovative features, such as:

- Real-time geo-visualization of offers and demands of materials.
- Predictive analytics to forecast material flows.
- Economic and environmental indicators to measure impact.
- Maintaining interoperability with other databases and marketplaces.

Though SKOP is not a project partner, MGP has contracted the company via an innovation public market, ensuring continuity and avoiding procurement delays. The platform has already undergone a first testing phase (completed in March 2025), integrating feedback from over 30 end-users. A second test phase will begin in April 2025 and run for 18 months. MoUs have been signed with three local municipalities to guarantee post-project deployment.

The physical platform network comprises two newly established "front-base" facilities: one for soil and inert waste (operated by EFGE) and one for reconditioning architectural fixtures and components (operated by DEMSI). These are complemented by two existing rear bases (in Dammartin-en-Goële and Gennevilliers), forming a modular and mobile infrastructure adapted to urban constraints. The system prioritizes double freight logistics, local reuse, and traceability. The platform also functions as a showroom and experimentation ground for new reuse protocols and digital tagging systems.

Partners involved in the pilot include: Cap Digital, MGP, Eiffage (EIGD), Université Gustave Eiffel (UGE), CSTB, Sitowie, and NGE. They bring in their specializations in the fields of material characterization, environmental analysis, traceability, digital systems, and operational testing.

4.2.3 Value chain analysis (VCA)

Pilot 2 value chain offers a holistic, systemic solution to circularity that integrates technological innovation, public sector coordination, and urban logistics. All nine value chain activities are covered by both digital and physical layers, making the model supportive of multi-scalar adoption of circular construction practices.

Inbound Logistics:

The physical inputs to the pilot's platforms comprise mainly demolition waste, excavated soil, and reusable building elements. The pilot takes advantage of prevailing local flows by mapping out and identifying main deposit points throughout the Métropole du Grand Paris. Inbound sorting is operated by the subsidiaries of Eiffage (EFGE and DEMSI) and analysis of upstream material character and potential reuse by NGE and UGE. Automated recognition technology (e.g., RFID tagging, image recognition) is also investigated by the pilot to streamline the intake process. While few of the materials are as yet certified as secondary resources, the pilot is setting the stage for standardized input qualification.

Operations:

Operations span both digital and physical platforms. On the digital side, the development of BTP Match includes back-end coding, user interface design, integration with public databases, and real-time mapping of material offers and demands. Testing and user feedback loops are key operational elements, enabling iterative development. On the physical side, Eiffage and partners are setting up modular infrastructure capable of treating and reselling materials within urban settings. Key innovations include mobile treatment lines, digital traceability of incoming batches, and certification protocols for fixture reuse. The pilot also supports live experimentation with environmental and economic scenario modeling, led by UGE and Sitowie.

Outbound Logistics:

The physical platforms support outbound logistics through resale channels, showroom demonstrations, and real-time catalog integration into the digital platform. Products range from recycled aggregates to refurbished fixtures, with logistics optimized through double freight strategies. The digital platform will enable construction actors to locate nearby materials and automate transaction matching. While outbound flows are still being tested, the integration of data analytics and logistics modeling aims to reduce transport distances and emissions while increasing the rate of reuse.

Marketing and Sales:

While not a commercial operation in itself, the experiment encompasses a range of marketing mechanisms. The physical platform serves as a demonstration zone that is accessible to professionals and public stakeholders. The online platform provides an easy-to-use interface that is advertised using local networks. BTP Match has a special area for sellers to generate offers and for buyers to establish notifications, raising transparency and transaction velocity. As part of the market of innovations, SKOP and MGP are co-designing governance and business models that can secure post-project viability and adoption in France.

After-Sales Services:

Long-term supporting capability is incorporated in the design of the digital platform. Traceability systems' development to the point of storing data about material properties, lifecycle data, and reuse certificates, so they are still available, is forthcoming. SKOP's software architecture is designed to accommodate over-time data updates, facilitate reuse tracing, as well as handling claims and integration in the form of material passport systems. After-sales services, although still a concept, still need to be operationalized, particularly in training users and in taking care of data.

Firm Infrastructure:

Coordination is ensured by MGP and Cap Digital, with active participation from subsidiaries and Eiffage. Top-level institutional action supports the pilot, particularly through the framework of the innovation market and urban MoUs. Digital platform governance is in the process of refinement, with a focus on active experimentation of balance among public control, private sector flexibility, and territorial coherence. A permanent project manager has been assigned in MGP to oversee deployment. A system of weekly progress monitoring and a midterm evaluation system has been established to check delays and preserve momentum.

Human Resource Management:

The multidisciplinary piloting team includes data scientists, urban planners, civil engineers, and software developers. Eiffage and NGE contribute operational personnel and training provision, and CSTB is working to create a MOOC in the topic of selective deconstruction. Postdocs and interns work in axis 3 to evaluate environmental performance and platform indicators. Predictive modelling and scenario simulation are supported by Sitowie. Wider workforce engagement, in SMEs and platform operators, remains in development and might benefit from further levels of upskilling.

Technology Development:

Pilot 2 is a technology development hub. On the digital front, the new capabilities are: matchmaking engines, indicator calculation engines, prediction of flows, and interoperable interfaces. On the physical front, experimental sorting, certification, and repairing protocols are in the test phase. The hybrid model tools of UGE bring LCA and 3D structural analysis together, and Sitowie offers predictive analytics of material aging. Interoperability of the data is still a core issue but is in the process of being solved through the open architecture of the digital platform.

Procurement:

Procurement processes are evolving as the pilot matures. The innovation market enables MGP to contract SKOP directly for digital platform development without public tendering, accelerating deployment. For the physical platform, procurement focuses on modular, mobile equipment that complies with urban constraints. Suppliers of reused and recycled materials are being onboarded progressively through platform outreach. The pilot is also mapping out how public procurement frameworks can embed circularity criteria, particularly for traceability, local sourcing, and reuse certifications.

4.2.4 Strengths, challenges & recommendations

Pilot 2 is Circ-Boost's most holistic and visionary initiative. Its strongest aspect is the connection of the digital and physical worlds in organizing the regional circular construction industry. Unlike isolated demonstrations, the pilot establishes a sustainable operational model, connecting logistics, data, and market reach.

The pilot is supported by strong institution partners (CSTB, MGP, Cap Digital) along with industry leaders (GE, Eiffage) and specialist researchers (UGE, Sitowie). The wide range of partners makes possible a high level of technical creativity and stakeholder involvement. The BTP Match tool development provides a scalable and interoperable solution to the recurring fragmentation of the reuse and recycling value chain. The physical frameworks illustrate a viable and modular business model in keeping with urban constraints.

However, challenges remain. Early delays from administrative turnovers slowed down development of the digital platform, necessitating measures such as the innovation market contract. Although practical, long-term governance and funding of the platform are still in negotiations. Intellectual property and ownership of data also need to be clarified, most notably between MGP and SKOP. On the physical front, although the two initial sites demonstrate robust use cases, the scalability to other types of waste and geography remains to be tested.

Recommendations include:

- Establish a formal governance and business model for the BTP Match platform to allow durability beyond the project period. Bring in more private sector stakeholders and establish roles, functions, and data-exchange protocols upfront.
- Ramp up interoperability with current materials marketplaces and databases, perhaps through standardization efforts or API integration, to prevent duplication and facilitate scalability.
- Expand training to cover SMEs, local government employees, and platform users. Its MOOC program needs to be incorporated within an overall learning and certification plan.
- Implement a common traceability and certification procedure for materials processed in physical platforms in coordination with insurers and standardization bodies.
- Document and share cost-benefit analyses of both digital and physical platform operations, including carbon savings, to build the economic case for replication.

Pilot 2 provides a roadmap for supporting the digital and physical facilitation of the circular economy in metropolitan construction. Properly supported, both institutionally and through a scaling strategy, it has the potential to function as a reference model for the metropolitan regions of Europe.

4.3 Pilot 3 – Modular house (Serbia)

4.3.1 Regional construction context

Serbia's construction industry is at the beginning of its development toward more sustainable and circular practices. Traditionally marked by linear systems – whereby construction and demolition waste (CDW) is sent to the landfill in bulk – the nation is now under growing pressure to converge with the environmental norms of the EU, as part of Serbia's EU accession process. Incremental progress as yet, but Serbia is now experiencing a surge in interest in resource efficiency, recovery of materials, and climate-resilient building models.

Serbia currently does not have a properly established infrastructure for the recovery, treatment, and reuse of CDW. Most of the waste resulting from demolition and refurbishment is sent to landfills or uncontrolled tipping sites, while merely a small portion is sorted for recovery. Construction waste makes up more than 40% of generated waste in the country, but recovery and recycling rates are under 5%. This is due in part to the fact that certified recovery facilities do not exist, little waste separation takes place at the source, and few economic incentives for the reuse of materials exist.

The unavailability of standardized, quality-certified recycled materials also hinders their application in new building ventures. Several developers find recycled aggregates to be unreliable or inappropriate for structural use. Building regulations and technical specifications presently do not contain detailed provisions supporting or obliging the application of secondary raw materials, even though Serbia has been striving to progressively harmonize its laws with the EU Construction Products Regulation (CPR) and the Waste Framework Directive.

Even if operational infrastructure lags, policy directions signal a change in national priority. Serbia's 2022–2031 Waste Management Programme, endorsed by the Ministry of Environmental Protection, aims, in explicit terms, to enhance the management of CDW and encourage recovery and reuse of waste. The strategy provides the groundwork for the development of treatment facilities, the application of economic measures (including landfill taxes), and the promotion of innovative recovery of materials. In addition, Serbia's Green Agenda for the Western Balkans, as supported by the European Union, makes the circular economy a strategic pillar. The action plan promises better waste sorting, increased recycling, and the application of eco-design in the building sector. Although implementation is in its early stages, the frameworks are important drivers of change.

In the face of this changing policy environment, Serbian universities and research institutes are assuming leading roles in advancing a science-driven approach to a circular construction paradigm. The Faculty of Civil Engineering (FCE) of the University of Belgrade has led the sector in conducting research into the mechanical and durability characteristics of recycled concrete, the lifecycle analysis of the built environment, and design principles for demountable and reusable building structures. Its engagement in projects financed by the EU, as well as in bi-lateral higher education networks, makes it a thought leader in the Western Balkan region.

These innovations are translated from the laboratory to the real world in Pilot 3, highlighting the ways that recycled and reclaimed materials can be incorporated into structural use, while continuing to meet the requirements of safety, reliability, and performance. The pilot both proves the feasibility of technology, as well as provides a platform to share knowledge, shape market perception, and inform regulation.

Through the use of recycled structural steel elements, RCA-based concrete, and demountable joints, pilot 3 offers valuable data and experience that can aid standardization, stimulate public and private sector stakeholders, and drive future reuse infrastructure investment.

Additionally, the project makes Serbia a regional leader, in a position to drive cross-Balkan co-operative action to adopt circular practices for the built environment. The ultimate value of the pilot, apart from its technical outcomes, rests in its potential to change perception and instill confidence in the application of circular construction solutions.

Pilot 3 positions itself as a unique opportunity to drive both technological and cultural shifts in the Western Balkans construction sector by showcasing how reused, recycled, and demountable structural systems can function under real-life operational conditions.

4.3.2 Description of the Pilot

Pilot 3 is led by the Faculty of Civil Engineering, University of Belgrade (FCE), and involves designing, building, testing, and promotion of a fully demountable modular ground-floor house based on locally available reused and recycled materials. The pilot is centered in the design of the load-bearing structure, proving their technical performance, environmental performance, and potential for the application of circular business models.

The house is conceptualized as an information pavilion, to be constructed and reconstructed several times, demonstrating its modularity and reusability. Some of the main structural elements are:

- Precast reinforced concrete columns and walls utilizing 100% recycled concrete aggregate (RCA).
- Steel frames made of recycled steel sections, connected by demountable moment-resisting joints.
- Profiled steel sheeting composite slabs using high-volume fly ash concrete (HVFAC) with certified fly ash from the first commercial fly ash producer in Serbia.
- The walls made of reclaimed bricks and recycled rubber tapes (INODIS connection) to achieve non-destroying installation and better seismic performance.

The house will be extensively physically and numerically tested, both in the laboratory and operationally, including in-site shaking and loading tests. All the pieces are meant to be disassembled and reassembled in 36 hours, with the possibility of application in temporary housing or modular designs.

Materials are drawn from local demolition sites and local suppliers, with active participation from companies such as Penta Ge.Co., Evrobrod, SDA Engineering, Peikko, Regupol, DOCA, and Ecopar as industrial or supporting partners. The pilot will also contribute to training, standardization, and stakeholder engagement in the region.

4.3.3 Value chain analysis (VCA)

Pilot 3 targets circularity over the entire value chain of construction, primarily in the area of load-bearing structural systems. Focusing on such a way enables profound innovation in reuse of materials, connection systems, modular design, and test methods.

Inbound Logistics:

Material procurement is undertaken by extensive market research as well as stakeholder involvement. Recycled concrete aggregate is supplied from the Belgrade Waste Treatment Plant, and reused steel components from the demolitions of buildings. Bricks that are reused are sourced from private demolitions, and recycled strips of rubber from donations by Regupol. Certified fly ash is now available from Ecopar, a valuable milestone in the use of green concrete in Serbia. Transport distances are kept low to minimize carbon footprint and align with the environmental KPIs. Procurement entails both first-order elements as well as primary connection technology (e.g., the use of Peikko mechanical couplers).

Operations:

Sequenced operations comprise structural and architectural design, development of prototypes, material testing, and full-scale construction. Numerical simulation, including failure prediction, modal analysis, and stress tests, is applied to all elements. Full-scale prototypes are inspected in FCE’s laboratory by employing advanced machinery, including 3D Digital Image Correlation (DIC), vibration shakers, and airbags for out-of-plane assessment. Test of reused materials is compared with reference elements using standard concrete to verify life performance that is equal or better. Structural elements are pre-assembled in Penta Ge.Co. and Evrobrod workshops under the aegis of FCE engineers and academics.

Outbound Logistics:

As a demonstrator, the pilot does not incorporate commercial distribution, but offers a proof of concept for broader replication. Structural components will be shipped in and installed in the field, with careful records of handling, reusability, and transport conditions. The modular home will be marketed as a model building for a range of applications (e.g., temporary housing, exhibitions, modular schools), with logistics advice in post-project reports. While outbound logistics are not commercialized, the pilot sets an example of best practices in reverse logistics and demountable building.

Marketing and Sales:

Marketing is organized around the dissemination of knowledge and stakeholder participation. Activities encompass:

- Webinars and technical workshops (e.g., "Step Toward Carbon Neutral Circular Construction Industry").
- Live demonstration events and training sites.
- Social media campaigns and project website promotion.
- Collaboration with national industry associations and the Green Building Council.
- Technical guidelines and promotion materials development.

These initiatives are directed at construction professionals, industry stakeholders, policymakers, and educators. The pilot also targets potential partners for commercialization and replication of the developed solutions.

After-Sales Services:

The project aims to provide technical manuals, catalogues, and design guidelines to facilitate future reproduction by prospective firms. While an after-sales commercial structure is not envisioned under the scope of the pilot, the team can offer advisory services and training after the project. Instructions for maintenance and reassembly will be incorporated into training and the project's knowledge deliverables.

Firm Infrastructure:

Pilot 3 is managed by FCE and backed by an in-house project management organization with sharply defined roles on work packages. The infrastructure involves administrative, legal, technical, and financial coordination, supported by specialized sub-teams for concrete, steel, rubber, and design. The management tools consist of Gantt charts, reporting templates, and milestone monitoring. Procurement is by public sector regulations, and delays were caused by them, but by applying contingency measures, they managed to continue on schedule.

Human Resource Management:

The project team comprises leading academics, laboratory technicians, and industry partner engineers. Training is embedded in each phase, from materials testing to simulation, and to the production of prototypes. Capacity building is also extended to external parties in the form of workshops and education platform materials. While the pilot is spearheaded by technically oriented personnel, the team realizes that they need extra capacity in the area of marketing and stakeholder engagement – an aspect that is being reinforced by work with WP7.

Technology Development:

Pilot 3 is distinguished by very high levels of technological innovation:

- Production of high-volume fly ash concrete utilizing certified local fly ash (first in Serbia).
- Welding free design of demountable structural joints.
- INODIS recycled rubber connection strips for non-load bearing walls.
- Application of advanced digital testing equipment (DIC, vibration analysis, numerical simulation).
- Modular structural design facilitating quick assembly, disassembly, and reuse.

Testing is done at the material and structure levels, comparing green with conventional materials to establish technical equivalence. The pilot also provides scientific data for standard development and contributes to subsequent regulatory measures for recycled materials in Serbia.

Procurement:

Procurement mechanisms are adapted to the Serbian environment, in which recycled materials are scarce and unstandardized. Materials are procured from demolition companies, waste treatment centers, and small-scale private vendors. Public procurement limitations impacted equipment procurement timelines, although essential equipment is now in position. FCE also organized in-kind donations from industry allies (e.g., fly ash, rubber, connectors), noting strong stakeholder relations and value co-creation. A supplier database of local materials has been established and will be developed for further market development.

4.3.4 Strengths, challenges & recommendations

Pilot 3 is a technologically advanced and very innovative project that targets the material and structural levels of the circular construction. Its main strengths are:

- **Comprehensive structural innovation**: The pilot showcases demountable, reusable structural elements based both on recycled and reused materials – something hardly ever done in the region to such an extensive extent.
- **Advanced technical capability**: FCE's scholarly knowledge, laboratory facilities, and robust industrial collaborations guarantee scientific integrity and consistent testing.
- **Contextual applicability**: The pilot is customized to the Balkan environment, providing solutions that are both environmentally appropriate as well as implementable by local industry.
- **Stakeholders engaged**: With its partnerships with several firms and public agencies, the pilot paves the way for subsequent commercialization and scaling up.

Nonetheless, several challenges must be addressed:

- **Market immaturity**: Serbia's recycling and reuse market is nascent. The availability of standardized secondary materials remains limited, and broader industry uptake is still uncertain.
- **Delayed procurement of equipment**: public procurement process has resulted in some delays in the acquiring of necessary test equipment. Though non-essential to near-term objectives, the need for quick procurement channels in public research projects is identified by this.
- **Limited marketing capacity**: The technical focus of the pilot is as yet not supported by specialized communication and outreach personnel. WP7 and WP8 need to be engaged at an increased level.
- **Certification and regulatory mechanisms**: Structural safety is shown experimentally, yet standardized certification procedures for recycled materials do not yet exist. That may hinder application in the field without concurrent work in policy integration.

Recommendations include:

1. **Extend stakeholder involvement** to beyond structural suppliers, to the inclusion of façade, insulation, and roofing solution providers – to enable a more comprehensive demonstration of the circular construction.
2. **Strengthen communication and dissemination efforts**, possibly by onboarding a dedicated external advisor or student assistant to support promotional activities, events, and material packaging.
3. **Work with national authorities** and standardization associations to document and validate new materials and joints, setting the stage for official recognition.
4. **Collaborate closely with WP5** to co-develop LCA communication materials that transfer technical data into easy-to-understand, graphical outputs for industry and policymaking.
5. **Foster market development of recycled materials**, utilizing the pilot house and supplier database as a tool for raising awareness and matchmaking in the construction sector of Serbia.

Pilot 3 presents a singular value proposition to demonstrate circular innovation in the very structural heart of buildings. Should the approach be successfully scaled, Serbia – and the broader Balkan region – can be a leader in climate-neutral building using modular construction.

4.4 Pilot 4 – Museum Nord (Norway)

4.4.1 Regional construction context

Northern Norway presents a unique construction context, shaped by the Arctic climate, dispersed population centers, and logistical challenges tied to geography and infrastructure. These factors have historically led to a heavy reliance on imported construction materials and energy-intensive transport systems. Despite the abundance of local construction and demolition waste (CDW), particularly concrete from aging or disused infrastructure, the reuse and recycling of these materials remain limited in practice.

In the Arctic, such as in the case of Vesterålen, where Pilot 4 is stationed, the environmental stakes are even greater. Freeze-thaw, permafrost dynamics, salt-contaminated sea spray, and long winter periods of darkness require extremely resilient construction materials. Historically, such environmental limitations have favored solidity at the expense of innovation, of course, partly as a result of the delay in the adoption of circular construction practices. Furthermore, the insufficient locally based recycling infrastructure, as well as the expense of exporting waste to central locations, makes recovery of materials even more difficult in that region.

Even with all these hurdles, Norway is increasingly moving in the direction of a circular economy, spurred by both EU policy guidelines and domestic environmental targets. The Norwegian government has explicitly prioritized circularity in the construction sector through its National Strategy for a Green, Circular Economy. The strategy includes construction as a key sector for intervention, highlighting the need to increase the reuse of materials, improve CDW sorting, and reduce the sector's overall climate footprint.

In addition, technical norms and regulations have been updated lately. The new Norwegian Concrete Association publication NB38 now makes the utilization of recycled concrete aggregates (RCA) in structural applications possible under controlled quality conditions, including strength category, level of contamination, and moisture content. These amendments signal an important policy change, enabling possibilities for industrial-scale and pilot-scale applications of RCA-based concrete, notably in public works and infrastructure developments.

It is particularly notable in the case of Pilot 4, one of the first construction projects in the Arctic Circle to apply certified RCA-based concrete under these new regulatory regimes. Pilot 4 is located in Sortland Municipality, a region with an increasing drive for sustainable development. The Gaia Vesterålen Museum project, a cross-sectoral development in partnership among the municipality, universities, and industry, aims to be a regional model of reuse of materials, selective demolition, and recycled aggregate concrete. The pilot is based on the early work of centers such as UiT – The Arctic University of Norway, who have extensively investigated concrete recyclability, environmental evaluation of CDW, and the performance requirements of construction in the Arctic.

As Arctic communities strive to achieve national carbon neutrality targets and reduce reliance on long-distance material imports, circular strategies offer both climate benefits and local economic resilience. Recycling and reusing materials on-site, or within a short radius, helps reduce the embodied emissions of construction projects – particularly important in regions where transportation contributes disproportionately to environmental impacts.

In the process, Pilot 4 acts as an example of system-level circularity in the Arctic. Not only does it validate the technical feasibility of RCA using actual conditions in the Arctic climate, but also investigates the entire life cycle of a circular construction, including the selective demolition of the previous Nortura slaughterhouse, followed by new construction from recycled concrete structural members. Additionally, its integration with wider public campaigning efforts and digital monitoring technology makes the process an example that can be repeated by municipalities in the wider Arctic and in rural Scandinavia.

By involving stakeholders from policy, academia, and industry, Pilot 4 acts as a catalyst to implement national guidelines at a local level, overcome cultural resistance, and demonstrate the economic and environmental feasibility of the circular approach in even the most challenging environments.

However, Norway has taken significant strides in aligning national policies with circular economy principles. Updates to national concrete guidelines now permit the use of recycled concrete aggregates (RCA) in structural applications – a major step forward for mainstream adoption. Pilot 4 emerges as one of the first practical test for these updated standards, and uniquely, it does so within the Arctic Circle, in a region where logistical and environmental constraints demand highly localized and resource-efficient solutions.

4.4.2 Description of the Pilot

Pilot 4, undertaken by Museum Nord in collaboration with UiT (The Arctic University of Norway) and the Sortland municipality, aims to implement an end-to-end demonstration of complete circular construction – from demolition to rebuilding – in one of the most ecologically sensitive areas in the world.

The hub of the pilot is the GAIA Vesterålen Museum, an advanced cultural centre aimed at presenting sustainable architecture, environmental narratives, and innovative interactive exhibitions (VR, AR, projection mapping). GAIA, however, is something greater than a building – a manifesto in concrete of how to close the loop in construction.

The three closely connected stages of the round workflow are:

- **Demolition of the Nortura slaughterhouse**, a 1960s industrial structure belonging to Sortland Municipality.
- **On-site production of RCA** from the demolished structure using mobile crushers, enabling local reuse and minimizing transport emissions.
- **Building GAIA**, with certified RCA-based structural concrete incorporated into major components such as columns, beams, and foundations, including underwater parts that are to be submerged in the Norwegian Sea.

The bold aspect of this pilot is taking control of the entire material lifecycle in one place, minimizing environmental effect as well as expense. It is, in effect, a pilot of more than just materials – of an entire circular construction system.

4.4.3 Value chain analysis (VCA)

Pilot 4 is an example of a circular economy in action – tracing the value chain from waste to resource, from a destroyed slaughterhouse to a museum looking to the future.

Inbound Logistics:

The pilot takes advantage of the sole benefit of single-site ownership: the ownership of both the building to be torn down and the new construction site by the same entity (Sortland Municipality). This facilitates a zero-cost transfer of materials from demolition to reuse.

UiT undertook a rigorous pre-demolition audit comprising:

- Drilling of the core and concrete contamination and strength testing.
- Environmental mapping of potential hazards (chlorides, coatings, etc.).
- Structural 3D modeling for the calculation of material quantities and recoverability.

About 7,500 tons of concrete were found, of which more than 3,500 tons qualified as RCA. The concrete encountered was of various types (lightweight and high performance) that necessitated careful evaluation and customized sorting.

Operations:

The pilot is organized under three operational pillars:

1. **Demolition**: structural dismantling is carefully planned using vibrating shovels, water cannons to suppress dust, and electrical machinery wherever feasible. Preservation of the material and the environment, as the area is adjacent to a kindergarten, is aimed at.
2. **RCA Production**: an on-site mobile crusher and sieving system will be used to crush RCA. Avoiding waste material to be transported unnecessarily, the carbon footprint of the project is minimized. The RCA will be stocked and tested to NS-EN 12620 and NS-EN 933-11 specifications to be graded as AN or BN grade.
3. **Construction**: the GAIA Museum will integrate multiple RCA-based concrete mixes, including some with 100% RCA substitution, pending certification. These mixes are being tailored for exposure to Arctic marine conditions (freeze-thaw cycles, salt spray), and will be used in structural elements such as submerged columns and load-bearing beams. UiT and local concrete producers are jointly designing the mixes and plan to certify them through industrial trials.

The reused materials will be monitored and analyzed at each step, adding to national lifecycle analysis, and setting new benchmark levels for the application of RCA in Norwegian industry.

Outbound Logistics:

In lieu of shipping a product, the output of the pilot is the GAIA museum itself, a living manifestation of circular construction. As a public institution, the museum is intended to illustrate the environmental and cultural worth of reuse, both in its composition of materials and in its experiential storytelling integrated into its exhibitions.

Also, pilot partners are designing a temporary outdoor structure composed of RCA-based concrete furniture and components. The mini-demonstrator functions as both proof-of-concept for the material as well as a public educational platform.

Marketing and Sales:

Promotion is strong and multi-channel. Major efforts are:

- Scientific publications and contributions to national guideline updates.
- Media in local and national media outlets.
- Stakeholder events, such as a workshop with more than 40 regional companies.
- Contact with the city's architects, engineers, and planners, especially through the architecture partner LUA.
- Public exhibitions and live demonstrations in the museum and in local locations.

Marketing is not confined to technical spheres – the pilot openly involves the general public and local youngsters, making the circularity concrete and understandable by using community-focused storytelling.

After-Sales Services:

Unlike commercial pilots, the Pilot 4 ends in a permanent public building – one that expresses and conveys its own afterlife. Long-term upkeep of the building is governed by Sortland Municipality, yet the pilot helps by offering:

- Real-life performance data in actual Arctic environments.
- Maintenance guidelines for RCA-based components.
- Input of recommendations and standards based on the outcomes of the pilot.

Firm Infrastructure:

The project has the backing of a robust governance structure:

- Museum Nord serves as the lead and liaison to public stakeholders.
- UiT oversees technical and scientific research.
- Sortland Municipality offers political and logistical support.
- RENO and concrete companies oversee demolitions and materials.
- LUA directs architectural design.

Monthly coordination sessions keep the partners in lockstep, and the pilot leader makes sure delays resulting from municipality decision-making are incorporated into modified timelines without sacrificing performance.

Human Resource Management:

The personnel chosen are based on experience with RCA and construction in the Arctic region. The demolition contractor was won by public tender. Scalability and local market focus are ensured by working with local concrete manufacturers. A temporary change of leadership of the pilots (parental leave) went smoothly, indicating institutional stability.

Technology Development:

Innovations in Pilot 4 cross both process and product:

- First use of vibrating shovels in concrete sorting in ice demolition.
- Utilization of in-site RCA production to prevent sequential transport stages.
- Creation of new concrete mixes with different RCA proportions, modified for exposure class M60 (maritime environments).
- Cooperation in development of EPDs for RCA and RCA-concrete, bridging important data gaps.
- Integration of RCA into high-performance structural concrete (C30/37 to C45/55).
- First use of RCA in underwater structural elements in Norway.

The pilot has contributed to Norway's new directives regarding RCA in concrete in a direct way by shaping updates to the Norwegian Concrete Association's national publications.

Procurement:

Procurement is facilitated by the fact that the materials are not purchased but reclaimed. Since both demolition and new building are municipally controlled, the project dispenses with the cost barriers of accessing materials. Public tenders have been called for construction and demolition works, and special care is exercised regarding certification requirements of RCA. The pilot also examines collaborating with certified RCA manufacturers from regions outside the region of operations as backup alternatives.

4.4.4 Strengths, challenges & recommendations

Pilot 4 presents an extremely resilient, fully integrated method of circular construction, arguably in a region such as the Arctic, where environmental and logistical limitations tend to limit creativity. Its strongest point is the full vertical integration of the value cycle. Not only does the Sortland Municipality own the structure to be torn down (the Nortura slaughterhouse), but also the GAIA Vesterålen Museum to be built using the recycled concrete aggregate (RCA) that is generated in-site. Such single, end-to-end control of the entire value cycle from demolition to new build allows the setting of a high level of coordination, transparency, and utilization of resources that is very seldom possible in projects utilizing the services of many, disjointed stakeholders.

Additionally, the pilot is at the forefront of the application of RCA to demanding structural applications – such as elements that will be exposed in the Norwegian Sea. The creation and proposed certification of RCA-based concrete mixes to exposure class M60 (maritime environments) established a new standard, not only for Norway but for the wider European situation. This is one of the first projects in the region to put RCA for high-performance, marine-exposed structural concrete into proposal, and, if the project proves a success, the implications for the use of sustainable construction in such coastal and Arctic environments are profound.

Another such strength is having the political stakeholders and the wider public firmly in the project's corner. Sortland Municipality's partnership has been invaluable in pushing the project ahead in the face of delays, and the GAIA Museum itself is conceived as a public symbol of sustainable development rather than a mere building. Integrating storytelling, interactive exhibitions, and outreach into the project's very fabric, the pilot ensures that its message – and its physical solutions – will resonate with the public long after the construction work has finished.

Meanwhile, the pilot itself is by no means problem free. The most significant problem to date has been the delay in the demolition process due to a change in the local political environment. Although the team responded quickly by revising schedules and sustaining stakeholder relationships, the reliance on political decision-making still poses a possible risk. Furthermore, the regional construction environment lacks previous experience with RCA at an industrial level. While local concrete manufacturers are eager to cooperate, extensive endeavors are still necessary to establish familiarity with RCA mix design, certification, and performance acceptance in general, as well as in aggressive environmental settings in the case of intended applications.

The process of certification also poses a bottleneck. Any newly developed concrete mixture needs to be certified based on national and European regulations, and if made using locally crushed RCA, both the mixture process as well as the process of preparing the RCA need to be certified. To overcome such technical and regulatory challenges, close coordination among demolition contractors, material experts, manufacturers, and certifiers is mandatory.

Another issue on the horizon is the potential excess of RCA. The amount of uncontaminated concrete from the Nortura building is more than the GAIA museum can immediately use, creating the issue of the proper utilization of this precious material. In the absence of a definite reuse plan, the risk of having some of the material underutilized or repurposed toward lower-value ends is a lost opportunity.

To address these challenges, several recommendations are proposed. First, it would be beneficial to identify additional use cases for RCA beyond the museum. As Sortland Municipality is actively developing other infrastructure – including housing and public spaces – there is a real opportunity to integrate surplus RCA into sidewalks, benches, retaining walls, or other civic structures. Additionally, developing modular demonstrators using RCA (e.g., public furniture, outdoor installations) could serve both a functional and educational purpose, showcasing the versatility of recycled materials in real-world contexts.

To streamline certification and expand impact, the pilot could also explore partnerships with companies that already possess RCA production licenses, potentially sharing certification frameworks or co-developing regionally tailored EPDs (Environmental Product Declarations). This would significantly lower the barriers to market entry for RCA and provide a scalable path for adoption by other municipalities.

Lastly, using the GAIA museum as a long-term training and dissemination center would facilitate the transfer of knowledge among sectors. Workshops, webinars, and exhibitions would help place GAIA as a building, yet a living laboratory of circular innovation – a venue for policymakers, builders, and the general public to engage with the future of building, literally, in concrete form.

4.5 Pilot 5 – Recycled aggregate concrete upscale (Czechia)

4.5.1 Regional construction context

The Czech Republic, and particularly Prague, has been facing increasing pressure to integrate sustainability into its rapidly expanding urban development. As one of the most historic and heavily populated capitals in Europe, Prague combines unique architectural heritage with intense pressure to modernize, driven by urgent demand for housing, office space, and infrastructure development.

The Czech construction industry is among the country's most important contributors to the national economy, with nearly 10% of the country's GDP and over 500,000 workers employed in the various trades and supply chains. Yet such active growth is accompanied by a massive environmental price tag. The Czech construction industry accounts for about 40% of the country's overall material usage, 30% of waste, and almost 40% of the nation's overall energy usage, consistent with the trends seen in the EU.

One of the region's most urgent challenges is the handling of construction and demolition waste (CDW), comprising about two-thirds of the nation's overall annual waste stream. Although metals, bricks, and other materials are consistently recycled, the recovery of structural waste concrete and secondary raw materials is underdeveloped. Fragmented infrastructure, non-standardization of the product, and inconsistent application of regulations were found in 2022 by the Czech Ministry of the Environment to be the main impediments to the uptake of mainstream practices in the circular economy.

However, there are definite indications of progress. The Czech Republic has endorsed the EU Circular Economy Action Plan and embraced the National Circular Economy Strategy that specifically mentions construction as a priority sector for decarbonization, reuse, and efficiency of materials. The strategy demands increased use of secondary raw materials, the use of digital passports for the materials, and the facilitation of demonstrator projects that can prove new technical and business concepts under real-life contexts.

In such a policy and market climate, Prague is becoming a national experiment in sustainable building inventiveness. Prague is experiencing area-wide redevelopment of once-industrial sites (for example, in the Modřanský cukrovar area) and its urban policy promotes climate-resilient architecture and green infrastructure ever more so. The Prague Climate Plan actively promotes circularity in buildings, among other aims, by working to minimize the embodied carbon and to foster reuse of materials.

Pilot 5, as developed at the Modřanský cukrovar project, is a prime example of the change. Led by Skanska and its subsidiaries in partnership with the Czech Technical University in Prague, the pilot investigates the viability of circular construction at a multi-building, urban level.

The project entails:

- Rebetong, a special concrete that contains recycled aggregate.
- Low-carbon concrete made from blended cements.
- 3D-printed building components.
- Façade elements from recycled material composites.

These are not technical demonstration projects – they are replicable and marketable, both in compliance with the Czech environmental legislation and the EU Taxonomy requirements for green construction.

The Czech case is differentiated by the industrial readiness of the main actors. Skanska Transbeton, to name just one, already manufactures certified recycled aggregate concrete (RAC), and they are trying to achieve even more demanding certifications under bespoke environmental product declarations (EPD). Czechia is thus leading many regional competitors in awareness to adopt the circular economy in construction.

Concurrent with that, increasing public and investor demand for ESG (Environmental, Social, and Governance) factors is fueling demand for green buildings – particularly in residential and commercial property. These forces are leading developers to re-evaluate material flows, emissions, and long-term building flexibility.

4.5.2 Description of the Pilot

Pilot 5, in Prague, is the large-scale residential development project known as “Modřanský Cukrovar”, comprising of approximately 800 apartments and 40 commercial units. Skanska a.s. coordinates the pilot, with involvement from Skanska Transbeton (ready-mix concrete supplier), Skanska Residential (developer company), and the Czech Technical University in Prague (ČVUT UCEEB) as the partner from the academic world.

Pilot 5’s main aspiration is to industrialize the use of sustainable and circular construction materials, led prominently by Recycled Aggregate Concrete (RAC) – under the brand name of Rebetong – and low carbon concrete with blended cements. The pilot also investigates a range of innovative technologies such as 3D printing, prefabricated facade panels, recycled material urban furnishings and wall tiles, and the reuse of concrete slurry.

Notably, the project does not end with material implementation. It also strives to demonstrate circularity in a visible way, for example, using recycled aggregate-exposed façade panels, and to experience test, certify, and market new mixes (such as the >70% recycled aggregate-containing Rebetong New Generation). The pilot offers a full value chain demonstration – from recycled aggregate production and testing to in-site application, to stakeholder engagement and market scaling.

4.5.3 Value chain analysis (VCA)

The value chain in Pilot 5 – developed within the large-scale residential project Modřanský Cukrovar in Prague – exemplifies a full-circle approach to sustainable construction. From inbound logistics to technology deployment, each segment of the value chain has been carefully designed to prioritize recycled content, low-carbon solutions, and industrial scalability.

Inbound Logistics:

Pilot material sourcing relies on a twin-track approach: centralized coordination by Skanska Transbeton, and flexible partnership with local recycling facilities. Recycled aggregates, such as brick-derived or mixed construction and demolition waste (CDW), are sourced from these facilities and processed to specification for use in structural and decorative applications. Low-carbon blended cements – CEM II, CEM III, and CEM V – are also sourced from established suppliers. An especially advanced aspect is the use of reclaimed cement slurry water from concrete plant processing. Not only does it minimize freshwater supply, but also helps drive the target of zero waste to the production environment in the circular economy.

Operations:

The operations of the pilot are delineated by its multi-stream technology application. Rebetong, a recycled aggregate concrete product that Skanska has developed, is used in many layers of construction – from sub-base and foundation components to structural walls as well as chosen architectural applications. The application of Rebetong in actual conditions in the pilot is supported by several rounds of testing and certification. Backed by robust support from the Czech Technical University in Prague (ČVUT UCEEB), experimental verification of the properties of fresh and hardened concrete ensures that they meet performance requirements. Testing of a myriad of parameters such as freeze-thaw resistance, shrinkage, carbonation, and compressive strength is undertaken. On-site application of Concrete sensor technology provides monitoring of temperature and maturity index for form removal in real-time - streamlining timelines and minimizing waste.

Parallel to these, other processes including the manufacturing of facade panels and 3D printing components further enrich the scope of operations. Façade components are experimented with in partnership with industry partners employing both sprayed and 3D-printed concrete, utilizing recycled aggregates in visual and structural use. Interior and exterior furniture as well as tiles are also produced with multi-layer concrete mixes, proving the freedom in design as well as the visual worth of the Rebetong.

Outbound Logistics:

The distribution strategies are customized to the product type. Ready-mix concrete mixes are supplied straight to the building site in truck mixers to allow just-in-time concrete delivery for big pours and structural projects. For pre-assembled pieces such as facade panels or city furniture, logistics are coordinated in partnership with the manufacturing partners, utilizing both Skanska's transport capabilities and external parties as necessary. As the elements, such as the 3D-printed sanitary modules, are printed in situ, logistics loads are also minimized in chosen applications – minimizing transport emissions and logistical complexity.

Marketing and Sales:

Internal promotion of the circular solutions under Pilot 5 is supported by internal dissemination as well as stakeholder outreach externally. Internally, Skanska makes Rebetong an integral part of its routine project services, promoting adoption in departments. Externally, training sessions, workshops, and actual demonstrations – including the "Art of Recycling" training program – have fostered client, designer, and industry professional awareness. Additionally, visible implementation of the circular components in high-visibility sites, including building facades and entrance tiles, act as a physical embodiment of the commitment to the environment from the pilot. These demonstrators not only improve public perception, but they also allow for conversation among architects and developers who want to implement the same solutions in their projects.

After-Sales Services:

The project is conceived with long-term commitment in mind. After testing and certification, concrete mix designs based on recycled aggregates and low-carbon cements become a standard part of Skanska Transbeton's range of available products. Continuous consultant advice is offered to customers, assisting them in the selection of the most suitable mix designs to satisfy their structural or visual requirements. Long-term durability monitoring to confirm the pilot's conclusions under actual environmental conditions – eventually for elements of the facade subject to freezing-thaw cycling and carbonation – is also scheduled.

Firm Infrastructure:

Pilot 5 is supported by a strong administrative and regulatory system. Skanska Transbeton's concrete production is covered by ISO 9001 (quality management), ISO 14025 (environmental declarations), and ISO 45001 (occupational health and safety). The Rebetong concrete product itself is introduced to the market under a certified building technical approval process, as the recycled aggregate portion exceeds the levels set by EN 206. The method provides the freedom to innovate through the limitations of available norms, while at the same time remaining fully in compliance with the law. Concurrently, careful record keeping of the material inputs, the mixes, and the volume monitoring provides traceability and maintains WP5 and WP6 reporting requirements.

Human Resource Management:

Skanska's experienced teams, who since as early as 2019 have worked in recycled material research and application, provide the human capital for the pilot. Recruits to be hired when extra staff are required are prioritized based on technical or environmental background, and new employees are guided by senior personnel with extensive histories in the development of Rebetong. Periodic in-department training keeps employees current in the latest technology and compliance protocols.

Technology Development:

Rebetong is more than a product – it's an ongoing source of invention. Advances during the pilot phase include multi-fraction aggregate design to enhance the mechanical performance, recycled slurry water integration, and range of structural-specific mix designs. On-site 3D printing of concrete modules and 3D-printed and sprayed facade panels represent new territory for the pilot. As part of the ongoing process of optimization, over-standard testing (e.g., creep, anchoring, shrinkage) is in progress to meet the unique needs of structural designers and to extend the market availability of these new materials.

Procurement:

Procurement processes, although not revealed publicly, are governed under Skanska's integrated sustainability and quality systems. Aggregates, cementitious materials, and other supplementary materials are procured through audited supply chains that conform to environmental as well as structural quality parameters. Localized procurement – reducing transport-related carbon emissions – is also investigated by the pilot, as well as the development of materials from which the lifecycle can be traced from demolition back to new construction.

4.5.4 Strengths, challenges & recommendations

Pilot 5 has quickly become one of the Circ-Boost project's most wide-ranging demonstrations of a circular approach to construction, providing a practical implementation that combines innovation with industrial scale. Its worth is not simply in the technical process of creating recycled aggregate concrete, but in developing an integrated system – from design and experimentation to making, delivering, and monitoring in real-time.

Another of the strongest points of the pilot is its applicability to industry. The more than 1,500 m³ of Rebetong already incorporated in structure during several phases of construction proves that circular solutions can be integrated into conventional construction without sacrificing performance. The experience of the partnership of Skanska and ČVUT UCEEB has allowed a high level of technical development, allowing each subsequent mixture to achieve not just the necessary strength, but secondary performance parameters such as durability, shrinkage, and resistance to carbonation. The visible integration of the use of Rebetong in the façades of the building and public space further closes the gap between technical success and public perception – reinforcing the project as a demonstration of sustainable urban development.

In tandem, the pilot has had to deal with a number of key challenges. Foremost among these is the variable quality and availability of recycled aggregate. Although mixed and brick-derived aggregates are more easily available compared to concrete-derived RCA, their variable properties make them challenging for high-spec applications. To counteract this, the project maintains a cautious, structure-specific approach, specifying varying recycled content levels for piles, horizontal slabs, and vertical walls. A second challenge is to overcome designers' resistance to specifying RAC, as a result of mistrust of long-term performance and insufficient standardization. The pilot meets this by subjecting the recycled aggregate to rigorous laboratory testing and certification, but more general acceptance is still in need.

In a regulatory environment, innovation precedes current standards. Since the application of RAC over 30% replacement is not yet addressed by European norms, Skanska has been obliged to seek other certification channels – particularly technical building approvals – in order to approve its mixes. Although an effective route, such a process introduces complexity and delays market entry.

To enhance the pilot's performance and ease replication, the following recommendations can be extracted:

- Ongoing partnership with the academic world should be a priority, most notably in order to maximize the testing database and aid in standardization work at the European level.
- Internal design guidelines and mixture templates can be disseminated to external architects and engineers, serving to demystify the application of RAC in structural elements.
- As low-carbon interest increases, the integration of recycled aggregates in blends with cements – as is the case in the Rebetong-LCC mixes – provides a twofold benefit and should be promoted more systematically.

In addition, the pilot's exposure can be increased through further public demonstrations, assisting both professional stakeholders and the general public. Lastly, the internal success of Rebetong in Skanska indicates that it can be upscaled to other projects and locations – so that Pilot 5 becomes not only a local innovation, but also a possible template for industrial circularity in Europe.

5 Conclusions

The outcomes of the Circ-Boost pilots highlight the transformative potential of circularity to reinvent the construction industry – technically, economically, and in a cultural sense. The pilots do more than illustrate technical viability; they show that the application of circular construction can be executed under very different circumstances, from municipalities in the Arctic to megacities in metropolitan environments, and from advanced industrial environments to environments with weak regulatory preparedness.

Every pilot provides a distinctive set of contributions to the overall European development toward a climate-resilient, resource-efficient, and socially oriented built environment. Most notably, their combined successes underpin a new paradigm for the industry in which waste is seen as value, buildings are built to be capable of adapting in the future, and data streams are as valuable as the flows of materials.

Key conclusions emerging from the pilot implementations include:

1. **Circularity is technically and economically viable**: among the most important findings in this phase is that circular construction is no longer a niche innovation. All five pilots confirmed the technical feasibility of the circular solutions such as reuse of structural elements (Pilot 1), RCA concrete as a structural use (Pilots 4 and 5), demountable systems (Pilot 3), and interoperable platform material traceability (Pilot 2). Additionally, pilots such as Pilot 5 illustrate that the solutions can be industrialized without detracting from performance, security, or design freedom. It has also been demonstrated to be economically viable, although with limitations. In most instances, reuse and recycling are still slightly more costly because of extra sorting, logistics, and certification. However, consistent with the pilots, cost equivalence can be achieved, even taking carbon taxes, ESG compliance, and lifecycle cost calculations into account.

2. **Context matters, but models can be adapted**: although the pilots face profoundly disparate geographical, economic, and institutional contexts, they have each been able to achieve success by applying round principles to local constraints and opportunities. Pilot 4's in-site RCA production handles the logistical challenges of the Arctic, as Pilot 2's digital platform handles coordination challenges in the urban congestion of Paris. It emphasizes the need for context-dependent implementation models – not a one-size-fits-all approach, but modular ones that can be scaled and replicated with regional variation.

3. **Regulation is both a barrier and facilitator**: across all five pilots, the regulatory environment emerged as a critical factor. Where clear national standards support circular materials (e.g., Norway and Czechia), implementation proceeds more smoothly. Conversely, in contexts like Serbia or even parts of France, regulatory gaps or ambiguity hinder progress, despite strong technical capacity. In the future, a robust need to harmonize recycled material norms in the EU, enhance schemes of quality certification, and make circularity a part of public procurement criteria is evident. The pilots provide important insight into informing these frameworks.

4. **Digitalization is indispensable**: these digital solutions – BIM integration, dynamic passports for materials, or data platforms – aren't additions to the circular construction process; they are essential. Examples from pilots in Spain and France showcase that without instantaneous data about the source of materials, their quality, availability, and logistics, reuse is a patchwork, ad hoc activity. Future action must be geared toward interoperable, easy-to-use digital ecosystems that can link demolition operators, designers, contractors, and policymakers. Investments here will generate exponential returns in scaling circularity.

5. **Cultural change involves engagement, training, and trust**: beyond the regulatory and technical environment is the most challenging one, perhaps: mindsets. Several pilots (Pilots 1 and 5, in particular) reported hesitation by designers and clients to work with reused or non-standard materials. Others mentioned logistical actors that were uncertain about how to sort, store, or certify CDW. As a result, universal uptake relies not only on equipment and standards, but additionally

capacity-building – by training programs, public campaigns, knowledge sharing among peers, and pilot-based demonstrators that generate confidence and change risk perception.

6. **The time for replication is now**: the Circ-Boost pilots were conceptualized as replicable prototypes of circular change, rather than stand-alone experiments. The solutions implemented – whether a BIM-based passport for materials in Spain, a French procurement procedure, or a certified recycled-concrete mixture in Czechia – can be scaled and implemented throughout Europe.

The Circ-Boost pilots are more than a series of technical demonstrations – representing a transformative change in how Europe conceives of, designs, and builds its built environment. Though the pilots vary in geography, size, and development, they demonstrate toward a common future: one in which circularity is possible, yet inescapable. The pilots act as a steppingstone between policy intention and action on the ground, showing the ways – and challenges – that lie ahead. Their success is as much in the innovations implemented as in the networks established, mindsets disrupted, and systems tested under actual conditions. As the project evolves to subsequent phases, it takes with it an increasing body of knowledge, tools, and partnerships ready to scale. These pilots are ultimately not terminals – they are catalysts, sowing the seeds of a regenerative building culture that values people, planet, and purpose equally.

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