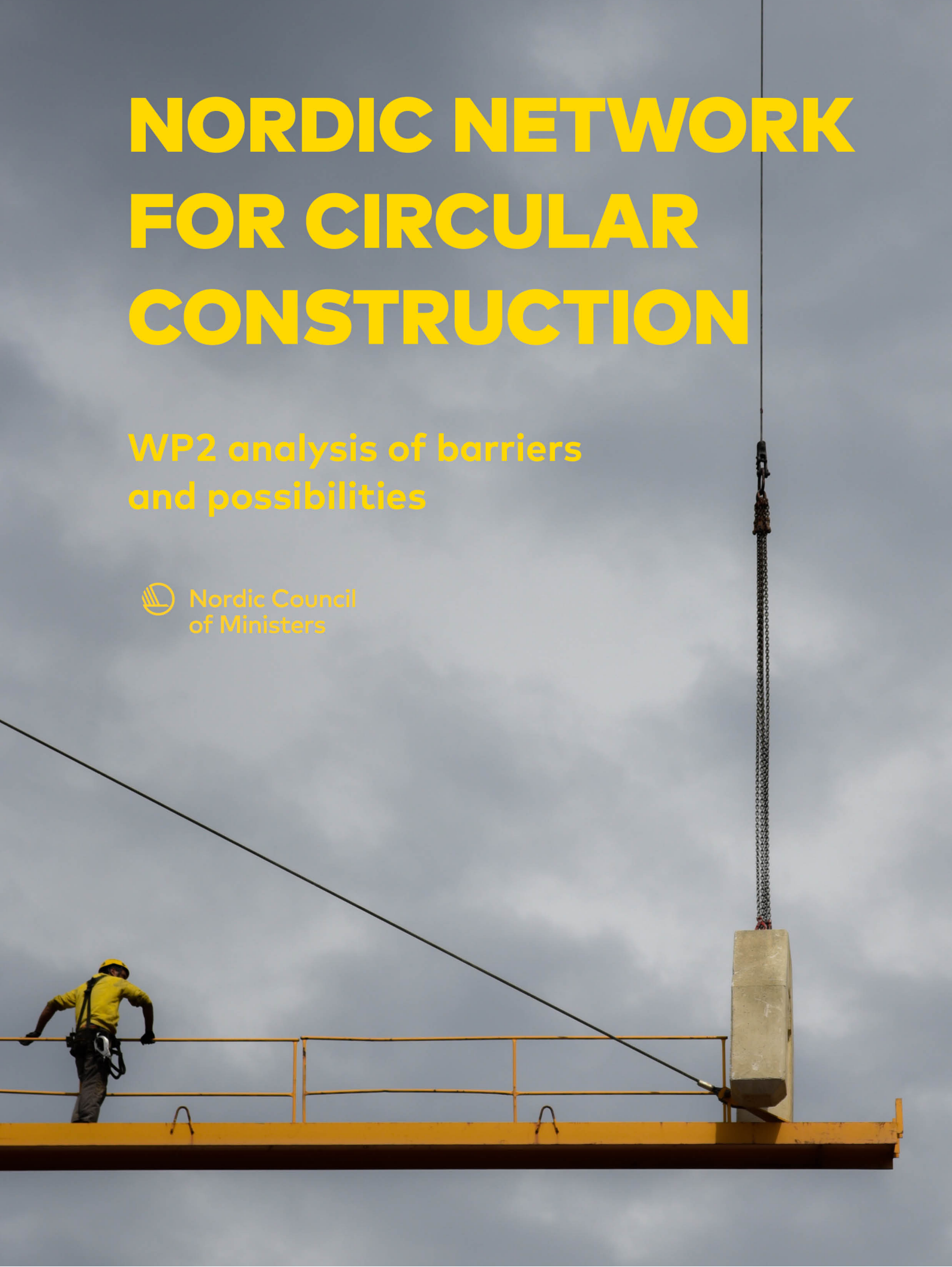
NORDIC NETWORK FOR CIRCULAR CONSTRUCTION

WP2 analysis of barriers and possibilities

Nordic Council of Ministers



Contents

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1. Summary

Renewal and expansion of the built environment enables us to simultaneously improve our quality of life and the performance of the buildings we inhabit—more efficient, better indoor air quality, improved light, lower sound pollution, and more spacious. However, it also uses non-renewable resources and energy and emits greenhouse gasses. Making better use of the existing building stock and its individual components and designing new buildings to be easier to adapt and reuse can help limit the input of virgin material required and greenhouse gasses emitted now and in the future.

A circular construction sector is one in which every part of the process of deciding, designing, and constructing new buildings is rethought to include exploiting the value of the materials already present in the built environment and ensure that the buildings designed and built today can maintain their value in the future, either as buildings, or in their constituent components.

This report explores the current state of and framework conditions for the development of a circular construction sector in the Nordic countries, and through consultation with the construction value chain, it identifies barriers that limit the transition to and opportunities that could be exploited to support a more circular approach in the circular construction industry.

Until recently, circular economy in the construction sector has been directly equated with the management of construction and demolition (C&D) waste. Most of the C&D waste in the Nordic countries is "recycled", although this definition includes backfilling and the practice of using inert waste materials for landscaping or other civil engineering works. While marginally better than landfilling, this is low-value utilisation of C&D wastes, and there is desire across the Nordic countries to move up the waste hierarchy by minimising the generation of these wastes and using them in higher-value applications when they do occur.

There is growing momentum for circular construction across the Nordic countries: all the Nordic countries promote circular construction as a necessity for a sustainable built environment. Given the massive material footprint of, and waste generation from, the construction industry, it's no surprise to find that policymakers identify construction as a cornerstone of the transition to a circular economy. At the strategic level, circular construction is addressed within overarching circular economy strategies and sometimes within sector-specific sustainability—such as in, for example, the Danish National Strategy for Sustainable Construction. While this strategic direction has been in place for some years, the integration of these strategic goals and methods into regulatory instruments has only just begun to

take force. Examples include the revised Finnish Construction Act (2023), the revised building regulations in Iceland (2022), the adapted Norwegian Planning and building Act and associated regulations (2022), and the Danish Construction Law and Building Regulations (2021, 2023). Similar revision processes are underway in Sweden and Finland. These typically mandate specific actions to promote circular construction: pre-demolition auditing, the promotion of reuse, life cycle analysis of buildings, designing for disassembly and reusability, and the utilisation of wastes.

The knowledge base supporting circular construction is also growing: many multi-annual, large-scale projects are underway across the region that are exploring and supporting the circular economy in the construction industry, while dedicated knowledge centres also provide specific and targeted information to actors along the value chain to help them in the circular transition (for example, the Danish VØCB). Sustainable building certification schemes that are used in the Nordic countries (DGNB in Denmark, BREEAM in Norway, Iceland, and Finland, and BREEAM, LEED and Miljöbyggnad and NollCO2 in Sweden) also help promote sustainability broadly, although they are not aligned specifically with circularity in construction. Further information about the framework conditions and state of circular construction in the Nordic countries can be found in Chapter 5.

Despite these recent advancements in the regulatory framework for circular construction, there are still significant barriers facing actors along the construction value chain. Be they developers and building owners, or architects, engineers and consultants, contractors and builders, product manufacturers and demolition companies and recyclers, they all face a range of different technical, regulatory, cultural, and economic barriers that hinder progress and block transformative actions. These can be found within the strategic planning process, within building regulations themselves, in the culture that pervades the industry and the broader society, economic framework conditions for the sector, the mechanisms by which markets can form and blossom, the logistics associated with reuse and recycling, the knowledge and experience within the industry at all steps in the value chain, the complexity of allocating (legal) responsibility outside of normal industry practice, documenting and data provision for reused products and buildings, and sharing that data beyond traditional silos within the industry. A main takeaway from the analysis of these barriers is that they are heavily interlinked. For example, lack of experience and knowledge within the sector stems from a lack of opportunity to gain that experience and knowledge, while that same lack of experience and knowledge means that it is difficult to commission projects with a circular focus. Lack of experience and knowledge also leads to longer project time frames and therefore higher expenses. A comprehensive catalogue of these barriers, together with potential solutions, can be found in Chapter 7 of this report.

- Strategy and planning: The circular approach to construction and the built environment is not currently integrated into the strategy and planning processes by planners and development decision-makers, and the tools to enable circular assessments are currently underdeveloped.
- Lack of knowledge and experience: Actors throughout the value chain do not have sufficient knowledge of or experience with the methods, processes, or routines required for circular construction, many of which do not yet exist.
- Building Regulations: The implementation of building regulations is geared toward building with new products and materials. The current system is ill-equipped to encompass reused products and does not actively support circular design principles.
- Product documentation: Reused products and materials lack the robust documentation demanded by the construction industry (CE marking, EPDs etc.)
- Allocation of risk and responsibility: existing allocation of risk and responsibility is ill-suited to the circular use of building products.
- Economy: Circular construction is more expensive than construction with new products and materials. This is primarily because of the additional time required to engage in circular processes along the value chain.
- Culture: The construction industry is institutionally (and perhaps understandably) risk averse, and circular construction represents an undesired risk.

Specific initiatives that can help alleviate and overcome these barriers are outlined in Chapter 9.

1.1. Recommendations

The following recommendations to actors throughout the construction value chain seek to address key barriers to and build upon key opportunities for the transition to a circular construction sector.

Recommendations for further work under the Nordic Network for Circular Construction:

Nordic Network for Circular Construction	The Nordic Network for Circular Construction can help overcome many of the challenges facing circular construction in the Nordic countries. It can: • Develop sector and sub-sector networks to share experience. • Develop and disseminate knowledge on best practices, case studies, and pilot projects. • Develop educational materials for the sector. • Develop new norms, methods, and practices around CC. • Coordinate guides for CC in the current building regulation framework. • Support the integration of CC into international building environmental certification schemes.

The main actors throughout the construction value chain also have a vital role to play in the transition to circular construction:

Developers & Owners	Developers and owners can help overcome the lack of knowledge and experience as well as any economic and cultural challenges by taking the lead and commissioning CC projects, and by including induced benefits in calculations. They can help overcome risk and responsibility challenges by engaging with the value chain to develop new negotiated responsibilities. To do so, they should plan for a long-term future, embed CC at the start of the process, and support the CC process by synchronising construction and demolition activities.

Architects, engineers and consultants	Architects, designers, and engineers can support developers in the move toward CC by proposing and developing CC solutions, supporting the negotiation of risks and responsibilities, and developing new norms for sourcing more sustainable and/or reused materials. They can also work on integrating CC into existing tools and methods and supporting the integration of CC into existing certification frameworks, all with the clear goal of narrowing, slowing, and closing cycles.
Construction Companies	Construction companies can support the transition to CC and reduce the knowledge and experience gap by engaging with their peers and learning from pilot projects, networks, and knowledge centres, as well as engaging with all stakeholders throughout value chain to increase collaboration, negotiate new allocation of risk and responsibility, and develop new sourcing routines. They can also support manufacturers in the development of circular tools and products while actively engaging in the revision and guidance of building regulations and product recertification initiatives.
Construction product manufacturers	Manufacturers of construction products can support the design of circular buildings by developing solutions that enable flexibility and adaptation, and they can play a key role in providing product information and supporting certification efforts. They can also develop methods for remanufacturing or preparing reclaimed products for reuse, as well as ensuring that construction products are suitable and ready for future cycles.

Demolition companies	Demolition companies will play a key role in implementing and defining the necessary process and data standards for pre-demolition material mapping and help build a robust market for reused construction products. This needs to be done in cooperation with developers, the design team, and construction companies. They can help overcome knowledge and experience gaps by engaging with the industry, the value chain, industry networks, knowledge centres, and they will need to build new competencies.

Public authorities	Public authorities are a vital node that can set the CC agenda, ease economic challenges, provide a favourable framework for CC, and coordinate the growth of knowledge and experience within the sector. They can help overcome regulatory barriers by leading the revision of national building regulations. They can also lead the negotiations related to recertification and the integration of reuse into existing product certification, as well as implement coming EU legislation on construction products and digital product passports. They can help steer the industry culture toward CC by developing national CC strategies and integrating CC-relevant content into national education curricula. They can also define a favourable economic landscape for circular construction by introducing taxes on carbon or other natural resources and reducing or removing VAT on reuse-related activities and reused products. Better enforcement of existing waste regulations would also provide an economic boost to circular construction.

Research Institutions	Research institutions can support the transition to CC by helping bridge the knowledge and experience gap through participation in or hosting knowledge centres and developing educational materials. They could also support sector networks as knowledge partners and support the public authorities in creating methods for recertification as well as the implementation of the digital product passports. They can take a leading role in developing standards for calculating induced benefits of CC while supporting the integration of CC into existing methods and certification schemes.

NGOs	Industry bodies can help overcome knowledge and experience gaps by acting as central nodes for industry networks and facilitating cooperation between value chain actors. They can also form knowledge centres, help develop and disseminate education materials, and run further education courses. They are also an ideal focal point for developing new norms and standards (data and process) around pre-demolition material mapping and reused product information, and they can support the integration of CC into existing industry routines. Similarly, they can help develop and disseminate guidance on CC in the current building regulations and positively influence the revision of building regulations.

2. Introduction

[Nordic Networks for Circular Construction]

This project is part of Nordic Networks for Circular Construction (NNCC), a multi-annual programme by the Nordic Council of ministers to drive circularity in the construction sector. The programme assesses the current state of circular construction, develops metrics for measuring progress, and engenders change in the industry through the development of networks and platforms for spreading knowledge and experience (NNCC, u.d.).

The programme runs from 2021 to 2023 with the following components:

- **WP2 – Barriers and opportunities**
- WP3 – Measuring progress´
- WP4 – Cultural change
- WP5 – Collaboration Platforms
- WP6 – National CC fora
- WP7 – Learning material

This report is the final deliverable for WP2.

Construction is responsible for a significant portion of both raw material use and waste generation in the Nordic countries, with around 45 per cent of total waste generation in the Nordic countries coming from construction and demolition activities (Eurostat, 2023). Construction and the built environment are (Regeringens klimapartnerskaber, 2019) also responsible for approximately one third of Nordic greenhouse gas emissions. As the energy efficiency of new buildings has increased in recent years, thus minimising emissions from the use-phase of a building's life cycle, the GHG emissions embodied in the construction materials becomes increasingly relevant. The transition to a more circular construction industry has the potential to save raw materials and help minimise the emissions related to construction and the built environment.

The national Nordic authorities have all identified the transition to a circular construction industry as an important component of the broader green transition. This is mirrored at the EU level, where a raft of strategies and regulations over the last decade have highlighted the role of the circular economy in moving toward a sustainable Europe, while at the same time identifying the construction sector and the built environment as important focus areas.

While many of the activities related to circular construction are already present in the sector, such as renovation, repair, and maintenance, the industry is currently geared as a linear system.

This report provides the foundation for the rest of the *Nordic Networks for Circular Construction* project. This includes providing an overview of circular construction today, the framework conditions for circular construction in Denmark, Finland, Iceland, Norway, and Sweden, and the barriers and opportunities to circular construction along the construction value chain.

2.1. Project aims

This project develops an overview of circular construction in the Nordic countries in 2022 and the main avenues that can be exploited to support further transition to a more circular construction sector in the future. Specifically, the project:

- Examines the *state* of circular construction in the Nordic countries in the year 2022.
- Explores the *barriers to,* and *opportunities for,* circular construction in the Nordic countries.
- Provides *recommendations* toward a circular construction sector.

3. Approach

This project combines an exhaustive literature review with targeted, in-depth interviews with key stakeholders throughout the construction value chain in Denmark, Sweden, Norway, Finland, and Iceland. The information collected was used to map the current state of circular construction in the Nordic countries, identify and describe the barriers to circular construction experienced by the different actors, and elaborate on potentials and solutions that would strengthen circular construction in the Nordic countries. The findings are then tested through a targeted online survey of experts within the construction sector.

3.1. Literature review

The current state of circular construction has been investigated though a literature study focusing primarily on reports from stakeholders in the sector as well as recently published and relevant scientific literature in the Nordic countries.

3.2. Interviews

Interviews have been conducted with approximately 30 stakeholders along the construction value chains in the Nordic countries. These include building developers and owners, architects, designers and engineers, contractors and builders, construction product manufacturers, demolition companies, national and local authorities, research, development & innovation institutions, and nongovernmental organisations. A list of interviewees can be found in Appendix A.

The interviewees were chosen based on their impact on and involvement in the circular construction sector, and on their availability. They represent a broad cross-section of the actors within the Nordic countries actively engaged in circular construction. They have been identified through a combination of literature searches, their public presence (for example, presentations at conferences, seminars, and webinars on circular construction), and their mention by prominent actors within the circular construction community and other interviewees. The interviews focused on exploring the interviewees' role in the circular construction process, how they work with circularity, the barriers they face in their work, and the opportunities and solutions they see for circular construction today and in the future, with the aim of being as specific as possible. The interview guide can be found in Appendix B.

The stakeholder groups and their role in circular construction are further described in Chapter 4.2.

3.3. Survey

Based on the results of the literature review and the interviews, key barriers and solutions were formulated and tested in an online survey of relevant actors within circular construction primarily in the Nordic countries. The survey also served to gather any additional barriers or elaborate nuances apart from those already formulated in order to ensure a comprehensive understanding of the landscape for circular construction in the Nordic countries.

The survey questions and a brief description of the process can be found in Appendix C.

3.4. Internal workshop

An internal workshop has been used to find pathways through the complex and interwoven connections between barriers and opportunities. This identifies the key barriers that prevent the circular economy from becoming standard practice within the construction industry; it then uses this to identify the most useful specific opportunities that could help overcome these barriers based on the amount of influence each opportunity has over the key identified barriers.

4. Circular construction

A circular economy is an industrial system where the value and usefulness of technical materials, products, and installations are maintained and, once at the end of an ideally prolonged life cycle, are recycled into new materials or products, or are safely returned to the environment. The activities that enable this have been developed over the last decade by a variety of organisations in a variety of configurations. One useful way to consider these activities is through the ten circular strategies, defined as the ten R's (Potting, et al., 2017):

Table 1 - The 10 Rs of the Circular Economy Hierarchy

Smarter product use and manufacture	R0 Refuse	Render a product redundant by abandoning its function or offering the same function with a different product
	R1 Rethink	Increase intensity of product use (through, for example, sharing)
	R2 Reduce	Increase efficiency in manufacturing or use—consuming fewer resources per unit service
Expand lifespan of products and components	R3 Reuse	Reuse by another consumer—prolonging the product life cycle
	R4 Repair	Repair defective products and maintain products to prolong product life cycle
	R5 Refurbish	Restore an old product to its original function
	R6 Remanufacture	Use functional parts of discarded products in new products with the same function
	R7 Repurpose	Use old product or parts in a new product with a different function
Recover materials and energy	R8 Recycle	Process materials to obtain the same (high-grade) or (lower) low-grade) quality materials for use in new products or components.
	R9 Recover	Incineration of materials with energy recovery (including recovery of ash for utilisation).

The ten Rs are a hierarchy, with R0 the most environmentally desirable and R9 the least. Transitioning to a circular economy requires moving our material economy upward in Table 1. Many strategies or activities can be a mix of the above. For example, R3 to R7 can often be used in conjunction with each other to prolong the lifespan of a product or a component.

Currently, most activity in the construction sector in the Nordic countries that could be described on the circularity ladder languishes around R8 recycling, although R5 refurbishment (renovation) and R4 repair are also widespread, as is common with high-value technical products. This report identifies the challenges preventing the construction sector from becoming more circular, i.e., moving toward the top of the table, and the potentials for enabling this transition.

Specifically, this report focuses on the processes and materials that could drive R3 to R7 in the hierarchy. As this project addresses the construction industry, it does not specifically address R0, R1, and R2, as these are largely outside the control of the construction industry itself, and outside the main target audience for the Nordic Networks for Circular Construction project.

Actions within R3 to R7 that are specific to the construction industry and form the basis of most efforts within the industry toward a more circular approach are:

- **Designing for disassembly** – designing buildings in such a way that enables easy disassembly, so that core components and building elements can be reused in other structures.
- **Designing for flexibility** – designing buildings that can be used for multiple functions and/or occupancies to maximise its usefulness.
- **Designing for adaptability** – designing buildings in such a way that they can easily be reconfigured to fulfil a new use purpose.
- **Designing with reuse** – including reused building elements, materials, or products in a building design.
- **Renovation** – refitting buildings with new interior or exterior components.
- **Reusing structures** – reusing the core structures of existing buildings as the basis for new buildings.
- **Disassembly** – carefully dismantling buildings to preserve and retain value in reusable elements.
- **Preparing for reuse** – cleaning, testing, and packaging products from disassembly so that they are ready for reuse in other construction projects.

4.1. The circular construction process/activities

A circular construction industry includes a variety of activities and actors as illustrated in Figure 1.

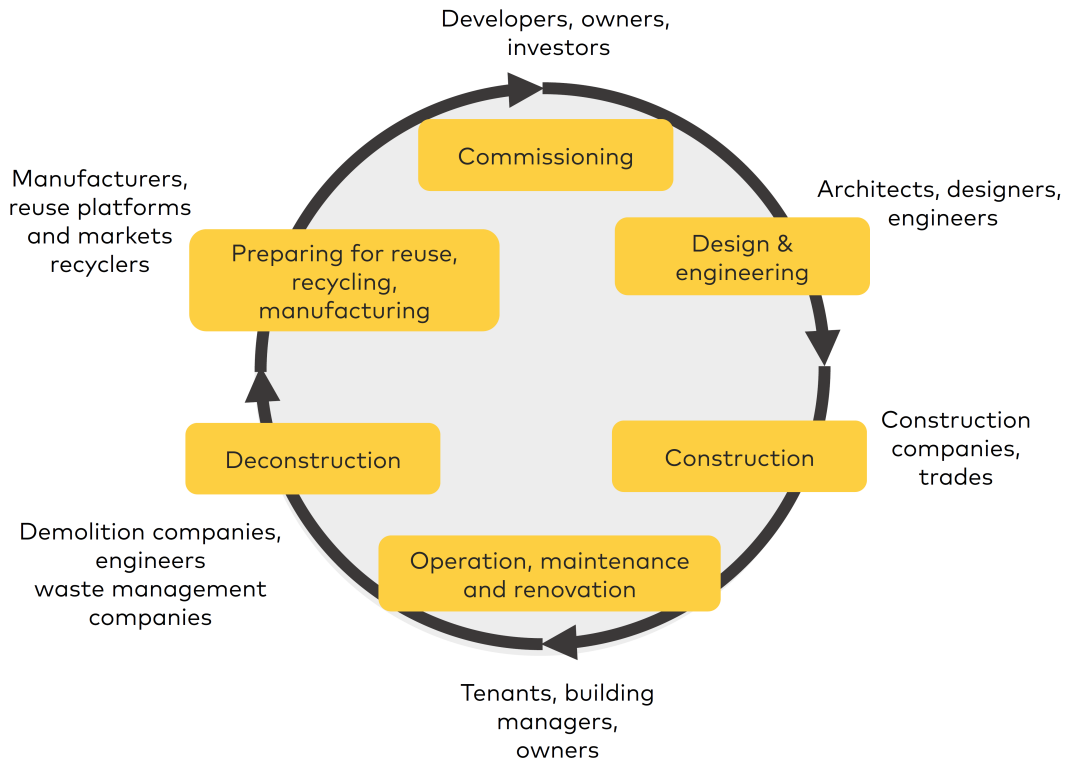

Figure 1 - Circular construction value chain

4.1.1. Commissioning

Once the demand for a construction project has been identified, the process of deciding how to meet that demand begins. This initial phase of the process is critical since factors defined here have an enormous influence on the quality and sustainability of the final building. Aspects like functionality, aesthetics, budget, and sustainability are evaluated and constitute the grounding premises for the construction process. This phase can be used to investigate whether the demand can be met by using or renovating existing buildings, or if parts of old buildings can be deconstructed and reused again in a new building (UHM, n.d.).

4.1.2. Design and engineering

It is estimated that up to 80 per cent of a product's environmental impact is determined in the design phase (EC, 2020) (EC, 2014). Products are usually produced with the linear "take-make-dispose" pattern, which encourages high consumption of resources (EC, 2020; Norouzi, et al., 2021; Karppinen, et al., 2020). To change this path, a transformation of the construction sector is needed (EC, 2020) (EC, 2020).

The entire life cycle impact of a building is highly influenced by the early design phase. The design phase is key to facilitating sustainable material use, easy maintenance, easy change of use, and increased lifespan (Karppinen, 2020). This can be achieved by:

- Designing for adaptability and flexibility, thus making it easier to change how the building is used by enabling easier changes to the internal configuration: for example, from an office space to a retail space, or to accommodation.
- Designing for disassembly, to enable components to be more easily removed and used again in another building, or to be replaced when necessary. This includes building materials, building components, and material connections (Guy, et al., 2002).
- Designing with reuse in mind, to minimise the material and climate footprint of the building and to get the maximum lifespan out of materials and products that have already been manufactured but are heading to low-value applications.
- Using non-hazardous materials that are of high-quality, durable, and non-composite, thus increasing the possibilities for disassembly and reuse in other construction projects.

This stage involves the coordination and cooperation between the developer, the architects, and the building engineers. It can also require consultation with the construction companies that will implement the design, and market screening to identify materials and products that can satisfy the architectural and engineering demands.

4.1.3. Construction

The construction phase turns the designs into reality. The construction phase should be undertaken with a keen focus on material efficiency (Karppinen, et al., 2020; UHM, n.d.). This involves minimising and correctly managing waste on the construction site and ensuring that materials that can be reused are reused, those that can only be recycled are recycled, and managing the construction process to minimise over-delivery of materials and products.

Managing the flow of materials to and from a building site is already a complex task and one that can be exacerbated by the requirement to include reused materials and products in the building. The delivery of reused products could potentially be more erratic, and their quality less uniform. Furthermore, the time and effort to integrate them into a new building may be greater than for approaches using only new, standardised products. Working with reused building elements or materials can also require additional skills and competencies, as the products are often non-standard, come with little or no technical documentation, and can be composed of novel (for the current skilled labour force) materials.

Some unused materials and products may be suitable for direct use in other construction projects or may be able to be returned to their source. This can help minimise waste during construction while also addressing concerns about potential delays from running the construction site too lean.

4.1.4. Maintenance/renovation

Once the building enters use, regular maintenance is essential to ensure that minor issues do not escalate into larger problems that require a more materially intensive and costly intervention. Regular maintenance helps prolong the lifespan of the building and maintain its value (Karppinen, et al., 2020; UHM, n.d.), while optimising and lengthening the lifespan of buildings helps minimise the demand for new construction. Generally, building maintenance is the responsibility of the property manager (UHM, n.d.). Prolonging the longevity of buildings is mainly driven by economic incentives and by preventing premature demolition activities (Karppinen, 2020).

Renovation similarly helps prolong the lifespan of the entire structure. Renovations can be minor, such as changing the windows or other sub-components, or more comprehensive, such as altering the internal configuration for other uses, changing floor plans, etc. Renovation activities can also be a valuable source of materials and products for reuse in other applications. Renovation can be driven by the need to repair the existing building structure, the need for a new internal layout, or aesthetic considerations. It is important to identify the precise construction demand and investigate whether renovating an existing building can satisfy this demand (Fernandez, 2020).

4.1.5. Deconstruction

Buildings inevitably reach the end of their useful life. Eventually they will be removed and replaced. Construction and especially demolition activities generate significant quantities of waste materials such as minerals (concrete, bricks, tiles,

mortar etc.), metals, wood, glass, and plastics. In the Nordic countries, most of this waste is typically reutilised, although the extent and quality of this utilisation is highly dependent on the type of waste material. At best, this tends to be recycling the materials to similar quality (in the case of metals), but more often the waste is used as a filling aggregate for infrastructures (inert wastes), recycled to a lower quality (plastics), or disposed of through incineration with energy recovery (wood, plastics). The EU Waste Framework Directive set a target of 70 per cent recycling of C&D waste by 2020, although this target did include backfilling and inert wastes.

A circular approach within the construction industry requires that demolition practices are geared more to recovery and reuse of building materials and elements so that they can be incorporated into new buildings rather than being utilised in low-value applications. This includes practices such as disassembly and deconstruction.

Currently, pre-demolition audits are primarily used to identify hazardous materials, which helps to ensure clean waste fractions for recycling. However, the process can also be used to identify materials and building elements that could be safely and carefully removed from the building and reused. This is often called material mapping. Material passports for new buildings can provide this and more information to enable future generations to find valuable and reusable materials and components more easily.

4.1.6. Preparing for reuse, recycling, and manufacturing new building products

The processes employed post-demolition are largely dependent on the waste fraction, its assessed hazardousness, and the quantity of generated waste. Building elements and/or materials that have been identified in a pre-demolition audit and then carefully disassembled can be prepared for reuse. This can involve a variety of processes that can take place either on the demolition site itself or at a dedicated facility. For example, bricks can be cleaned of excess mortar, tested, and packaged for reuse, wood can be cleaned, de-nailed and planed, fixtures can be cleaned and tested, windows can be reframed, steel elements can be tested and cleaned, etc.

Materials unsuitable for reuse should be collected separately and sent to undergo the highest possible material recycling/recovery operations. These can then often feed the manufacture of new construction products and materials. Materials containing hazardous substances should be disposed of in a responsible manner, although materials and elements of only limited hazardousness may be reusable in a suitable application that does not endanger health of the environment.

4.2. Circular construction actors and stakeholders

The construction industry consists of a range of actors that influence the course of construction projects. These are categorised as follows:

1. Developers and owners
2. Architects, engineers, and consultants
3. Contractors and builders
4. Manufacturers of construction products, processors of reused products
5. Demolition, deconstruction, and material banks
6. Government, regulators and local authorities
7. Research and innovation
8. Nongovernmental organisations

The following section describes each group of actors together in the context of their role in circular construction.

4.2.1. Developers and building owners

Developers are the driving force behind any construction project. Due to their vested interest in these projects, they fundamentally influence circularity in the construction sector through their demands and preferences as they filter through the planning and design phase of the project. The initial procurement of design and engineering consultancy services defines how the project will proceed, and it is crucial that the developer forms a comprehensive understanding of what the other actors in the value chain can deliver in terms of circularity and reuse (Wennersjö, et al., 2021).

Private-sector developers are profit-driven and therefore unlikely to engage in circular construction unless it has a clear financial payback, while public-sector developers also work within financial constraints, and incorporating sustainable or circular criteria into tender documents can be challenging.

It can be useful to quantify both the economic and environmental value in a project so that circular approaches are not only viewed as an additional cost and risk but also as a contribution to the project's value proposition (Wennersjö, et al., 2021). This can include using Circular Economy Life cycle Costing tools (CE- LCC) (Jansen, et al., 2020).

The EU taxonomy that came into effect in 2022 provides definitions and security for investors and insurance providers to help companies shift to more sustainable activities. One of the EU taxonomy's six environmental objectives—areas where an

economic activity can positively contribute to sustainability—is "The transition to a circular economy" (EC, 2020). The issuing of "green bonds" can also encourage property developers to increase circularity and other environmentally sustainable activities in their projects.

4.2.2. Architects, engineers, and consultants

The design team of architects, engineers, and other consultants is responsible for developing the project in accordance with the requirements set out by the developer. As such, they can have an enormous influence on circularity through their design and material choices. Through their expertise and knowledge, they can also positively influence developers toward more circular solutions. As they are involved early in the process, architects and engineers can help identify products in soon-to-be-demolished buildings that are suitable for reuse.

Architects working with circular design must engage in the principles of reuse and designing for reuse and repurposing, while simultaneously meeting the aesthetic demands of the developer and their own professional expectations. Technical consultants and architects engaging in circular construction should also be able to quantify the benefits of reuse as well as understand, and preferably document, how reused products can be integrated into new designs, and the benefits that this brings.

4.2.3. Contractors and builders

Contractors and builders coordinate and execute the project in the construction phase. They work directly with construction products, logistics, and waste—the practical stages of construction. In addition to carrying out the actual construction activities, they are typically responsible for material and product procurement, logistics, and waste management.

Most companies in the construction industry are SMEs; less than 1 per cent of companies in the Danish construction sector have more than 250 employees, and 85 per cent of the construction workforce is employed in an SME (Danmarks statistik, u.d.). However, even within this group, there are significant differences in size and competency areas within building companies. Around 65 per cent of the construction workforce is employed in companies with less than 50 employees, and 30 per cent in companies with fewer than 10 employees. The sector also covers a highly diverse range of skills and competencies, which is reflected in the number of distinct trades within the construction sector. Similarly, there is a huge variety in the size and complexity of projects—from simple renovations and repairs of small buildings to the construction of entire neighbourhoods.

Waste prevention within the construction sector has, in recent years, focused on the role of contractors and builders—both in terms of waste management at the construction site, and by avoiding the over-procurement of building materials and products: the economic incentives and tight construction deadlines typically mean that having a little extra material as a buffer is preferable to having a very lean supply and risking delays.

As builders and contractors work directly with the construction materials and products, their involvement in and influence on the effectiveness of circular construction is decisive. In many cases, they must adapt existing practices to non-standard reused products and materials, develop and maintain new competencies, and work with new and unknown material flows and supply chains. This in turn influences their procurement and logistics processes (Wennersjö, et al., 2021).

4.2.4. Construction product manufacturers, processors of reused products

Manufacturers of construction products and processors of reused products provide the material used in the sector. Manufacturers of new building products create products that fulfil the technical requirements demanded by the sector in a highly competitive environment.

Manufacturers of construction products have an important role in facilitating the transition to circular construction. For example, designing for reuse and flexibility demands new, innovative products that enable buildings to more easily be adapted during their lifespans and dismantled when they reach their end of life. Manufacturers can also have a role to play in take-back schemes and remanufacturing, which could be particularly relevant for high-value and high-complexity assets.

Preparing construction products for reuse is a specialist activity with close ties to the demolition/disassembly sector. Preparing for reuse can include a range of activities, from sourcing materials for reuse, to cleaning, repairing, and testing products to ensure they meet the technical and aesthetic requirements of the construction industry.

4.2.5. Demolition companies and material banks

Demolition companies are responsible for removing a building at end-of-life and ensuring that the resulting waste materials are properly managed and end in the correct treatment operation—recycling, energy recovery, or landfill. The original design of the building heavily influences the processes involved in deconstruction and demolition.

Within the framework of circular construction, demolition companies have a vital role to play in identifying and safely removing products for reuse. Selective demolition is not new, but it mostly focuses on hazardous materials that must be removed prior to demolition to ensure clean waste fractions for recycling. As with the builders and contractors, circular construction demands additional skill sets within the demolition industry to enable reusable products to be safely and carefully removed from buildings, packaged transported and stored when necessary in such a way that avoids damaging the reused products. Circular construction is a significant opportunity for deconstruction and demolitions contractors, and their skills will have a positive impact on the transition.

However, disassembly takes significantly longer and is considerably more complicated than demolition, and as such is more costly. Finding time within the development schedule to undertake these extra activities is essential (Wennersjö, et al., 2021).

Material banks and resellers of reused products play an important role in mediating the transfer of products between the old and the new building. There is an economic interest in storing materials for reuse or recycling rather than disposal since it reduces waste management fees. It is also a benefit for the site owner or developer, who can decrease their environmental impact (Wennersjö, et al., 2021).

Until recently, interest in reused construction products has been primarily driven by economic factors—in some instances it can be cheaper than buying virgin new products. Appreciation of the environmental benefits has, however, begun to become a factor driving reuse. This affects what is being recovered from demolition sites and what is later reused (Wennersjö, et al., 2021).

4.2.6. National and local authorities

National and local authorities are responsible for the legislative framework conditions for the construction sector. National authorities are responsible for developing new regulations and strategies as well as enforcing existing regulations. Public authorities, often at the local level, also control permission for construction activities, and therefore have a great influence on the construction process and the direction of development within the Nordic countries.

Government and local authorities can also play a vital role in the transition to circular construction by creating an incentive structure that rewards circular construction activities. For example, policy and regulations can promote reuse and recycling by making them more economically advantageous or mandatory.

Aside from their regulatory role, local and national authorities are also among the largest building owners and developers in the Nordic countries. This means that

public procurement of construction activities and real estate can be a powerful driver for change in the industry.

4.2.7. Research and innovation organisations

New materials and processes are needed to make the shift from linear to circular systems possible. Research and innovation programs aid the transition into a circular economy. Network platforms for actors within the construction sector can offer a range of services such as webinars, marketplaces to sell and buy recycled products, education, guides, and reports that can help foster new practices in the construction sector. These programmes allow stakeholders such as architects, consultants, contractors, researchers, and public actors to cooperate and find sustainable solutions to increase circular construction.

Research and innovation organisations can also help challenge old perceptions and values in the industry. Changes to practices and processes are often perceived as threats to the status quo and existing power balances within the industry, and changes in the industry will affect the entire value chain to some extent.

4.2.8. Nongovernmental organisations

Industry organisations represent the construction industry at the political level and often provide networking and knowledge-sharing facilities. These can be useful for coordinating initiatives within the industry and provide a channel for communicating with all the actors within the industry. Similarly, they can coordinate responses to challenges within circular construction, which can be particularly relevant in relation to regulatory or the administrative barriers faced by the industry.

4.3. Construction materials and potential for reuse

Buildings are complex structures with multiple materials that in turn provide multiple functions. Building design and material selection can be driven by a wide variety of factors including technical requirements, price, aesthetics, and climate impact. The longevity of the built environment means that decisions taken now about both design and material choice define the nature of the building for several generations.

The concept of building layers (Brand, 1994) can help frame discussion about the longevity of building materials and components and how they adapt to changing

requirements over longer periods. It can help frame decisions pertaining to the design of circular buildings—designing for flexibility, designing for adaptability, and designing for disassembly. Adapting and reusing existing buildings can provide significant environmental and financial benefits.

The different building layers are illustrated in Figure 2: *site* is the location and will outlast the building; *structure* is the foundation and load-bearing elements that are costly to change and can last 100+ years; *skin* is the exterior surfaces that are exposed to the environment, *services* include the installation systems within a building, *space* represents the interior layout such as walls, ceilings, floors, and doors, and *stuff* is furniture and appliances. Generally, the rate of substitution increases as one moves from structure at one end of the scale toward stuff at the other.

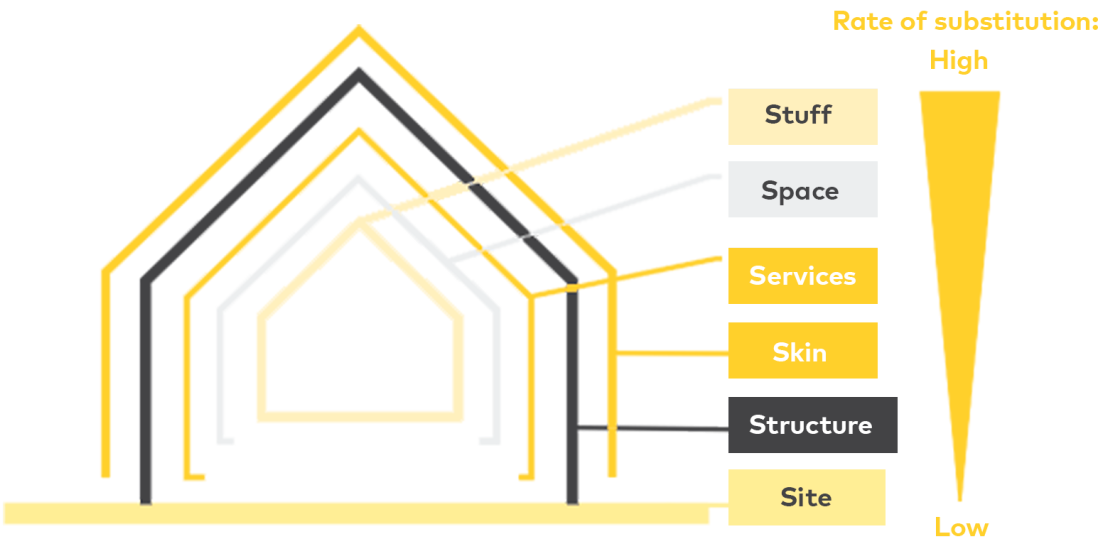

Figure 2 - Layers of a building
Adapted from (Brand, 1994).

The following short sections provide a brief overview of the reusability and recyclability of some key materials in the built environment.

4.3.1. Concrete

Concrete has a high climate impact stemming from the production of cement, but it has a long functional life cycle and can generally be recycled into acceptable aggregate at end-of-life (Svensk Betong, 2021). Although these characteristics make concrete a suitable candidate for reuse, the way concrete is used in the construction of buildings makes reuse difficult in practice. Where concrete elements have been cast in place, disassembly and transportation for reuse becomes cumbersome compared to using new concrete (Bohne & Waerner, 2014). Cast-in-place concrete is today commonly crushed after use and recycled as aggregate for new constructions or used for back filling and ballast (Svensk Betong, 2021). A lack of certification and traceability also hinders wider uptake in structural applications.

Prefabricated concrete elements allow for more modular construction and deconstruction. It is assumed that prefabricated elements, when used in an existing building, possess reliable technical qualities and in some instances can be more readily removed during deconstruction, which can enable reuse in new applications (Gabrielsson & Brander, 2021). Prefabrication can allow for elements with longer lifespans, which in new buildings can provide greater adaptability to future needs through changes in floor plans (Svensk Betong, 2021). To benefit from the longevity of concrete, buildings should be designed to enable change, adaptation, and modernization to new needs.

Crushing concrete into aggregates and using it as a filling material can help minimise extraction of virgin raw materials, shorten material transport distances, and save energy. However, the environmental benefits of using concrete for landscaping and backfilling are much smaller than those of reusing it in structural applications.

4.3.2. Steel/iron

The production of steel has a high climate impact, but steel also has a long lifespan. In addition, steel has an almost closed-loop material recycling process: most steel waste is recycled since there is an economic incentive to do so. Reprocessing steel into new products is still energy intensive, but the overall environmental impacts are significantly lower than for virgin steel.

There is also high reuse potential for steel (SCI, 2019). The ease of directly reusing and recycling steel depends on the type of component. Rebar (steel reinforcement elements in concrete structures) is relatively difficult to separate from concrete, while components with welds and rivets can also complicate the process (Husson & Lagerqvist, 2018).

A lack of knowledge, delayed delivery leading to higher costs, and problems with CE-marking, certifications, and traceability have been identified as key barriers to the reuse of steel in the construction industry Husson & Lagerqvist (2018). It can also be difficult to remove structural steel from an end-of-life building without damaging the steel component. The requirement of a CE-marking and DoP for load-bearing constructions in Sweden also presents a significant barrier: reused steel components cannot be CE-marked in the same way as virgin steel components. However, based on controlled testing, a certificate or other technical verification can be issued to demonstrate that the demanded technical requirements are fulfilled (Husson & Lagerqvist, 2018)

4.3.3. Wood/timber

Wood is widely used in many applications in the construction industry. Wood can be an integral part of a building; for example, it can be used as the structural element or in the roofing structure; it can be used in or as a space divider, as a skin/façade component, or even as sound insulation (Svenskt Trä, n.d.). It is also used as a consumable component of construction, such as in moulds for pouring concrete. The material can be used in the form of pure wood, wood-based boards (glued wooden boards), and impregnated wood. These wooden building elements are often combined with other materials such as paint, sealant, and glue (Johansson, et al., 2017). This can be a challenge for the reuse and recycling of timber (Cristescu, 2020).

Non-hazardous and uncontaminated timber is often reused or recycled, often as chipboard or other fibreboards, while contaminated timber waste is either incinerated for energy recovery or landfilled. Contamination can result from surface treatments (paint, glue, varnish, and oils) and impregnation, often for applications to treat exposed elements or biological contamination. Norway, Finland, and Sweden have an ample supply of virgin wood, which may explain why building companies choose virgin rather than recycled wood materials.

Reusing timber structures can help preserve heritage value and minimise the use of virgin material (Bergås & Lundgren, 2020). In addition, the timber and wood in existing buildings can be of higher quality than that which can be economically achieved from virgin wood, which also provides qualitative incentive for reuse, while reusing existing components like prefabricated wooden wall elements may also be cheaper than a newly produced element (Sigma, 2019).

4.3.4. Bricks & Tiles

Bricks can often be reused, although the type of mortar used to bind the bricks in existing buildings is often a decisive factor. Until around the 1960s, brickwork from older buildings typically used lime-based mortar. Bricks from these buildings can usually be cleaned and reused depending on the state of the individual bricks. Brickwork in more modern buildings (after the 1960's) is typically bound with cement-based mortar, which makes preparing them for reuse technically more challenging since the mortar is harder than the bricks themselves (VCØB, 2022) (VCØB, u.d.). However, even where cement-based mortar is used, it is still possible to reuse brickwork by removing panels of the brickwork, which can then be reused directly in a new construction project.

The harmonised standard for new bricks is not directly transferable to reused bricks, which means that the CE marking must be voluntarily completed (Gabrielsson & Brander, 2021). Brukspecialisten, a Swedish company specialized in bricks and related services, offers reused brick products that are CE-marked and have a frost guarantee. *Gamle Mursten* provides a similar service in Denmark. A CE mark and frost guarantee promote circular construction since they provide assurance that the reused brick is just as technically reliable as new bricks.

Using reused bricks rather than new bricks reduces the climate impact of that component by 96 per cent (Brukspecialisten, u.d.). The processes involved in the demolition, collection, cleaning, and quality assurance of reused bricks is time consuming, however, and means that they typically cost more than new bricks, which is an economic disincentive. In addition, the execution time for building with reused bricks can be longer due to their weight: new bricks normally have small holes throughout the material, thus reducing their mass (Gabrielsson & Brander, 2021).

Roofing tiles can similarly be reused, although they may require some preparation to remove either the binder or biological contamination depending on the condition and environment of the existing building.

5. Circular construction in the Nordic countries

The circular economy is a key pillar of the sustainability agenda in the Nordic countries, with the construction sector regarded as having significant potential. The following sections outline the framework conditions for and state of circular construction in the Nordic countries.

5.1. Denmark

5.1.1. Framework conditions for circular construction

Policy & strategy

Denmark's *Climate Plan for a Green Waste Sector and Circular Economy (Klimaplan for en Grøn Affaldssektor og Cirkulær Økonomi, (Regeringen, 2020)*) describes the main strategy for the circular economy in Denmark. It builds on earlier work in the *Strategy for a Circular Economy* (Regeringen, 2018) and the results and recommendations of the *Advisory Board for a Circular Economy* (ABCE, 2017).

The construction sector is noted as having an important role to play in the transition to a circular economy since it produces approximately one third of all waste in Denmark and is responsible for a significant amount of total resource use in the country, and has the potential for reduction in the same.

In particular, the *Climate Plan for a Green Waste Sector and Circular Economy* calls for the introduction of standardised demolition plans and demands on competencies for selective demolition in order to ensure that valuable materials can be captured and reused and recycled rather than "recovered" as aggregate for roads and other infrastructure projects (Regeringen, 2020). These initiatives were implemented in the *Action Plan for a Circular Economy* (Miljøministeriet, 2021). This Action Plan contains 129 specific initiatives to drive the circular economy in Denmark up until 2032. One central component focuses on sustainable construction, which includes 20 initiatives under five themes, most of which are relevant to circular construction. However, the following are particularly relevant:

100. Further support for the VCØB (2021)

101. Development of a voluntary sustainability class for buildings (2022)

102. Limitation of values for life cycle CO2 emissions from new buildings (2023–2029)

103. Further development of LCC and LCA tools (2024)

106. Holistic evaluation for renovation (2023)

108. Demands for standardised selective demolition plans and competency demands for selective demolition (2023)

109. Demand for selective demolition (2022)

110. Safe and healthy reuse of buildings (2023)

113. Clear rules enhancing the traceability of construction and demolition waste (2021)

Several of the above initiatives are part of *The National Strategy for Sustainable Construction* (*National Strategi for Bæredygtig Byggeri, (IM, 2021)*) which describes 21 specific initiatives to strengthen sustainable construction in Denmark. Of these, five are directed squarely at driving circular construction under the title *Durable high-quality buildings* in order to:

1. *Analyse the potential for more sustainable construction (a green check of the Eurocodes)*
   Seeks to ensure that the use of Eurocodes does not lead to unnecessary material use, and that revision of the Eurocodes facilitates sustainable construction while maintaining safety standards.
2. *Ensure safe and healthy reuse in construction.*
   Seeks to move existing building waste and recycling up the waste hierarchy by exploring best-practice cases in reuse, developing a material and building passport coordinated with similar efforts in the Nordic countries and the EU, and developing closer ties along and among the construction value chain in order to identify barriers and develop solutions.
3. *Promote climate-friendly construction materials.*
   Uses different approaches to facilitate the further development and implementation of timber in construction, with a primary focus on buildings with up to five floors, together with efforts to quantify the environmental benefits of timber as a building material.
4. *Develop more accurate environmental data on materials.*
   Seeks to provide more reliable and broader environmental information on building and construction products, primarily through developing and supporting more widespread use of EPDs and ensuring that the underlying data reflects actual production conditions.

5. *Perform holistic assessments for refurbishments.*
   Will develop more robust tools to support the decision to either renovate or demolish and rebuild, for example, using a more holistic approach to assessing the entire building's life cycle, including embodied energy and the influence of material decisions. This initiative will also investigate the primary reasons for demolition in the current construction paradigm.
6. *Reduce the waste of materials on construction sites.*
   This initiative will analyse waste generation on construction sites, which will provide the basis for specific initiatives targeting problematic fractions, including through induced collaboration.

All six initiatives should be finalised by 2024 at the latest.

A fundamental pillar of the *National Strategy for Sustainable Construction* is the phased introduction of minimum life cycle emissions standards for new buildings, which was introduced to the market in January 2023. These define specific targets for buildings under and over 1000 m^2 and set standards for a voluntary sustainability class of buildings that go beyond the baseline demands. LCA calculations will be necessary for any new construction starting in 2023. An LCA calculation tool, LCAbyg, has been developed and is accessible online for free together with instruction videos and continuous updates (LCAbyg, u.d.).

The principle behind the targets is to move away from a singular focus on in-use energy consumption and to integrate the embodied energy in construction products as an important part of all the life cycle emissions. This is especially relevant as energy for heating, lighting, and power increasingly comes from renewable sources. For projects over 1000 m^2, a threshold limit value is set at 12 kg CO_2-eq/m^2/year. Every two years the limit value will be reduced further, and after 2025 it will also include smaller projects (IM, 2021).

These targets have, however, been criticised for lacking ambition: critics claim that the targets are largely in line with current developments within the building industry and therefore do not provide any additional impetus to decrease overall life cycle emissions (Kjerulf, 2022). Initially, the new calculation model included no provision for reused materials and elements—they were conferred the same CO_2 emissions as new products within the calculation model (BR, 2022). This will be rectified in an amendment coming into force in 2024 (Social-, Bolig- og Ældreministeriet, 2023).

Building regulations

The *Danish Construction Law*, which legislates the construction of buildings in Denmark, *(Social-, Bolig- og Ældreministeriet, 2016)* is implemented through the *Danish Building Regulations* (BR, 2020), which define the technical criteria that buildings and the construction process must meet. They currently do not contain any specific provisions that address the challenges of circular economy in construction. All buildings, materials, and components must meet the technical standards defined in BR18.

In November 2021, the Construction Law was amended to include the following components in BR18 (Social-, Bolig- og Ældreministeriet, 2021):

- Demands on life cycle analysis and CO_2 limit values.
- Demands on total economic analysis (life cycle costing).
- Demands on resource use at construction sites.
- Demands on documentation for problematic (hazardous) substances in construction materials.

Together, these provide for the inclusion of sustainable and, to some extent, circular parameters in the *Danish Building Regulations*. At the time of writing, only the demands for life cycle assessment and CO_2 limit values have been implemented; they entered into force on 1st January 2023. These implement the targets set in the *National Strategy for Sustainable Construction*. The other criteria have not yet been implemented in BR18, although steps are being taken to develop criteria under the above areas.

Work has begun to lay the groundwork for a new regulation in 2023 that mandates selective demolition. The exact nature of the regulation is not yet known, and there will be ongoing industry consultation on the development of the regulation.

Public Procurement

Public procurement for buildings and infrastructure comprises about one sixth of the total public procurement budget and is responsible for approximately 2.6 million of the 12 million tonnes of associated greenhouse gas emissions—it is the single largest contributor (Regeringen, 2020). As such, buildings and infrastructure are a key area of focus for green public procurement. Most effort has so far been placed on highlighting the role of energy consumption, although other sustainability criteria for buildings and construction are beginning to receive more attention.

Waste regulation

Danish municipalities are responsible for the classification of waste by determining whether an article is waste, and thereafter what type of waste it is (Miljøministeriet, 2021). Furthermore, the municipality is also responsible for determining when a material ceases to be waste: the waste must be destined for use in a specific application, or there must be a market or demand for the material or item, the material or item must meet the technical requirements, legal requirements, and norms for that specific application, and the application of the material or item must not negatively affect the environment or be a health hazard (*Affaldsbekendtgørelse*, Article 6) (Miljøministeriet, 2021).

Danish waste legislation (*Affaldsbekendtgørelse*, Chapter 11) (Miljøministeriet, 2021) demands that a screening and mapping of hazardous substances (e.g., PCBs, chlorinated paraffins, PAHs, asbestos, and heavy metals) be carried out and filed with authorities before any building, renovation, or demolition work can begin. This mapping only addresses the presence of hazardous materials and does not address potentially reusable components or materials. However, as indicated above, this will be addressed soon with mandatory material mapping and obligatory standardised demolition plans.

Article 35 of the Danish waste regulations demands that municipalities ensure that construction and demolition waste is reused, recycled, or used in another material recovery process. As per Article 63, construction companies must also separate waste into the following categories: stone, tile and brick, concrete, mixed mineral, metal, plasterboard, mineral wool, earth and soil, asphalt, and mixed concrete and asphalt. (Miljøministeriet, 2021)

The regulation on the utilisation of waste products (*Restproduktbekendtgørelsen*) provides more targeted regulation on the reuse, recycling, and utilisation of construction and demolition waste (Miljøministeriet, 2016). Annex 6 states that uncontaminated construction and demolition waste such as bricks, tiles, and plasterboard can be reused for their original or similar purpose without prior authorisation and may be stored on the demolition site for a maximum of 12 months.

Standardisation

Danish Standard, the Danish standardisation body, holds the secretariate for the CEN/TC 350/SC1, the European Committee for Standardization's working group developing standards for the Circular Economy in the Construction Sector (CEN, u.d.). This positions Denmark at the centre of developing the coming standards that will govern the construction industry for the whole EU.

Nordic collaboration

Danish authorities are managing Work Package 5 in the Nordic Council of Minister collaboration project *Nordic Sustainable Construction (Nordic Sustainable Construction, u.d.)* together with representatives from other Nordic countries. The focus is on collaboration and knowledge sharing. In addition, in 2023-2024 a new project will be launched that will produce supplementary training material to increase the skills in vocational education regarding the use of reused construction materials when dealing with old, refurbished, or new buildings.

Networks and support mechanisms

A variety of networks, organisations and knowledge centres support circular construction in Denmark. These include the following:

Videncenter for Cirkulær Økonomi i Byggeriet – (VCØB) is a knowledge centre and network that supports and promotes circularity in the construction industry (VCØB, u.d.). It collects, develops, and communicates experience and knowledge about the circular economy in the construction industry in Denmark. It targets the whole construction value chain, which includes public and private owners, architects, engineers, developers, building companies and trades people, and construction product suppliers. It publishes a range of guides on elements of circular construction, and the homepage can be used by the sector as a knowledge resource (VCØB, u.d.).

Værdibyg is a cooperative development programme uniting some of the most prominent construction organisations in Denmark: BAT-Kartellet, Bygherreforeningen, DI Byggeri, Danske Arkitektvirksomheder, Foreningen af Rådgivende Ingeniører, and TEKNIQ Arbejdsgiverne (Værdibyg, u.d.). It seeks to develop and promote new construction methods and processes that minimise value loss in the industry. Circular construction is a core component of its work, and it has developed a range of educational and communicational materials that aim to move the sector in a circular direction.

These include:

- A guide addressing the main dilemmas faced in circular demolition. It includes guidance on issues such as demolition and renovation, choosing materials for reuse and recycling, and circular demolition regulations.
- A guide to the circular demolition process providing specific instructions on how demolition projects can be planned and carried out so that reuse and reutilisation are promoted as much as possible.
- A guide to environmental surveying and demolition clarifying how environmental surveying constitutes a value-creating element in demolition and renovation projects.

We Build Denmark is the official cluster organisation for the building and construction industry in Denmark. It is supported by the national authorities, municipalities, sector organisations, and the largest construction-focused fund in Denmark (We Build Denmark, u.d.). It works broadly with innovation and sustainability, drawing on expertise from a strong field of Danish technical research institutions including Danmarks Tekniske Universitet, Dansk Brand- og forsikrings Institut. Københavns Universitet, Roskilde Universitet, Syddansk Universitet, Aalborg Universitet, Aarhus Universitet, and leading architecture and professional technical schools. Circular economy is part of We Build Denmark's ongoing agenda, and there is an advisory panel working on the issue under the overall umbrella of sustainability.

5.1.2. State of circular construction

Denmark recycles and recovers a high level of construction and demolition waste: it had already met and exceeded the EU's Waste framework targets for the treatment of construction and demolition waste when the targets were launched (Eurostat, 2023). However, much of the recycled construction material was recovered in low-value applications. In 2021, Denmark recycled, prepared for reuse, or otherwise recovered 87 per cent of the generated construction and demolition waste (Table 3). However, the share of generated construction and demolition waste that was prepared for reuse or recycled (excluding other utilisation) fell from 36 per cent in 2018 to 33 per cent in 2020 (Table 3).

The share of buildings certified by svanemærket, DGNB, LEED, or BREEAM increased yearly, with almost one out of four new buildings certified in 2020.

Table 2 - Share of certified buildings, and reuse, recycling, & utilisation of C&D waste in Denmark

	2016	2017	2018	2019	2020
Share of buildings certified by svanemærket, DGNB, LEED, or BREEAM		7%	16%	23%	23%
Share of construction and demolition waste prepared for reuse or recycled			36%	33%	33%
Share of construction and demolition waste prepared for reuse or recycled, or other material utilisation	85%	88%	88%	87%	87%

Source: (Miljøstyrelsen, 2022)

Anecdotal evidence indicates that there is increasing recognition that circular construction is an essential element in creating a sustainable built environment. This includes not only recycling and reuse of building materials and components, but also making better use of existing structures. For example, there have been a significant number flagship and research and development initiatives addressing the subject, while the coming regulations regarding selective demolition and disassembly also indicate an ongoing and deep commitment to circular construction at a structural level.

Experience and involvement are growing throughout the construction industry value chain. For example, several of the leading demolition companies have recently invested in Greendozer, a digital marketplace/platform for reusing used building products (Greendozer, u.d.), while two leading construction companies have invested in Genbyg, a physical reuse marketplace (Genbyg, u.d.). This should help expand expertise further, broaden awareness of reuse of building materials and components within the industry, and foster better utilisation of existing construction materials in future construction projects.

As with the other Nordic countries, there is little information on the renovation rate in Denmark. Focusing on single family houses, 33 per cent underwent some form of renovation in 2019–2020, with a larger share in houses built before 1990 than those built after (Eberhardt, L. et al., 2022).

5.2. Finland

5.2.1. Framework conditions for circular construction in Finland

Policy & Strategy

The 2017 *National Climate Law* sets out the government's goal of becoming the first welfare society in the world to reach climate neutrality by 2035. The country's climate law is being revised and reformed to enable Finland to reach this goal. Transitioning the Finnish economy to a circular economy is one of the key components to achieving climate neutrality.

In April of 2021, the Finnish Council of State (fin. Valtioneuvosto) started the process of developing a strategic program to describe the conditions for a successful transition to a circular economy. The goal is to make circular economy the basis of the state economy by 2035, in line with the climate goal (YM, 2021a).

The *Strategic Program for a Circular Economy in Finland* contains 18 central measures through which the different ministries are bound to endorse a circular

economy during the period of 2021–2024 (YM, 2021b). Of these, the following are relevant and important adaptions for the construction industry:

- Improvement of tax regulations and legislation to create financial incentives for wider use of circular business models.
- Making information available to the public regarding circular economy services, such as repair and resale services for home improvement projects.
- Development of strong digital platforms linking material and data flows to increase the traceability of material flows, resource-efficient production, and data-based decision-making.
- Procurement of circular economy solutions for the public sector within construction and infrastructure projects.
- Integration of circular economy expertise into educational systems and work-life skills of all relevant business areas (Valtioneuvosto, 2021).

Building regulations

The building and construction industry in Finland is under direct governmental control through the Ministry of the Environment (fin. Ympäristöministeriö, YM). YM oversees, legislates, and develops strategies for improvements in terms of:

- the national climate work,
- nature and water resource utilisation,
- housing,
- building and land usage,
- the circular economy,
- environmental research and development.

Finland is in the process of reforming the national construction and land use regulations. The new law addressing construction—the *Construction Act*—provides for a raft of initiatives for promoting the circular economy in the construction sector (YM, 2021c). This will include:

- Demand for new low-carbon building that promotes the use of recycled and reused content in new buildings.
- Demand for life cycle qualities in new construction that promote long service life, flexible building design, and designs for disassembly and reusability.
- Demand for pre-demolition material reporting promoting the reuse and recycling of end-life materials.

The new *Construction Act* is expected to be passed in February 2023 and enter into force in January 2024.

Waste legislation

Construction and demolition waste in Finland is regulated by the Waste Legislation. Section 15 of the Waste Act requires the separate collection of wastes of different types at source, although it does not specify the specific waste fractions that must be separately collected (Ministry of the Environment, 2021). In line with the Waste Framework Directive, the *Waste Law* includes provisions for not separately collecting waste where it does not improve recovery, where it is disproportionately expensive, where it is not technically feasible, and where it doesn't lead to improved environmental results. Similarly, it also legislates the end-of-waste conditions for generated waste, which is in line with the Waste Framework Directive. This thus allows waste to become a resource when it will be used for a specified purpose, when there is a market for it, when it meets the technical requirements of the application, and where it does not pose a danger to the environment or health (Ministry of the Environment, 2021).

The *Waste Act* also dictates the terms of Finland's waste taxation (fin. jätevero). The tax is paid when waste is transported to a final disposal site, although this excludes some types of waste that can be utilised in the maintenance and development of the waste facility itself (Ministry of the Environment, 2021). For example, asphalt waste or crushed bricks used for surface improvements of the infrastructure within the waste facility are exempt from taxation (Verohallinto, 2021).

The tax aims to make it less profitable to ship demolition waste directly for disposal and instead incentivises the recycling and reuse of materials. The tax is paid by the waste facilities for waste sent to final disposal either above or beneath the ground. The tax applies to both private and public waste facilities and is set to 70 euros per ton for the year 2021 (Verohallinto, 2021).

Voluntary agreements

In 2020, the Finnish Ministry of the Environment entered a comprehensive "Green Deal" with Rakli, the trade organisation for property owners and developers, to promote material efficiency in demolition. The agreement aims to increase the reuse and recycling of demolition materials by encouraging property owners and developers to conduct pre-demolition surveys for any demolition or large-scale renovation project. Specific targets have been put in place for pre-demolition mapping: by 2022, 50 per cent of demolition/renovation projects conducted by Rakli members should include a pre-demolition survey; this should rise to 75 per cent by 2025. It is anticipated that the agreement will help strengthen the knowledge base,

promote the reuse and recycling of used building elements, and help further develop the available tools and platforms supporting circular construction, specifically the pre-demolition surveys and the online materials marketplace (Sitoumus2050, u.d.). The voluntary agreement runs until 2025.

Environmental Certification Schemes

The following environmental certification systems are used in Finland:

- BREEAM - Building Research Establishment Environmental Assessment Method, EU
- LEED - Leadership in Energy and Environmental Design, Global
- Nordic Swan (fin. Joutsenmerkki), Nordic countries
- RTS Environmental certificate (fin. RTS - Rakennustietosäätiön ympäristöluokitus), Finland

RTS is a domestic certification system used only in Finland. It is based on the European CEN TC 350 standards and is managed and supervised by Rakennustieto Oy. It is adapted to Finnish construction practice and national building regulations, like the Swedish equivalent Miljöbyggnad.

RTS certification system

The RTS environmental certificate gives a value of 1–5 stars and is divided into two main categories: Housing and Office & Service buildings. In each category, the certificate is available for both renovation and new development, and audits are carried out during both the construction phase and the property management phase.

The RTS certificate has four major areas of criteria:

- The Construction Process
- Economy (construction phase as well as LCC)
- Environment & Energy
- Indoor Air Quality & Climate

Material efficiency is a subsection of the Environment & Energy category.

Circularity is present in the criteria set for Office & Service Buildings. The first requirement for point gain is that the project in question must have already stated the required amount of recycled materials during the planning phase. In other

words, a goal must be set in the project planning phase, and it must be included in the project documentation. After the construction phase is finished, a follow-up is conducted within the certification audit, and points are then given according to the following table:

Percentage of total amount of available points in the category:	Criteria for material efficiency are met in:
25%	1 type of construction material
50%	3 types of construction material
75%	6 types of construction material

RTS table (RTS ymprisötluokitus v1.1, 2020)

Depending on how many different types of construction parts are affected by the circularity requirement, the project will gain between 25–75 per cent of the total available points in the category of material efficiency. The remaining 25 per cent can be gained from the use of environmentally conscious materials.

For a construction material to qualify as circular according to the table above, it must meet at least one or a combination of the following requirements (RTS ymprisötluokitus v1.1, p. 41):

- 10% recycled materials that have been salvaged from the building site itself.
- 25% recycled materials (EPD secondary material)
- 50% industrial leftover materials or waste
- 50% renewable materials
- 80% of the construction material/construction element has been conserved during the renovation

Stakeholders involved in CE activities

RAKLI is the leading organisation representing Finnish property owners, investors, developers, and contractors within the building and construction sector. The organisation's main duty is to safeguard the interests of its members, partake in the public debate regarding construction related issues, and contribute to a positive development in the country's climate work.

RAKLI has several expert groups covering different areas of the building industry. These comprise representatives from members, which include both public and private actors, and provide the organisation with a broad and nuanced perspective in the public debate. RAKLI entered into a "Green Deal" with the Ministry of the Environment to promote high-quality recovery of demolition materials using pre-demolition audits (see above) (YM, u.d.).

RAKLI's road map for lowering carbon emissions identified the amount of vacant, empty spaces and locales within the building stock as a key issue: there are three times as many vacant locales in Helsinki compared to other Nordic capital cities (RAKLI, 2021). Adapting vacant and empty buildings and spaces for new purposes is a very important way of achieving a functioning circular economy.

5.2.2. State of Circular Construction in Finland

Finland has not yet achieved the Waste Framework Directive recycling target for non-hazardous C&D waste of 70 per cent by 2020 (EC, 2008). In 2020, the share of non-hazardous C&D waste prepared for reuse, recycled, or subject to material recovery was 63 per cent (Eurostat, 2023) in Finland, although this rate varied significantly over the preceding years, peaking at 87 per cent in 2016.

The Finnish building stock is heavily based on wooden construction—approximately 45 per cent of the material in Finnish buildings is wood, and in the past decade, Finland has invested significantly in constructing new wooden buildings with the goal of replacing steel and concrete as building materials. Correspondingly, approximately 30 per cent of C&D waste is also wood (Lindgren, 2018). In 2020, the Finnish construction and demolition industry[1] generated approximately 273,000 tonnes of wood waste. Almost all the wood waste generated by construction and demolition activities in Finland is incinerated for energy recovery[2].

Since the mid 1990's, concrete waste in Finland has mainly been used as a foundation material for streets, roads, and other infrastructure projects (Nordqvist, 2016). Crushed waste concrete is commonly used for road structures since it is not permitted for use in the base structure of any type of building other than warehouses and industrial facilities (Valtioneuvosto, 2018).

The Finnish classification standard SFS-EN 5884, originally published in 2001 and updated in 2018, aims to support socially responsible and environmentally ethical repurposing of concrete waste materials within the construction sector. The standard divides concrete waste into four different categories, BeM I BeM IV

1. NACE categories F41-43 – thus including infrastructure, construction, and demolition activities.
2. Niu, Y et al, (2021) Prolonging life cycles of construction materials and combating climate change by cascading: The case of reusing timber in Finland. Journal of Resource conservation and recycling, Vol 170, July 2021.

according to its quality and purity, which then determines the best-suited targets for its reuse:

- BeM I class concrete waste derived directly from the concrete industry, making it the purest type of concrete waste.
- BeM II – BeM IV, all derived from demolished buildings and other structures and categorised based on their inherent amount of other construction materials such as plastic, brick, and mineral wool as well as their endurance properties (Suomen Standardiliitto SFS ry, 2018).

Concrete wastes that do not meet the requirements for commercial reuse have typically been used in the management and on-site improvements of the recycling centres where the concrete waste has been transported for final disposal (Nordqvist, 2016).

There are currently many approaches seeking to enable and ease the process of recycling and reuse of construction materials. The ongoing efforts by the authorities to promote circular construction and projects grounded in circular principles, in particular the reuse and recycling of construction and demolition waste, indicate that there is growing momentum for circular construction in Finland.

5.3. Iceland

5.3.1. Framework conditions for circular construction

Policy & Strategy

The revised circular economy and waste strategy, *Towards a circular economy – waste management policy* (*Í átt að hringrásarhagkerfi Stefna umhverfis– og auðlindaráðherra í úrgangsmálum*) (Umhverfis– og auðlindaráðuneytið, 2021) aims to promote sustainable resource use by increasing recycling and other reuse of waste, reducing landfilling, and ending landfilling of biodegradable waste.

Local governments play a key role in waste management. It is up to the local government to determine the arrangements for the collection of operational waste within the municipality, compared to waste management law. The local governments are also responsible for promoting the collection and sorting of waste in such a way that it can be reused rather than disposed of.

Let's Build a Greener Future (Byggjum grænni framtíð, 2022) is a joint project between the government and the building industry's stakeholders targeting more environmentally friendly construction. The project has its roots, among other things,

in Action C.3 - Climate impact of the construction industry: systematically reducing emissions of greenhouse gases from the construction industry in Iceland.

As a part of this project, a *Roadmap for ecological construction 2030* has been created. The roadmap introduces 11 action points aimed at promoting the introduction of a circular economy in the infrastructure sector:

1. Establish a marketplace for soil and minerals (MölUndur).
2. Map and establish guidelines for the potential utilisation of different construction wastes.
3. Promote new classification requirements for construction and demolition waste by operators.
4. Start a conversation and encourage the state or local authorities to offer preferred areas where it is possible to give, sell, access, and buy building materials.
5. Amend building regulations to demand that architects' reports contain information on the maximum utilisation of building materials.
6. Record in the national building register the buildings that have received permission for demolition.
7. Establish a clear requirement for the submission of real figures on the amount of waste and activate follow-up procedures.
8. Identify which provisions in the law on building products and building regulations could be revised to promote the increased effectiveness of the circular economy without compromising safety and quality.
9. Issue guidelines on waste prevention, preparation for reuse, recycling, and other reuse of building materials for the design of new structures and renovation projects.
10. Issue guidelines for responsible demolition.
11. Emphasise construction activities in the waste prevention policy *Together against waste*.

All these actions are planned to be completed by the end of 2023.

Together against waste – strategy for waste prevention (Umhverfis– og auðlindaráðuneytið, 2016) is Iceland's waste prevention policy that applies from 2016 to 2027. The Minister of the Environment, Energy, and Climate established the policy, and it is managed by the Environmental Agency.

The policy focuses on nine priority categories—six for the coming two years and three that will require longer-term efforts. Green buildings will be a priority in 2024-2025.

Article 13 of the *Icelandic Waste Management Regulation (Reglugerð um meðhöndlun úrgangs)* (Alþingi, 2003) defines and establishes the principle of the waste hierarchy in Icelandic regulations. It states that when handling waste, and when establishing rules for management and policy regarding waste, the following hierarchy of priorities shall be followed:

- waste prevention,
- preparation for reuse,
- recycling,
- other reuse, such as for energy production
- disposal.

Preparation for the reuse, recycling, and other reuse of materials other than natural materials, including in backfills/landscaping where waste is used instead of other materials, in relation to general waste from construction and demolition activities, shall be increased to a minimum of 70 per cent by weight no later than 2020. This is in line with the targets for C&D waste in the EU's Waste Framework Directive.

The waste management regulations have been amended to ensure that construction and demolition waste must be separately collected in at least the following fractions: hazardous materials, wood, minerals, metal, glass, plastic, and plaster. This took effect starting on 1 January 2023 (Alþingi, 2021)**.**

The legislation for classifying construction waste is changing starting on 1 January 2023. Construction companies, contractors and other actors have been in negotiation throughout 2022 on the related issues. These discussions have focused on, among other things, the following topics:

- Incentives are needed to recycle more concrete. Today the economic advantages of the linear economy are too big compared to those offered by the circular system. There is a lack of financial incentives and a clearer legal authority for this.
- Some public tenders include incentives that award construction companies for reusing materials, but there is a lack of a platform/channel to sell and buy reused materials. The contractors do not always have the possibility of storing materials for a long time.
- Currently limited demand for used products. Reused products need to be included in the design. Products for which there is no demand should not be stored.
- There is already an incentive in waste costs, but is the cost difference between classified and unclassified waste large enough?

The *Law on Processing Fees* aims to create economic conditions for the circular economy of waste, and it imposes financial extended producer responsibility (EPR) on a range of products. By increasing the price of new products with a processing fee, economic conditions are created for the reuse and recycling of waste. A processing fund handles the administration and disposal of the processing fee. The cost of handling the product and its packaging should be included in the product price and not paid afterwards. Examples of product categories covered by the processing fee are paper and cardboard packaging, plastic, glass, wood, and metal packaging, batteries and accumulators, paint, hazardous materials, and electrical and electronic devices.

Building regulations

The Icelandic *Building Regulations* (*Byggingarreglugerð*) define what and how construction takes place in Iceland. The following components for the building regulations have a particular impact on circularity in the construction sector *(Húsnæðis- og mannvirkjastofnun, 2022):*

15.2.1. art.

- Buildings and structures and their individual parts must be designed and built to last. It is recommended that a life cycle analysis be carried out for new structures, extensions, the reconstruction of structures, and major maintenance projects.
- Recycled and reusable building materials should be chosen for building structures, if possible, according to the circumstances for each project.
- Construction waste must be kept to a minimum; this includes, for example, leftovers, and unused building materials or building parts.

6.1.1. art.

- When building and designing buildings, materials and methods should be chosen that are suitable for Icelandic conditions, negative environmental effects should be minimised, eco-friendly solutions should be chosen where possible, and the design should take the entire life cycle into account. The use of resources should be minimised, and usability, efficiency, and user comfort should be maximised.

15.2.4. art. Management of construction and demolition waste.

- All construction waste must be transported to an approved reception centre.
- By no later than January 1, 2020, at least 70 per cent of construction and demolition waste must be sorted in such a way that it is suitable for reuse before it is returned to an authorised reception centre.
- For buildings that need a permit, a list of construction and demolition waste generated must be made. This list must record the material types and their quantities.

16.1.1

- Before the final assessment of a structure is performed, the construction manager must hand over the structure's manual to the owner and the permit applicant.

In addition, the *Guidelines for Building Regulation 112/2012 - General requirements (delivery of building manual)* (Húsnæðis- og mannvirkjastofnun, 2020) demand that information be provided on the purchase of all specialized technical equipment as well as the main construction products. This includes where the product was purchased, the type and model, and information about the manufacturer. Information must be presented in such a way that the characteristics and type of the product are known. When CE certification is required, certificates/declarations of conformity must be included in the manual.

Sales platforms

MölUndur is a software and database project currently being developed as part of the *Roadmap for Ecological Construction 2030*. It is intended to become a central marketplace for soil and minerals for the public sector. The platform provides an overview of construction sites in Iceland along with information on soil and mineral waste generated at each location. MölUndur aims to minimise the transport and storage of soil and minerals and use materials as close to their source as possible. It will promote the reuse of soil and minerals throughout Iceland.

Efnismiðlun Góða hirðisins is a market at Sorpa's recycling sites in Sævarhöfði and Breiðhella. There you can find used building materials and products that can be reused in construction**,** and there are plans to establish a "mineral park", which would be a reception site for soil, minerals, and inert waste that can be reused elsewhere – in Álfsnes.

Stakeholders involved in Circular Economy activities

Aside from the key public authorities, key stakeholders in circular construction are:

Green Building Council Iceland (companies, organisations, institutions, and individuals are members of Green Building Council Iceland)

Let's Build a Greener Future (Byggjum grænni framtíð) is a joint project between the government and construction industry stakeholders which has its roots, among other things, in Action C.3 in the government's climate action plan. The project management team is made up of representatives from:

- Green Building Council Iceland
- The Federation of Icelandic Industries
- The Icelandic Road and Coastal Administration
- The Environment Agency of Iceland
- Icelandic Association of Local Authorities
- Ministry of Social Affairs and Labour
- The Institution of Housing and Structures

Nordic collaboration

The Ministry of Infrastructure, Institution of Housing and Structures, and Green Building Council Iceland are currently working on Nordic Sustainable Construction Work Package 4: Emission-free construction sites, which includes the production, transport, and disposal of building materials.

5.3.2. State of Circular Construction in Iceland

In 2020, construction and demolition activities in Iceland generated 524,000 tonnes of mineral waste (incl. soil). The largest part of the construction waste was excavation material, e.g., clean soil, gravel, and sand (Umhverfisstofnun, 2020). In 2018 (the most recent Eurostat data for Iceland), 98 per cent of non-hazardous C&D waste was prepared for reuse, recycled, or subject to material recovery (Eurostat, 2023). This waste is mainly reused in backfilling or landscaping applications (Umhverfisstofnun, 2020).

The largest part of the construction waste excluding excavation waste is also inert (e.g., concrete, tiles, ceramics, and glass). Table 4 shows the treatment of both building and demolition waste (excluding excavation waste).

Table 3 - Building and demolition waste in Iceland 2020 (Grænni byggð, VSÓ ráðgjöf, 2022)

	Recycled, reused, or recovered (tonnes)	Disposed (tonnes)
Timber (non-hazardous)	7,183	2,061
Timber (hazardous)	194	0
Inert waste (non-hazardous) e.g. concrete, tiles, gypsum, glass	24,944	1,996
Asphalt (non-hazardous)	21,683	4
Mixed waste (non-hazardous)	134	3,226
Waste with Asbestos (hazardous)	0	118
Total	54,138	7,405

Concrete is the main construction material in 70 per cent of buildings in Iceland. Around 80 per cent of the concrete waste is recycled, although mainly as aggregate and filler (Grænni byggð, VSÓ Ráðgjöf, 2022).

In Iceland, glass is also used as a filling material. Only a small fraction of glass waste is reused, and none is recycled in the country. Even though glass is an easy material to recycle, it has not been considered profitable to export it for recycling, nor invest in local recycling capacity due to the small quantity of waste. There is a plan to export bottle glass abroad for recycling, and window glass is also under consideration. Tiles are generally also crushed and used as filling material for landscaping.

In 2019, the Green Building Council Iceland, in cooperation with other stakeholders, published a series of reports on construction waste addressing the circular economy and construction industry, the mapping of construction waste, instructions on how to handle construction waste, and the assessment of hazardous substances in construction and demolition waste and their treatment plan.

There is a marked difference in the composition of the wastes generated in construction activities compared to demolition activities, as shown in Figure 4 and Figure 5. The data is aggregated for the years 2018-2022 and is based on the analysis of wastes from a sample of new construction and demolition activities covering approximately 9,300 tonnes of waste in total. As such, it should be interpreted with caution. There is only limited supervision of construction waste generated in Iceland, and The Environmental Agency has that role. It proved difficult to access data on construction waste, and there is no uniform method for classifying construction and demolition waste in Iceland (Grænni byggð, VSÓ Ráðgjöf, 2022). As a result, more than 18 per cent of the waste generated in new construction is "*not classified*".

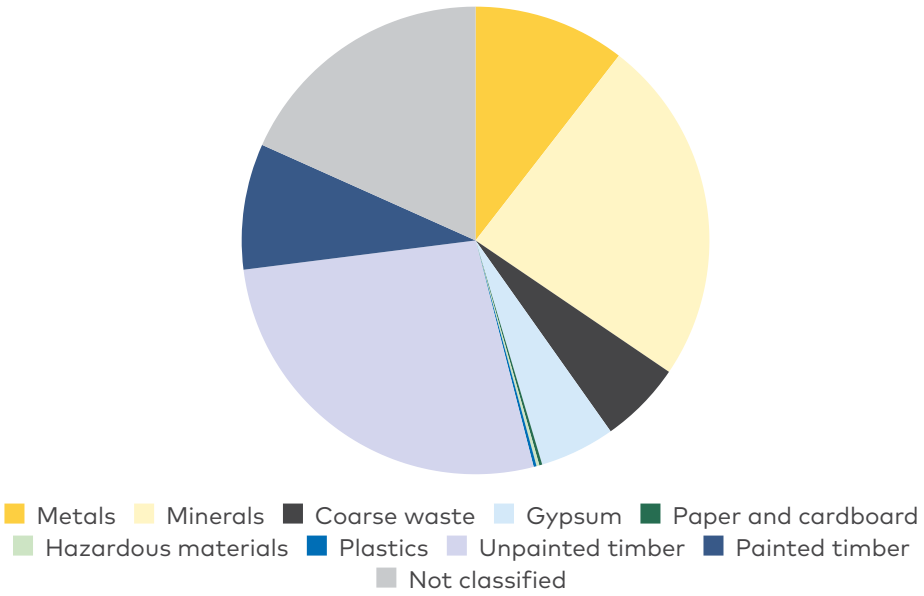

Figure 3 – Waste from new construction, Iceland, 2018–22

Waste from a sample of new buildings. (Grænni byggð, VSÓ Ráðgjöf, 2022)

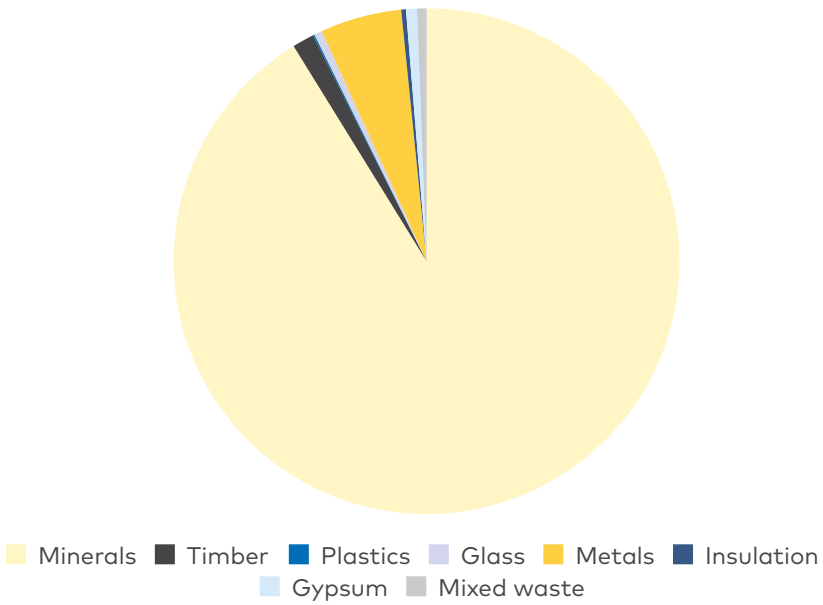

Figure 4 – Waste from demolition activities, Iceland, 2018–22

Waste from a sample of demolition projects. The amount of demolition waste was based on a plan, so only a small part was classified as "mixed waste".

Minerals make up 24 per cent of new construction waste and 91 per cent of demolition waste. Most mineral in demolition waste is from concrete buildings (the most common type of building in Iceland), although it also includes some tiles and ceramics. Mineral waste from new buildings is mainly residual material such as cut-off tiles etc. (Grænni byggð, VSÓ Ráðgjöf, 2022).

As with other Nordic countries, stone wool is a widely used, locally produced insulation material in Iceland. Stone wool offcuts from new construction projects can be used and reused instead of being thrown away. There is interest in reusing the material and finding recycling channels (Grænni byggð, VSÓ Ráðgjöf, 2022).

Materials such as unused modular walls, pipes, timber, tanks, and many others that could have easily gone into reuse or repair often go to landfill. The scale of this type of waste has never been mapped properly, but most of the "recycling" that takes place is actually down-cycling, which signifies a loss of value and material quality (Grænni byggð, Mannvirkjastofnun, 2019).

5.4. Norway

5.4.1. Framework conditions for circular construction in Norway

Strategies and policy

Norway is a member of European Economic Area (EEA), so it acts in accordance with most of the EU policy regarding climate change and circular economy, including the Green Deal and the Circular Economy Action Plan. The Norwegian Government has an ambition for Norway to play a pioneering role in the development of a green circular economy that makes better, more efficient use of resources. Norway will achieve this by developing policy and policy instruments, both nationally and in cooperation with the EU, to develop a framework for value creation and green competitiveness in Norway (Klima- og miljødepartementet, 2021).

The Climate Change Act (Klimaloven) entered into force in 2018 to align Norway with the *EU Green Deal (Lovdata, 2017)*. The Act aims to cut greenhouse gas emissions by 50-55 per cent by 2030 and by 90-95 per cent by 2050 compared to 1990. The aims were evaluated in 2020 and will be re-evaluated every 5 years.

In line with the *EU Circular Economy Action Plan*, the Norwegian government has developed a *National Strategy for a Green, Circular Economy (Klima- og miljødepartementet, 2021)* with the following main tasks to achieve:

1. Sustainable production and product design
2. Sustainable ways to consume and use materials, products, and services
3. Non-toxic circular circuits
4. Circular economy which drives innovation, value creation, and workplaces in Norway

The overall aim of the *Strategy for a Green, Circular Economy* is:

"*The transition to a more circular economy should contribute to achieving the adopted climate and environmental goals and the UN's sustainable development goals, and at the same time contribute to value creation, long-term competitiveness, and social justice. The transition should contribute to reducing the loss and preventing the deterioration of natural resources and double the use of secondary raw materials over the next ten years.*"

This vision and the overall objectives make it clear that the Government does not consider the transition to a circular economy to be a goal itself. However, it is viewed as a process that will contribute to value creation and sustainability, and simultaneously contribute to Norway's climate and environmental policy targets, including Norway's efforts to achieve the UN Sustainable Development Goals.

The *Strategy* will underpin the Government's efforts to exploit the potential for value creation in Norwegian businesses and industries more fully, with a more circular economy as the basis. It includes specific action points for the sectors that have been identified as having the greatest potential for circularity and green competitiveness in Norway; these are the bio-based sectors, the process industries, the construction and buildings industry, and the service industries, including retail and wholesale trade.

The main aims of the *National Strategy for a Green, Circular Economy* relevant to the construction and buildings industry include:

- Utilising the entire country to create a circular economy based on local and regional resources and business structures.
- Supporting the opportunities Norwegian industry provides for strengthened green competitiveness on the basis of a circular economy.
- Building and operating more circular buildings through legislation and targeted efforts. The state as property manager takes particular responsibility.
- Taking care of Norwegian interests in the EU's work via a strengthened product framework for more sustainable products.
- Strengthening the role of the waste sector to take care of material resources and supply secondary raw materials for circular cycles.
- Working towards non-toxic circular cycles through a continuously ambitious chemical policy in collaboration with the EU.
- Exploiting the possibilities of digitisation for accessing information about product properties and markets for secondary raw materials for all market participants.
- Focusing on research-based knowledge and innovation. The means of action shall develop a circular economy as a transverse area of focus.
- Ensuring a holistic knowledge base for how economic tools can contribute to better resource utilisation and a circular economy.
- Promoting sustainable public consumption and green innovation through public procurements.

The strategy promotes a concrete target stating that 70 per cent of construction waste must be prepared for reuse or recycling, which is in line with the EU's Waste Framework Directive. Furthermore, it identifies the need to adjust national requirements to better facilitate increased reuse (Klima- og miljødepartementet, 2021)

The Hurdal platform (The Government platform presented by the Labor Party and the Center Party in 2021) includes the development of a new action plan for a circular economy. The government will "require that city buildings and facilities are built with climate-friendly materials and designed for low energy use and reuse, as well as facilitate fossil-free construction sites" (Deloitte, 2022).

EU's Taxonomy is also anticipated to be one of the drivers for circular construction in the years to come in Norway even though it is outside the EU. The timeline for implementing the Taxonomy in Norway is a little different from that of the EU since there is a need for new laws and legislations to be implemented.

Public procurement

The 2023 national budget suggests prioritising changes to the procurement regulations and other measures that promote sustainability and environmental considerations in public procurements. It also suggests that climate and environmental considerations should account for at least 30 per cent in procurement evaluations in order to accelerate the establishment of a circular economy in the building, construction, and property sector (Deloitte, 2022).

The main goal of the Ministry of Finance and the Norwegian Agency for Public and Financial Management (Direktoratet for forvaltning og økonomistyring, DFØ) is that *"the public sector should carry out efficient and sustainable procurements*". Several initiatives aim to integrate circular thinking into the procurement process, including (Deloitte, 2022):

- The "Get started with green procurement" programme
- A hotline for sustainable procurement
- A support team,
- A criteria guide for sustainability in buildings, constructions, and property

DFØ manages the web platformwww.anskaffelser.no, which is a support and knowledge-sharing portal on public procurement. The site contains information about the procurement process for efficient and sustainable procurement as well as contact details for the hotline for sustainable procurement (DFØ, u.d.).

Building regulations

In recent years, several changes have been implemented in the Norwegian legislation regarding the reuse of materials. These changes pertain to facilitating dismantling, keeping greenhouse gas accounts, mapping materials suitable for reuse, waste sorting, and energy flexibility.

The Planning and Building Act (Plan- og bygningsloven) determines the use and regulation of land in Norway (Lovdata, 2008). The Act shall promote sustainable development in the best interests of individuals, society, and future generations, and sets certain material requirements for construction works. The Regulations on technical requirements for constructions (TEK 17) set further technical requirements for constructions (Lovdata, 2017).

In December 2020, Kommunal og moderniseringdepartementet suggested changes in the Planning and Building Act aiming to increase the reuse and lifespan of buildings. The changes imply that the municipalities can allow exemptions from certain technical requirements for rebuilding, rehabilitating, and changing the use of buildings.

The changes involved the following regulations:

- Regulations on technical requirements for construction works (TEK 17)
- Regulations relating to building applications (Lovdata, 2010) (SAK 10)
- Regulations on sales and documentation of products for construction works (Lovdata, 2013) (DOK)

The changes in TEK 17, SAK 10, and DOK were implemented 1 July 2022, and will apply starting 1 July 2023. The aim of the changes is to help minimise hazardous substances, reduce the amount of construction waste, and increase reuse and material recycling. The main changes are:

- New buildings must be designed and built in such a way as to facilitate dismantling. The new regulation comes in addition to the prior regulation, in which it was required to choose products which are suitable for reuse and material recycling.
- Materials must be mapped for reuse prior to major (renovation) works in existing buildings.
- The requirement for sorting waste on construction sites increases from 60 to 70 per cent.
- A requirement for greenhouse gas accounting for apartment blocks and commercial buildings.

Waste management plans were already required for renovation or demolition projects. "Hazmat Surveys" to map all hazardous substances are also mandated. In practice, this means that a complete environmental mapping report and reuse mapping report must now be prepared for the demolition of smaller buildings and for rehabilitation, where only simplified assessments were done in the past.

The aim of the "reuse mapping" is to identify reusable building components in existing buildings, either for reuse in the same building or in another building, thus maximizing reuse and recycling. The reuse mapping report must describe all building fractions or materials that are suitable for reuse. However, it is not necessary to describe how these materials can be reused or that they will be reused.

The Regulations on sales and documentation of products for construction works (DOK) ensure that buildings are safe and meet the requirements for harmful substances and construction and fire safety. They can, however, also be a barrier to establishing a circular economy in the building industry. As from 1 July 2022, the requirement to document characteristics of used building materials for sale was removed. This means that it is no longer required to meet the documentation requirements in the DOK if the used building materials are sold or given away. The documentation requirement still applies if the building material is changed significantly. The aim of the change in the DOK is to make it easier to sell used building materials.

This change helps make establishing a circular economy in the building industry easier, but the documentation requirements can still be a barrier. For example, TEK17 still demands documentation that all construction products used have appropriate properties that help the building meet the requirements of the TEK regulation.

Waste regulations

The revised *Waste Regulations (Lovdata, 2004)* from 1 July 2020 include a new chapter regarding concrete and brick from demolition projects (Waste regulations). The aim of the new regulations is to promote the recycling of concrete and bricks from demolition projects and to remove and destroy the environmental toxin PCB. If the requirements of the revised waste regulations are fulfilled, it will no longer be necessary to obtain permission from the Norwegian Environmental Directory (Miljødirektoratet) to reuse brick and concrete waste. Concrete and bricks from demolition projects can be used for construction work if:

- they replace materials that would otherwise have been used, and
- they do not contain substances hazardous to health and the environment above the limits specified in the regulations,
- they are not covered in chemicals that can be harmful to health or environment,

- they do not contain grout, rebar, or plastics,
- they are made of shotcrete.

If these requirements are not fulfilled, permission from the Norwegian Environment Directory is required to reuse the brick or concrete waste.

National action plans for construction waste were launched on a regular basis starting in 2001 and set goals for waste reduction, waste sorting and recycling of construction waste, in addition to identifying measures to achieve the goals over the subsequent 3 years. The fifth and newest action plan was published in 2021 (NHP5) and defined four milestones (NHP5, 2021):

- Reduce waste in building and construction projects.
- 80 per cent of generated waste from building and construction is material recycled within 2023.
- Better and proper handling of all hazardous waste.
- Prevent recycling of prioritised hazardous pollutants in the transition to a circular economy.

Standardisation

There is ongoing activity in coordinating existing and new standardisation activities related to the circular economy.

The Norwegian committee (SN/K 583 Circular economy) for a circular economy was established in 2019 and is part of the international work in ISO/TC 323, Circular economy. The committee shall contribute to Norwegian expertise and encourage interested parties in developing international standards around a "circular economy". In addition, the committee (SN/K 605) is engaged with the international work under "CEN/TC 350/SC-1, Circular economy in the construction sector".

The committees will assess the need to prepare supplementary Norwegian documents for internationally adopted standards and assess the need for translation into Norwegian, including Norwegian terminology.

Organisations and initiatives

Circular construction has received significant attention in recent years in Norway, as can be seen by the number and size of initiatives addressing the subject. There is an increasing number of actors offering services for reuse, material recovery, and recycling on material-exchange and circular economy platforms.

SINTEF is one of Europe's largest research institutes, with multidisciplinary expertise in technology, the natural sciences, and social sciences. SINTEF manages or is involved in several projects related to reuse, the circular economy, building materials, and other topics related to circular construction.

REBUS (Reuse of Building materials – a User Perspective) is a research project financed by the Research Council of Norway through the "MILJØFORSK" programme. The project started in January 2020 and will continue until December 2024. The main objective of REBUS is to develop knowledge that will enable wider and more efficient implementation of reusable building materials for a transition to a circular built environment. The REBUS project work is divided into five work packages, each addressing a different aspect of the project's objective.

1. User requirements: analyse user awareness, knowledge, needs, and social practices to find solutions and create a knowledge platform.
2. Assessment of construction products for reuse: Identify best methods for assessing both technical performance and the content of hazardous substances in construction products or components that are considered for reuse.
3. Life cycle sustainability assessment: Identify how existing evaluation and labelling methods can be developed for distinguishing reusable materials from a life cycle perspective.
4. Pilot testing and toolbox: Co-implement the practical knowledge of assessed methods and solutions through pilot projects. Pilots testing will build in-depth knowledge of how to deal with implementation issues such as the suitability of test and evaluation methods, policies and requirements, and markets for reused products.
5. Networking and procurement: Develop network strategies and recommendations for incentives through procurement and regulations to ensure a high level of engagement among users and stakeholders in co-creating common knowledge.

The project will generate new knowledge pertaining to the legal procedures and quality assurance schemes as well as the technical, environmental, economic, and social performance of reuse and how these aspects are related. By cooperating with the industry, the project aims to find practical solutions as well as develop and implement more relevant methods to reuse building materials more quickly.

REBUS' work has already resulted in producing several publications, including *Barriers, success factors, and perspectives for the reuse of construction products in Norway* and the *Guide on how to assess building materials for reuse*.

The Norwegian Green Building Council (Grønn byggallianse) is a non-profit organisation for businesses in the real estate sector in Norway. Their vision is to develop the Norwegian real estate (BAE) sector in a way makes consideration for the environment and sustainability a natural choice.

The Norwegian Green Building Council and Norsk Eiendom (Norwegian Property) has created a "*Property sector roadmap toward 2050" (Eiendomssektorens veikart*

mot 2050). This roadmap provides recommendations to owners and managers of commercial buildings regarding the long- and short-term choices that will contribute to a sustainable society by 2050. There are 10 recommended immediate actions for building owners, and 10 recommended immediate reactions for the authorities (Grønn byggallianse, n.d. a). Some of the actions are particularly relevant to the circular economy. One intermediate action is to plan for reuse in buildings projects, with focus on how to acquire and use materials that are suitable for reuse and how to plan design for future reuse. One immediate action is to request reusable materials, either from other projects within the organisation or from external projects.

The Norwegian Green Building Council manages the environmental certification scheme BREEAM-NOR, which is the most frequently used environmental certification for buildings in Norway. BREEAM-NOR is adapted to Norwegian standards and aims to go further than the Norwegian legislation. The latest version of the technical manual launched in 2022 has significantly increased the focus on circular construction. The scheme rewards projects facilitating the reuse of building materials, sorting and preparing materials for reuse, recycling, and projects designed for reusability and flexibility.

Pådriv is a non-profit sustainable development network in Norway started in 2016. The network is an association in which small and large actors are equally involved, and it is open to both individuals and businesses from all sectors and industries. One of the projects, "*National knowledge arena for reuse in the construction industry,*" was established in 2022 and is led by "*Sirkulær ressurssentral*" (Circular Resource Center). Its purpose is to facilitate increased circular reuse of materials in the construction industry in Oslo and the surrounding area, thus helping to reduce the climate footprint from material use in construction and construction activities. The Circular Resource Center has established a multi-purpose resource centre for used building materials in a large warehouse in Oslo. Several actors in the building and construction industry are involved as partners (Pådriv, u.d.). Pådriv has arranged several seminars to raise issues related to the reuse of building materials.

FutureBuilt is an innovation programme and showcase for the most ambitious actors in the building sector in Norway. Their vision is to show that climate neutral urban areas based on high-quality architecture are possible. FutureBuilt's goal is to complete 100 pilot projects which cut carbon emissions by at least 50 per cent compared to current regulations and best practices. Each pilot project needs to fulfil certain criteria within specific areas, one of which is circular buildings (FutureBuilt, u.d.).

A circular building must facilitate resource utilisation at the highest possible level and consist of at least 50 per cent reused and reusable components. The criteria are elaborated into five parts:

1. Environment-based decisions on rehabilitation or demolition.
2. Resource utilisation in the demolition and construction phase.
3. Reuse of components.
4. Reusability.
5. Ability to change.

Support schemes

Enova is managed by the Ministry of Climate and Environment (Klima- og miljødepartementet) and aims to support Norway's transition to a low-emission society. In 2021, Enova assigned 4.6 billion Norwegian kroner to more than 5,500 projects and 7,100 measures in Norwegian homes, which is expected to reduce emissions by approximately 301,000 tons of CO2-equivalent (Enova, u.d.).

Enova offers targeted support in several areas, including circular building, in order to speed up the transition to a circular economy, help facilitate the availability of reuse materials, and increase knowledge and expertise. It is possible to apply to Enova for support for a "feasibility study regarding reuse and flexibility" and "project planning for reuse".

Klimasats is a support scheme for municipalities and counties established in 2016 that aims to cut emissions of greenhouse gases and contribute to the transition to a low-emission society. Projects involving circular buildings are among the projects which are prioritised for subsidies. In the National Budget for 2023, 100 million NKR is set aside for Klimasats, and the Norwegian Environmental Directory decides which projects are supported each year (Miljødirektoratet, 2022).

Tools

There are several tools which have been developed to overcome the barriers regarding the challenging logistics and markets for selling used building materials. The Norwegian Building Authority (Direktoratet for byggkvalitet, DIBK) launched a digital guide on how to utilise used building materials.

A marketplace for selling and buying used building materials is essential for implementing a circular economy in the building and construction sector. Some of the tools which are currently used in the Norwegian market are mentioned below.

The tools **Rehub**, **Loopfront**, and **Materia** facilitate the mapping and sharing of reusable goods, as well as the sale of reusable materials. Rehub offers technical testing and re-documentation, logistics such as storage and transport, the mapping of materials, and risk distribution. Loopfront, launched in 2019 and updated in 2021, covers the process from mapping and documentation to logistics and reporting. Materia is linked to other platforms, such as the Circular Resource Center initiated by Pådriv.

Madaster contains reporting and analysis tools for new and existing buildings and infrastructure. The platform facilitates a circular economy by assigning materials an identity in a digital register. The tool contains a carbon calculator for the building's various life cycle phases. Madaster is used in several European countries and was launched on the Norwegian Market in the fall of 2022.

Tvinn Solutions (previously Vriml) and Again X are other tools which have been developed to facilitate the reuse of goods and materials.

5.4.2. State of circular construction in Norway

The construction and real estate sector play an important role in the green shift and is of great importance for Norway to reach its climate goals. The sector uses large volumes of primary materials, and a large amount of waste is not recycled. Approximately 50 per cent of the total climate impact of buildings over a lifetime originates from the use and transport of materials (Grønn byggallianse, n.d. b).

The Norwegian construction sector has a resource footprint of 43 million tonnes that accounts for 18 per cent of the entire material footprint in the country. The sector also directly emits 4 million tonnes, or 6 per cent, of the country's CO_2 equivalent and 9.5 million tonnes, or 15 per cent, when operational energy use is considered. Only 2.4 per cent of the 235 million tonnes of materials consumed in Norway each year is circulated. Norway's circularity rate is thus below the global average of 8.6 per cent according to Circle Economy (CE, 2020).

In 2021, the construction sector in Norway generated 1.8 million tonnes of waste, a decrease of approximately 15 per cent compared to 2020, but it is still the leading sector generating waste. About 42 per cent of the waste originated from demolition, 33 per cent from new constructions, and 26 per cent from rehabilitation projects (SSB, 2022a). In 2020, 64 per cent of non-hazardous construction and demolition waste was prepared for reuse, recycled, or subject to material recovery (Eurostat, 2023).

Brick and concrete waste are the largest fraction, totalling 700,000 out of the 1.8 million tonnes of C&D waste generated in 2021. Brick and concrete waste originate from demolition activity (450,000 tonnes), rehabilitation (450,000 tonnes), and new constructions (100,000 tonnes). Approximately 160,000 tonnes of brick and concrete waste was classified as hazardous in 2021. In 2021, most of the brick and concrete waste material was recycled (70%), whereas the rest ended up in landfills (27%) (SSB, 2022a).

Material recycling of construction waste in Norway has varied over time. At around the turn of the century, approximately 80 per cent of the waste ended up in landfills (NHP5, 2021). In 2021, approximately 55 per cent of the total waste material from the construction industry was recycled or prepared for reuse. Approximately 19 per cent underwent energy recovery, and 23 per cent ended up in landfills (SSB, 2022b). It is assumed that the amount of waste that has been sent to landfills has been reduced due to changes in the Waste Regulations.

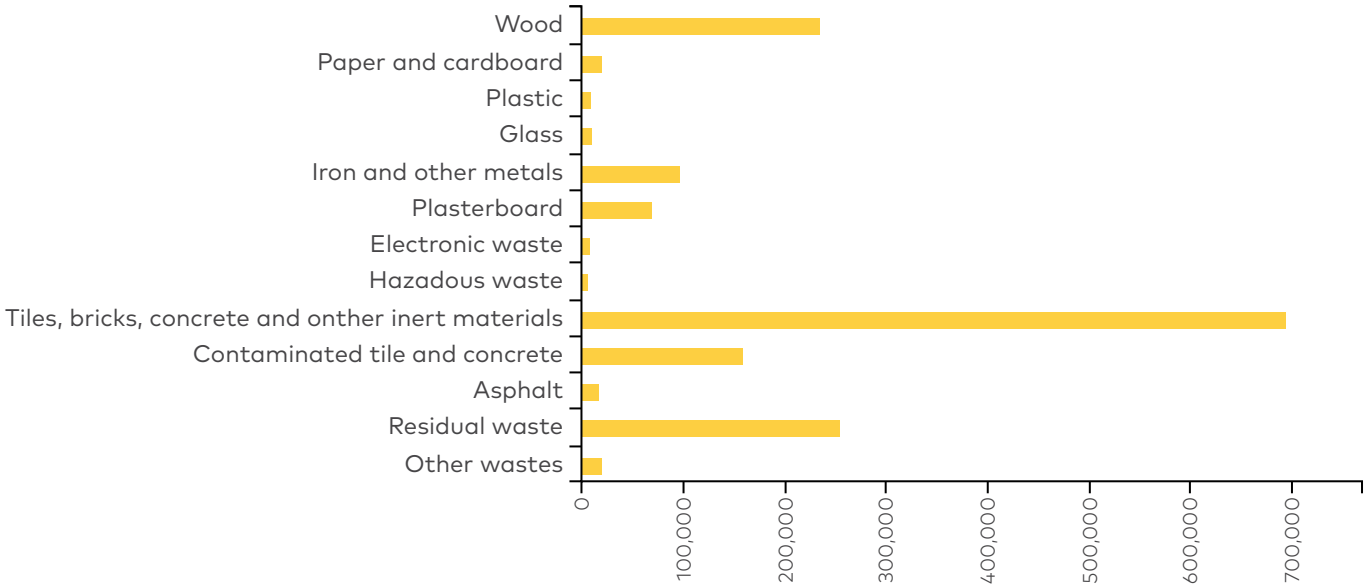

Figure 5 – Waste amounts fractions (tonnes)

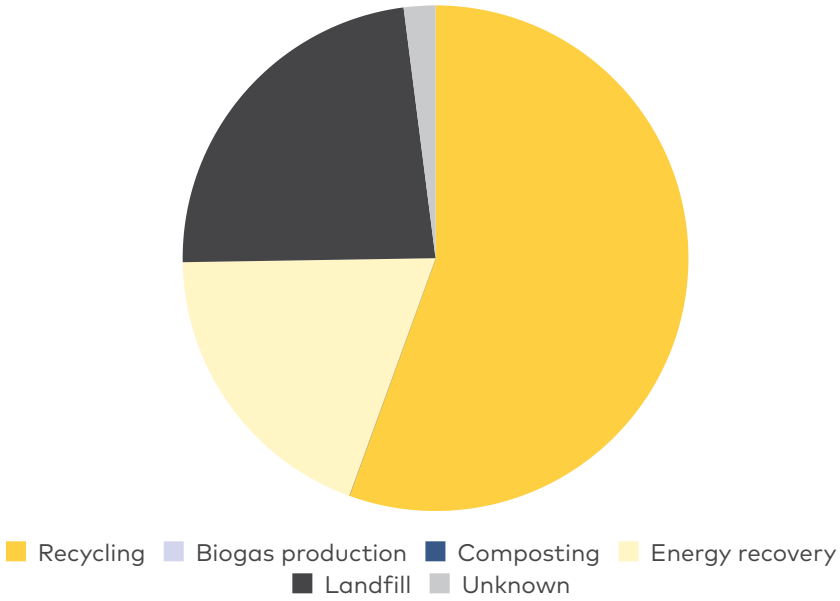

Figure 6 – Waste amounts and treatment of waste originating from construction, rehabilitation, and demolition in 2021

5.5. Sweden

5.5.1. Framework conditions for circular construction in Sweden

Strategy and Policy

In July 2020, a national *Strategy for a Circular Economy* was launched by the Government of Sweden (Government Offices of Sweden, 2020b). The strategy aims to accelerate the implementation of the transition to a circular economy in Sweden and to achieve the global goals set out in the 2030 Agenda.

The Strategy contains the following focus areas (IEA Bioenergy, 2020):

1. A circular economy through sustainable production and product design
2. A circular economy through sustainable ways of consuming and using materials, products, and services.
3. A circular economy though toxin-free and circular eco cycles
4. A circular economy as a driving force for the business sector and other actors through measures to promote innovation and circular business models

The actions described are divided into four different focus areas that describe the transition goals and contain sub-targets. Specific sub-targets that concern circular construction are (Government Offices of Sweden, 2020b):

- Product passport for better knowledge
- Climate declarations for new buildings
- Mission to transform premises to housing
- Public circular procurement

Sweden aims to reach net-zero emissions by 2045 and remain climate-positive thereafter. This means that the territorial emissions must be 85 per cent lower than those of 1990 by 2045 (Naturvårdsverket, 2022a). There are four intermediate goals to measure progress. The 2045 goal includes total territorial emissions, but the milestone goals include not what is within the EU ETS (Emission Trading System), but rather the incineration plants and energy-intensive industry (Naturvårdsverket, 2022b).

The building and infrastructure sectors in Sweden are responsible for 20 per cent of total emissions and one third of all waste. The largest sources of emissions are the production of materials and products and energy use in the use-phase of the building. The building sector is included in the national goal of net-zero emissions 2045. By 2030, the building sector should have cut emissions by 50 per cent. In the roadmap for a fossil-free sector, circular flows are included as a measure to decrease the amount of waste and lower the impact on global warming (Fossilfritt Sverige, 2018).

Building regulations

PBL, BBR and EKS

Constructing and renovating buildings in Sweden is done within the framework of the *Boverkets byggregler* (BFS 2011:6, BBR) and the EKS (*European construction standard*) (BFS 2011:10, EKS).

The BBR regulates technical requirements such as fire safety, noise protection, and energy management, thus implementing the demands laid out in the Planning and Building Act (Plan- och bygglagen (2010:900), PBL). The EKS contains regulations regarding the carrying capacity and strength of materials and products. These regulations are adapted over time to reflect changes in the PBL, new knowledge, or adjustments to the EU laws (BBR, 2021). In addition, Boverket is currently working on providing guidance in terms of the dismantling and reuse of load-bearing structures (i.e., steel beams). The main focus is clarifying what the building legislation actually requires and how a contractor can assure that the products are suitable for use.

The contractor is responsible for ensuring that the building products are suitable for the intended application. The PBL includes requirements on the completed building, the used building products, and their properties. These requirements include, for example: load-bearing capacity, fire protection characteristics, insulation properties, and moisture durability. Material properties can change in-situ in a building and during the removal process. However, for materials to be reused, they must meet the same technical requirements as new materials. This is important for circular construction since the products' properties affect how they can be reused or recycled.

The PBL states that building products should be appropriate for the intended use of the construction for which the builder is responsible. To decide if they are appropriate, the properties must have been assessed and documented. If no assessment is made, the builder must otherwise verify the suitability of the products/components, a process which will be clarified in the coming construction regulations currently under development (Boverket, 2021).

Waste regulations

Regulation of waste management in the construction sector in Sweden is divided between the Environmental Code, which sets the framework for waste management, and the Planning and Building Act (PBL), which provides further rules for waste generated during renovation and construction.

PBL

In areas subject to zoning plans, it is often necessary to apply for and obtain a demolition permit before demolition or removal begins. Outside zoned areas, it is usually only necessary to notify the relevant authorities of the intention to demolish a building. The application should include a control plan, which includes a waste management plan. This should include the results of a material inventory, which details what components can be reused and how they will be disposed of, and what wastes will arise during demolition and how they will be disposed of, all with the aim of increasing recycling and the removal and safe treatment of hazardous wastes (Boverket, 2017).

Waste Ordinance (2020:614) (Riksdagen, 2020) demands the separate on-site collection of:

- wood,
- minerals consisting of concrete, brick, clinker, ceramics, or stone,
- metal,
- glass,
- plastic,
- plaster,

- hazardous wastes (must be kept separate from these fractions *and* each other),
- waste falling under the producer's responsibility,
- combustible waste (i.e., the combustible waste that remains after the above types of waste have been sorted out).

The Environmental Code

Before deconstructing or demolishing a building, a material inventory must be made (Swedish EPA, n.d.). This identifies any hazardous substances present in the building and materials that can be recycled or reused. Generally, the materials and building components in an end-of-life building are in a different condition than their initial/original state. The load-bearing capacity of a wooden beam may be reduced, the bricks on the façade stuck to the mortar, or the gypsum panels may be fire-damaged. This means that they may no longer have the appropriate properties or qualities, and their technical certification of performance may no longer apply. This may prohibit the reuse of a component in another building. Since the requirements from Boverket are compulsory, the materials/products must be, if possible, recovered or reconditioned before reuse in another project. If products are recovered and/or reconditioned, the products' suitability to be reused is recognised, thus facilitating circular flows of materials in the construction industry.

Climate declaration

As of 1 January 2022, it has been mandatory for building developers to publish a climate declaration in order to achieve final notification for a building. The climate declaration should be prepared according to the standard EN 15978 and include module A1-A5, for the foundation, climatic barrier, and interior walls. The legislation currently only demands a calculation: there is no demand to meet a specific performance criterion. However, the process of drafting these declarations and the supporting calculations will dramatically increase the knowledge and available information about embedded carbon among stakeholders throughout all parts of the value chain. Boverket has suggested that limits for the climate impact should apply from 2027 and be 20-30 per cent lower than a reference-value study (Boverket, 2020).

However, on behalf of Boverket, the Royal Institute of Technology, KTH, is investigating the possibility of introducing limit values before 2027, and how the demand can be broadened to cover renovation and extension projects. It might also include further life cycle phases (some relevant aspects of Modules B and C) as well as provide groundwork for the calculation. KTH will present its findings in the first half of 2023 (Boverket, 2020). Since reuse is an effective way of lowering the climate impact (Andersson, et al., 2022), the limit values may be important to increase reuse in the construction sector.

Certifications

The main certification systems used in Sweden are BREEAM, LEED, "Miljöbyggnad", and the new NollCO2. The certification systems include different aspects of sustainability. These certification systems have components focusing on LCA or climate impact from a life cycle perspective. Moreover, LEED has credits that include recycled material and extended producer responsibility (U.S. GBC, 2022a).

The Swedish sustainability certification body, SGBC (Sweden Green Building Council), is currently working on adapting the certification systems (BREEAM, NollCO_2 and Miljöbyggnad) to the EU Taxonomy and the USGBC (U.S. Green Building Council), and adapting LEED to the EU Taxonomy (U.S. GBC, 2022c), thus providing a much larger focus on circular construction than the systems have today.

[EXAMPLE – NollCO_2]

NollCO_2 is a new certification programme developed and administered by the Swedish Green Buildings Council. It functions as an extension to existing certification schemes and aims to achieve net-zero life cycle climate impact in new buildings. It seeks to push developers toward net-zero projects by supporting and recognising carbon reductions beyond those of existing certification schemes and allows developers to balance any emissions above what would be considered net-zero by investments in renewable energy, energy efficiency, and in some cases, carbon off-setting (NollCO2, u.d.).

Networks and support mechanisms

Centrum för cirkulärt byggande (CCBuild, u.d.) is a knowledge platform and knowledge centre for the circular economy in the Swedish construction sector. It is anchored in the Swedish Environmental Institute (IVL, u.d.) and developed within the Swedish Innovation Agency's (Vinnova, u.d.) Challenge-Driven Innovation Program. It provides digital tools and services, a marketplace for materials, products and circular services, and exhaustive reference projects.

5.5.2. State of circular construction in Sweden

Sweden extracts 266.7 million tonnes of resources each year—26.4 tonnes per capita—which is the fourth biggest resource extraction per capita in the world. Furthermore, the consumption of resources is 24.8 tonnes per capita, which represents twice the global average (CE, 2022).

The building sector produced 14.6 million tonnes of waste in 2020, approximately 5 per cent of which was hazardous waste. This is close to 40 per cent of all waste in Sweden excluding mining waste. A little over 50 per cent—or 7.4 million tonnes—of this waste was recycled, while a further 12 per cent was incinerated for energy recovery. The remainder was disposed of, primarily in landfills and "other" disposal sites (Naturvårdsverket, 2020).

According to Eurostat, 74 per cent of non-hazardous construction and demolition waste in 2020 was prepared for reuse, recycled, or subject to material recovery (Eurostat, 2023). However, nearly half of this was utilised in backfilling and landscaping operations (Almasi, 2018).

Aside from national initiatives, larger cities are also deeply involved in circular construction. For example, the Stockholm municipality has developed an action plan for circular construction (Stockholms stad, 2021), while the City of Göteborg has launched similar initiatives centred around Circular Göteborg (Göteborgs stad, u.d.) that are based on an investigation of cooperation between Sweden's metropolitan areas on circular construction (Göteborgs stad, 2021).

Boverket is currently working intensely with the tools and methods for the transformation to a circular economy in the building sector (Boverket, 2021c). Expected to be finalised in 2024, the work involves:

- Suggesting measures to promote circular construction **and** circular management
- Analysing the extent to which demolition can be avoided as a whole and promoting this measure
- Developing indicators that can be used to track the transition
- Disseminating information and providing guidance

A study of the current state of reuse in the Gothenburg region showed that many of the bigger real estate managers and clients are interested in reuse; however, smaller real estate managers must also be engaged. For architects, the same problem arises; bigger firms offer reuse-services, but this is not common for smaller firms (Wennersjö, et al., 2021).

5.6. European regulatory framework

This section briefly outlines the key components of the EU regulatory framework that influence the development of circular construction in the Nordic countries.

5.6.1. European Green Deal

The European Green Deal (EC, 2019) is the overarching EU strategy tying economy, development, climate, and sustainability together. It aims to transform the EU into a modern, resource-efficient, and competitive economy ensuring:

- No net emissions of greenhouse gases by 2050
- Economic growth decoupled from resource use
- No person and no place are left behind

One of the core efforts of the European Green Deal is "*building and renovating in a resource- and energy-efficient way*" and ensuring that "*the design of new and renovated buildings at all stages is in line with the needs of the circular economy*" (EC, 2019). The renovation of buildings is a vital part of the European Green Deal, and specific targets for renovation are anticipated.

5.6.2. Circular Economy Action Plan

The EU's new Circular Economy Action Plan (CEAP) is one of the key building blocks of the European Green Deal. It addresses with the European economy broadly, although it does have specific initiatives directed at the construction and building sectors (EC, 2020). These include:

- Revising the Construction Product regulation
- Promoting tools to improve the durability and adaptability of buildings
- Using the Levels framework to integrate LCA into sustainable procurement and sustainable finance frameworks
- Considering recovery targets for specific fractions of C&D waste
- Promoting the rehabilitation of brownfield sites, minimising soil sealing, and increasing the safe, sustainable, and circular use of excavated soils.

A proposal for a revised Construction Products Regulation was published in 2022 (see below), while the Levels framework forms the backbone of the KPIs used in the construction-relevant parts of the Corporate Sustainability Reporting Directive (CSRD) (EC, 2022).

5.6.3. Waste Framework Directive

The Waste Framework Directive (EC, 2008) defines the overarching framework for managing waste in the European Union. Article 11 of the Waste Framework Directive sets a recycling target for non-hazardous construction and demolition waste of 70 per cent by 2025. The definition of "recycling" in the context of this target includes preparing for reuse, material recycling, and material recovery, including backfilling operations. Article 11 also demands source-separation of at least wood, mineral fractions (concrete, bricks, tiles and ceramics, stones), metal, glass, plastic, and plaster. Furthermore, Article 11 includes a clause specifying that by the end of 2024, the Commission shall consider setting targets for preparing construction and demolition waste *and* its material-specific fractions for reuse and recycling.

5.6.4. CPR, CE-marking, DoP

The Construction Products Regulation (CPR) (EC, 2011) dictates that building products that are covered by a *harmonised standard* and sold in Europe must bear a CE-mark and comply with the DoP (Declaration of Performance) when put on market (EC, 2011). A *harmonised standard* for a given construction product according to the CPR was a standard developed by CEN following a mandate by the European Commission published in the Official journal (OJ).

The producer, distributor, or importer of the product is responsible for ensuring that their product fulfils the CE-marking requirements. Criteria for the CE-mark address safety, health, and environmental protection (Your Europe, 2022). However, it is the responsibility of the developer to make sure the building product is used in the right way according to the national building regulations. The CE-mark also defines the monitoring process for ensuring that products continue to meet the requirements: the monitoring process is usually performed from the perspective of new production based on a prescriptive manual and controlled at the factory; it is not possible or permitted to reapply the CE-standard outside that setting. A developer may reuse products in a building but must make sure the product is fit for the new usage (Gabrielsson & Brander, 2021).

The DoP (Declaration of Performance) provides information about the performance of products. Apart from the harmonised standards, if a European Technical Assessment has been performed for a product, it also needs a DoP (EC, u.d.).

A revision of the Construction Products Regulation is currently underway, and a proposal for a revised version was published in 2022 (EC, 2022). The key objectives of the revision are to improve the functioning of the internal market for construction products, enhance the sustainability of construction products, and introduce further health, safety, and environmental requirements for construction

products. Of particular relevance to circular construction, the new product requirements aim to make construction products more durable, recyclable, repairable, and easier to remanufacture (EC, 2022).

5.6.5. Level(s)

Level(s) is an assessment and reporting tool for the sustainability performance of buildings. It was created by the European Commission to align the building sector with several Sustainable Development Goals (SDGs), the 2030 Agenda, and the European Green Deal. It is a tool to measure the environmental impact of a building throughout its life cycle. Furthermore, it is part of the technical screening of the taxonomy (EC, u.d.). It is based on six main goals measured by 16 indicators which include energy performance, Life cycle Global Warming Potential (GWP), construction and demolition waste, and water usage (EC, u.d.).

5.6.6. REACH

The EU's REACH Regulation (EC, 2006) aims to increase the protection of people and the environment from the risks of chemicals. REACH is short for *Registration, Evaluation, Authorization, and Restriction of Chemicals*. If a building product contains a substance that is on the REACH list and present in a concentration higher than 0.1 weight-percent, the substance must be declared to ECHA (the European Chemicals Agency) (Boverket, 2017). It is the responsibility of the developer to make sure that the building products that are used are safe to use: in the case of reuse, it may be difficult to know what chemical substances are in these older products.

5.6.7. EU taxonomy

The EU Taxonomy Regulation (EC, 2020), along with the associated Implementing and Delegated Acts, seeks to steer capital toward identifiable sustainable investments, drive compliance with the European Green Deal (EC, 2019), and meet the EU's climate objectives. The Taxonomy demands that an increasing number of public interest companies (large companies and publicly traded companies) calculate and report the share of their activities that are *aligned* with the Taxonomy. The EU Taxonomy defines economic activities that *can* be sustainable within six environmental areas, and then defines criteria within these six environmental areas that relevant activities must meet to qualify as sustainable. Criteria for each of the six environmental areas define conditions that provide a "significant contribution" and create conditions that "do no significant harm" (DNSH-criteria). For an activity to be classified as aligned with the EU Taxonomy and thereby "sustainable", it must make at least one "significant contribution" across the six environmental goals while doing "no significant harm"' within the other five.

The six objectives that are established in the taxonomy (EC, 2020) are:

1. Climate change mitigation
2. Climate change adaptation
3. The sustainable use and protection of water and marine resources
4. **The transition to a circular economy**
5. Pollution prevention and control
6. The protection and restoration of biodiversity and ecosystems

The criteria defining a significant contribution to "the transition to a circular economy" are only in the draft phase at the time of writing—only the criteria for the first two environmental goals have been published so far.

The activities defined within the Taxonomy Regulation and implementation acts that are relevant for the construction industry are presented in the Technical Annex of the Taxonomy Report (EU Technical Expert Group on Sustainable Finance, 2020):

7.1 Construction of new buildings

7.2 Renovation of existing buildings

For the building sector, the activities that are considered sustainable are aligned with the Level(s) framework, which is the standardised method used to measure the sustainability of buildings by the European Commission (SGBC, 2022).

5.6.8. Corporate Sustainability Reporting Directive

Continuing from the EU Taxonomy Regulation, the CSDR Directive (EC, 2022) implements mandatory non-financial reporting standards and requirements for companies operating in the EU. These standards are set out in the currently draft form of the European Sustainability Reporting Standards (EFRAG, u.d.). One of the five thematic areas under Environmental standards is *Resource Use and Circular Economy (EFRAG, 2022).* This focuses on how businesses report their policies for addressing resource use, the flow of materials into and out of the business, the setting and monitoring of targets for these flows, and their financial implications.

5.6.9. New European Bauhaus

The New European Bauhaus initiative (EC, 2021) connects the essence of the European Green Deal with the built environment. It aims to bridge science and technology, art and culture, harness the green and digital challenges in transformation, and address complex social problems though co-creation. The New European Bauhaus initiative is based on a desire for sustainability, aesthetics, and inclusion in the built environment. As well as drawing on the existing policy framework, the initiative will be implemented through a variety of mechanisms

including financing innovative projects, generating knowledge and experience, promoting the New European Bauhaus culture, investigating innovative funding methods, and regulatory analysis and experimentation.

6. Circular construction projects, support platforms and tools

This section provides examples of circular construction tools, platforms, and construction projects in the Nordic countries.

6.1. Tools, platforms, and support mechanisms

6.1.1. Handbook for a Circular Economy, Copenhagen, Denmark

The buildings division of the City of Copenhagen has developed a handbook for a Circular Economy (*Håndbog i cirkulær økonomi*), which contains a description of circular services in construction, a sustainable price pyramid, a catalogue of material-specific circular demands that can be implemented in the process of commissioning construction, and inspirational examples of circular construction. The material-specific circular demands cover concrete, plaster, bricks, wood, glass, mineral wool insulation, and steel, as well as aspects like how to reintegrate recovered materials, sorting demands, certification, and use scenarios. There are also demands concerning resource mapping before demolition and proper source separation of waste fractions during demolition.

The handbook is operational and designed to help the City of Copenhagen integrate a circular economy into their construction activities. It is inserted as an annex in consultancy contracts, and there are passages used selectively as necessary and relevant within contracts with building companies.

The 2023 version of the handbook can be found here:
https://byk.kk.dk/sites/default/files/2022-12/H%C3%A5ndbog.pdf

6.1.2. Circular Builders, Sweden, Denmark

The Circular Builders project developed, tested, and revised circular solutions in construction in thirteen specific case studies across nine municipalities in Sweden and Denmark. The project took a primarily practical approach by focusing directly on construction projects in the respective municipalities. This led to solutions and lessons that reflect real-life problems when facing attempts to integrate circular construction in the Nordic countries.

The main lessons learned from the project fell into three categories: (a) integrating circular construction into plans, strategies, and internal processes forms the core driver within the individual cases, (b) the resulting efforts and initiatives to drive circularity in the actual construction and demolition processes, and (c) how these

processes interface within the wider construction sector through market dialogue and ensure local anchoring of circular construction projects. More specifically, the key lessons are: try to reuse first, since a lot can actually be achieved within existing budgets, demonstration projects are an effective way to anchor circular construction, a new understanding of risk and risk sharing is required (and is developed), and the market is ready to start moving, but it's not at full speed yet—new knowledge and experience is needed across the board (Gate21, u.d.).

6.1.3. Digital Construction Material Passport, Denmark

Stakeholders in the Danish construction industry have been working since 2016 to develop a way to address the data challenge related to mapping and communicating information on the content of construction materials, which can also challenge the reusability of products. This work has produced the "Digital Material Passport" (Materialepas, u.d.). The Digital Material Passport collects the data on construction products. This is a prerequisite for the actors in the construction industry in order to make informed and well-founded decisions. Today, it is unthinkable to buy food without a product declaration. Unfortunately, this is not the case when it comes to the building materials that form our technical environment.

The material passport declares important information about a product; for example, it provides information about ingredients, the chemical processes used in production, and its ability to be part of circular or sustainable construction and future resource flows.

6.1.4. BusinessReuse, Denmark

BusinessReuse is a *Grand Solutions* project that aims to overcome the uncertainty of reusing load-bearing or other structural elements in new buildings by developing a system to classify recycled materials. This seeks to measure and document the remaining life span of the recovered materials in such a way that destructive testing of every element for reuse is avoided, as well as document the load bearing strength of the elements. The project is financed by Innovation Fund Denmark and RealDania. It is a broad coalition of actors from the construction sector: Lendager, DTU, DTU Skylab, Danish Standard, Adsbøll Renovering, Gate 21, Rambøll, and the Center for Små og Mellemstore virksomheder Aarhus BSS.

The first part of the project establishes a baseline demand for acceptable risk within the industry, as well as what the documentation demands of that risk and what the physical properties of the building elements are. The second part will develop non-destructive testing methods that can be used to meet these documentation requirements. This should then be scaled up to national technical specifications through the existing standardisation channels, fully integrating and normalising reuse within the construction industry (BusinessReuse, 2021).

6.1.5. CCbuild, Sweden

CCbuild (The Center for Circular Building) is led by the IVL Swedish Environmental Research Institute and developed with CCbuild's partners. CCbuild is a collaborative platform started in 2015 with a few partners, and now it has slightly more than 100, which include real estate owners, sector organisations, material manufacturers, etc. (CCBuild, u.d.). They share knowledge and arrange meetings to spread knowledge about circular construction. CCbuild was developed in three steps. In step 1, a few partners discussed and evaluated the following questions: "Why are we not working more circular?", "Why are we not working with reuse?", "What are the challenges and solutions?". In step 2, two pilot reuse projects were established. In step 3, a few services were developed: a Digital inventory app, a material bank, and a marketplace (Lindholm, 2022).

Vasakronan, a real estate company that develops, administers, and owns offices in the biggest cities in Sweden, has been partners with CCbuild since 2015 (CCBuild, u.d.). They are also part of Business Region Gothenburg. Their goal is to include reuse in every project, and the amount of reused material is exponentially growing; this includes doors, kitchenettes, fittings, etc. (Höjer, 2022). In one renovation project of an office in central Gothenburg, they set a goal of 100 per cent reuse without lowering the quality or compromising design or functionality. Having this clear goal helped focus efforts on reuse, and in the end, 91 per cent of the materials or products from the pre-renovation building were reused (Vasakronan, 2020).

6.1.6. Materialbanken, Malmö, Sweden

Materialbanken was developed as a supporting tool for the redevelopment of the Varvsstaden area of Malmö. Work on the Materialbanken began before demolition, and soil remediation work began with the intention of gaining an overview of the areas resource assets. This included not only information on the materials' type, size, and potential value, but also the embodied CO_2 emissions. It enabled the Varvsstaden organisation to understand and direct materials to correct treatment or preparation processes for their eventual reuse. It has since developed into a vital tool for calculating and communicating the environmental benefits of reusing building materials.

Materialbanken can be searched to identify specific materials as well as find comprehensive information on the environmental effects of reusing and recycling these materials. They are used to present the environmental and economic benefits of recycling and reuse broken down by building and material—even to specific items. While most of the recovered material and building products will be used on the Varvsstaden site, it is anticipated that many of the materials will be used in applications in the local area (Materialbanken, u.d.).

6.1.7. Guide to Pre-demolition Audit, Finland

As a response to the need to increase recycling and recovery of C&D waste to meet Waste Framework Directive targets, The Finnish Environmental Protection Agency published three guides in 2019 to support better and more resource-efficient demolition. The guides covered the procurement process, the implementation of the demolition process, and the process for conducting pre-demolition material audits.

The Finnish pre-demolition audit is based on the EU-initiated audit procedure. The Guide provides a step-by-step walkthrough of pre-demolition audits. It explains the stages of conducting a pre-demolition audit, how to understand the materials, their anticipated application and their potentials for recovery, the process steps involved in field research and site visits, how the results should be reported and communicated, and what should appear in the materials inventory.

This provides practitioners and procurers with a solid knowledge base with which to design and conduct pre-demolition audits and gain useful results that can lead to the better reuse and recycling of materials in buildings scheduled for demolition (Valtioneuvosto, 2019).

6.2. Circular construction

6.2.1. Pikku-Finlandia (Little Finlandia), Helsinki, Finland

Pikku-Finlandia was designed as a temporary replacement events facility during the three-year renovation of the landmark Finlandia Hall. The project was organised by Aalto University, the City of Helsinki, and Finlandia Hall in the autumn of 2019. It began with a graduate-level joint design studio at the Aalto University Department of Architecture, which resulted in a design proposal by student Jaakko Torvinen called Finlandia-forest, inspired by a Finnish boreal forest. The design used whole untrimmed tree trunks as load-bearing columns, thus minimising processing costs and impacts. The 2000 m^2 Pikku-Finlandia has four multifunctional halls, a gallery, and a cafe. Three of the multifunctional halls can be combined into one large area together with the lobby. This flexibility allows the building to fulfil a variety of functions and meet a variety of needs. Following the renovation, the building will be disassembled and moved to a new location and continue its life serving another function, such as a school or day-care centre for example, for at least the next 50 years. In this way, this circular, low-impact building not only uses natural, non-hazardous recyclable materials, but can also be moved, reused, and adapted as needed (Jaakkotorvinen, 2022).

6.2.2. Varvsstaden, Malmö, Sweden

Varvsstaden is an old industrial area in Malmö covering 180,000 m^2 between the city centre and the West Harbour. The area is undergoing redevelopment to provide extra capacity to the city. Circular construction is a key principle for the development, so the buildings already on the site are seen as material assets rather than waste challenges. The buildings were constructed in the second half of the 19^{th} century or the beginning of the 20^{th} century, and as such many have cultural value and contain high quality materials. The goal is to maintain the integrity of as many of the old factory buildings as possible (Varvsstaden, u.d.). The buildings that cannot be kept are carefully dismantled and the material is reused in the same area. Bricks, glass, wood, concrete, and steel are circulated from the old buildings to new constructions and installations either within Varvsstaden or in other nearby projects (Materialbanken, u.d.).

Offices, residences, and schools are being built in the area. Since buildings are deconstructed, there is an opportunity for reuse, and Varvsstaden can carry out the activities in the reuse process themselves: deconstruction, material storage, documentation, upcycling of material, and construction. Apart from the positive environmental effects from reuse, there is also an economic gain, and the value of the old buildings remains intact. A key tool used in facilitating the reuse of materials from Varvsstaden is Materialbanken (Materialbanken, u.d.), an online catalogue of materials in the existing buildings on site (Wennerholm, 2022).

6.2.3. House building experiment, Svartlamon, Norway

In Svartlamon in Trøndelag, Norway, a test house was built primarily out of reused building materials. The study intended to increase understanding of the potential of reusing materials in new buildings. The experiment was the basis for understanding the interaction between people and materials in relation to the environment. Using recycled materials and products can be justified as a conscious choice of materials. Resource consciousness is integrated into the design as well as into social and ecological sustainability in the development of architecture.

The project had special prerequisites that simplified the building, such as not having to modify the façade. The project gained permission to build without complying with some general building regulations, which otherwise would have made it more challenging. For example, the project was not adapted for accessibility, nor did it meet insulation requirements.

A conclusion made after the investigation was that building with recycled products is not necessarily easier than with conventional materials since it is more time consuming when processes such as material inventory and cleansing need to be done. However, it does indeed give a more personal and unique look. When building

with recycled products, it is important to be innovative and creative with the products and their functions, such as reusing a door as an indoor wall façade.

Building products such as doors, windows, moldings, and floorboards were examples of products with high reuse potential.

By using recycled materials, climate footprints can be lowered. But apart from being environmentally friendly, the building retains its cultural value since the components can continue to recount its history (Lundmark, 2019).

6.2.4. Rehabilitation of Kristian Augusts gate 23, Oslo, Norway

Kristian Augusts gate 23 (KA 23), built in 1950 in Oslo, Norway, was originally the headquarters of the Norwegian employer's association. The office building was bought by Höegh Eiendom in 2019. The building's façades are protected pursuant to the Planning and Building Act. Höegh Eiendom has renovated the building in line with FutureBuilt's criteria for circular buildings, and 50 per cent of the materials and building components are reused or reusable. The façades have been retained along with the load-bearing system, covers, stairwell, footing, and foundations, in addition to as many of the interior walls as possible. Details and materials such as the dark wood panels, terrazzo floors, and scagliola walls and roof have been retained, as well as several building components and interiors. The inclusion of new building parts has been conditioned on their reusability, in line with circular principles.

A greenhouse gas inventory was conducted in line with FutureBuilt's criteria to ensure that total emissions were reduced by at least 50 per cent. The inventory was used actively during planning to keep emissions in check (FutureBuilt, 2023).

6.2.5. Brákarborg kindergarten, Reykjavik, Iceland

Brákarborg Kindergarten was awarded the Icelandic Green Buildings Council's Green Shovel award in 2022 and was certified *very good* under the BREEAM certification scheme. The project consisted of renovating an existing commercial property at Kleppsvegi 150-152. A concerted effort was made to reuse the existing concrete structure, which eased the construction process and minimised the production and transport of virgin building materials. This was verified in the design process by undertaking a comparative renovation vs new build LCA on the site. The design phase also included detailed waste reports that estimated the amount of waste by category, along with a plan for treatment of that waste. Many of the installations of the commercial property were recovered for reuse by the architect, Arkís, in the construction and design of their new offices in Kópavogur. This included toilet bowls, sinks and faucets, door pumps, and curtains. As the site was going to be replanted with new vegetation, the existing vegetation was carefully removed and replanted elsewhere in Reykjavik, while the new building owners, the City of

Reykjavík, reused various electrical and computer equipment from the site in other projects (Grænni byggð, 2022) (Grænni byggð, u.d.) (Grænni byggð, 2021).

6.2.6. Loftkastalinn, Gufunes, Iceland

In Gufunes in the northeast of Reykjavik, old industrial buildings have been renovated and turned into apartments, workshops, and studios for artists. The buildings have been renovated by reusing building materials that have been collected and stored at the construction site. Inga Lóa Guðjónsdóttir and Hilmar Páll Jóhannesson are responsible for the project, which goes by the name of Loftkastalinn. The surrounding area will become a diverse settlement of entrepreneurs and creative industries, including a "film village" that will become the centre of Icelandic film production. Inga Lóa and Hilmar have collected a large amount of used building materials and interior items that have been reused in the renovation of the buildings. This project illustrates that reuse can be a viable solution for used construction materials as long as the commitment is strong.

In most instances, little time is spent removing reusable materials from buildings that need to be demolished, so when Seljavegur 2, a building in the west of Reykjavik, was demolished, Loftkastallin had the opportunity to remove material that could be reused. Examples of materials removed include stone wool (500 m^2), dense wool (300 m^2), electrical panels, electrical cables, fire systems, fire hoses, plugs and switches, suspended toilets and sinks, bathroom fixtures, industrial doors, fire doors, sound doors, exterior doors, furnaces, timber, etc. Loftkastalinn has also received materials from other demolition or refurbishment projects, including steel beams, parquet flooring, and a steel spiral staircase. Loftkastalinn will also uses visually defective sandwich panels for various purposes (Grænni byggð, Mannvirkjastofnun, 2019).

7. Barriers to and opportunities within circular construction

This chapter draws on recent literature, interviews with key stakeholders throughout the construction value chain, and an industry-wide survey to map the barriers to and opportunities for circular construction in the Nordic countries. The barriers and opportunities presented are a synthesis of the findings from these three sources. The references provided should be understood as indicative to how one or more sources have voiced similar concerns.

The barriers and opportunities have been grouped into 10 themes:

- Strategy & planning
- Building regulations
- Culture
- Economy
- Market
- Logistics
- Knowledge and experience
- Responsibility
- Product Documentation/certification
- Digital collaboration

It should be noted that many of the barriers (and related opportunities) are closely interlinked and overlapping. The above ten themes are used to provide an analytical structure but are not intended to be definitive or exclusive. It should also be noted that while the barriers are quite specific in their nature, many of the opportunities address multiple barriers simultaneously. For example, opportunities in planning and strategy can help reduce the market, economic, and responsibility barriers, and help build knowledge and experience.

7.1. Strategy and planning

Circular building starts with strategy and planning, which consists of determining what should be built and where, and defining the building's attributes and its overall profile. If circularity is thoroughly integrated into the building process at this stage, it is more likely to be implemented throughout the project.

7.1.1. Barriers

- **These arise from the broad lack of awareness** of circular construction and the environmental and economic potentials therein. Public and private developers have many other considerations that must be addressed when planning a construction project, including economy, function, time frames, and other sustainable construction approaches such as sustainable certification (DGNB, BREEAM, etc.). These factors are currently more deeply engrained in developers' strategic processes than circular construction (Höjer, 2022).
- Circularity often **enters the process too late.** Even when recycling and reuse provides an opportunity to minimise the environmental impacts of a development, key decisions may already have been taken that preclude inventive or impactful circular approaches.
- Circular approaches can **demand new forms of dialogue and collaboration**. Adopting more comprehensive approaches to circular construction often requires dialogue and collaboration with parties throughout the construction value chain, and many developers are not used to this process or cannot fit these processes into the allotted time frame for the project.
- Circular construction **demands different methods, processes, and routines** compared to business as usual. Most developers, both public and private, have not yet developed these routines, and it can be difficult to find the time to develop them within already tight budgets (Grænni byggð, VSÓ ráðgjöf, 2022).
- Circular construction can **demand better coordination between different authoritative bodies** or different departments within an authoritative body (Steen, 2022).
- Circular construction is **seen as complex and difficult** compared to more conventional approaches to construction, which dissuades developers from starting out on the journey (Lunneblad, 2022).
- **Insufficient investment in innovation and design** within the industry, and a lack of industry focus on reuse and circular construction in general (Kristjánsdóttir, 2022).
- **Lack of holistic assessments of environmental impacts from building life cycles**. Specifically, existing methods seldom address issues such as whether a product can be deconstructed and reused, the maintenance required over its lifetime, or the impacts stemming from waste management at end of life (Steen, 2022).

- **Lack of communication and cooperation throughout the construction value chain** is seen as a barrier to implementing circular practices in the construction industry, and one that is very ingrained in the way the industry has functioned until now.
- **Circular construction *is* difficult.** It can be quite attractive at the start of a project, but later in the process, the difficulties become apparent, and enthusiasm and ambition wanes (Seilskjaer, 2022).

7.1.2. Opportunities

- **Embedding circularity at the core of the planning and decision-making process**. Circularity must be there from the start since it can be difficult to integrate it later. This means considering not only recycled materials or reused building products, but also how best to meet demand with existing structures through renovation and modification while considering multi-use projects which can fulfil multiple needs with one building (Steen, 2022) (Höjer, 2022) (Lunneblad, 2022) (Laurikainen, 2022) (Brix, 2022) (Jacobsson, 2022).
- **Promoting designs targeting flexibility, adaptability, and disassembly**. Buildings should be able to be extended, moved, deconstructed, and converted into a new building. This means ensuring that the buildings we build now will not be torn down in thirty years but can be adapted to address a new demand and fulfil a new function. This maintains the value of the building stock and ensures that they have a longer useful life (Kilvær, 2022).
- **Focusing on better management of existing building renovations.** The best building for the environment is the one that is not built at all. At the planning stage, there must be stronger focus on how existing buildings can be transformed to fulfil a new function or updated to modern standards (Eriksson, 2022) (Kilvær, 2022) (Kjerulf, 2022) (Koch-Ørvad, 2022) (Wærner, 2022) (Lahtinen, 2022).
- **Using Green Public Procurement to drive demand** for circularity in construction projects. This could be achieved by making the reuse and recycling of materials an obligatory component for public procurement of construction services (Runge, 2022) (Wennerholm, 2022). This can include **adopting innovative public procurement processes.** For example, the city of Gothenburg engages in market dialogue by inviting selected actors to address long-term challenges that are not yet suitable for specific procurement calls. This means that the city helps support the development of product and services that it may require, without committing to a purchase (Jacobsson, 2022).

- **Establishing public-private partnerships** can help minimise many of the barriers experienced by stakeholders since responsibility and economic risk can be spread more widely (Kilvær, 2022).
- **Improving cooperation between public departments**. Several stakeholders mentioned the need for better cooperation and coordination between public departments and agencies (Dahlgren, 2022).
- **Expanding consequence analysis in order** to include soft factors and move beyond CO_2.
- **Using multidisciplinary, multi-faceted design teams** (architects, engineers, sustainability specialists, trades). Many people who work with reuse are environmental consultants and not civil engineers. To understand the performance of constructions and better map construction products, an interdisciplinary team is needed (Wærner, 2022).
- **Better and earlier communication** throughout the value chain and between project team members. Architects, consult engineers, contractors, and the client/developer need to communicate earlier in the process and throughout the entire value chain (Steen, 2022) (Brix, 2022).
- **Synchronising timelines for different building projects** would allow materials to more easily be extracted from one project and used directly in another, thus avoiding the environmental and economic impacts from the intervening storage and transport *(Bjarnadóttir, 2022).*

7.2. Building regulations

Building regulations codify the technical demands placed on new buildings and the processes involved in their construction. These are a highly necessary component of a stable and safe construction industry and built environment, and they are the primary mechanism by which authorities can introduce new demands on the sustainability of buildings and construction. They also present a challenge to innovative sustainable approaches, both in the codified demands placed on building products, but also in the way in which these demands are interpreted and processed by the responsible authorities.

Building regulations appear to be a contentious area for many stakeholders and generate split opinions; some feel that the existing building regulations are a significant barrier to circular construction, while others experience them as an unavoidable hinderance, but one that can be overcome. In any case, current building regulations are not considered a particular enabler of circular construction within the industry.

7.2.1. Barriers

- **Technical demands**. In some cases, environmental and structural demands cannot be met with reused materials (Wennerholm, 2022). This can be particularly true when dealing with fire safety and the structural integrity and acoustic properties of construction products, but it can also be related to accessibility and safety for example (Eriksson, 2022) (Kristjánsdóttir, 2022).
- **Rigidity of regulations.** The rigidity of the regulations in the national building codes prevents the use of reused products (Eriksson, 2022) (Kilvær, 2022) (Kjerulf, 2022) (Hippinen, 2022).
- **Interpretation of regulations.** The way in which regulations are interpreted and implemented by the authorities and certified engineers can hinder novel applications of materials and prevent reuse. In Denmark, for example, fire certification is carried out through certified private consultants, and they are understandably risk-averse in the case of used and bio-based products (Gate21, u.d.). While some stakeholders are subject to the regulatory demand that products have a CE-marking and documentation (Kjerulf, 2022), others indicate that although building regulations rarely prohibit the application of reused materials and circularity, they can still function as a barrier since they more easily facilitate the continuation of work as usual (Koch-Ørvad, 2022).
- **Gearing towards linear construction with new products.** Overall, there is a broad understanding within the industry that current building regulations are not geared towards circularity but rather are optimised for linearity and the use of new products (Kjerulf, 2022) (Seilskjaer, 2022) (Steen, 2022).
- **Building regulations can have conflicting criteria.** For example, the Danish building regulations have stringent requirements for product properties such as acoustics, fire safety, and emissions. However, the acoustic and fire safety requirements call for more material per area, which will increase the environmental footprint, thus contradicting the requirements for emissions (Gustafsson, 2022).
- **Lack of a standard or guide for resource mapping existing buildings, and no common platform for dissemination.** This results in either ad-hoc resource mapping actions or different practitioners following different methods, thus generating different outcomes. It reduces certainty in the process, and makes it more costly (Runge, 2022). Resource mapping results are rarely in the public domain, which limits the availability of materials and construction elements to those commissioning the resource mapping (Kilvær, 2022).

Besides building regulations, planning and zoning regulations can hinder circular construction:

- **Inflexible planning and zoning.** A major consideration for circularity is repurposing existing structures. This is made more difficult by building plans and zoning regulations, which may restrict the types of activities permitted at a given location. This in turn limits the flexibility of reusing existing structures (Laurikainen, 2022).

7.2.2. Opportunities

- **Revising building regulations to better accommodate reuse is** a common theme in the literature and when speaking to stakeholders. In general, current regulations implicitly assume building with new products, which makes building with reused products a challenge (Kilvær, 2022) (Laurikainen, 2022) *(Bjarnadóttir, 2022).*
- **Developing guides** to help stakeholders who adopt a reuse strategy navigate the existing building regulations. This seems to be particularly pertinent to those actors who do not see intrinsic barriers in current regulations (Höjer, 2022) (Seilskjaer, 2022) (Runge, 2022) (Lahtinen, 2022) (Fjeldheim, 2022) (Hippinen, 2022)(Falk, 2022) (Lunneblad, 2022).
- **Demanding pre-demolition resource mapping** is seen as a fundamental necessity if valuable resources are to be successfully identified and removed from buildings flagged for demolition. Swedish (Sveriges Riksdag, 2010) and Norwegian (DIBK, 2022) building regulations already demand pre-demolition resource mapping, while a similar demand is anticipated to be implemented in Denmark in 2023. Developing a standard methodology could provide a significant increase in the quality and supply of construction materials, products, and elements for reuse (Kilvær, 2022) (Lindholm, 2022) (Steen, 2022).
- **Minimising demolition through regulatory procedures** could provide an incentive for developers to consider renovation and other alternative solutions rather than demolition. This could be achieved through a regulatory request for authorisation before demolition, whereby the developer must justify the demolition of the building (Kjerulf, 2022) (Kilvær, 2022).
- **Enforcing the existing separate-collection waste regulations for** construction and demolition waste could provide a significant boost to the quantity and quality of material for reuse and recycling (Kilvær, 2022) (Lahtinen, 2022).
- **Demanding material passports for all new buildings** would enable easier disassembly and utilisation of the materials currently being used in construction at end of life, as well as facilitate maintenance and renovation throughout the life cycle (Lahtinen, 2022).

7.3. Culture

Culture within the construction industry and value chain, as well as in society at large, has a significant influence on the openness to innovative approaches, the acceptance of risk, the issues that intersect sustainability and the built environment, and ultimately how the construction industry adapts to the circular transition.

7.3.1. Barriers

- **Organisational momentum.** The construction industry and related value chains are mature, with deep-rooted processes that tend to change incrementally rather than categorically. The processes involved in circular construction can be a significant departure from existing practices throughout all parts of the value chain. This manifests in an (perhaps healthy) aversion to risk, resistance to change, and highlights the lack of knowledge and experience within the industry and thus its hesitancy to commit.
- **Sustainability discourse.** There are already well-known and well-used sustainable construction paradigms focusing primarily on certification based on sustainability criteria. The existing schemes—DGMB, BREEAM, LEED, Nordic Swan etc.—all fulfil a market role and drive sustainability for some actors in the construction industry. Certification is often associated with a premium project/product, and most efforts to date have focused primarily on minimising energy consumption during a building's life cycle (which comes with an economic bonus to the final user), minimising hazardous substances, and improving indoor climate. Broad demand for sustainable buildings has yet to filter down to end consumers.
- **Ownership rather than stewardship**. Within the construction sector, materials and components are still considered linear—they are bought and installed with the expectation that they will be discarded. The concept of material stewardship and buildings as material banks is still relatively unknown (Wittrup, 2022).
- **Conservative attitudes in the industry**. The building sector works with complex projects with significant unknown elements and across many groups of actors that form new constellations for each project. The competition for projects is considerable, and the net gains are very small. By following the established structure, everyone is secure in their roles; therefore, any challenges to the established structure are a threat to the value chain actors since their role may change or disappear. In addition, there is a deep and

deserved respect for safety and health within the industry, which often trumps environmental sustainability (Koch-Ørvad, 2022).

- **Demand from developers and end users for clean and new products**. There is a broad expectation from developers and end consumers alike that new buildings should be "new"; therefore, there is a lingering scepticism about the aesthetic and quality attributes of buildings containing reused or recycled materials (Jacobsson, 2022).
- **Lack of broad support for sustainability as a goal.** Not everyone in the sector is concerned about or engaged in sustainability, which means that it is still a niche activity (Koch-Ørvad, 2022).

7.3.2. Opportunities

Opportunities include:

- **National programmes for Circular Construction**. The development of national strategies and programmes for Circular Construction would indicate a clear strategic direction for the industry and provide a clear framework for future work concerning circular construction.
- **Dedicated support programmes for circular construction within industry organisations.** Industry organisations are in an excellent position to help drive the circular agenda. This leadership and network provide an excellent basis to both promote circular construction practices and draw on, collect, and synthesise experiences with circular construction from the industry. Industry organisations can also help identify specific challenges and develop solutions together with industry actors. Architects and designers can be particularly strong advocates for change.

7.4. Economy

Construction can demand significant capital investment. Both private and public developers experience tight budgets and want to create as much value as possible for their investment. For public developers, this often means the most quality and most service from a building, while for private developers, it means getting the best rate of return on investments.

7.4.1. Barriers

- **Higher costs of circular construction processes and products, even if material is free at source.** The addition costs are not limited to a single part of the process since planning, designing, and the construction process itself all involve additional steps that add to total costs (Kjerulf, 2022) (Kilvær, 2022) (Lunneblad, 2022) (Grænni byggð, VSÓ Ráðgjöf, 2022). This is a key challenge for demolition companies. The disassembly process is more labour intensive than demolition, especially given the current lack of experience in the practice. This factor is aggravated by the uncertainty about the demand for and pricing of reused goods (Bjarnadóttir, 2022) (Hippinen, 2022).
- **High labour costs** are a significant factor in making new products more cost effective than reused products. New products are well understood, can be used directly in the construction process, and satisfy a well-defined application. Reused products can be more difficult to handle, often require some level of preparation for reuse, and construction workers have little experience working with reuse products in general. All of this means that the process of reuse can be more labour intensive and consequently more costly. This is not unique to the construction industry—it is often more cost effective to replace mass-produced products than to repair them, especially when the product was not designed to be deconstructed.
- **Relatively inexpensive new construction products**. Utilising reused materials and products is more expensive than using new products despite the increasing costs of materials (Dahlgren, 2022). In one building project, for example, reusing hollow core slabs was 5 times more expensive than using new slabs, which are not only cheap, but also easier to order and have delivered within a tight schedule (Wærner, 2022).This is heavily linked to the high labour demands for reuse, which is exacerbated by a lack of knowledge about the processes involved. In some cases, and for some product groups, it is also linked to the ability to outsource production of new products to locations with lower labour costs and often lower environmental standards (Wittrup, 2022).
- **Uncertainty about payback**. When sustainability is seen as a premium, it only appeals to a certain market segment. Circular construction, with its additional costs, can potentially be sold as a premium product, but that approach only addresses a limited share of the total construction market (Wittrup, 2022). What's more, other sustainability approaches—for example certification according to one of the recognised schemes—can provide a proven premium for a developer, while the direct financial benefits of circular construction are less clear.
- **Lean margins.** There is rarely room in the economy of a construction project for innovation, experimentation, or taking on extra risks. This means that

that there is rarely room for circular approaches given the uncertainties involved and the related additional costs (Gustafsson, 2022). Sustainability is often the first expense to be minimised to maintain budgets (Kjerulf, 2022).

- **Environmental externalities are not priced in** to the construction products market, which helps to keep the price of new products and materials low enough to outcompete reused products (Wærner, 2022).
- **Requires investments.** New investments may be required for a company to engage in circular construction—in equipment or training for example—and technical solutions might be seen as expensive and complicated; it is thus not clear how and when this investment will be recouped (Eriksson, 2022).
- Demolished material (not deconstructed) is a profit for demolition companies since they can sell the recovered material fractions as material for recovery (wooden chips or scrap metal, for example). Disassembly demands that the demolition company must rethink their business model (Lunneblad, 2022).

7.4.2. Opportunities

- **Lowering VAT on reuse and recycling**. This would also help make reused products more economically attractive compared to new products. This could be applied to reused products at points of sale, and/or to the services involved in generating products: dismantling, preparing for reuse, or even building with reused products (Lahtinen, 2022) (Wærner, 2022).
- **Implementing a broad Carbon Tax**. A carbon tax that included all carbon emitting activities and imports associated with carbon emitting activities would see an increase in the price of raw materials, including cement and steel. This would have a direct positive effect on the relative competitiveness of reused components, although the magnitude of that impact is uncertain (Wittrup, 2022) (Bjarnadóttir, 2022).
- **Modulating property and utility taxes for circular buildings**. This would help make circular buildings less expensive to run than conventional buildings, making them more attractive to investors (Bjarnadóttir, 2022).
- **Increasing waste management costs.** This would help make reusing products a more cost-effective strategy for addressing end-of-life buildings. This could be achieved by specific charges like landfill gate fees (Wittrup, 2022) (Grænni byggð, VSÓ Ráðgjöf, 2022).
- **Targeting funds for pilot/flagship circular construction projects and for specific technical problems in circular construction.** Providing direct funding for innovative projects that seek to address specific challenges in circular

construction or develop standards that can be applied in circular construction. This would help mature the circular construction industry and broaden the experience base (Bjarnadóttir, 2022). The City of Copenhagen allocates extra resources to developing circularity in the construction sector (Runge, 2022).

- **Increasing the costs of virgin construction products by integrating the costs of environmental externalities**. This could, for example, be implemented through targeted fees/taxes on construction products or resource taxes (Koch-Ørvad, 2022) (Wittrup, 2022).
- **Reducing the financing costs of circular projects.** The EU Taxonomy should itself make financing sustainable buildings more affordable in the coming years, but this could be supplemented by national measures that incentivise investments in circular projects, or more broadly in sustainable projects (Wennerholm, 2022) (Eriksson, 2022) (Wærner, 2022) (Kristjánsdóttir, 2022) (Brix, 2022).
- **Increasing focus on creating employment and other social benefits from circular construction.** Circular construction practices are typically more labour intensive than conventional practices. While this is associated with additional costs, it also increases employment in the local area (Jacobsson, 2022).

7.5. Market

The market for circular construction, like the practice, is still in its infancy and currently suffers from both supply-and-demand side challenges, many of them interlinked and self-perpetuating:

7.5.1. Barriers

- **A lack of access to both materials and services**. Since demolition managers usually don't have an interest in reusing the materials themselves, time and energy are not spent on inventory, deconstructing, storing, and selling materials (Lindholm, 2022). In contrast, new products are easy to procure and have all the necessary information. A similarly fluid market for reused products does not yet exist (Lunneblad, 2022) (Steen, 2022), and a lack of supply of products and services also serves to keep prices high through a lack of competition. This applies not only to the dismantling services, but also the packaging and transporting of those products to where they are needed and the discovery of products for reuse (Jacobsson, 2022) (Höjer, 2022).

- **A lack of capacity, methods and practices**. Established actors in the market need to work with different methods, and new actors and services are needed within all areas. Few actors are currently working with disassembly, preparing for reuse, reconditioning, storing, and selling deconstructed materials, and there is little reason to develop additional capacity if there is no demand for reused products (Lindholm, 2022) (Jacobsson, 2022). At the same time, a lack of actors working with, and practical examples of, reused materials in construction deters developers from requesting reused materials for their projects (Steen, 2022).
- **Product discovery.** Products that are available for reuse are difficult to find. A fragmented market with many platforms, all using different data standards and product descriptions, makes it challenging for developers and builders to quickly and reliable identify the products they need. No common repository for pre-demolition material audits exists (Dahlgren, 2022) (Johannesson, 2022).
- **Security of supply**. Even if high-quality, well-documented reused materials come onto the market, there is no guarantee that they will be on the market when they are needed, nor is there a guarantee that they can be supplied in sufficient volume within a given time frame. This is a significant problem for large construction projects and construction projects that are intended to be implemented in stages with significant time lags (Hippinen, 2022) (Kjerulf, 2022) (Brix, 2022).
- **Administrative burden.** The administrative processes involved with suppling, documenting, cataloguing, and marketing reused products requires new competencies and capacities, and these processes take time and money (Eriksson, 2022).
- **The ease of business as usual**. The building sector is used to existing practices, and incorporating new routines is hard. It is easier to order materials and products using existing practices (Höjer, 2022) (Kristjánsdóttir, 2022). This is another example of (perhaps understandably) conservative attitudes within the construction sector (Hippinen, 2022).
- **Difficulty in balancing supply and demand**. As the market is still in its infancy and the required tools, methods, and planning routines are still being developed, it is very difficult to establish a stable equilibrium between supply and demand.

7.5.2. Opportunities

Opportunities for increasing the number of circular projects, services, and materials for reuse include:

- **Mapping resources in buildings well before demolition.** Pre-demolition audits are already obligatory in Sweden and Norway, and they will be obligatory in Denmark in 2023. However, circular planning would be greatly aided by having knowledge of the material content of buildings to be demolished at some time in the future, not only those buildings scheduled for imminent demolition (Wærner, 2022) (Kristjánsdóttir, 2022).
- **Digital resale marketplaces and platforms.** A variety of sales platforms for reused building products already exists in the Nordic countries; some are state-supported, and others are private initiatives. Broadening awareness of these platforms throughout the industry could help products flow more freely between stakeholders.
- **Open standards and APIs for product data.** Interoperability and open standards for product specifications and documentation can help mitigate market fragmentation. A common database for the whole sector instead of several different ones would make it easier for the client (Wærner, 2022).
- **Skills, methods, and networks for disassembly.** The demolition sector is already moving toward disassembly for reuse, but this could be accelerated by providing education and technical training, and developing routines and new networks for the disassembly, packaging, and transportation of products.
- **Public developers** can help drive both supply and demand within circular construction. They can integrate circular criteria into their procurement processes, all while also taking advantage of a large portfolio of buildings that are ripe for renovation or demolition, which represents a huge potential material bank for future construction projects (Wennerholm, 2022) (Bjarnadóttir, 2022).

7.6. Logistics

Managing the flow of products and materials from deconstruction to a new building project is a complex process and faces some specific challenges that increase costs and hamper the development of a robust market at scale:

7.6.1. Barriers

- **Lack of space on building/demolition sites**. Space is often at a premium on demolition and construction sites. This makes intermediate storage on either type of site impractical. This is particularly the case for fragile or easily damaged products (Kristjánsdóttir, 2022) (Kjerulf, 2022).
- **Distance**. The distance between the demolition site and the construction site might make transporting materials and products less economically or environmentally attractive (Johannesson, 2022).
- **Storage space**. There is a lack of suitable storage space for products between projects, and storage can be expensive, especially when given the relatively low value of the stored products. This is particularly a problem in urban areas. The storage space must be able to house and suitably protect the relevant recovered products satisfactorily over the long term (Dahlgren, 2022) (Kilvær, 2022) (Brix, 2022) (Eriksson, 2022) (Johannesson, 2022) (Höjer, 2022) (Kilvær, 2022) (Hippinen, 2022)(Grænni byggð, VSÓ ráðgjöf, 2022).

7.6.2. Opportunities

Opportunities include:

- **Synchronizing demolition & construction** across sites in order to facilitate reuse, minimise storage requirements, and begin to balance supply and demand.
- **Developing local solutions** and coordination so that long-distance- and long-term storage is unnecessary.
- **Reusing own materials or materials on the site** to minimise transaction costs (Kilvær, 2022).

7.7. Knowledge & experience

The construction process is built upon a wealth of knowledge and experience in terms of the products, materials, skills, methods, and routines required to create our modern built environment safely and efficiently. These are deeply rooted in the specialist activities required by the demolition and construction processes and their practitioners, which include developers, architects, engineers, builders, the multitude of specialist trades, and demolition experts.

Activities contributing to circular construction, such as circular planning, designing with reused products, designing for disassembly, construction with reused products, preparing for reuse, and disassembly, require additional competencies that are currently rare in the industry.

7.7.1. Barriers

- **Circularity is still broadly a new concept**, as are the various activities it includes (Jacobsson, 2022). Circularity requires a new way of thinking (Seilskjaer, 2022) (Eriksson, 2022).
- **Lack of knowledge and experience with circular approaches in developers**. Driving circular projects requires knowledge and know-how from the developer, and this is currently lacking and difficult to attain (Dahlgren, 2022).
- **Lack of skills and know-how** throughout the value chain in methods and techniques for circular construction:
    - **Designing for flexibility, adaptability, and disassembly (Lunneblad, 2022)**.
    - **Designing with reused products (Lunneblad, 2022)**.
    - **Working with reused products** and recycled materials (Wennerholm, 2022) (Höjer, 2022) (Wennersjö, et al., 2021) (Steen, 2022).
    - **Safe and careful disassembly**, packaging, and transport of products and materials for reuse (Höjer, 2022) (Seilskjaer, 2022). In existing buildings, where reuse is not a design criterion, it can be difficult to remove otherwise suitable materials or components because of the surrounding structures or the way in which they are attached; this can result in damage to the potential reuse product (Lunneblad, 2022) (Kristjánsdóttir, 2022) (Grænni byggð, VSÓ Ráðgjöf, 2022).
    - **Planning and conducting pre-demolition audits.** Although guides to this practice are appearing, the knowledge is not yet widespread in the industry.
- **Lack of capacity and lack of time and money to develop the required new competencies**. Construction projects have little leeway for learning and experimentation, which limits the ability of actors throughout the value chain to develop the required competencies and capacities (Kristjánsdóttir, 2022).
- **Lack of coordination and knowledge-sharing between stakeholders**. Despite the growing interest in circular construction, there is still a broad lack of experience with reuse and circular construction throughout the value chain (Hippinen, 2022) (Kristjánsdóttir, 2022) (Höjer, 2022) (Wennerholm, 2022). The knowledge that does exist is scattered and has yet to become common knowledge (Eriksson, 2022); furthermore, there are legacy incentives for not sharing knowledge in order to maintain a competitive advantage.

7.7.2. Opportunities

- Developing and maintaining **national & regional knowledge centres** can act as focal points for the entire industry or for specific parts of the value chain. They can help by building knowledge and sharing experiences, developing and distributing common practices, methods and standards, and providing a network of engaged actors within the industry (Høibye & Sand, 2018) (Karppinen, 2020) (Jacobsson, 2022) (Lahtinen, 2022) (Lunneblad, 2022) (Kilvær, 2022) (Koch-Ørvad, 2022) (Runge, 2022) (Seilskjaer, 2022). For best effect, these should include or be open to the industry in order to ensure that all needs are addressed, not just those of the actors currently engaged in circular construction (Koch-Ørvad, 2022). Working across the traditional borders of stakeholder interest and understanding the concerns of the other actors in projects is the key to change (Brix, 2022).
- **Targeted Workshops**: Having workshops that focus on implementation, design and material flows, including aspects from business and engineering (Kristjánsdóttir, 2022). This includes workshops with the housing authorities, financial institutions, and municipalities working on issues that currently limit circular construction.
- **Using Pilot projects** to build knowledge and experience (Bjarnadóttir, 2022).
    - **Learn-by-doing**. Hands-on experience is invaluable for learning how to work with reuse and other circular construction practices. This also helps build new relations and networks, and by starting small, it provides a base from which to scale up operations (Eriksson, 2022) (Kjerulf, 2022).
    - **Dare to try.** Just undertaking a project can help mitigate the expectation of circular construction being too difficult and complex (Lunneblad, 2022).
- **Increasing Nordic cooperation.** Harmonising collaboration between the Nordic countries regarding approaches and best practices within CC is necessary. This will create a larger and more stable market for CC materials and products (Laurikainen, 2022) (Kristjánsdóttir, 2022).
- **Training in specific technical aspects of Circular construction.** This is particularly relevant for disassembly methods and practices as well as working with older products in new construction.
- **Preserving trade skills** from older, more experienced employees. This is particularly relevant to the above potential regarding training for construction with reuse (Höjer, 2022).
- **Developing standard routines** for construction and dismantling processes, contract forms, data gathering, product testing, and packaging norms, so as to bring stability to circular construction.

- **Using digital tools** to spread knowledge within the value chain. For example, a database of important projects and contacts can be created in order to provide a useful reference and encourage direct contact with actors that have faced and overcome similar challenges (Gustafsson, 2022).
- **Developing a common terminology** and language around circular construction: An important part of making the transition to CC successfully is to have an agreed-upon terminology in place. The FIGBC (FIGBC, u.d.) is currently attempting to address this issue in Finland (Lahtinen, 2022).
- **Integrating circular construction into national school curricula:** This will help embed circularity as a concept in the next generation of experts and help provide the necessary expertise in circular approaches in the coming decades.

7.8. Responsibility

Reliability is a core pillar of the construction industry, and new construction products are rigorously standardised and tested. Reusing building elements and materials introduces a degree of uncertainty in the building process. Circular construction challenges how responsibility for this reliability is allocated between actors throughout the value chain.

7.8.1. Barriers

- **Allocating responsibility between parties.** Usual building processes and contracts hand the builder responsibility for the finished building for a fixed period after completion. Should problems occur that are not the result of misuse of the building or other exclusions, the builder is held responsible for any repair and remediation. Builders are reluctant to enter into the same agreement when their control over the quality of individual elements is reduced through the application of reused products (Brix, 2022) (Gustafsson, 2022) (Höjer, 2022) (Kjerulf, 2022) (Koch-Ørvad, 2022) (Wennerholm, 2022).
- **Sourcing products for reuse.** Builders operate within a known supply chain, with well-known suppliers and standardised products, and are typically responsible for sourcing the products they use in construction. Builders are reluctant to engage with projects that demand reused products since these products cannot be sourced from their usual suppliers, come with less documentation, and can require non-standard methods to work with them (Gate21, u.d.).

7.8.2. Opportunities

Opportunities include:

- **New forms of cooperation and dialogue**. Existing relationships and responsibilities are challenged, and new arrangements can help overcome some of these challenges related to responsibility for a product's technical capabilities and for the final construction (Brix, 2022). This can be done within the framework of existing regulations and standard practices or, if need be, by modifying or re-interpreting them to better suit the challenges concerning responsibility and risk in circular construction (Koch-Ørvad, 2022).
- **New roles in product sourcing**. Rather than passing responsibility on to the builder, the architects, advisors, and commissioning authorities can play a much more active role in identifying and sourcing used building components for reuse. This works together with the previous opportunity for differentiated responsibility for the products themselves (Gate21, u.d.). It is important to have trust between the developer and the contractor. This can be reinforced by the developer taking responsibility for the reused products. The developer usually has knowledge about the products, which helps to make correct decisions about how they can be used again (Höjer, 2022).

7.9. Product documentation / certification

Documentation of product properties is essential to foster trust and confidence in products from the construction value chain. Documentation is a base demand for products within the construction value chain. There is broad agreement within the industry that a lack of documentation for used products dissuades their use in new buildings. Documentation and certification often go hand in hand with new products (with CE-labelled products manufactured using documented processes). This is more challenging with products for reuse. While documentation can provide the information necessary for making a design decision, this information alone does not confer responsibility for the product or its properties.

7.9.1. Barriers

- **No widely accepted methods or standards for the re-documentation and recertification of reuse products.** Even in the unlikely event that the original documentation for a product can be found in the original building documentation, this may not satisfy current or future documentation demands, and it is not always evident whether the technical properties detailed in the existing documentation are still valid at end of life (Wærner, 2022). There are no established methods and standards for generating documentation for reused products, which reduces trust in any documentation and increases the costs of providing documentation (Grænni byggð, VSÓ Ráðgjöf, 2022) (Wittrup, 2022).

- **Testing can be challenging.** If materials and products need to be tested before they can be reused, this can be difficult to achieve in a non-destructive manner (Kristjánsdóttir, 2022). This is a particular problem with unique, rare, or low-count products.
- **Documentation and certification are often comprehensive**. Many criteria must be documented depending on the product: There is also uncertainty within the industry about which properties need to be documented for a given reuse product.
- **Invalid warrantees on reused building and construction products.** Warranties on building and construction products are typically not valid after first application. This creates a degree of concern relative to the reliability of reused products as well as where responsibility for the quality and technical performance lies in reuse applications (Gustafsson, 2022) (Koch-Ørvad, 2022) (Wittrup, 2022).
- **Suspected presence of hazardous substances.** In the absence of comprehensive documentation, testing, or resource mapping, there is no guarantee that products intended for reuse are free of hazardous materials. The presence or suspected presence of hazardous materials is a commonly cited reason for avoiding reused products in construction.
- **Lack of digital information standards for generating, storing, and communicating product information.** This leads to the fragmentation of the potential market for reused products and limits the potential for reusing recovered construction materials and products.

7.9.2. Opportunities

Opportunities include:

- **Standardised documentation for reuse & recycled materials.** Ideally, this could take place at the EU-level alongside existing construction product documentation and certification demands. Alternatively, Nordic or national standards would also help developers trust reused products, and they could be tailored to the materials and products used most frequently in each respective country.
- **Developing standardised methods for CE-marking (or equivalent) reused products.** This would allow reused products to re-enter the market on equal footing with virgin products. Brukspecialisten in Sweden and Gamle Mursten in Denmark have achieved this for reused bricks.
- **Including a reuse guide and conditions as an additional component in existing harmonised standards for new products.** This would provide clear guidance on how and under what conditions a given product can be reused at end of first life.

- **Transferable guarantees**. Enabling guarantees to extend beyond first life, or transferring the guarantees on to a third party, which could enable products to re-enter the market.
- **Promoting take-back and re-manufacturing**. This would put the onus on the original manufacturer to control the quality of and provide documentation and guarantees for products as they are remanufactured.
- **State-backed guarantees for reused products.** A governmental insurance pool (for example "Byggeskadefonden for genbrug") could drive the agenda forward by removing some of the economic risks for clients, designers, and contractors. This could be particularly relevant for "non-fatal" risks such aesthetic or even premature functional failures. When looking at structural components, other measures need to be considered since there may be fatal consequences if something goes wrong (Gustafsson, 2022).
- **Digital twins for new products** could reduce this problem for future circular construction projects by providing comprehensive and up-to-date information on a given element or product in a building.
- **Online database of (standardised) documentation for reused products.** This could streamline the documentation of products for reuse and provide easier access to documentation for designers and builders.

7.10. Digital collaboration

Some technical challenges limit the development of fully circular solutions within the construction industry, particularly those related to the digitalisation of the construction industry. This is strongly linked to common standards and regulations for governing the construction industry.

7.10.1. Barriers

- **Closed and isolated digital silos.** Digitalisation in the construction industry often works within closed systems with proprietary data.

7.10.2. Opportunities

Opportunities include:

- **Sharing data.** It will be imperative in the future to make data on buildings and products more freely available, open, and transferable in order to enable a higher level of transparency, better utilisation of the existing building stock and construction products, and facilitate high-quality maintenance, renovation, and disassembly.

8. Quantitative results

The previous chapter mapped the barriers and opportunities for Circular construction experienced by actors throughout the value chain in the Nordic countries. The barriers serve to reinforce each other, and the opportunities identified could each help overcome one or more of these barriers.

This chapter presents a broader quantitative analysis of the survey results in order to prioritise the barriers and opportunities presented above.

8.1. Quantitative results from the survey

Actors throughout the value chain were consulted through an online survey based on the above findings. This provides a broader understanding of the barriers, their direct and indirect impacts, and their power to prevent circular construction from becoming a reality. Similarly, the survey indicated which opportunities had the most potential to significantly overcome the barriers.

The barriers and opportunities used in the survey were formulated based on a detailed analysis of the results from the interview process and literature review. As such, the barriers and opportunities formulated for the survey differ somewhat to and expand on the overarching barrier and opportunity groups listed above. In particular, the survey did not specifically address the overarching challenge of integrating circular construction into strategy and planning routines; rather, it focused on specific challenges faced throughout the value chain—twelve in all. Similarly, the survey formulated a raft of specific opportunities based on the inputs from the literature review and interviews.

The survey was taken by 237 respondents spread across the Nordic countries and beyond. Table 4 indicates where they come from and what actor groups they represent.

Table 4 – Survey respondents by country and actor group

	DK	FI	IS	NO	SE	Other	Total
Developers / building owners	5	2	4	3	5	2	21
Architects, engineers, consultants	26	5	7	10	17	2	67
Contractors and builders	7	5	5	3	5	-	25
Construction product manufacturers	5	10	4	-	4	2	25
Demolition experts	4	1	-	-	1	-	6
National and local authorities	1	4	9	1	5	3	23
Research and innovation	1	2	3	-	3	5	14
Nongovernmental Orgs	5	2	4	3	1	2	17
Other	11	5	5	7	10	1	39
	65	**36**	**41**	**27**	**51**	**17**	**237**

This provides a reliable base for prioritising the barriers and the opportunities uncovered in the literature survey and the interviews.

8.1.1. Barriers

The survey asked participants to select five of the twelve formulated barriers as the most pressing. Figure 6 show what percentage of the respondents included the respective barrier in their top five.

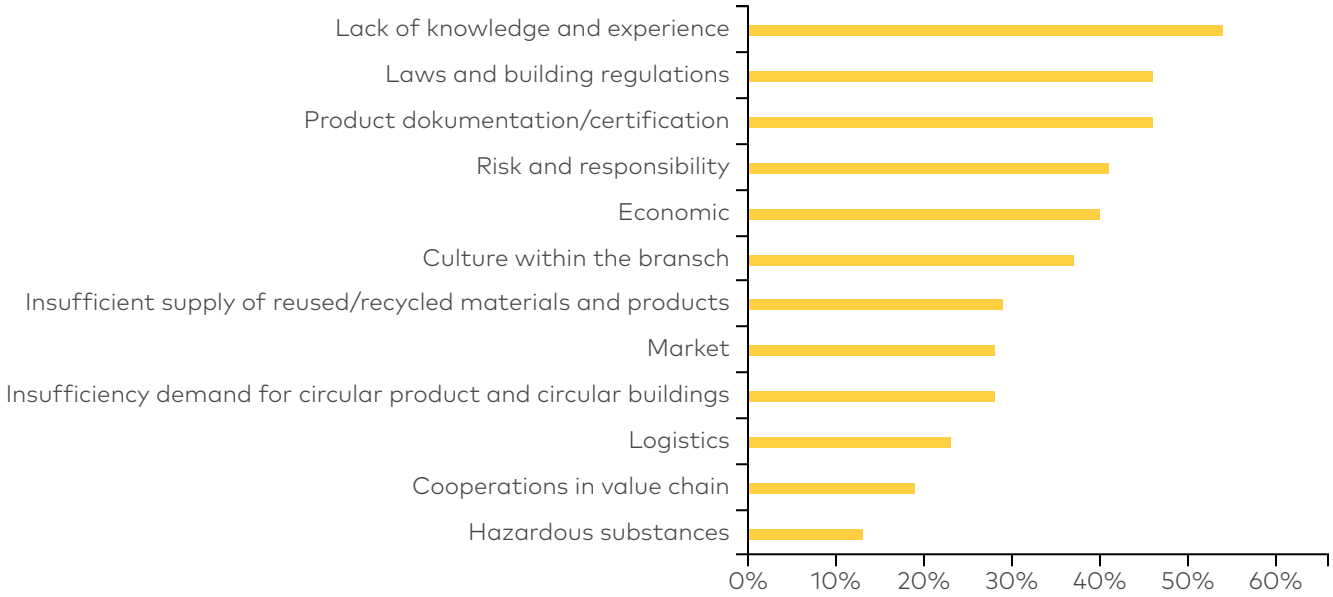

Figure 7 – Survey results - Barriers to circular construction

According to the survey respondents, a lack of knowledge and experience across the Nordic countries is seen as the primary barrier hindering the development of circular construction, with over half of the respondents indicating that it is one of the top five barriers. However, laws and building regulations were also seen as a significant barrier along with the challenges surrounding product documentation. These often go hand in hand, as many of the regulatory challenges are related to building with products without sufficient documentation or certification. Similarly, defining responsibility for risk in circular construction projects is also seen as a significant problem, again linked to the above challenge of regulation and documentation. Finally, the economics of circular construction were also seen as challenging.

At the other end of the scale, few stakeholders felt that hazardous substances in materials presented a serious barrier to circular construction, and few felt that cooperation throughout the value chain and logistical challenges were among the most pressing.

Barriers	DK	FI	IS	NO	SE	Other	Total
Risk and responsibility (difficulty in defining, assigning, and accepting the risks and responsibilities of CC)	64%	31%	16%	52%	30%	44%	41%
Product documentation/certification (uncertainty about technical capabilities and lack of certification)	64%	25%	30%	68%	30%	69%	46%
Market (lack of visibility, security of supply and market size)	16%	38%	38%	44%	15%	25%	27%
Cooperation within the value chain (difficulty in creating effective communication and cooperation throughout value chain)	13%	25%	35%	20%	15%	6%	19%
Laws and building regulations (existing regulations hinder reuse and circular construction)	46%	50%	49%	36%	50%	44%	47%
Culture within the sector (difficult to change existing approaches, methods, expectations, and structures)	34%	34%	41%	28%	45%	38%	37%
Logistics (expensive and cumbersome storage and transport of materials and elements for reuse)	16%	13%	27%	44%	33%	6%	23%
Economic (circular building practices and products are often more expensive)	39%	44%	22%	52%	43%	56%	40%
Insufficient demand for circular products and circular buildings (from all parts of the value chain, but especially developers and commissioning authorities)	23%	47%	32%	12%	18%	38%	27%
Insufficient supply of reused/recycled materials and products (due to Logistics, strategy, technical knowledge & experience, material mapping)	29%	16%	46%	32%	30%	6%	29%
Lack of knowledge and experience (In disassembly for reuse and construction with reused components)	46%	50%	68%	56%	55%	44%	53%
Hazardous substances (makes reuse more challenging and introduces risk)	16%	16%	8%	4%	15%	13%	13%

Note: Dark is more important

There also seems to be broad agreement between countries about what themes are the most important to tackle (Table 5). Knowledge and experience are widely appreciated as a key challenge in most countries, as are the issues surrounding certification, documentation, responsibility, and building regulations. Actors from Denmark were particularly concerned about product documentation and allocating responsibility for risk.

Table 6 - Survey results: barriers by actor group

Barriers	Building owner/ investor/ advisor	Design team (engineer, architect)	Con-tractor and builder	Construc-tion product manu-facturer	Demo-lition expert	Govern-ment/ regulator/ local authority	NGO (nonpro-fit entities indepen-dent of govern-mental influence)	Academia	Other:	**Total**
Risk and responsibility (difficulty in defining, assigning, and accepting the risks and responsibilities of CC)	50%	47%	45%	8%	67%	22%	65%	25%	44%	41%
Product documentation/ certification (uncertainty about technical capabilities and lack of certification)	56%	60%	35%	25%	50%	11%	47%	58%	53%	46%
Market (lack of visibility, security of supply, and market size)	44%	24%	5%	21%	50%	33%	47%	0%	33%	27%

Cooperation within the value chain (difficulty in creating effective communication and cooperation throughout the value chain)	17%	16%	20%	25%	17%	11%	24%	33%	19%	19%
Laws and building regulations (existing regulations hinder reuse and circular construction)	56%	45%	35%	42%	83%	39%	41%	67%	47%	47%
Culture within the sector (difficult to change existing approaches, methods, expectations, and structures)	28%	38%	40%	38%	0%	39%	29%	33%	47%	37%
Logistics (expensive and cumbersome storage and transport of materials and elements for reuse)	33%	15%	30%	13%	33%	33%	35%	8%	28%	23%
Economic (circular building practices and products are often more expensive)	44%	42%	35%	50%	50%	33%	29%	50%	36%	40%
Insufficient demand for circular product and circular buildings (from all parts of the value chain, but especially developers and commissioning authorities)	17%	22%	25%	38%	17%	28%	29%	42%	31%	27%

Insufficient supply of reused/ recycled materials and products (due to Logistics, strategy, technical knowledge & experience, material mapping)	22%	33%	20%	38%	17%	28%	35%	25%	25%	29%
Lack of knowledge and experience (In disassembly for reuse and construction with reused components)	56%	60%	45%	46%	0%	78%	41%	58%	53%	53%
Hazardous substances (makes reuse more challenging and introduces risk)	11%	13%	10%	4%	17%	22%	18%	8%	14%	13%

Note: Dark is more important

The different actor groups active throughout the construction value chain also largely agree on the main challenges facing circular construction (Table 6). *Knowledge and experience* are seen as a key barrier by most stakeholders, and public authorities place it as by far the most pressing challenge. Risk and responsibility are seen as important by building owners, the design team, and contractors and builders—those directly affected by the implications of allocating risk. Construction product manufacturers are not so concerned by this issue, rather, they are more concerned by meeting building regulations, the economic consequences, and a broad lack of knowledge.

8.1.2. Opportunities & enablers

The opportunities identified in the interviews and the literature were also prioritised in the survey. Respondents were asked to identify the seven most important opportunities for enabling circular construction.

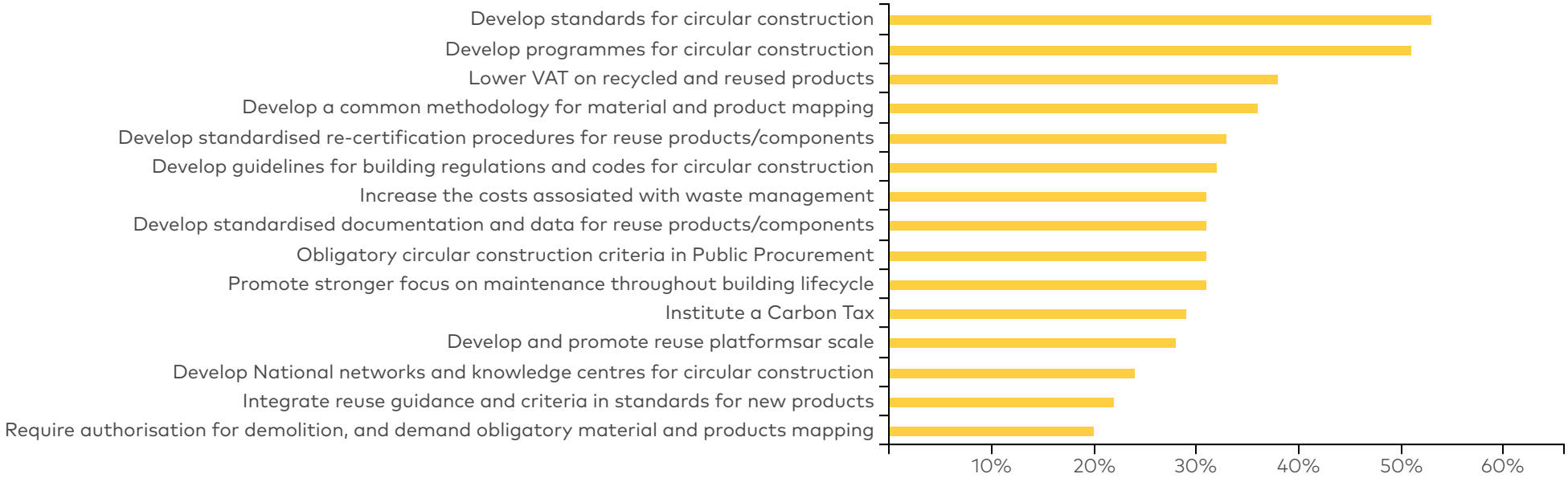

Figure 8 - Survey results – most important enablers for circular construction

Two opportunities clearly stand out (Figure 8):

- the development of standards for circular construction both for specific products and, even more importantly, for the processes, methods, and routines for implementing circular construction actions in practice. This reflects the uncertainty in the construction industry around these issues.
- national programmes for circular construction were also felt to be hugely important. They would provide visibility for circular construction across the industry, help create the demanded standards, and function as a meeting point for developing roadmaps for future work.

Lower VAT on reuse products was seen as a quick fix for making reused products more economically competitive with new products, while a common methodology for material mapping was also a popular request.

As indicated in Table 7, the actors within the value chains in the five Nordic countries are largely in agreement as to the most important enablers: developing standards and national programmes for circular construction. Norwegian respondents were particularly interested in the potential of reduced VAT on reuse and recycling products and activities.

Table 7 - Survey results: favoured enablers by country

Enablers	DK	FI	IS	NO	SE	Other	Total
Develop national programmes for circular construction	52%	48%	67%	50%	41%	42%	51%
Lower VAT on recycled and reused products	23%	37%	47%	64%	34%	50%	39%
Institute a Carbon Tax	31%	30%	33%	18%	31%	25%	29%
Increase the costs associated with waste management	25%	22%	50%	50%	16%	33%	31%
Develop national networks and knowledge centres for Circular Construction	21%	26%	30%	18%	13%	58%	24%
Develop standards for circular construction	46%	70%	37%	77%	47%	50%	53%
Develop and promote reuse platforms at scale	27%	26%	30%	27%	28%	33%	28%
Develop a common methodology for material and product mapping	31%	26%	47%	45%	34%	50%	37%
Require authorisation for demolition, and demand material and product mapping	19%	19%	30%	18%	16%	17%	20%
Develop standardised documentation and data for reuse products /components (EU-wide).	27%	33%	23%	45%	28%	42%	31%
Develop standardised recertification procedures for reuse products/components.	29%	41%	30%	36%	38%	25%	33%
Integrate reuse guidance and criteria into standards for new products.	15%	37%	27%	14%	28%	8%	22%

Note: Dark is more important

Looking along the value chain (Table 8), building owners in the Nordic countries would most like to see a standardised recertification process for reused products and lower VAT on reuse, while designers and contractors/construction companies, demolition companies, and government and NGOs would really like to see national programmes for circular construction to help steer the industry as a whole in a sustainable direction.

Table 8 - Survey Results – favoured enablers by group

Enablers & opportunities	Building owner/ investor/ advisor	Design team (engineer, architect)	Con-tractor and builder	Con-struction product manu-facturer	Demo-lition expert	Govern-ment/ regulator/ local authority	NGO	Academia	Other:	Total
Develop national programmes for circular construction	43%	60%	53%	48%	75%	46%	50%	40%	45%	51%
Lower VAT on recycled and reused products	57%	40%	33%	26%	50%	38%	25%	40%	45%	39%
Institute a Carbon Tax	21%	36%	33%	17%	0%	23%	38%	40%	29%	29%
Increase the costs associated with waste management	36%	27%	20%	30%	50%	46%	38%	20%	32%	31%
Develop national networks and knowledge centres for Circular Construction	36%	16%	27%	26%	25%	15%	25%	50%	23%	24%
Develop standards for circular construction	43%	42%	40%	70%	50%	38%	50%	60%	71%	53%
Develop and promote reuse platforms at scale	36%	29%	13%	22%	75%	38%	38%	0%	29%	28%
Develop a common methodology for material and product mapping	29%	27%	27%	48%	75%	38%	50%	20%	45%	37%

Require authorisation for demolition and demand material and product mapping.	0%	27%	20%	13%	0%	15%	31%	40%	16%	20%
Develop standardised documentation and data for reuse products /components (EU-wide).	29%	24%	33%	48%	50%	15%	38%	50%	23%	31%
Develop standardised recertification procedures for reuse products/components.	71%	27%	27%	39%	50%	15%	56%	20%	23%	33%
Integrate reuse guidance and criteria into standards for new products.	7%	22%	27%	22%	50%	38%	13%	30%	19%	22%
Develop clear guidelines on how to use circular building practices within current and future building regulations and codes.	36%	29%	33%	39%	50%	38%	31%	20%	29%	32%
Obligatory circular construction criteria in Public Procurement of buildings and infrastructure.	7%	18%	33%	39%	75%	15%	50%	30%	45%	31%
Promote increased focus on maintenance throughout building life cycles.	43%	36%	27%	30%	0%	23%	25%	30%	32%	31%

Note: Dark is more important

9. Conclusions

Based on the above and drawing on the expertise within the project team, the barriers and opportunities have been prioritised and elaborated upon. The process directly connected specific solutions with broad problem areas.

Unsurprisingly, given that lack of knowledge and experience was identified as one of the essential barriers to tackle—this lack of knowledge and experience fundamentally minimises activity and, as it means that circular construction is a more time-consuming process, it also increases the costs of circular construction—increasing knowledge and experience was the most prominent opportunity for circular construction, prompting the largest number of specific suggestions.

What is clear from the mapping of the barriers is that they are heavily interlinked and often reinforcing. For example:

- Lack of experience and knowledge within the sector stems from a lack of opportunity to gain that experience and knowledge, while that same lack of experience and knowledge means that it is difficult to commission projects with a circular focus. Lack of experience and knowledge also leads to longer project time frames and therefore higher expenses.
- Lack of documentation leads to uncertainty about the quality and safety of products and buildings, so the allocation of responsibility becomes a key challenge, which is itself hampered by a lack of experience within the value chain for addressing responsibility in new ways.
- The supply of products for reuse is hampered by the lack of knowledge and experience in terms of disassembly for reuse along with the additional costs associated with these practices and the lack of demand for reused products. The lack of demand for reused products stems at least in part from the uncertainty regarding supply and again about the potential for additional and potentially unknown/hidden costs.

Strategy and Planning

The circular approach to construction and the built environment is not integrated into the strategy and planning processes by planners and development decision makers.

OPPORTUNITIES

- **Plan for the future and design for flexibility, adaptability and disassembly.** Ensure that future generations do not have similar challenges maintaining the value of, adapting, and reusing their built environment.
- **Embed circularity at the core of the planning and decision-making process, on even footing with other sustainability consideration.** A circular approach is difficult to introduce as an add-on and provides more value and environmental benefit if integrated at the very start of the planning phase.
- **Synchronise demolition and construction across sites to facilitate reuse and minimise storage requirements.** Develop a long-term understanding of the demands on and for the built environment, the lifetime of existing assets, and develop synergies between renovation, demolition, and new construction activities.

This signifies that interventions are required throughout the entire value chain to ensure that a single issue in one area doesn't block progress in all others.

The following presents the most pressing barriers as identified by the survey responses across the Nordic countries along with the challenges of integrating circular construction into strategy and planning processes. It pairs these challenges with forward-looking opportunities.

BARRIER 1: LACK OF KNOWLEDGE & EXPERIENCE

Actors along the value chain do not have sufficient knowledge or experience of the methods, pro-cesses or routines required for Circular Construction.

OPPORTUNITIES

- **Pilot projects**
  Enable new actors to enter the circular construction market under favourable conditions, build experience, and develop and test new methods for all phases of circular construction.

- **Networks**
  Provide a meeting place for interested actors to expand their network and learn new competencies.

- **Knowledge centres**
  Provide central hubs that collect, collate, and communicate knowledge, experience, and best practices on circular construction.
- **Educational materials**
  Provide standardised learning within the sector, both though tertiary education and training, as well as apprenticeship training and education.
- **Case studies**
  Collect Nordic case studies of tangible and successful examples of circular construction done well, detailing not only the final product, but also the processes involved, and the challenges overcome, the solutions developed, and a contact reference for each of the responsible actors.
- **Public procurement**
  Drive the propagation of knowledge about circular construction in the industry through projects for public works.
- **Closer cooperation throughout the value chain**
  Build new relationships throughout the value chain with partners who work in circular construction. Communicate quality demands and negotiate responsibilities.

BARRIER 2: BUILDING REGULATIONS

The implementation of building regulations is geared toward building with new products and materials. The current system is ill-equipped to encompass reused products.

OPPORTUNITIES

- **Guidelines for both authorities and contractors**
  Make it easier for authorities and contractors to navigate the existing building regulations to enable and facilitate circular construction.
- **Revision of building regulations to better accommodate reuse**
  Facilitate and standardise the use of reused products in new settings while ensuring that existing safety standards are maintained.
- **Mandatory pre-demolition material mapping**
  Create a reliable and catalogued flow of reusable materials from end-of-life buildings, thus fostering a more stable marketplace for reused and recycled materials
- **Standardised and open data formats for both pre-demolition and material mapping**
  Consistency in material mapping and openness with the results will help establish a reliable and robust market for reused building products.

BARRIER 3: PRODUCT DOCUMENTATION

Reused products and materials lack the robust documentation demanded by the construction industry. For example: material passports, CE-labelling, EPDs etc.

OPPORTUNITIES

- **Develop recertification routines**
  Enable reused products to inspire the same level of confidence as new products through standardised recertification processes.
- **Work with EU to integrate reuse into existing product certification processes**
  Expand the scope of the demanded standard product information to include reuse-relevant parameters. This will make reusing products easier when they reach end-of-life.
- **Transferable warranty/guarantees**
  Standardised legal process for transferring warranty/guarantees (with or without modification) from original manufacturer to recovery agent of other party
- **Digital product passports**
  Increase the transparency of and access to information about a product for current and prospective users, thus facilitating easier maintenance during lifetime and more streamlined path to reuse at end of life.
- **Non-critical application**
  Increase reuse of elements by allowing and designing for reuse in non-critical elements, where the reused item lacks documentation (but passes the necessary screening for hazardous materials).

BARRIER 4: RISK/RESPONSIBILITY ALLOCATION

Existing approaches to allocating risk/responsibility are insufficient for the circular use of building products.

OPPORTUNITIES

- **Negotiated responsibility**
  New forms of cooperation and dialogue throughout the value chain facilitate a common understanding of where responsibility for reuse products and final buildings lie. Allows all actors to react with confidence throughout the value chain.
- **New roles in product sourcing**
  A broader approach to sourcing construction materials and products facilitates easier entry into circular construction for building and construction companies.
- **Standard contracts that reflect these new norms**
  Transforming new norms into standardised contracts stabilises circular processes within the construction industry broadly.
- **Public procurement**
  Public tenders help pave the way to developing many of these forms of collaboration, norms and standardised contracts, and allows for quicker propagation of these within the industry and along the value chain.

BARRIER 5: ECONOMY

Circular construction is more expensive than construction with new products and materials. This is primarily because of the additional time required to engage in circular processes throughout the value chain.

OPPORTUNITIES

- **Lowering/removing VAT on circular processes/products**
  Rendering the price of reused products more competitive with products made with virgin materials. Incentivising actors throughout the value chain to adopt reuse processes, particularly dismantling and preparing for reuse.
- **Enforcing existing waste regulations**
  Full compliance with separate collection and disposal demands increases the total costs associated with waste generation and raises the baseline costs for demolition, making disassembly and reuse more competitive.
- **Carbon tax**
  An economy-wide or industry-specific carbon tax increases the costs of virgin products and helps make reuse (and recycling) more competitive.
- **Targeted financial support**
  Direct injection of capital into the construction industry tied to circular construction projects. Needs to be targeted at projects that develop new knowledge or skills for best return.
- **Taxes/fees on virgin products/materials**
  Increases the total costs associated with new products and virgin materials, making reuse and recycling more financially competitive.
- **Focus on induced benefits**
  Incorporate the induced benefits (for example, increased employment) of circular approaches to construction into the total cost-benefit analyses and strategic decision making. Particularly relevant to projects for public authorities.
- **Public procurement**
  Specifying circular construction criteria in all public tenders for construction works provides a gateway for the industry to build capacities in new circular methods while maintaining economic viability.

BARRIER 6: CULTURE

The construction industry is culturally and institutionally risk averse (some would say conservative), and Circular Construction is an undesired interruption.

OPPORTUNITIES

- **National Programme for circular construction**
  Provides a clear declaration of intention for the construction industry that indicates not only the direction to take, but also the methods and milestones for transition and the underlying drivers making it necessary.
- **Fit circular construction practices into existing practices and routines**
  Stepwise integration of circular construction practices into existing processes to enable actors throughout the construction value chain to acclimatise to the concepts and tools associated with circular construction.
- **Integrate circular construction more deeply into existing (environmental) certification systems**
  Promote circular transition among the sector's most ambitious actors, thus allowing concepts and methods to propagate from certification practitioners.
- **Education, networking, and knowledge centres**
  Develop, collect, and disseminate knowledge, best practices, standards, and norms through industry networks to ensure that circularity as a concept takes root in the industry.
- **Pilot projects with a broad range of actors**
  Integrating new actors into pilot projects to broaden the reach and knowledge of circular construction within the industry.

10. Recommendations

The following recommendations are a synthesis of the results from all the input and analysis in the project. They indicate the role that actors throughout the value chain can play in helping foster the transition to a more circular construction industry. Also identified are key focus areas that the Nordic Network for Circular Construction programme could help address.

Recommendations for further work under the Nordic Network for Circular Construction:

Nordic Network for Circular Construction	The Nordic Network for Circular Construction can help overcome many of the challenges facing circular construction in the Nordic countries. It can: • Develop sector and sub-sector networks to share experience. • Develop and disseminate knowledge on best practices, case studies, and pilot projects. • Develop educational materials for the sector. • Develop new norms, methods, and practices around CC. • Coordinate guides for CC in the current building regulation framework. • Support the integration of CC into international building environmental certification schemes.

The main actors throughout the construction value chain also have a vital role to play in the transition to circular construction:

Developers & Owners	Developers and owners can help overcome the lack of knowledge and experience as well as any economic and cultural challenges by taking the lead and commissioning CC projects, and by including induced benefits in calculations. They can help overcome risk and responsibility challenges by engaging with the value chain to develop new negotiated responsibilities. To do so, they should plan for a long-term future, embed CC at the start of the process, and support the CC process by synchronising construction and demolition activities.
Architects, engineers and consultants	Architects, designers, and engineers can support developers in the move toward CC by proposing and developing CC solutions, supporting the negotiation of risks and responsibilities, and developing new norms for sourcing more sustainable and/or reused materials. They can also work on integrating CC into existing tools and methods and supporting the integration of CC into existing certification frameworks, all with the clear goal of narrowing, slowing, and closing cycles.
Construction Companies	Construction companies can support the transition to CC and reduce the knowledge and experience gap by engaging with their peers and learning from pilot projects, networks, and knowledge centres, as well as engaging with all stakeholders throughout value chain to increase collaboration, negotiate new allocation of risk and responsibility, and develop new sourcing routines. They can also support manufacturers in the development of circular tools and products while actively engaging in the revision and guidance of building regulations and product recertification initiatives.

Construction product manufacturers	Manufacturers of construction products can support the design of circular buildings by developing solutions that enable flexibility and adaptation, and they can play a key role in providing product information and supporting certification efforts. They can also develop methods for remanufacturing or preparing reclaimed products for reuse, as well as ensuring that construction products are suitable and ready for future cycles.
Demolition companies	Demolition companies will play a key role in implementing and defining the necessary process and data standards for pre-demolition material mapping and help build a robust market for reused construction products. This needs to be done in cooperation with developers, the design team, and construction companies. They can help overcome knowledge and experience gaps by engaging with the industry, the value chain, industry networks, knowledge centres, and they will need to build new competencies.
Public authorities	Public authorities are a vital node that can set the CC agenda, ease economic challenges, provide a favourable framework for CC, and coordinate the growth of knowledge and experience within the sector. They can help overcome regulatory barriers by leading the revision of national building regulations. They can also lead the negotiations related to recertification and the integration of reuse into existing product certification, as well as implement coming EU legislation on construction products and digital product passports. They can help steer the industry culture toward CC by developing national CC strategies and integrating CC-relevant content into national education curricula. They can also define a favourable economic landscape for circular construction by introducing taxes on carbon or other natural resources and reducing or removing VAT on reuse-related activities and reused products. Better enforcement of existing waste regulations would also provide an economic boost to circular construction.

Research Institutions	Research institutions can support the transition to CC by helping bridge the knowledge and experience gap through participation in or hosting knowledge centres and developing educational materials. They could also support sector networks as knowledge partners and support the public authorities in creating methods for recertification as well as the implementation of the digital product passports. They can take a leading role in developing standards for calculating induced benefits of CC while supporting the integration of CC into existing methods and certification schemes.

NGOs	Industry bodies can help overcome knowledge and experience gaps by acting as central nodes for industry networks and facilitating cooperation between value chain actors. They can also form knowledge centres, help develop and disseminate education materials, and run further education courses. They are also an ideal focal point for developing new norms and standards (data and process) around pre-demolition material mapping and reused product information, and they can support the integration of CC into existing industry routines. Similarly, they can help develop and disseminate guidance on CC in the current building regulations and positively influence the revision of building regulations.

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Appendix A: Origin of respondents

Country	Organisation/company
Denmark	A:GAIN Copenhagen municipality Enemaerke & Petersen Lendager Group Matter bybrix Vaerdibyg
Finland	FIGBC Materiaalitori RAKLI
Iceland	Hornsteinn IGBC/EFLA Loftakastlinn
Norway	Aspelin Ramm FutureBuilt Multiconsult Norge Resirqel Skanska
Sweden	Bruksspecialisten Familjebostäder Framtiden IVL/ CCBuild Varvsstaden Vasakronan White Xcen

Appendix B: Interview guide

Introduction of the actor

Identification of actor

- Name and role in the company?
- Location and were does business occur?
- What is your position in the construction supply chain?

Describe your suppliers and customers

- What does you demand from your suppliers?
- What does your customers demand from you?

Your role for circularity

- Describe your process. In which way does it contribute to CC?
- Do you have any goals related to resource efficiency and circularity?
- What initiatives are you working towards when it comes to circular construction?

Actor specific questions for CC

Construction materials/product/service (if more general actor or actor that are overall responsible)

Based on your process, what construction elements/products/materials are normally circulated today?

- What are key activities/possibilities to enable circulation of these?
- Can you see any barriers to this?

What is the reason building materials and product reaches end-of-life?

- In relation to technical performance?
- In relation to consumer demands?
- In relation to costs?

Which criterions can you identify for building products and materials to become more resource efficient?

Construction materials/product/service (if more specific actor, involved in a specific product or process)

What are key activities to enable circulation of these?

- Are there any barriers to your business?

What is the reason to 'dispose' your product, why does it reach end-of-life?

- How does this affect how the product can become circular?
- How long is the longevity for your products?
- Are there measures that can increase resource efficiency for your product?

Which criterions are important to consider for your product to become fully circular?

General questions for CC

How do you view circularity in the construction sector?

Can you mention a good example of resource efficiency/reuse/circularity in the construction sector?

- What were key activities for its success?
- Can any conclusions be drawn from it?

What barriers and possibilities do you see with existing regulations and policy instruments?

- What could facilitate a circular construction sector in your country?
- How are the current regulations affecting your ability to be and become more circular?
- Are there policies you see are driving the circular process?
- Are there policies you see can be a barrier to the circular process?
- What policies/incentives would you like to see for the future circular process?

Ending open thoughts on the theme 'Circular construction'

- What main barriers do you see for a circular construction sector?
- What solutions would you like to see for a more circular construction sector?
- Are there anything else you would like to add on the topic?

Appendix C: Survey questions

Circular construction – challenges and solutions

The Nordic Networks for Circular Construction project aims at accelerating the implementation of the best practices of circular economy in the Nordic construction sector through collaboration, peer-to-peer learning and common metrics.

This online survey feeds into an analysis of challenges and solutions from the viewpoints of different stakeholders. By gathering input from a large section of the Nordic construction industry, it will help identify and prioritize challenges and potential solutions to circular construction.

This survey has been informed by an exhaustive literature review and long-form interviews with experts along the construction value chain, from investors and commissioning authorities to construction and demolition companies.

The project is part of Finland's chairmanship of the Nordic Council of Ministers.

What country is your organisation primarily active in?

- Finland
- Denmark
- Sweden
- Norway
- Island
- Other _____

How would you describe your organization?
[If you fall under more than one, choose the option that is the primary activity] (dropdown)

- Building owner/investor/advisor
- Design team (engineer, architect)
- Contractor and builder
- Demolition expert
- Construction product manufacturer
- Government/regulator/local authority
- Academia
- NGO
- Other _____

IMPORTANT BARRIERS TO CIRCULAR CONSTRUCTION

Please evaluate the following barriers to circularity in the building sector. Select the five most important.

1. Risk and responsibility
   – difficulty in defining, assigning, and accepting the risks and responsibilities of CC.
2. Product documentation/certification
   – uncertainty about technical capabilities and lack of certification
3. Market
   – lack of visibility, security of supply and market size
4. Cooperation in value chain
   – difficult in creating effective communication and cooperation along the value chain throughout the construction process
5. Laws and building regulations
   – existing regulation hinders re-use and circular construction
6. Culture within the branch
   – difficult to change existing approaches, methods, expectations, and structures
7. Logistics
   – expensive and difficult storage and transport of materials and elements for reuse.
8. Economic
   – circular building practices and products are often more expensive
9. Demand
   – insufficient demand for circular product and circular buildings from all parts of the value chain, but especially developers and commissioning authorities
10. Supply
    – insufficient supply of reused/recycled materials and products due to Logistics, strategy, technical, knowledge & experience, material mapping)
11. Knowledge and experience
    – lack of in disassembly for reuse and construction with reused components
12. Hazardous substances
    – makes reuse more challenging and introduces risk.

Additional comments/challenges:

1. What is the single most important barrier for you?

   _____

2. What is the single most barrier for circular construction in general?

   _____

IMPORTANT ENABLERS TO CIRCULAR CONSTRUCTION

Please evaluate the following enablers to circularity. Select the five most important.

1. Develop National programmes for circular construction, including education, guidance, and standards.
2. Lower VAT on recycled and reused products.
3. Institute a Carbon Tax.
4. Increase the costs associated with waste management.
5. Develop national networks and knowledge centres for Circular Construction.
6. Promote Nordic cooperation.
7. Develop standards for circular construction [construction & demolition processes, planning processes, documentation, and contract forms].
8. Develop standard process for identification, evaluation and reuse for hazardous substances
9. Develop and promote reuse platforms at scale.
10. Develop a common methodology for material and product mapping of end-of-life buildings.
11. Require authorisation for demolition of end-of-life buildings, including analysis of reuse potential and obligatory material and product mapping.
12. Develop standardised documentation with standardised data for reuse products/components (EU-wide).
13. Develop standardised re-certification procedures for reuse products/components.
14. Integrate reuse guidance and criteria in standards for new products.
15. Develop clear guidelines on how to use circular building practices within current and future building regulations and codes.
16. Provide state-backed guarantees for reuse products/elements.
17. Obligatory circular construction criteria in Public Procurement of buildings and infrastructure.
18. Promote a stronger focus on maintenance throughout building lifecycle.
19. Promote Public Private partnerships to hedge responsibilities and risks in Circular construction projects.

- Additional comments/ opportunities:

  _____
- What is the single most important enabler for you?

  _____
- What is the single most enabler for circular construction I general?

  _____
- Does your company have any goals related to resource efficiency and circularity

  _____
- What are the goals?

  _____
- Other Comments:

  _____

About this publication

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Nordic co-operation

Nordic co-operation is one of the world's most extensive forms of regional collaboration, involving Denmark, Finland, Iceland, Norway, Sweden, and the Faroe Islands, Greenland and Åland.

Nordic co-operation has firm traditions in politics, economics and culture and plays an important role in European and international forums. The Nordic community strives for a strong Nordic Region in a strong Europe.

Nordic co-operation promotes regional interests and values in a global world. The values shared by the Nordic countries help make the region one of the most innovative and competitive in the world.

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